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Foreword

Welcome to the 4th International Conference on Quality Engineering and Management!

It is my pleasure to welcome you to the **International Conference on Quality Engineering and Management 2020**, the 4th edition, this time, due to the current worldwide situation caused by the SARS-CoV-2/COVID-19 pandemic, organized online. However, I'm sure it will be a great event as the previous ones!

The **ICQEM** is an international forum to present and discuss the progresses in the Quality Management, Quality Engineering and Organizational Excellence fields. Consequently, since the beginning, the conference covers different topics as: Standards, Continuous Improvement, Supply Chain Quality Management, Management Systems, Lean Six Sigma, Quality Tools, Quality Management in Higher Education, Quality Management in Services, Total Quality Management, Organizational Excellence, The Future of Quality and Quality 4.0, among others.

This conference provides the unique opportunity to share the latest insights of academic and industrial research and applications on Quality and Organizational Excellence.

The **ICQEM20** keynote speakers will include:

- **António Cunha**, President of the Collaborative Laboratory on Digital Transformation at University of Minho, Portugal, that will deliver a speech entitled "Digital transformation for intelligent quality assurance".
- **Benito Flores**, Dean of the School of Engineering at University of Monterrey, Mexico, and Past-Chair of the American Society for Quality. Benito will talk about "Quality 4.0: More than Technology".
- **Christianna Hayes**, CEO at Impact Performance Solutions, USA. Chris will deliver a speech entitled "Achieving Personal Goals through Quality".
- **Jorge J. Román**, International Consultant in Business Excellence & Benchmarking at Dubai Police Headquarters in Dubai UAE, that will deliver a speech focusing "Intellectual Property Crime and Business Excellence Framework. Dubai Police case study".
- **Maxim Protasov**, CEO at Russian Quality System, Russia that will talk about "What is the Russian National Quality System all about?".

More than 100 presentation proposals have been submitted. Proposals accepted correspond to authors from all around the world, with more than 20 countries represented at this level. Therefore, a warm acknowledgment to all the speakers and authors is well deserved – Thank You! I would like to give also a special thanks to all the Members of the Scientific Committee for all the important work they have done by revising the full papers submitted.

Finally, I must acknowledge the institutional support received from the University of Minho, the Research Group on Quality and Organizational Excellence (RG-QOE), the ASQ University of Minho Student Branch, the University of Coimbra, the University of Girona, the Universitat Internacional de Catalunya (UIC Barcelona), the Portuguese Association for Quality (APQ), the Brazilian Association of Production Engineering (ABEPRO), Cempalavras, the European Organization for Quality (EOQ), the Russian System of Quality and the Brazilian Society for Quality and Excellence in Management (SBQEG).

Let's take advantage of this great opportunity and make with your contributions an event with Quality, shared and built by such a top level group of participants, thus contributing to "A better world with Quality!".

Conference Chair

Paulo Sampaio
University of Minho

Conference Co-founders
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António Ramos Pires, Polytechnic Institute of Setúbal,
Pedro Saraiva, University of Coimbra
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Submitted papers

A dynamic approach to teaching LSS at Universities

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ABSTRACT

Alongside the European Students of Industrial Engineering and Management (ESTIEM) a team of students from the University of Minho, in cooperation with a corporate partner, developed a free and scalable Lean Six Sigma (LSS) Green-Belt level course for Engineering students.

Purpose: The authors aim to depict how free access to LSS Green-Belt knowledge before graduation can positively impact both engineering education and the students when in real-life projects. The purpose is not to build on existing literature, but to provide a practical teaching structure.

Methodology: The authors chose to follow the hypothetico-deductive method which consists of formulating hypotheses and comparing them with real-life brought up from their personal experiences while teaching the course.

Findings: This case study found a positive impact on both the students responsible for facilitating the training sessions, as well as the ones receiving practical and theoretical knowledge. With more than 60 course graduates, this model is generating positive results in growing awareness for LSS methods.

Practical implications: This paper describes a practical application of a novel approach to teaching LSS in Universities along the obstacles surpassed to design it, blending it in the course curricula. It aims to foster similar implementations in other institutions.

Originality: A teaching system built with students for students is scalable, low-cost, and highly engaging. Its deployment not only shows how it is possible to advance education by blending an existing LSS course structure but also how students can greatly benefit from a deeper LSS knowledge before their graduation.

Keywords: LSS, Industrial Engineering, and Management, Engineering Curricula, Teaching methodology

Paper type Case Study

INTRODUCTION

The world is changing every single day. The economy is changing, technology is evolving and most importantly the authors, as human beings, are changing. This means our behavior, our beliefs, and our necessities are changing. So, how can the authors adapt and prosper in such uncertainty? Considering what Universities have been doing to prepare the future workforce and leaders of the incumbent industries and the new sectors yet to arise, engineering graduates still seem to be closing themselves down to the same old classic tools from the mass production days of Ford - learning how to answer, but not how to question the context around them. This is the reason it was created the first free certified LSS Green Belt course at the University of Minho, designed by students for students with the future in mind.

This paper was prepared by the students who participated in the structuring of this course, with the involvement of ESTIEM (European Students of Industrial Engineering and Management) as an educational partner - giving support and feedback on our first trial edition at the University of Minho; and remained active through its design, development, and deployment in the following edition as instructors. Here they describe, for the historical record, the motivation, sequence of activities, successes, and obstacles felt over two years since the first idea concept until a fully implemented model involving a symbiosis between companies, University, and students of Industrial Engineering and Management.

Throughout this paper, it will be understood how important it is for companies to be involved in University initiatives related to LSS and the impact of hiring graduates with Green Belt knowledge capable of stimulating change in their organizations. Secondly, the authors will go through the importance of creating free and easy access to LSS knowledge to provide a higher quality of education, in Universities, and, ultimately, to better prepare the next generation of leaders.

Afterward, it will be shown how this course was adapted to the University of Minho educational context and, finally, what were the direct results on the students, the University, and the corporate partners involved.

The authors will present their vision to provide a scalable LSS Green Belt course structure integrated into the Industrial Engineering and Management educational curriculum, given by students (Green Belts, and, hopefully, one day also Black Belts) to their peers. By joining the Green Belt course and using the LSS method in an internship in a company, students have the chance of obtaining a Green Belt certificate given by ESTIEM and signed by Gregory H. Watson himself, before their graduation.

This work does not aim to improve the existing literature, but rather to describe a practical case study of how engineering curricula can be enhanced when students and teachers collaboratively work towards filling gaps on the existing teaching methods, is based solely on the real-life experience of the authors as instructors of the course. The authors aim to show the benefit of encouraging and promoting such courses in the preparation of students for their future challenges, but also in a closer connection between students and teachers that is believed to lead to better education and understanding of the subjects.

BACKGROUND

It all began with ESTIEM - most important European Association for Students of Industrial Engineering and Management, along with Gregory H. Watson, in an event called Summer Academy - one of the many events that ESTIEM organizes and offers to its students. In that event, the concept of LSS was brought to discussion and a participant got interested in this methodology and took the Green Belt course that same summer (Jarrett, Matti & Rajala, 2016).

The following summer, Gregory and Jukkis (the participant mentioned above) began thinking about how they could start building a Green Belt course for ESTIEM and its members, by focusing on a never worked on a gap in the LSS education industry - students. They had the vision to make a high-quality Green Belt training easily accessible to Industrial Engineering and Management students from around Europe and equip them with tools to solve even more complex problems in companies before they are even graduated, which would allow them to be better suited to enter the job market and lower companies' training costs to new hires. The idea was for Gregory to build the course content and the students to be deploying and expanding it in Europe through ESTIEM's network. To do so, the course's content was to be presented to participants through videos where Gregory would explain all the concepts necessary. The team developing the course, along with Gregory, filmed and edited 80 videos, whose length varied from 4 to 20 minutes, depending on the content and complexity of the subjects being presented.

It was time to present the course to the whole ESTIEM community. It happened in Council Meeting Porto 2016 – ESTIEM's general assembly where students from all member Universities vote on matters relevant to the future of the student association, where the council voted to launch the LSS Initiative for ESTIEM. The first ESTIEM LSS Green Belt Course took place at Aalto University in November and December 2016. After that many other courses were given across all of Europe.

The result of all this process was a full week course with a blended approach between theory and practical lessons (Turtiainen, Rajala & Jarrett, 2017), being the first one shared with the students through multiple videos and practical sessions facilitated by ESTIEM Instructors, that already had done the Green Belt Course. After that week, the participants must have to complete a Green Belt Project on a company to get the final certificate of Green Belt in LSS.

STRUCTURE OF THE UNIVERSITY OF MINHO'S GREEN BELT LEVEL COURSE

Two years ago, after realizing the potential of these courses and seeing how many people from our university was interested to take the Green Belt Course and analyzing the industry surrounding our University and their demand for highly talented students, the authors have decided to design our own Green Belt course, leveraging on the already existing ESTIEM's structure, but adapting it to the Portuguese educational context. On a high level, teaching the course can be divided into three individual components: 1) teaching the theory, 2) facilitating training sessions and case studies, and 3) project monitoring (Turtiainen, Rajala & Jarrett. 2017).

To start designing the course the authors had all the needed resources to do so: 5 ESTIEM Instructors, support from our local Industrial Engineering and Management Student Association, and our University department and a corporate partner interested in being involved in training future quality professionals. With the help of ESTIEM, the authors developed a free 10-Week Green Belt Course where participants had to see weekly webinars with the theoretical Green Belt knowledge. Additionally, they had to attend a weekly 4-hour practical session, where they would put into practice the tools they learned in the webinars. The course finished with a final case study - a simulation of a real-life LSS project in which they applied the contents they learned throughout the 10 weeks.

This structure as the global teaching methodology used in ESTIEM translated the cognitive domain of learning to the context of the course. Rather than seeing the learning journey as a step-by-step process, the model is built on the premise that sufficient knowledge on the lower levels is a prerequisite for better uptaking more complex higher levels of knowledge. Following it, the instructors aim to enhance the ability of the students to recall what they've learned about LSS in the previous DMAIC by bringing real case studies to class; to apply the topic onto an actual problem in a structured way; to synthesize their action plan by selecting from a panoply of quality tools the best ones for the context at hands; and, ultimately, to stimulate the ability of the student to clearly understand the impact of each tool in a real-world context, which is mostly gained in the case studies presented throughout the course, but most importantly during the internship to achieve the green belt level certificate.

One aspect that was always considered from the beginning was the sustainability of the course. Considering students are leaving every year and new students arrive, it was seen as crucial to guarantee that new students were available to pick up where others had left. Therefore, in the two editions, 3 to 5 students were selected to attend the course and to step up and play their role of instructors in the following year. To guarantee the quality of the courses, ESTIEM developed a mentoring system for the trainers. It currently has special programs for want-to-be trainers where black belts share facilitation skills and dive into deeper LSS knowledge, mostly focusing on more complex statistical concepts. This method avoids a spiral flawed guidance effect which could compromise the sustainability of the course in the long-run. It assures the authority of the trainer is preserved, assuring high-quality standards of those involved in teaching every year. To achieve so, trainers are taught how to handle difficult situations that can arise during the teaching sessions, and receive coaching to fully grasp the content of the course. Besides, the content of the ESTIEM LSS course is standardized and built so that the students can facilitate them with sufficient confidence. This minimizes the potential variation in the learning of the course content, which could be introduced by changing the instructors. As the learning material is maintained, as well as the examples and case studies, quality is guaranteed every year regardless of who leads the teaching.

Regarding the preparation of the classes, the instructors, being handed the materials by ESTIEM, have adapted them with their knowledge on the subject, but also adding a strong practical component and real-life applications. This was made by researching real case studies of the application of LSS to several problems, from healthcare to operations, or software development. The goal was to tackle a problem pointed very often by students to education: the lack of real-life situations where techniques can be applied. Every class, a real LSS project was brought to students to review the content taught in the previous classes. This was done throughout the entire course.

Even though the authors developed a conceptually impactful project, the implementation roadmap of the course was crucial for it to turn into a success. To reach the best students at our University and make them interested in a 10-week course about a tool they did not fully understand, the authors partnered the course with two different and important partners: The University of Minho and LSS-driven company. Regarding the University, the authors integrated the training course into the course of “Advanced Quality Engineering and Management”, which is taught in the fourth year of the Industrial Engineering and Management Integrated Master Program. This meant that the students taking this subject had priority to do this course and their participation was valued in the final evaluation. Regarding the partnership with the company, they supported all the costs regarding materials needed to do the sessions and gave the students the opportunity of visiting the company and to implement what they learned on a real company problem, with the help of two black belts and one master black belt running the factory plant.

It is important to note that the authors, being students, are aware of the flaws pointed out by their peers concerning their teachers. Knowing this, the instructors have tried to avoid and improve upon those flaws, especially in the teaching method and approach to content.

RESEARCH METHODOLOGY

To frame the evaluation of this innovative method to teach an LSS course, the authors followed the hypothetico-deductive method, creating strong hypotheses that were tested through direct observation from all the actors involved, the students that enrolled the course, trainers, companies, and teachers. To do this, the authors gathered not only their opinion, but also the opinion of teachers, students, alumni, and companies. This was made by promoting questionnaires and interviews with parties involved.

The hypothesis presented and explained below were created considered all the stakeholders that played a role in this course, ensuring that the methodology chosen would have enough opinions from people who have experienced it to validate the author's assumptions.

Hypothesis 1 – Does the LSS Green Belt Course benefit the students?

Throughout the years, the idea of an engineer faced many changes. Before modern times, engineers were classified as problem solvers with an excellent mastery of technical skills and knowledge. They needed to fully understand the technical context around their work or product, and they were easily stereotyped regarding a specific industry, product, or service, specializing in a specific topic. Nowadays, this idea of an engineer has evolved and grew into a much more complex concept. Today, they are not problem solvers but also problem finders. They need to identify, evaluate, formulate, and solve problems with people from other scientific, technical, and artistic areas and from other cultures. They need to understand much more than the technical context around their work or product. Currently, they combine their technical skills with so-called soft skills. In the age of information, it no longer matters what one knows, as information is accessible to everyone, but rather how one is capable of filtering data to efficiently find answers.

Based on this, the authors believe that the LSS Green Belt course that was about to be implemented could bring a really big impact on students' development since this course incites the participants to lead and work with a team in projects to identify and solve problems. By teaching a problem-solving framework like DMAIC with useful and impactful tools allied to each phase could provide a lot of opportunities for students to participate and engage in better projects, better companies, achieving better results in the end.

In short, the implementation of this course would allow students to be more prepared to face their professional careers and to be more motivated to incite change inside organizations.

Hypothesis 2 – Does this new approach incites change in Universities?

The word "University" was once upon a time referred to as the lighthouse for knowledge, illuminating the way scholars, students, teachers, had to go through to be able to defy present dogmas and create new concepts.

The problem is that the times the authors are living intend to be in constant change, where nothing is seen as static anymore. More than ever Universities are lagging what the future of the industries are looking for, with its pillars set on old teaching models built for mass production and not innovation management. The authors are conscious about the difficulties to follow side by side with what enterprises are doing, mostly due to resource constraints, but there is where complement courses can have a vital action, providing educational institutions a boost on their transformational path to build the defiant of tomorrow and not the worker of today.

Our hypothesis lies in the belief Universities gain external recognition as producers of excellent students and professionals by giving students the chance of acquiring important knowledge for companies and institutions without any costs.

To test this hypothesis, teachers and partners of the ESTIEM LSS course were interviewed, highlighting professor Paulo Sampaio, who was one of the main responsible for bringing this unique LSS Model to the University of Minho in a unique structure; and Christoph Hagedorn, who holds the position of Head of Corporate Quality & Environment at Continental. Both will give their personal and institutional points of view regarding the importance of leveraging methodologies like LSS, integrating them into the University's curricula.

Hypothesis 3 – Does this innovative course incites change in Companies?

Nowadays companies are facing a diversity of challenges, most of them never faced before. The agility that is needed to overcome those obstacles is increasing exponentially in recent years. At the same time, they are facing those transformations, they are also competing for the most talented and prepared graduates.

The University of Minho is at the center of an industry-based region in the north of Portugal and so, the need to improve and polish processes is always a must. The problem was that those companies were not able to find the best human resources with the data-driven problem-solving skills needed, due to the theoretical approach the University curricula still keeps. To tackle these companies are spending a lot of money on training courses focused on tools they should already have acquired during their academic years.

By understanding all these problems, first contacts between the founders of the course and enterprises were made to understand how the practice sessions should be to prepare the students for real-life cases and to benchmark with existing corporate certified training courses on LSS.

In theory, with this course companies would have access to employees with problem-solving and process improvement skills like never before. When you are betting on continuous improvement, in the long run, this kind of talent is critical. Besides, the Green Belt Course would have a huge impact on lowering onboarding costs.

Regarding the students, the authors assumed that they would be better prepared for the professional future and, when it comes to recruiting, they could have an edge over the others.

Having the opportunity of being certified in a methodology so much valued by the leaders of the industries still in their academic path is unprecedented in the Portuguese educational context.

RESULTS

Result 1 – Benefits for Students

After 2 years of teaching students LSS, the authors ended up with an exceptional number of 63 students with the Green Belt level of knowledge.

After the course they had the skills to work inside a specific work process, to assure standard work, to lead correction of non-standard work, and to encourage and lead work process improvement, always project and teamwork-based.

Accordingly, to what the authors expected, the students developed both hard skills and soft skills with this course, making them even better and more prepared engineers with competencies valued by the employing companies. During the time as trainers, students also deepen their knowledge of the LSS, as well as get valuable experience in facilitating group work, learning, and teaching. The skills and experience they gain during their instructor journey will be very valuable in a business context.

Finally, the interest of working in this field of Industrial Engineering and Management and the number of projects has increased throughout the 2 years. By the end of the first year, 6 students decided to do their master thesis on Quality Improvement and Management and, after these 2 years, more and better projects, internships, and master thesis were presented to students (the numbers will be presented later in the article).

Result 2 – Benefits for the University

LSS is all about having a framework that allows anyone who masters it to, in a methodical and simplified way, question their context and, step by step, with a specific tool-kit, iterate on their hypothesis to find solutions capable of improving whatever they set themselves to improve. In the end, providing nothing less than excellence to the customer is the goal.

The implementation of this 10-weeks course, worked as a valuable addition to what was already being taught in the quality management field at the University of Minho, giving a world-recognized methodology with no costs to every student in the penultimate year of Masters in Industrial Engineering and Management. This allows the students to be better prepared for their master thesis projects, and to apply for the company's vacancies with a Green Belt level already acquired, before finishing the course.

In the eyes of the companies, the University is capable of training better graduates, who will afterward show higher levels of performance in comparison to other students, as they are more prepared to face different problems in a structured way.

Concerning the tight relationship with enterprise and its impact to the overall quality of the course, the knowledge shared and leveraged to structure the course according to the best green-belt level practices in the industry were paramount for the course success, especially when looking to the training skills of the students sharing LSS content. Often, the atmosphere in the training sessions could become a bit tense when the students started asking questions beyond the standard teaching scope, questioning the competence of the trainer. To tackle this situation the course' partner company knowledge was very valuable to hold the reigns of the course, better preparing the trainers to answer doubts about broader topics than those listed in the original, standard course curricula.

Over the last two years, the authors provided LSS Green Belt level knowledge to 63 students without any costs, in addition to company visits, and real-life case studies to test the content acquired during class.

Testimonials regarding the impact the course has on Universities

How do you value the ESTIEM Lean SS Course?

“This course is a great opportunity for the Industrial Engineering and Management students for two main reasons: (1) they have the chance to learn one of the most well-known methodologies for process improvement, thus allowing them to go to the companies with that knowledge when they graduate; (2) during the course they have the chance to see and study real-life examples of LSS projects, thus promoting the link between academia and industry.”

How do you value projects coming from graduates of the course?

“To graduate students must develop an applied project in a company for 9 months. After the ESTIEM LSS Course was established at the University of Minho, the number of LSS project proposals by companies had increased, thus reflecting that the companies are recognizing the quality of the training that is provided to the students through the ESTIEM LSS Course.”

How important was to integrate this course into your quality management track?

“I teach a course of “Advanced Topics on Quality Engineering and Management” and since the first minute that I'm enthusiastic about this “partnership” with ESTIEM by integrating the LSS course in my track. It was possible to teach LSS without this partnership as I have done for several years, but it was not the same. Currently, I have students teaching other students and it is resulting in a great experience.”

Professor Paulo Sampaio, Professor of Quality and Organizational Excellence in the Department of Production and Systems at the University of Minho

How important do you think it is to integrate more of these complement courses in University curricula?

“Looking at a large corporation it is nearly an impossible task to train the entire organization in structured problem-solving. As such training needs theoretical knowledge and practical application it is only in selective cases possible to integrate this in the daily work. Therefore, learning and applying the LSS methodology already during university time makes each graduate of such a course a much more valuable employee for any company. They bring a piece of knowledge and mindset that every company is looking for. Having such a course is in my eyes a perfect win-win situation for the student, the university, and the companies.”

Christoph Hagedorn, Head of Quality in Continental – partner of ESTIEM LSS course

Result 3 – Benefits for Companies

The Lean Six-Sigma Green Belt Course was all about teaching students how to apply the DMAIC framework, analyze problems, collect information, and provide solutions based on data that could help companies to perform better and to save costs.

After two years, the results have gone beyond our highest expectations. It was created a partnership between a leader in the automotive industry where the students can solve a real case-study in the company for one day and finish the course with a hands-on immersive experience with black-belts and master black-belts. Ten students already realized three to six months projects (internships or master thesis) where they applied the knowledge acquired from the course in five different companies from different industries (automotive, healthcare, metal related sectors). Furthermore, the companies were able to have outstanding results such as eighty thousand euros indirect savings and forty percent fewer activities necessaries in requiring an ambulance for patients in a public hospital; forty-two thousand euros saved a year in a metalworking automotive company; decrease by 30% the defect units in an electronic automotive company; the decrease of quality costs and increase customer satisfaction were some of the results driven by the projects our graduates started. In total, the financial impact of the LSS projects rounds up to almost 130 000 euros.

Unfortunately, the authors were not able to collect qualitative information from companies who have received the graduates from our LSS course, but the feedback from our partners was nothing but positive.

Companies are conscious of the impact of going beyond the normal standards of engineering education has on real-life cases and the integration of new hires recently graduated from University.

Testimonials about the impact of the course on companies

What does it mean for students to able to acquire LSS knowledge so early in their careers?

“Learning LSS methodology has opened doors for students to perform projects, which they would not be given otherwise at that point in their professional career. This reflects the importance of training undergraduates in problem-solving frameworks.”

Jukkis Turtiainen, LSS Black Belt and Founder of the ESTIEM LSS course

How do you value the ESTIEM Lean SS Course?

“The LSS course is a great opportunity for the students as well as the companies that offer them a project. The students learn a structured problem-solving methodology that allows them even as young professionals to achieve results experienced colleagues could not achieve. Thus they become a great asset in any improvement project, develop confidence through the success of their project, and learn to trust the method and follow the facts. This will make them a very valuable employee for every company that sees continuous improvement as a key cultural element.”

How do you value projects coming from graduates of the course?

“The graduates from the LSS course employed by Continental have exceeded our expectations. In a recent project, the student achieved within four-month to generate an annual saving of more than 3 times the cost. So, it was a perfect investment. Continental will continue to offer projects to LSS graduates.”

Christoph Hagedorn, Head of Quality in Continental – partner of ESTIEM LSS course

ACKNOWLEDGMENTS

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CONCLUSIONS

Over the last two years, the authors provided LSS Green Belt level knowledge to 63 students without any costs, in addition to company visits, and real-life case studies to test the content acquired during class. Eight of those students were on their final year of bachelor and became ESTIEM instructors which gave sustainability for the years to come. The other 55 were in the first year of their Master's Program and they were presented with the opportunity to complete their thesis on an LSS project.

The goal of this article was to take the reader into the journey the authors took, once upon a time, and understand how to design a scalable LSS Green Belt level course in their own companies or institutions, by leveraging on our personal experience of diagnosing our client’s needs (in this case the students, university and industry around us) and creating a 10-week course from scratch aligned with the best courses of its kind in the world. By the end, it is about the impact of democratizing access to such a costly certificate, only acquired when one already has two to three years of experience, by implementing a teaching model blending theory with practice, with students teaching students, and endorsing the LSS movement.

This course not only gives students a structural way to solve problems but also opens future opportunities: they graduate more prepared to face the business world and they get better offers from better companies.

However, this project did not affect only the students. This Green Belt Course, by being associated with a University course, impacted the way knowledge was being shared and acquired in our degree, by putting the student at the heart of learning experience. By the end, students are not only receiving information but also, after taking the course, they have the opportunity of becoming trainers.

Finally, by implementing the LSS concepts based on the DMAIC cycle, students changed organizations' decision making and operation processes, by evolving to a more data-driven and quantitative approach. Not only these projects prove how students can change the organizations but also make the companies understand how impactful LSS can be to their activities and results.

Now, going back to the question made at the beginning of the article: how can the authors adapt and prosper in such uncertainty? By embracing and inciting change, and LSS has an important role in this pathway that companies and institutions must undertake. LSS, by being a problem-solving methodology based on projects focused process improvement, sets itself onto finding new, innovative, and impactful changes to scale upon the organization to higher levels of quality and efficiency. Implementing this university project not only introduced in a deeper way the LSS topic to engineering students, endorsing the methodology but also trained students to embrace, incite and manage change within the companies they will work in the future. By making LSS Green Belt knowledge easily accessible for these students, the authors gave them another tool to help them to think and question the world around them, and to look for great answers to take organizations to the next level.

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DMAIC for Process Digitalization: A Hospital Case Study

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ABSTRACT

Purpose - This paper presents how to implement the DMAIC cycle as an element to X-ray the progress of a digitalization initiative focused on the ambulance's request system for daily transport of patients initiated in a Portuguese hospital, which was not achieving the expected results. The research has the goal of not only contributing to the literature on the application of the Lean Six Sigma methodology to healthcare operations but also, of giving practical recommendations on how managers can leverage on the same approach, and apply the concept in their internal process improvement initiatives to reduce friction in digitalized processes. Ultimately, it is shown how a methodology like DMAIC, presents in itself a great option to start and methodically lead a business process digitalization project.

Methodology - The authors chose to follow an Action Research methodology while approaching the problem at stake with the DMAIC framework.

Findings - DMAIC can be a relevant problem-solving structure to measure the success and support the digitalization of business processes.

Originality – The originality of this paper lies in the application of a logical structure such as the DMAIC cycle to analyze the quality issues inherent to the digital version of an ambulance's request system.

Practical implications – This case study depicts how the operationalization of digitalization initiatives using the DMAIC framework can be more effective while allowing organizations to adequately and actively react to the implementation problems. It presents improvements of 23% lower lead times for a redesigned digitalized ambulance's request system.

Keywords: Healthcare, Lean Six Sigma, DMAIC methodology, Digitalization

Paper type: Case Study

INTRODUCTION

Healthcare today is said to be evidence-driven. However, even though huge amounts of data are collected, clinical practice is often not governed utilizing these data for learning, improvement, and innovation. With this said, even though individual health care professionals are performing excellent and dedicated work, the provider might be flawed in its core and patient outcome is far from optimal, or even unacceptable. With multiple problems caused by human errors, it is paramount to raise the bar for processes, services, and businesses (Taner, Sezen and Antony, 2007).

As we witness the emergence of new technologies, reduction of financial support and more informed customers, an increasingly challenging and demanding environment seems to be an underlying paradigm for the future healthcare industry. These services must now focus, more than ever, on continuously looking for methods for optimizing process performance, with technology as a potential ally for decreasing operational costs, improve the speed of service, and reduce risks and errors.

The need for such improvement initiatives is rooted in the rising expectations from customers (which are the patients, their family, and friends) regarding the quality of care they receive. They are no longer willing to accept poor quality services, and suffer long waiting times, on the contrary requiring transparency, and high-value interventions, with a minimal cost. In this scenario, Lean Six Sigma (LSS) principles and tools have been used to tackle principal causes of inefficiency, reduce slack, and optimize operations. It should be highlighted that LSS, with particular emphasis on DMAIC (Define-Measure-Analyze-Improve-Control), is not only a step-by-step guide to understand and deconstruct problems in a manufacturing setting but also business-related processes (Mast and Lokkerbol, 2012). Its importance is based on a data-driven view of the problem, with statistics and general analytics being used to support and improve business decision making (see, for instance, (Kuvvetli and Firuzan, 2019)).

In light of this research, the authors of the paper present and discuss the key characteristics and results achieved of an LSS project developed in a Hospital, focused on the ambulance’s request system digitalization initiative which results were below the expectations of the management team. It was deployed with the intent of understanding why there has not been visible progress on its implementation, and how much of the existing friction in the process could be mitigated. On top of this, it was also used to measure the impact of the potential digitalization of different steps, before any improvement foresight could be designed, while also looking for new ways to reduce the overall costs of the request system eliminating defective outputs which were identified along with the analysis.

RESEARCH METHODOLOGY

The paper presents a case study developed with an Action research perspective (Eikeland, 2012), where the authors worked closely with the parties involved in the process at stake. In detail, this section reports on the implementation of an LSS project in the Patient Management Department, with a focus on the ambulance's request system for patients with economic constrains or reduced mobility conditions in a Hospital of large size. Yearly, the Hospital performs around 2000 medical appointments/day, 120 surgeries/day, and a total of 5500 transportations per year. The project was developed over 3 months. Historical data was collected and analyzed before the beginning of the LSS intervention. Further data and information were collected and analyzed cooperating with the transport team in charge of the process and conducting several interviews with senior figures and professionals working in the Hospital and contacting daily with the procedure at stake. The main goal pursued with the LSS project was to increase physicians' productivity, reduce operational costs, and deliver services of increased quality. More specifically, the LSS project was aimed at reducing the resistance to the digitalization of the ambulance's request process and minimizing the errors associated with the requisition form. These errors lead to multiple problems, which are described and drilled down throughout this paper. DMAIC was selected to operationalize LSS and keep the different parties engaged, as subsequently discussed.

For the sake of confidentiality of the parties involved, the numbers presented in the paper may have been modified.

LITERATURE REVIEW

Lean Six Sigma:

LSS emerges as a viable option for improving performance at the level of effectiveness and efficiency, with particular emphasis on processes, within the reach of healthcare organizations (Bisgaard, 2009). Optimizing efficiency is one way for providers to control their costs without sacrificing the quality of the outcomes they plan to achieve.

Six Sigma is a data-driven process improvement methodology used to achieve stable and predictable process results, reducing process variation, risks, and defects. Snee, (2010) defined it as: "a business strategy that seeks to identify and eliminate causes of errors or defects or failures in business processes by focusing on outputs that are critical to customers". While both Lean and Six Sigma have been used for many years, they were not integrated until the late 1990s and early 2000s (Snee and Hoerl, 2007). Today, Lean Six Sigma is recognized as a business strategy and methodology that increases process performance, with DMAIC serving as the compass to guide the projects to success (Koning and Mast, 2006). Lean Six Sigma combines the best of two distinct methodologies:

- Six Sigma, which helps in reducing the number of defects and the variation of the outputs, improving overall process efficacy.
- Lean thinking which helps in reducing the cycle and lead times, improving overall process efficiency.

Although the Lean Six Sigma approach has in the past predominantly been used to improve manufacturing processes, it is now increasingly been transitioned to a wide variety of non-manufacturing related operations. This is an important development, as there are potentially more advantages to be achieved in those areas than in traditional manufacturing where decades of good work have already paid off (Nave, 2002). The key to understanding how Lean Six Sigma can be applied more broadly is to recognize that non-manufacturing operations are also processes; they process inputs from suppliers and provide output to customers. Some applications of Six Sigma have been suggested in healthcare (Barry, Murcko and Brubaker, 2002; Heuvel, Does and Koning, 2006). In the last-mentioned paper, project examples are highlighted, concerning complexity reduction in hiring personnel, improving operating theatre starting times, and improving a maintenance system. However, there has also been some endeavors usually approached from the perspective of efficiency of the management of flows (see, for instance, Hanne, Melo and Nickel, (2009)), as well as some examples on DMAIC as a methodology to improve software development (see, for example, Karout and Awasthi, (2017)), little research has been executed with interest on how Lean Six Sigma can help in endorsing the digitalization of processes by measuring its impact on the elimination of waste, errors, and overall quality increase of the results produced. Also, it can be a driver for understanding the underlying factors that cause resistance to the transition to digital processes, by always using DMAIC as the compass for the project. Taking this in mind, the authors propose a new paper to continue to fill the gap in the literature related to how DMAIC as a problem-solving framework, can be used in digitalization initiatives, using LSS principles in its core.

DMAIC Cycle:

Based on the defined objectives, this project was conducted under the umbrella of the Lean Six Sigma methodology. The selection of the tool to solve the problem presented fell to DMAIC. DMAIC is systematic and data-driven providing a sound framework of results-oriented for end-to-end project management. The methodology may appear to be linear and explicitly defined, but it should be noted that the best results are achieved when the process is flexible, thus eliminating unproductive steps (Sokovic, Pavletic and Pipan, 2010).

The DMAIC (Define-Measure- Analyze-Improve-Control) methodology, works as a roadmap for problem-solving and process improvement, making it the best candidate for the problem presented throughout this paper. It will be used to tackle it in five phases:

1. **Define (D):** Define the problem at hands;

The main purpose of this stage is to clearly define the problem to be resolved with all parties involved or affected by it. There is also the goal of verifying if the action plan, deliverables, and timeline for the project to be started are aligned with the priorities in the organization and its business objectives. There must be support from the management and availability of required resources to achieve success (Abu Bakar, Subari and Mohd Daril, 2015).

It starts with clarifying the problem statement and the overall advantages for the business.

2. **Measure (M):** Quantify the problem identified;

To better understand all the processes in the organization, customers' expectations, suppliers' specifications, and identification of the possible places where a problem may occur, it is important to qualitatively and quantitatively define the problem at hand. This allows not only more data-driven decisions on how to move forward but also a better understanding of the process improved in the Control phase by benchmarking the same Key Performance Indicators. In this stage potential problems have to be proven to be real problems.

3. **Analyse (A):** Analyse the problem and identify the root causes for process imperfections;

In the analysis phase, multiple tools and methods are applied, taking into account the data acquired and treated in the latter stage, to find root causes, assess the risk, and prepare the ground for improvement measures to be proposed. In this phase it is needed to define process capability, clarify the goals based on real data gained in the measure phase and start root cause analysis which has an impact on process variability and the errors produced as the process is executed.

4. **Improve (I):** Propose improvement measures to be implemented to achieve the goals set for the project;

The goal of this stage is to take necessary information to create and develop an action plan to improve the functioning of the organization, financial aspects, and customer relationship issues. The possible solutions for the action plan should be presented to the team involved in the process and executed iteratively. Some kind of pilot solutions should be deployed on a risk-reward optimization basis, confirming the validity and accuracy of analytical work which allows making any corrections before carrying out the solutions on a large scale.

5. **Control (C):** Create mechanisms to help continue to measure the evolution of the changes applied to the process and guarantee their continuity in the future. Also, aims at building another step on the continuous improvement journey, making sure that the level of operational excellence achieved is set as the basis for further initiatives.

The control stage is about confirming if the changes implemented at the *Improve Phase* are sufficient and continuous by verifying the quality of the re-designed process. It also controls the future state of the process to minimize variation from the objectives and ensure that the correction is fully implemented before generating results misaligned with the business targets. Control systems such as statistical process control should be implemented. The process has to be continuously monitored.

Each of the phases D, M, A, I, and C encompasses in itself several steps and tools to be applied (Shankar, 2009), which will guide through the execution of the presented improvement project, from identifying the problem to measuring it, and correcting it taking into account the targets to be achieved.

CASE STUDY

The project first arises because of the need to reduce backlogs detected in the administrative processes within the Hospital, which were causing delays in patient-related activities, such as the lead time of accessing personal clinical records, or of receiving confirmation of the right ambulance at the right time to transport patients from their homes to the scheduled appointments, and vice-versa. This paper aims to describe a real case study focused on internal administrative processes presented by a Hospital's Senior Management team in Portugal converted into a Green Belt level Lean Six Sigma project and tackled using the powerful problem-solving framework - DMAIC, to diagnose the operations and understand where divergences from the documented procedures are happening, and, not less important, why they are happening. This supports the creation of new procedures and the re-design of existing ones.

In the end, it will be presented the analysis made to the process of scheduling ambulances for trials, exams, hospital stays, and medical appointments happening on the same day of the request. The project of digitalization of this business process, transitioning to an entirely paperless task, was not running as expected. This procedure was generating a lot of faulty requests, to mention a few:

1. The wrong type of ambulance;
2. Ambulance requested without the needed equipment for transporting a patient with a particular condition;

3. Requests made for the wrong time, or day;
4. Requests for transportation without having any link with a medical appointment;
5. Transports that were activated and paid for, but never happened in practice.

The goal was to redesign the process reducing the steps needed to register the request of a new ambulance, reducing defects and money lost with faulty requests. On top of this, to understand where and why the digitalization initiative was falling behind the targeted results.

The Hospital was testing the hypothesis of digitalizing most of the process activities related to the ambulance’s procedure described above, to achieve 100% paperless requests in all medical wards. The problem was suffering from a lot of resistance from the parties involved (physicians, nurses, secretariats of the medical departments, etc). With it, the physicians were fully responsible for the end-to-end process of requesting an ambulance. Thus, the analysis done was also focused on endorsing this digitalization project with proposals to help the transition. Future yearly savings were calculated to support its scaling to all the medical specialties where patients needed transportation.

Phase 1: Define

The research study started with a meeting in the Hospital to discuss the problems to be solved. To clearly understand the situation and the underlying bottlenecks disrupting the expected workflow, more than 40 people were interviewed, from physicians to the secretaries of each medical specialty in the Hospital. On top of this, it was crucial to set a line between the current ambulance’s prescription process (in a paper format), where the secretary of the medical ward was the central piece, passing the information from a physical form filled by a physician into an IT system, and the fully digitalized process, where the physicians were fully accountable for requesting an ambulance to transport the patient in the day of the appointment. This way a paperless process could be achieved. The digital request would then reach the “Ambulances team”, which would follow-up with contracting a company to execute the trips needed, at the time needed, and issue the responsibility terms for the transportation of a patient.

To make sure, everyone in the team responsible for leading this project was aware of the goals and had the same level of understanding of the problem, a project charter was created and presented. The data needed to start was also defined and requested for senior management.

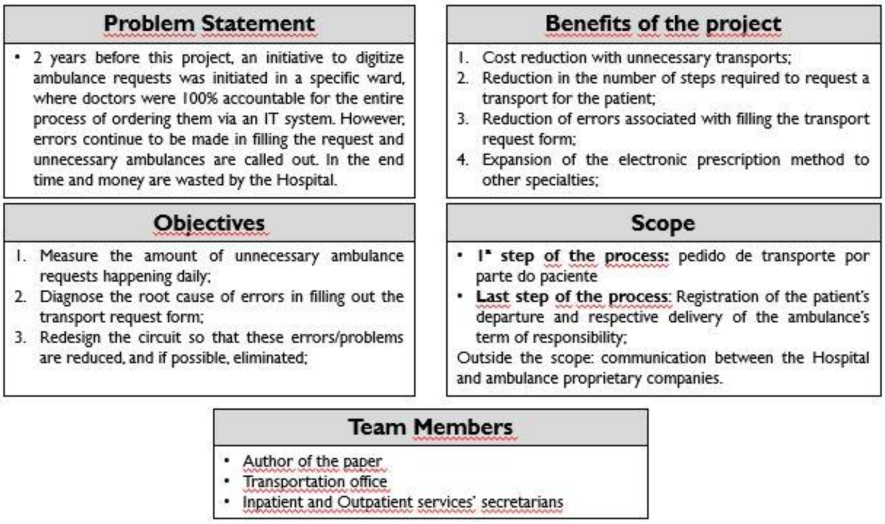

Figure 1: Project charter

As one of the focus of the whole Lean Six Sigma methodology is to center the analysis on the customer's requirements, his needs regarding how the process should behave and which outputs should produce had to be defined from the start. In this case, the customer is always the patient, and all processes should be designed taking him into account.

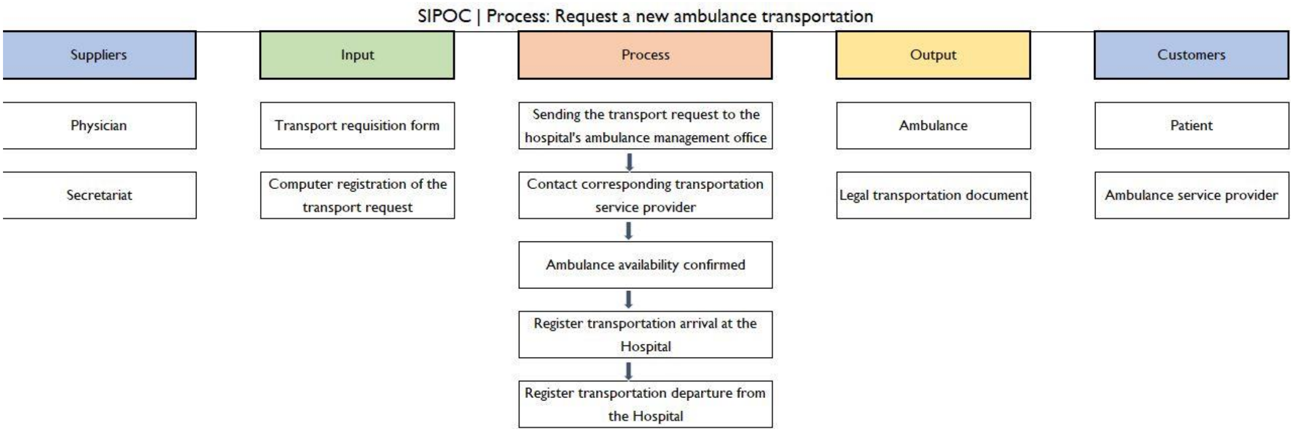

Figure 2: SIPOC map to create a high-level view of the ambulance's request process

The main requirement of the patients was to have the needed transportation on the exact date, at the exact time so that they would never miss an appointment. As most of the patients with access to this kind of service were mostly elders, to provide high-quality service the request's process needed to run smoothly with the greatest effectiveness and without any unnecessary delays.

To understand how the current parties involved in the process viewed the situation, a Voice-of-the-Customer (VOC) matrix was created to collect and prioritize each staff member's opinion regarding the defined problem. This gave the improvement team deep insights from those directly involved with the situations created by a poorly designed procedure. The prioritization was calculated by multiplying 4 different metrics, defined alongside senior management: frequency, impact on quality, level of dissatisfaction, and the level of risk to the customer.

Who?	What are they saying?	Why are they saying it?	What do they want?	Grade
Secretariado	Tratamento da documentação não é eficaz	Muitas vezes documentos são perdidos, esquecidos ou nem entregues na secretaria	Haver preocupação do médico em explicar ao doente o processo de requisição de transportes	28.8
Central de transportes	Folha de requisição dos tranportes é mal preenchida	Não são preenchidos todos os campos necessários: datas incorretas; incoerência com os episódios clínicos	Sejam impostas regras de preenchimento para perderem menos tempo e reduzirem os erros na chamada de transportes	57,6
Coordenador	Central de transportes tem problemas internos de comunicação com os secretariados	Consultas com transportes afetos são remarcados sem a central de transportes ser avisada; não é verificada se há realmente transporte para aquela nova consulta	Estar indicado de alguma forma que aquele paciente tinha um transporte alocado // Criar um mecanismo de segurança para estas coisas (doentes que já se sabe que têm transporte terem um procedimento próprio para estes casos)	51,2
Central de transportes	Médico devia ser responsável por preencher todos os campos clínicos incluindo a justificação	Dá informação importante às cooperativas para prepararem os transportes corretos, de acordo com a condição do paciente	Que sejam impostas regras de preenchimento, para o médico e secretariado ou que tudo seja lançado informaticamente pelo médico	51,2

Figure 3: Voice of the Customer matrix

Using the VOC, the team was capable of further narrowing the analysis from 10 different directions to only 3. These were the basis for the investigation shown in the Measure phase.

Phase 2: Measure

In the Measure phase, both the standard ambulance request's system and the digitalized one were mapped and analyzed to identify the value-adding activities. By defining the steps in the process, which contribute with value to the patient, it is possible to start designing a roadmap to optimize them and reduce or, if possible, eliminate the ones that do not add value to the desired outcome. In the case of the first process, only 75% of the total activities taking place in the process currently implemented for scheduled transport, add value to the patient. On the other hand, only 70% of the total activities taking place on the digital circuit currently implemented for daily transport, add value to the patient.

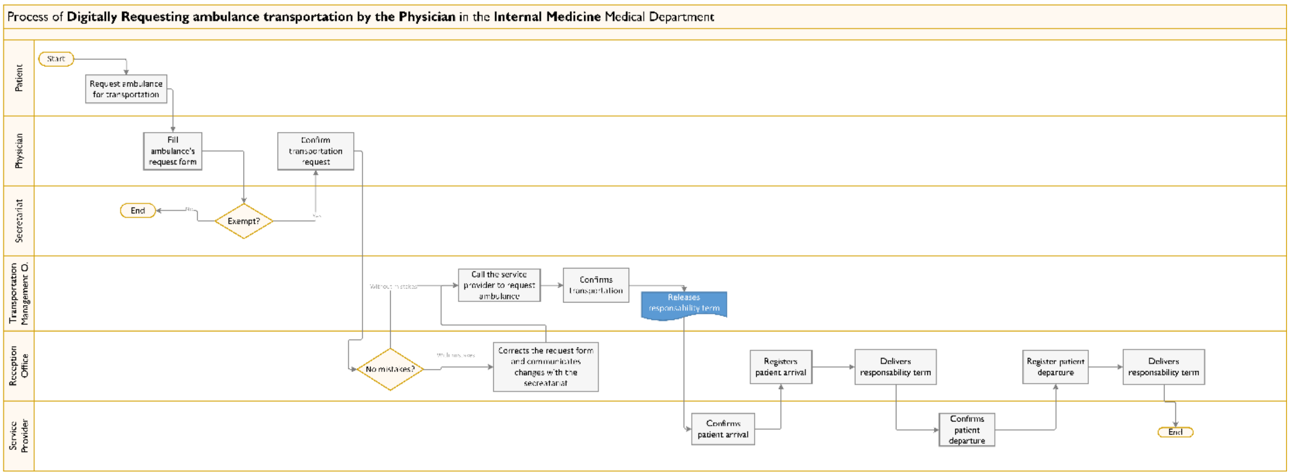

Figure 4: Deployment diagram of the digital request of ambulances

Here, it is presented the deployment diagram for the digital prescription model and the original model used in all other specialties, albeit with constraints. The digitalized process took only 16 steps to achieve the goal of setting up transportation with a company, whereas the other one took 21 activities in total to fulfill the objective, and one more lane (intervenient/resource for the process to be executed). This means that, even with all the inefficiencies present in the digital prescription process, there is already a 24% reduction in the total number of activities/steps needed to perform to complete the procedure. In terms of lead time, the digitalized request system takes less than 9 minutes than the standard procedure, making it a much better choice for the future.

KPIs	Standard Request System	Pilot Project (Digital Prescription)	Advantages of the Digital Model
Nº of steps needed	21	16	*24% fewer activities*
Nº of people involved	7	6	*15% fewer intervinients*
Lead Time (minutes)	32,5	23,5	*28% less time needed*

Figure 5: Comparison between standard and digitalized request's process

These measurements gave management a better understanding of the advantages of a paperless system, where the physician is the one responsible for filling the digital form and requesting the ambulance for the patient, without needing the involvement of a second party – the secretary of the medical department.

However, as both processes were being mapped through walk-throughs and interviews with personnel, different problems became evident. These are, as follow:

1. The physician is still dependent on the secretary to check if the patient is entitled or not to have transportation financially supported by the Hospital;
2. The responsible for the reception welcoming all patients arriving with ambulances has to check each transport documentation of this type to ensure that they are well done;
3. There is no control over the entry and exit of users. Ambulance staff, which are not working for the Hospital are responsible for confirming and validating these events. This leads to errors in the count of patients and, as a consequence, in the payments to be formalized by the hospital.
4. Lack of a control mechanism for the single-way trips, to check if the patient warned or not that he did not need transport. Many times, in cases where only single-way trips are happening the patient alerts the ambulance's companies that another person will pick them up, and, thus, there is no need for transportation financially supported by the hospital. However, taking advantage of the current system, the companies perform the trip either way, without informing the hospital, and then demand the payment.

Following the identified problems, mentioned above, a root cause analysis was performed and presented in the next stage.

Phase 3: Analyse

Taking into account the multiple disturbances detected when the staff was requesting ambulances, a fishbone diagram was used to categorize problems, and link them with two main issues: unnecessary ambulance requests, and resistance to the transition to a paperless model. From it, 7 root causes were selected as the main drivers of the problems that arise constantly. These problems are:

1. With the digital prescription, nurses no longer had access to the scheduled transport time for the patients they are following, which leaves them a little lost when it comes to preparing patients for departure;
2. The system allows transports to be scheduled when the patient is still hospitalized;
3. There is no guide to assist in filling out ambulance request forms in the IT system;
4. Physicians, now 100% responsible for filling out digital transport order forms, still ask their secretariats for help in many of the requirements;
5. Physicians do not inform changes in medical appointments for patients with a scheduled ambulance, which leads to an unnecessary ambulance trip to pick up a patient with no appointment in the Hospital;

6. There was little involvement of physicians, nurses, and secretariats (the main stakeholders of the process) in the transition to 100% digital requisitions;
7. Lack of feedback meetings throughout the implementation process.

Most of the time, ambulance's proprietary companies are called to do a transport when the patients had their stay in the Hospital extended due to multiple reasons. This situation leads to unnecessary trips for the companies, and payments with no justification for the Hospital, as the patient does not need the requested transport. To tackle this, the Hospital assembled a workstation to verify if each patient needed an ambulance, by calling them one by one (feasible in this case of schedule trips to check if they had already someone to pick them up, and thus no need for transportation by other means or their stay was extended, or appointment rescheduled. However, this station was terminated, because there was the belief it was not changing anything.

To understand the impact of this workstation, and thus, on the Hospital's financials, a Pareto chart was used, to check how many requests were canceled, due to the work described above, and the main reasons for cancellation. By knowing the reasons for cancellation, more granular improvement measures could be recommended to the management team.

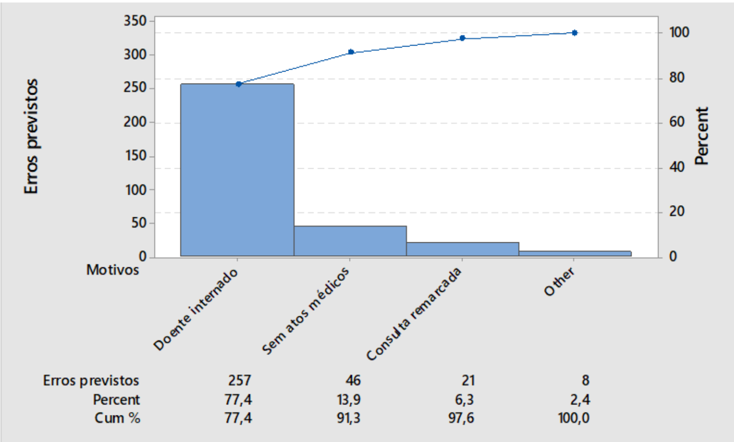

Figure 6: Pareto Chart on the reason for the cancellation of ambulance requests

As seen in the image above, 80% of all the cancellations result from the situation of a patient still being in the Hospital, and almost 10% resulting from cases where there was not any medical act scheduled for the day of the transport. The problems of internal communication – staff from the medical department or even the software used to manage information not alerting the transport's team that a patient with medical acts is still undertaking exams, and thus does not need the scheduled transportation, or, ultimately, needs it to be rescheduled, costs around 10 000 euros to Hospital annually.

In the case of the single-trips that are executed by the ambulance's companies, without a confirmation that the patient is indeed transported costs to the Hospital (in the cases where the transport is issued, and the payment is demanded by the companies) around 40 monetary units. As said previously, these are driven by a lack of control of which patients arrive or depart from/to the Hospital. This information is given by the ambulance's staff, which are not employees from the Hospital. Also, there were some cases detected were the companies went directly to the hospital, stating that the patient was not home, but in fact, the patient communicated that did not need transport, so the Hospital should be informed and cancel the payment.

Calculations lead the author of the paper to predict savings of around 70 monetary units, and less 95 ambulances requested within a year.

Phase 4: Improve

Considering the latter stages, an improved process was proposed as follows:

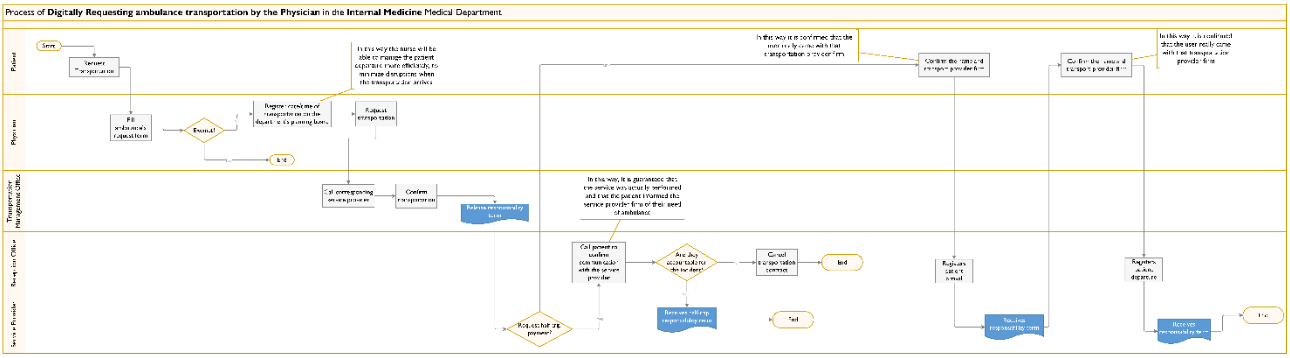

Figure 7: Deployment Diagram of the improved process flow

1. The physician is responsible for placing the date and time of transport on the whiteboard of the service so that the nurse and the secretariat have this information always available;
2. A guide with quick questions and answers was built to assist physicians and the secretariats to answer issues about filling the digital request form, and thus minimize errors;
3. When it comes to single-way trips, the transport's reception is responsible for contacting the patient and confirming that the companies went to the home of the patient and that there was communication between both parties;
4. Entrances and departures are given by the patients themselves, indicating the name and carrier with which they came / will go, to prevent cases in which "ghost transports" occur;
5. Formal workstation dedicated every working day to call the scheduled patients 1 day before to confirm the need for transportation.

Applying the proposed improvement measures, it is expected that the quality of operations improves considerably.

KPIs	Digital Transport Request	Improved Digital Prescription process	Winnings
N° of activities	16	14	12,5%
N° de intervinients	6	5	17%
Lead Time	23,5	18	23%

Figure 8: Comparison between current digitalized process and the proposed process

Phase 5: Control

To assure the continuity of the improvement measures proposed in the "*Improve phase*", a control plan was established and presented as follows:

1. Secretariat should be involved in administrative process improvement projects;
2. Weekly meetings should be scheduled to collect feedback and understand the obstacles that have arisen in the implementation of the pilot project;
3. Constant training must be given to the physicians with the goal of mitigating errors regarding the type of ambulance, time and date fulfillment in the transports requisition online form;
4. Training and follow-up should be given to requesting doctors, as a way to reduce resistance to the transition to a paperless requisition model;
5. Create a data culture, so that metrics associated with the quality of processes are constantly collected and analyzed (time is taken, number of steps, number of people involved, constraints, etc.)
6. In the period of transition to the digitalized process, in which transport arrivals and departures are given by the patients themselves, information must be transmitted to patients and carriers consistently and effectively. Carriers should be involved as it is also in their interest to optimize ambulance utilization.

These recommendations have the goal of realigning the parties involved and helping the management team to continue to push digitalization, by monitoring crucial Key Process Indicators used to analyze and compare processes throughout the DMAIC cycle.

CONCLUSIONS

LSS as a concept with its practical application mostly in the form of DMAIC in improving administrative processes in both manufacturing and service companies has been already in use for several years. Still, it can be said that the application of the Six Sigma-driven thinking in healthcare-related processes is still to be mainstream in management practices, because of the difficulty to implement and control improvement measures, and every successful use case provides another important example to build on existing knowledge. Successful execution of simple projects in hospitals can enable practitioners to tackle tougher initiatives in the future and create clinical/non-clinical process transformations on a broader scale.

Achieving Six Sigma level in operations requires organizations to have a macro and micro understanding of their operations, the underlying drivers for processes variability, and the effective and continuous assessment of their costs. The operationalization of such initiatives following a logical structure such as the one provided by DMAIC can increase the effectiveness while allowing an adequate and proactive answer to expected roadblocks in every transformational project. Appropriately implemented, it produces benefits in terms of better operational efficiency, cost-effectiveness, and drive higher process quality, which then translates in greater profit and higher customer satisfaction. Also, it has the potential of driving improvement in a set of different verticals within a Healthcare provider, such as infection control, surgery room turnover, or access to clinical information.

In the exposed case study, the proposed solutions may bring many different benefits not only for the Hospital, but also for the patients it serves, and the employees involved in the ambulance request system. The benefits of this implementation can be as follows:

- *Hospital* – savings of around 70 monetary units, with the mitigation of unnecessary requests of ambulances and correcting transportation requests related to single-way trips;
- *Patients* – Increased customer satisfaction, as they receive their transport when they need it, at the right time, with the right characteristics;
- *Employees* – Less time focusing on correcting incorrect ambulance requests. Time saved in reworking is time utilized for the effective execution of activities and services, which is added to productivity.

As presented, it can be used to analyze the impact of the digitalization of specific business processes building a benchmark with the original manual operations, while still looking for ways to reduce the friction in the new one. For the ambulance’s request system, a new digitalized process was proposed with an expected reduction of 23% in terms of lead time since the moment the need for a transport triggers the request of a new ambulance until the patient arrives or departs from the Hospital. Also, other issues in the process were identified, related to an excessive request of ambulances which represented a significant overhead cost for the Hospital, for which improvement recommendations were proposed.

As a closing remark, the authors see the need for LSS in the digitalization era, applied in close collaboration with other process improvement tools, such as process mining and other advanced process analytics methodologies, to improve the results of the implementation of new technologies and other data-driven transformations.

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ISO 9001 and Organizational Excellence Models in Small and Medium Sized Enterprises: Current State and Comparative Analysis

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STRUCTURED ABSTRACT

Purpose - The purpose of this paper is to understand the current state of quality management practices in Small and Medium Enterprises. The main concepts of Quality Management and its practices in Small and Medium Enterprises were reviewed from the literature in order to understand the key practices in these organizations, and a data analysis on their use was performed.

Design/methodology/approach - Analysis was performed by consulting and understanding the evolution of Organizational Excellence Models and Quality Management Systems. This research incorporates data since the beginning of the 90's from the last century and allows us to comprehend how these models and management systems have evolved and if there is any correlation between the adoption of each one of them- evaluation of interdependencies.

Findings - The findings suggest that while the number of ISO 9001 certified companies has increased over the years, the number of organizations accessing Business Excellence frameworks have been decreasing. The available data suggests that Small and Medium Enterprises seem to follow these trends. It is particularly noticed that there is a considerable gap between Small and Medium Enterprises and Large Enterprises in the usage of Business Excellence frameworks.

Originality/value – This article offers a global perspective of the current state in the use of ISO 9001 and Organizational Excellence Models by Small and Medium Sized Enterprises (SME's).

Keywords: Quality Management, Small and Medium Enterprises, ISO 9001, Business Excellence Frameworks.

Paper type: Research paper

INTRODUTION

Implementing a quality program is no longer a privilege directed towards large enterprises (LE) (Kratochvíla & Friedecký, 2010). The market in which SMEs operate is extremely competitive (Man, Lau, & Chan, 2002). On the one hand, modern consumers are more conscious and demanding (Braskamp, Brandenburg, & Ory, 1987), and these companies need to secure their success in their markets while exploring new ones. On the other, and faced with fierce competition, SMEs find it is fundamental to reduce costs associated with management and production, through quality management. This can only be consistently achieved with well-structured quality programs that solve problems throughout the entire company (Kratochvíla & Friedecký, 2010). Throughout the years, it has been noted that SMEs use ISO 9001 and Business Excellence (BE) frameworks to achieve higher performance levels (Astrini, 2018). Some authors argue that ISO 9001 is the right choice for SMEs, offering the same benefits to these companies as to LE. It is also reported that BE frameworks play a big role on maintaining SMEs competitive in the different markets they operate (Bauer, Falshaw, & Oakland, 2005). Thus, with this study the research team intends to analyze the tendency among SMEs to access ISO 9001 certification or the implementation of a BE framework. In order to this, an initial extensive literature review was undertaken focusing on the topics of Quality Management, SMEs, Quality Management in SMEs, ISO 9001 and Business Excellence frameworks. Furthermore, and in order to complement this review, a data analysis is presented on the dissemination of ISO 9001 and BE frameworks across the world. The data available for ISO 9001 includes both SMEs and LE, as it is not possible to analyze SMEs individually provided on ISO official database. Regarding BE frameworks, data was collected from the databases of all three models studied in this paper (EFQM Model, Malcolm Baldrige Framework and Shingo Model), and the research team analyzed which reported companies are SMEs or LEs. Before advancing with this work, it is important to acknowledge that there are several definitions for what characterizes an SMEs. Therefore, a definition must be adopted. In the context of this study, SMEs will be those organizations which employ less than 250 employees, in line with the numbers that the European Commission establishes.

LITERATURE REVIEW

Current State of Quality Management in SMEs

Quality has been a part of LEs for more than 30 years. However, only recently this concept became widely used in SMEs (Rocha Kachba, Souza Plath, Gomes Gitirana Ferreira, & Forcellini, 2012; Assarlind, 2014). In fact, LEs already used quality management because of their extensive amount of resources. In contrast, with more limited resources, SMEs cannot invest as much as LE in-quality management (Wierzbinski, 2015). However, SMEs have a clear understanding of the impact that quality has in the pursuit of their in organizational objectives. Quality can bring costs down and promotes processes efficiency, which culminates in an increase in competitiveness (Assarlind, 2014). Quality has come a long way to get to the point it is today. This long journey was made up of complex steps, which led to quality of processes, products and organizations (Toma & Marinescu, 2018). From its debut in 1984, ISO 9001 quickly became a world-class management system (Natarajan, 2017). This resulted in companies, including SMEs, looking for this certification to ensure competitiveness. Since the late 1980's, also Business Excellence frameworks established as world class models to achieve organizational excellence, drawing the interests of both LEs and SMEs (Baporikar, 2017). This had much to do with the evolution and increased competitiveness of the marketplace: while ISO 9001 provides the standards and specifies requirements for a quality management system, BE integrates the different dimensions of quality in an organization and provides the criteria to help deploy quality through performance. Nevertheless, ISO 9001 is still used by companies worldwide to ensure stable and reliable quality management systems and is often seen as the first step in a path towards quality and excellence (West, 2008).

Over the years, new quality tools and philosophies have been developed. Thus, both the implementation of BE frameworks and ISO 9001 certification have suffered changes. These changes have led some authors to become increasingly skeptical about these methodologies. Some quality experts argue that managers have lost focus of ISO 9001 as a management system, starting to see it as a marketing tool to enter new markets (West, 2008). Additionally, several reports and scientific papers report that BE frameworks were specifically designed for LE, making it hard for SMEs to successfully implement and efficiently use these models in their full potential (Dahlgaard, Chen, Jang, Banegas, & Dahlgaard-Park, 2013). Although shorter, adapted versions of these models have been developed later with a focus on SMEs, this does not seem to be enough to fully align with their needs (Olaru, Dinu, Stoleriu, Sandru, & Dinca, 2010). SMEs comprise more than 80% of worldwide companies but LE are still seen as priorities when looking for answers when they report problems (McAdam, 2000). In face of this reality, quality professionals must look at ISO 9001 and BE frameworks and analyze their implementation in SMEs. With this study, we intend to partially do that, uncovering gaps and opportunities for Quality Management in SMEs, and laying the ground for further understanding in this field.

ISO 9001 and Quality Excellence

There are many reasons for a company to decide to implement a Quality Management System (QMS), such as those established by the ISO 9001 standard. However, all those reasons usually share one main objective, which consists in costumers' satisfaction (Oliveira, Corrêa, Balestrassi, Martins, & Turrioni, 2019). Managers need to have a vision that their customers do not change supplier if they are satisfied with the service or product consumed (Vermeeren et al., 2014). With a QMS implementation, production will increase by eliminating waste (Psomas, Fotopoulos, & Kafetzopoulos, 2010).

Studies have revealed the following results for the factors that costumers consider most important when buying a product: (1) Performance, (2) Durability, (3) Ease of use and reliability of after-sales service, (4) Price, (5) Design and, finally, (6) Brand (Douglas & Davies, 2005; Psomas et al., 2010). The objective of implementing a QMS in SMEs -besides costumers' satisfaction - has thus to do with the numerous process-related advantages that these companies could obtain if the implementation process is successful (Ahmudi, Purwanggono, & Utami Handayani, 2018). Companies that adequately meet the principles of quality management can implement a well-structured QMS allied to continuous improvement, guaranteeing the success of the organization in the search for the best service to the external and internal costumers (Ahmudi et al., 2018). In fact, over the last decades SMEs have been searching for programs or methodologies that allow them to meet continuous improvement and become the best version of themselves. In this sense, they also have been trying to access excellence programs. These programs are commonly taken in the form of the implementation of BE frameworks. In what concerns to this study, we will address three models that are frequently used worldwide, consisting in the European Foundation for Quality Management (EFQM) Model, the Malcolm Baldrige Framework and the Shingo Model (Yusuff, Ismail, Ismail, Zadeh, & Jassbi, 2012; Baker, 2016; Prize, 2018; R. Edgeman, 2018). A BE framework is a set of good practices that allow the implementation of a results-oriented organizational culture (R. Edgeman, 2018). There are three main models that are used in different regions in the world. First, we have the EFQM Model, mostly used by companies based in Europe (Young Kim, Kumar, & Murphy, 2010). In addition, there is the Malcolm Baldrige Framework, being this one mostly used by companies based in North America (Kumar, 2007). Lastly, there is the Shingo Model, being this one used by companies based in several countries, all over the world (Prize, 2018). In this study, we will focus on the phenomena of the dissemination of these three main models and the QMS ISO 9001 among SMEs.

SMEs' Perception on ISO 9001 and Business Excellence Frameworks

Organizational excellence is the standard that all organizations aspire to achieve (Yarrow, Robson, & Owen, 2004). Usually, these organizations already have mature QMS and the motivations for moving to a total quality management approach are expressed proactively, even when customers had a significant influence on the adoption of ISO 9001 (West, 2008). On the other hand, organizations' social responsibility is increasingly more important, with the emergence of issues related to ethics, and environmental and social aspects, which promote a global perspective inside organizations and increase the integration of various aspects of quality through BE frameworks (R. L. Edgeman, 2000; Ruiz-Carrillo & Fernández-Ortiz, 2005; Latham, 2013). Many organizations consider the competitive advantages of ISO 9001 exhausted. However, they do not advance to different approaches regarding quality management, due to constraints of different orders (West, 2008; Sfakianaki & Kakouris, 2018). The most common constrains are economic or related to organizational culture. Besides that, many organizations consider that QMS and BE frameworks compete for the same space inside an organization (Russell, 2000). This a limited view, since ISO 9001 and BE frameworks can be adopted as complementary methodologies (Gotzamani, Tsiotras, Nicolaou, Nicolaides, & Hadjiadamou, 2007; Araújo & Sampaio, 2014), rather than as an option or choice that the organization must perform. Nevertheless, regardless of its many advantages, both ISO 9001 and BE frameworks have been criticized by different authors. In fact, some researchers look at ISO9001 as a marketing tool and not a management system that promotes organizational success (Psomas et al., 2010; Nikpour, 2017; Sfakianaki & Kakouris, 2018). It is reported that many companies use ISO 9001 certification as a marketing tool to get more costumers and partnerships, instead of taking advantage of all its potentialities. Regarding BE frameworks, many companies report that they are too complex and decontextualized from SMEs' reality and market (Ghobadian & Gallear, 1996; Armitage, 2002). Thus, SMEs feel very reluctant to implement a BE framework since they feel they have been developed for LE's purposes and not theirs.

RESEARCH METODOLOGHY

This analysis was performed by consulting the data on the use of different Organizational Excellence Models and ISO 9001 certification. However, it must be recognized that the type of data available for public assessment brings some limitations to the analysis, such as: not all ISO 9001 certified companies are registered in the database to which we had access; Several companies implement Organizational Excellence models, however don't formally register this implementation. This research incorporates data since the beginning of the 90's from the last century and allows us to comprehend how these models and management systems have evolved and if there are any clear trends on the adoption of each one of them. Data was collected from the ISO Survey database concerning ISO 9001 diffusion (ISO Committee, 2020), and from each Business Excellence Framework official website (Baldrige Award Recipients Listing | NIST, 2020; EFQM, 2020; Utah State University, 2020).

Data was aggregated and systematically analyzed in such a way that it was possible to evaluate patterns in the cumulative number of companies that are ISO 9001 certified or that implement organizational excellence models. The comparison between ISO 9001 certification and the implementation of organizational excellence models enables the possibility of exploring whether there is a connection between ISO 9001 certification and the implementation of OE models, or whether the introduction of such a model corresponds with a decrease in the introduction of others.

RESULTS

Diffusion of ISO 9001 Certification

As it becomes patent from the literature review, it is of the utmost importance to understand what has been happening in companies in terms of quality practices- more specifically in what concerns the adoption of Business Excellence frameworks and the pursuit of ISO 9001 certification. Figure 1 shows the data for the diffusion of ISO 9001, between 1993 and 2017, in Europe, North America and worldwide. It is notorious that this QMS has been consistently used by companies, regardless of the geographical place. However, as reported in the literature review, we must recognize that many companies adopt ISO 9001 as a requirement from clients and not as a strategic tool for organizational performance, which will not translate into the achievement of the very best results allowed by the deployment of QMS. Even though the data collected encompasses all types of companies (SMEs and LEs), since SMEs comprise more than 80% of worldwide companies (Wang and Wang, 2011), the evolution shown in Figure 1 is expected to, to a large extent, represent also the behavior of SMEs. Furthermore, the growing use of ISO 9001 by SMEs has been consistently reported (Brown, van der Wiele, & Loughton, 1998; Ilkay & Aslan, 2012; Astrini, 2018).

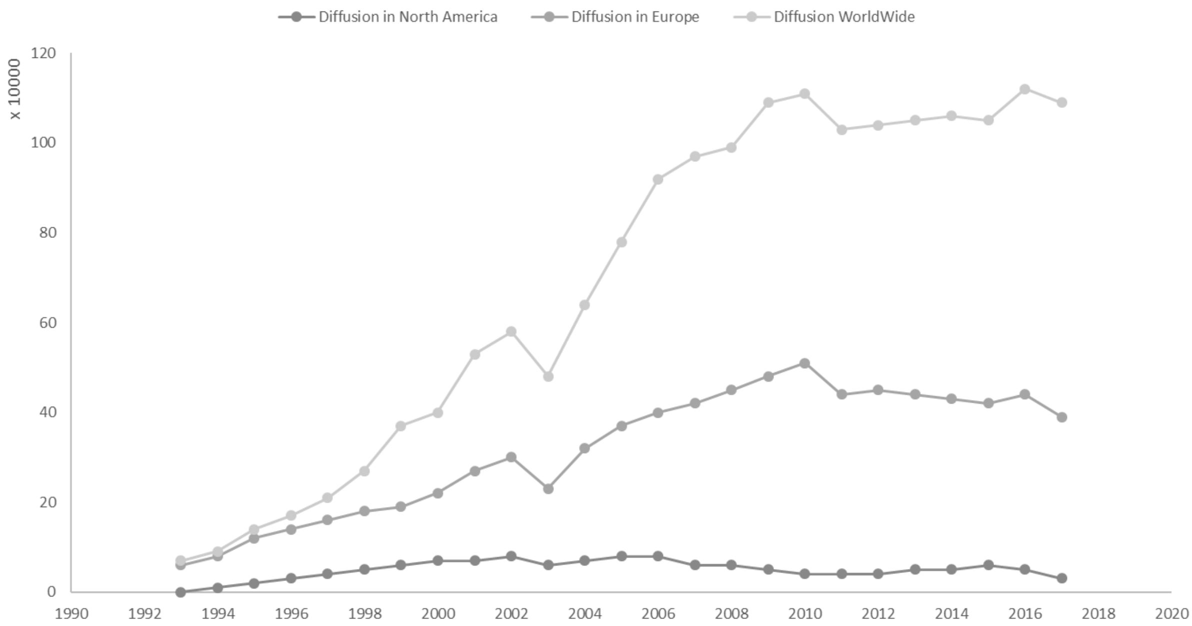

Fig. 1. ISO 9001 diffusion (ISO Committee, 2020).

Diffusion of Business Excellence Frameworks

Regarding BE frameworks, the database format for each framework made it possible for the research team to verify which companies implementing the models are SMEs or LEs. Starting with the EFQM Model, shown in Figure 2, the scenario is very different from the one we saw regarding ISO 9001. In fact, throughout the years the use of the EFQM Model has been fluctuating both for SMEs and LEs. However, what stands out the most is that, since the beginning, there were always more LEs using the EFQM model when compared to SMEs. This may be a result of what was previously reported in the literature review- SMEs find BE frameworks too complex and decontextualized from their reality.

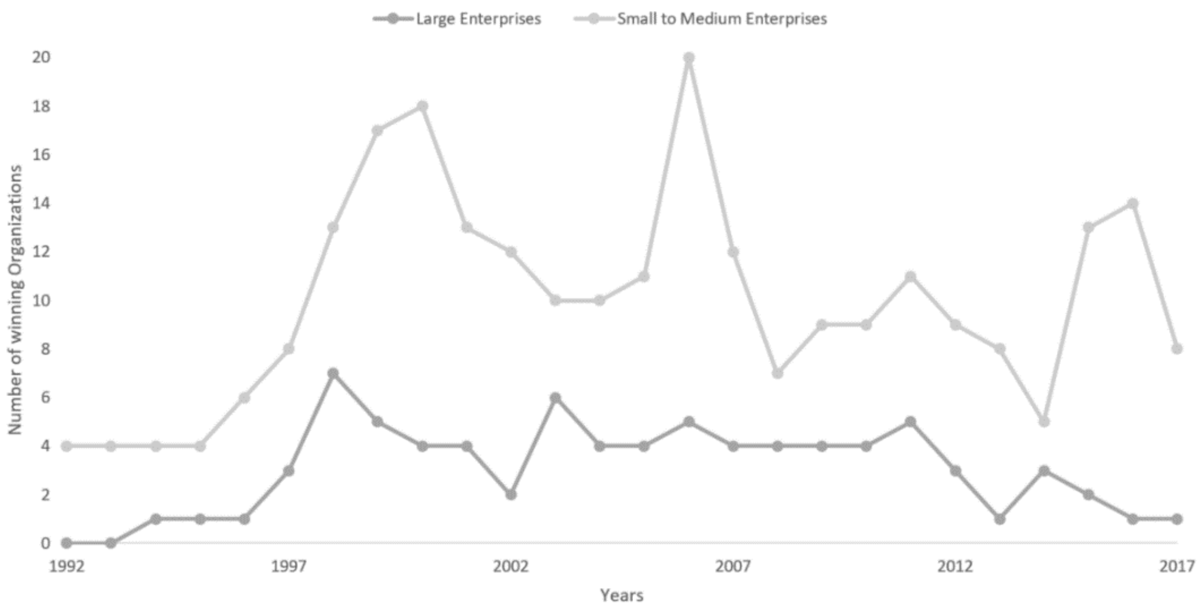

Fig. 2. EFQM Model diffusion (EFQM, 2020).

If we outline the data in a pie diagram (Figure 3) is easy to notice the astonishing difference between SMEs and LE when it comes to the EFQM Model implementation. In fact, only 19% out of more than 350 companies that use/have used the EFQM Model are SMEs.

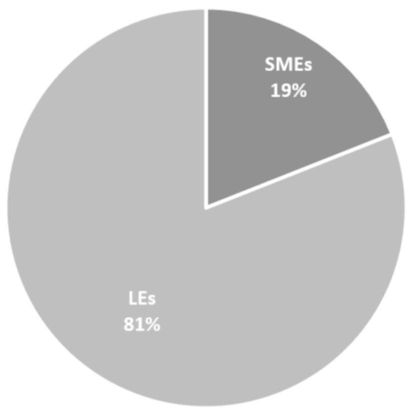

Fig. 3. Percentage of large enterprises and small and medium enterprises using the EFQM Model (EFQM, 2020).

When we access the data for the Malcolm Baldrige Framework the scenario is not very different from what was determined for EFQM (Figure 4). In this case, since 1998, the difference between LEs and SMEs accessing this model is even bigger and, for more than 20 years, there has been multiple LE implementing the model and few to none (depending on the year) SMEs accessing it.

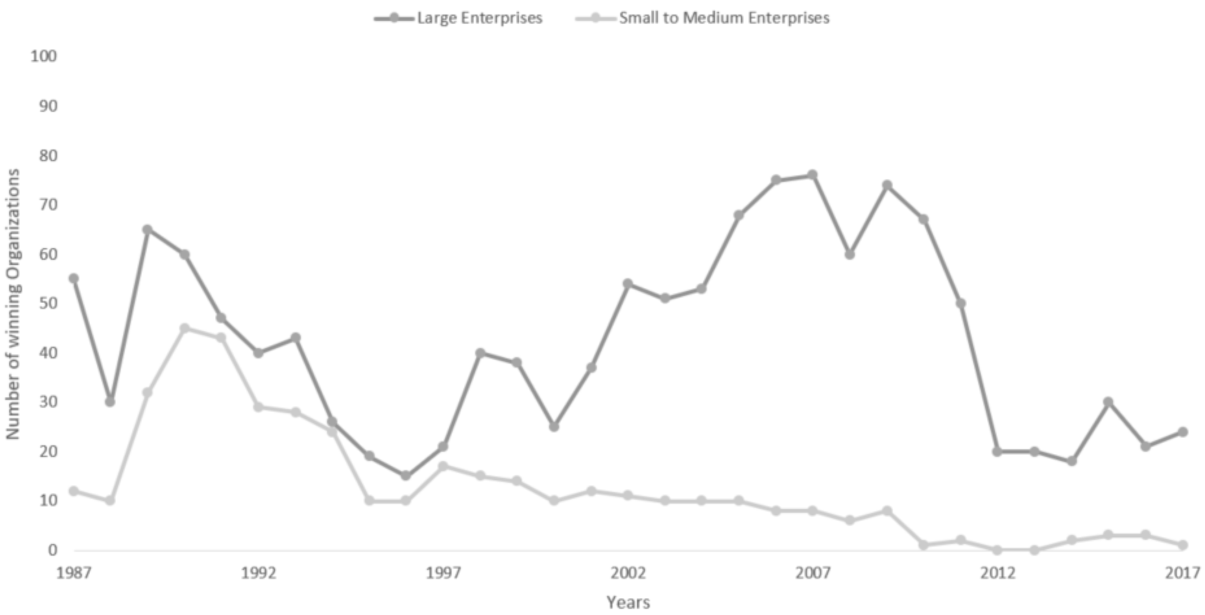

Fig. 4. Malcolm Baldrige Framework diffusion (Baldrige Award Recipients Listing | NIST, 2020).

By compressing the data in a pie diagram (Figure 5) is notable that out of more than 2000 companies accessing the Malcolm Baldrige Framework since 1987, only 7% correspond to SMEs, being this even a more worrying scenario than the one showed previously.

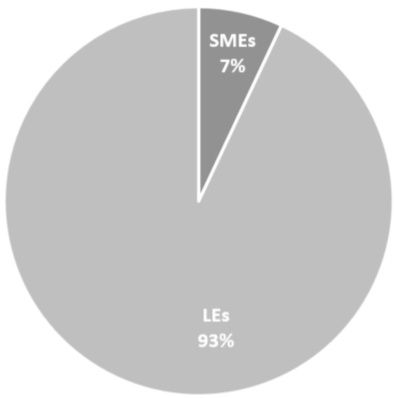

Fig. 5. Percentage of large enterprises and small and medium enterprises using the Malcolm Baldrige Framework (Baldrige Award Recipients Listing | NIST, 2020).

To complement this analysis, it is important to access data from a model that is used by companies across the world (as the Malcolm Baldrige Framework is mostly used by North American companies and the EFQM Model is mostly used by European companies). This brings us to the deployment of the data regarding the Shingo Model implementation, by both SMEs and LEs, since 1989. Figure 6 shows that in a model used by companies from all over the world, the difference between LEs and SMEs implementing the model remains. It is, once again, verified that there are less SMEs implementing the model when compared to the numbers of LEs accessing it.

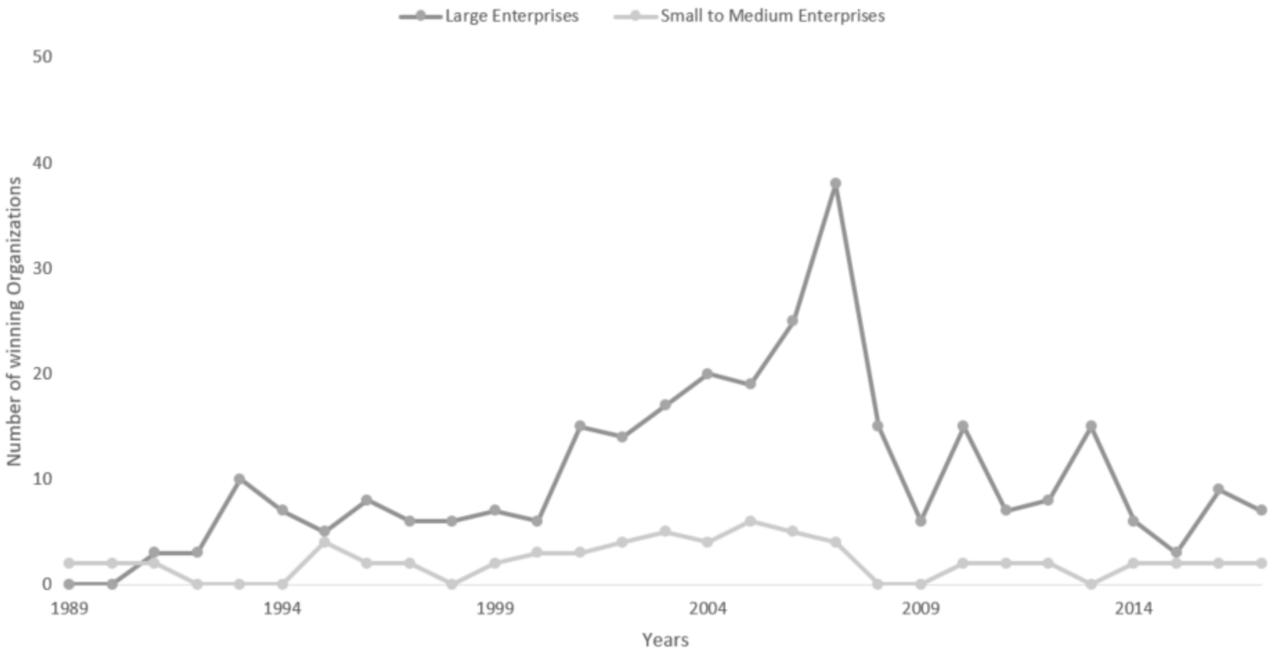

Fig. 6. Shingo Model diffusion (Utah State University, 2020).

Similarly, when deploying the data in a pie diagram (Figure 7), the research team concludes that only 13% out of more than 300 companies are SMEs.

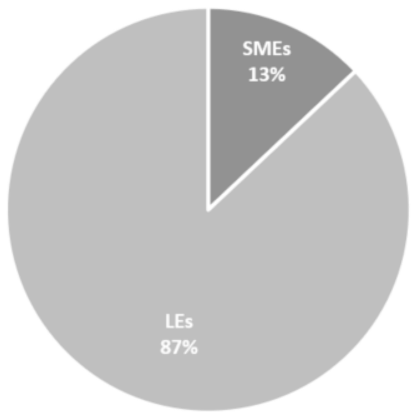

Fig. 7. Percentage of large enterprises and small and medium enterprises using the Shingo Model (Utah State University, 2020).

CONCLUSIONS

Over the years, the use of ISO 9001 as a quality management system by SMEs has been consistently reported (Brown et al., 1998; Ilkay & Aslan, 2012; Astrini, 2018), and this growth is notorious in a North American, European and worldwide approach. However, SMEs' motivations to pursue the certification remain unclear. It might be pursued by external pressure to get a certification (to gain or maintain market share, or even to stay in business) rather than by the will to improve the management systems available in companies (Brown et al., 1998; Astrini, 2018). At the same time, and when analyzing Business Excellence frameworks, it is explicit that these models have been through ups and downs throughout the years - a trend that is visible both in SME's and LE's (Carvalho & Sampaio, 2020).

There is scientific evidence that while some companies look at ISO 9001 and Business Excellence frameworks as complementary (Gotzamani et al., 2007), others see them as competing alternatives (Bandyopadhyay & Leonard, 2016) - which may suggest that the numbers observed in the last decades in the use of ISO 9001 may be one of the many variables that contribute to the decrease of Business Excellence models' adoption. However, with the analysis that was performed, the research team cannot point out a direct relationship between the increase in ISO 9001 use and Business Excellence frameworks' use decrease, being this a topic to be explored in the future.

Further on this topic, and having in mind the increase in ISO 9001 certification and the decrease in the use of Business Excellence models, it is important to point out that this phenomenon has been affecting all types of organizations (Carvalho & Sampaio, 2020) - small, medium and large sized. A decline in the adoption of organizational excellence models results in companies lacking the ability to use effective resources on their way to outstanding management practices. Simultaneously, institutions and practitioners that promote organizational excellence and which, directly or indirectly, rely on the use of these models will be affected by this decrease that seems to tend to continue in the next years if measures to counteract this effect are not developed.

Throughout this study, a considerable difference was noted in the engagement that SMEs and large enterprises have with the Excellence frameworks analyzed (EFQM Model, Malcolm Baldrige Framework and Shingo Model). In fact, this study shows that Business Excellence frameworks are mainly used by large enterprises, with small and medium enterprises representing a very small part of these numbers, regardless of the geographical area.

Based on these findings, and considering SMEs make up the larger part of the world economy, important conclusions can be drawn. There are undoubtfully different levels of engagement with Quality and Excellence frameworks depending on the size of organizations. As such, it is important that the scientific community better understands the needs of SMEs in regard to Quality management. In fact, most small and medium enterprises have been showing, proportionally, much less engagement with Business Excellence frameworks – even when these frameworks are highly promoted and also targeted at them. This demonstrates that small and medium enterprises have a specific perception of Business Excellence, and this represents a research opportunity that should be addressed in the future.

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Application of DMAIC method in an industrial case study

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ABSTRACT

Purpose. In the present work DMAIC methodology is implemented in a Portuguese enterprise. The main goal is to reduce the percentage of non-conformities in an injection molded part for the automotive industry, through the elimination of defects that appear after painting.

Design/methodology/approach. The DMAIC method was adopted to find an optimal set of factors that reduce the existing non-conformities. Along the five DMAIC phases, different quality tools were implemented to identify the root causes of the problem and to develop an action plan to reduce defects and minimize the process variability.

Findings. In the application of this method, teamwork and brainstorming were essential for satisfactory results in a short period of time. A key finding is that the analysis of the possible causes that gave rise to the problem must be carried out separately, in order to easily identify the changes that created a significant improvement in the process.

Research limitations/implications. The project is not fully completed since some of the improvement actions are being implemented.

Originality/value. This paper describes a practical application of DMAIC methodology that contributed to reduce part defects and improve the production process of a Portuguese company.

Keywords: DMAIC, quality improvement, non-conforming.

Paper type: Case study

INTRODUCTION

The automotive industry is part of a very demanding market, where the search for innovative products and technologies is constant. There is a great competition in this market, creating an increased concern within companies to implement methods that improve processes, eliminate faults, defects and errors, reduce cycle times and costs of operations. Implementing DMAIC methodology leads to increased customer satisfaction as well as the profitability of the company by improving the quality of products and processes (Cavanagh *et al.*, 2005).

The opportunity to develop the present work came from the challenge to implement DMAIC methodology at Fehst Componentes, Lda, Portugal. This methodology was selected with the aim of increasing the value of the organization through scientific methods, in order to reduce the percentage of non-conforming parts and minimize the process variability. This company is a supplier for the automotive industry, specialized in plastic interior decorative components.

To achieve the intended objective, it was necessary to define the problem, collect historical data, analyze the actual process, implement statistical methods and quality tools, create an action plan, and lastly, develop a strategy to maintain good quality.

The paper is organized around four main sections: an introduction; a brief overview of DMAIC methodology; a case study with discussion of its results and its practical implications; and finally, the conclusions.

DMAIC

For the development of a business through continuous improvement of the processes, products and services, the Six Sigma is strategically applied as a systematic and organized method to achieve quality (Allen, 2006; Mast and Lokkerbol, 2012; Costa *et al.*, 2019). Six Sigma combines statistical and scientific methods to measure and improve the operational performance of an organization by drastic reductions in customer-defined defect rates, adding value to the product and process (Allen, 2006; Costa *et al.*, 2019). Within Six Sigma framework DMAIC appears as a method to find and reduce the variations and to eliminate defects (Patel, 2016). The DMAIC is the most popular approach to support the Six Sigma strategy, in improving products and processes already existent in the organization (Mehrjerdi, 2011; Costa *et al.*, 2019). In order to solve a problem identified by the organization, the DMAIC methodology uses a set of tools and techniques in a logical fashion to arrive at sustainable solutions that will minimize or eliminate the problem, placing the organization in a competitive position (Shankar, 2009). The DMAIC methodology consists of the Define, Measure, Analyze, Improve, and Control phases and each phase covers a set of chronologically interlinked rational and statistical tools (Shankar, 2009; Hutwelker, 2019). The following stages should be considered during the implementation of DMAIC: Define (D), which the main purpose is to identify the problem that needs a solution, to define initial goals and targets (Patel and Shah, 2015; Smętkowska and Mrugalska, 2018), and to create the team responsible for the implementation of the DMAIC method (Zasadzien, 2017; Hutwelker, 2019). Measure (M) where the goal is to gather information about the current performance of the process (Antony, 2006; Mehrjerdi, 2011), namely the strengths and weaknesses, to determine the gaps for improvement (Antony, 2006). During Analyze (A) phase, different tools and methods are used to find the root causes of the problem (Smętkowska and Mrugalska, 2018; Hutwelker, 2019) and to determine the key process variables linked to defects that are affecting the output of the process. (Antony, 2006; Patel and Shah, 2015). In the Improve (I) phase an action plan is created to fix the problems identified and to prevent them from recurring (Antony, 2006; Mehrjerdi, 2011; Smętkowska and Mrugalska, 2018). Control (C) is the last phase of the DMAIC methodology, the results of changes implemented at the improve stage are evaluated and monitored (Mehrjerdi, 2011; Smętkowska and Mrugalska, 2018).

CASE STUDY

The case study was born at Fehst Componentes, Lda. with the challenge to reduce the percentage of non-conforming parts in injection moulded components that are painted. The company used the DMAIC method on the most critical product, defined as High Gloss Blend. The steps to manufacture this product are described in Figure 1.

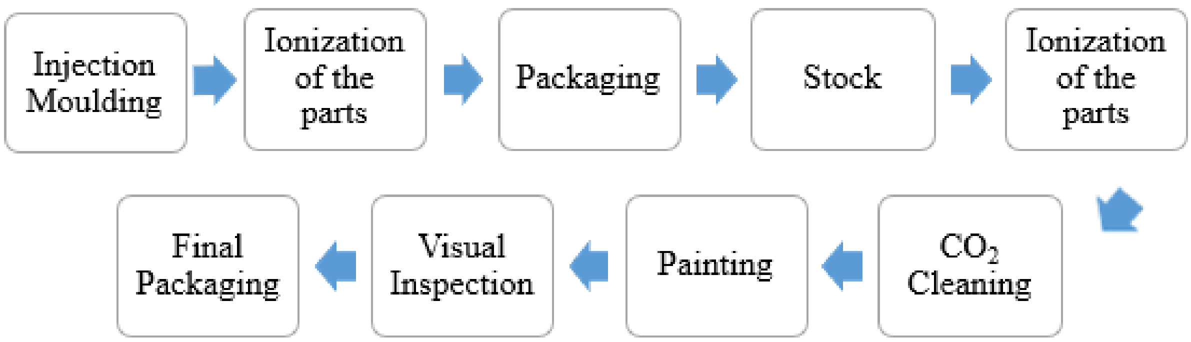

Figure 1 – Manufacture steps of the High Gloss Blend parts.

Define

The first stage started by defining the problem and by identifying the objectives to be achieved. An in-deep analysis was performed from April to September 2019 to find the component that presented the highest percentage of non-conforming parts. Therefore, the problem is the high level of non-conforming parts on the High Gloss Blend after paining.

Due to the fact that High Gloss Blend parts have a high gloss finish, a complex geometry and a high-quality requirement from the customer, the company considers a percentage of up to 22% of non-conforming parts acceptable. However, as observed in Figure 2, in the last semester the percentage of non-conforming parts reached values higher than the objective defined by the company. The most critical result occurred in September, reaching a value of 47.6% of non-conforming parts.

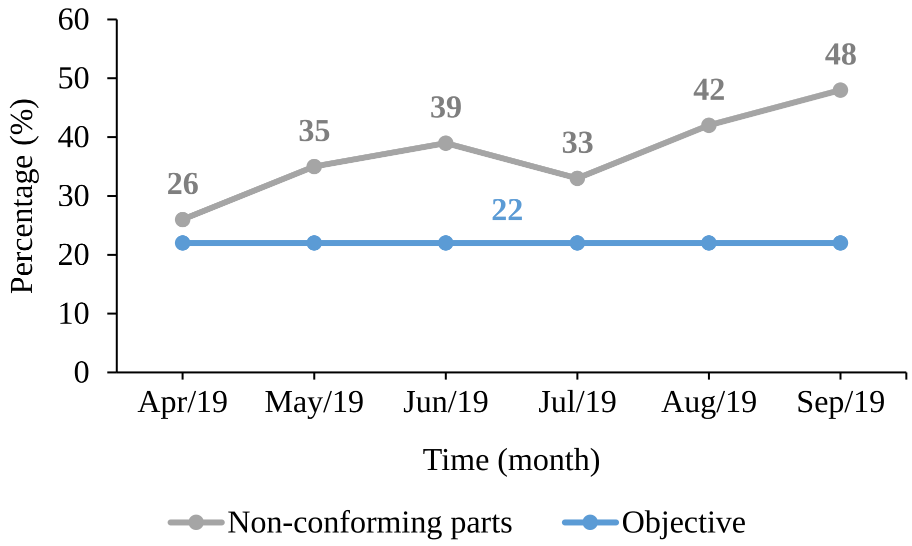

Figure 2 – Percentage of non-conforming parts between April and September 2019, in the High Gloss Blend component. Source: Internal data of Fehst Componentes, Lda, 2019.

Measure

To know the main defects and its quantity a visual inspection is made through a system with sensors, where all non-conforming parts are counted. However, the company's system only distinguishes two types of defects, inclusions and pits, that are depicted in Figure 3. Other types of defects are counted by the sensor like "others". A Pareto chart was used to analyse the results (Figure 4). It is observed that the defect that requires priority in resolution are the inclusions.

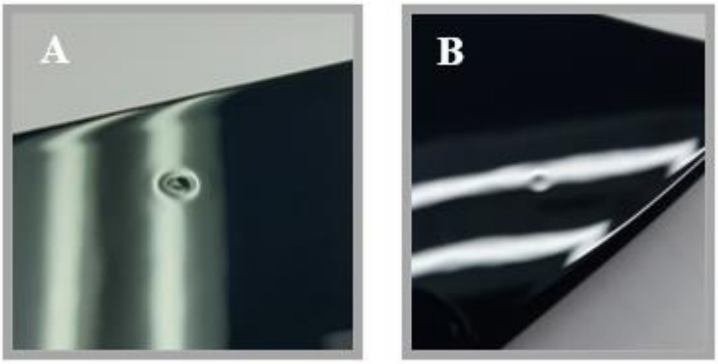

Figure 3 – Main part defects detected by the sensor: (A) Inclusion (B) Pit.

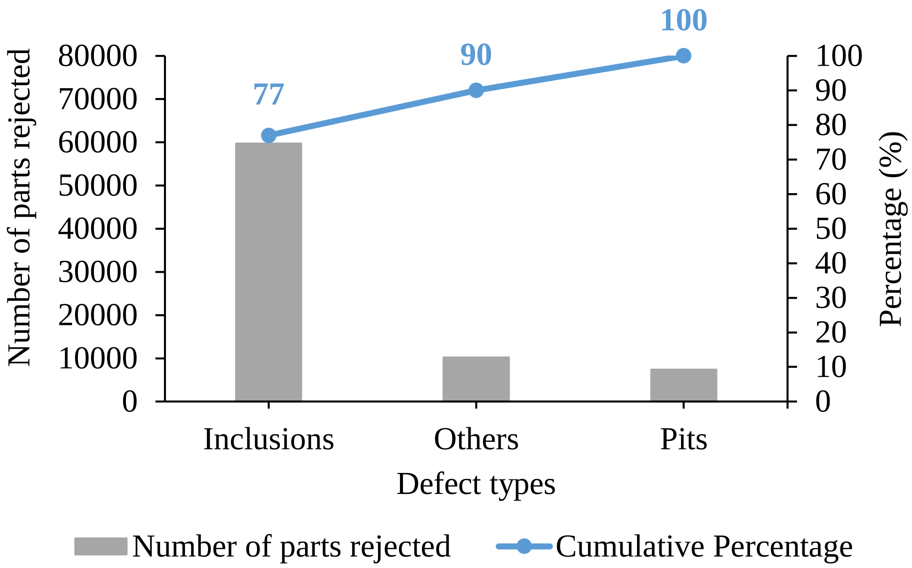

Figure 4 – Pareto chart for the number of parts rejected during the month of April through September 2019. Source: Internal data of Fehst Componentes, Lda, 2019.

Analyse

The inclusion defect is characterized by the appearance of a protrusion on the surface of the part after painting, as seen in Figure 3. The cause for it may be the static electricity of plastic parts that is prone to accumulate impurities during the operations between the injection phase and the painting phase, leading to the inclusion defect (Crawford, 1998).

To discover the possible causes of this defect, brainstorming sessions were made, which brought together process engineers and quality engineers. Ishikawa diagram was built and 5 Whys method was applied. They are presented in Figure 5 and Table 1, respectively. In view of all the information collected, the main causes that require a thorough analysis were selected, namely: handling of parts after injection production; packaging; and cleaning of parts with carbon dioxide (CO_2).

Improve

To eliminate the root cause of the problem it is important to analyse them and to implement solutions. Regarding "Handling of parts after injection production" it is important to refer that when parts are painted, more care should be taken. Fingerprints or other types of contaminations influence greatly the adhesion of the paint. For this reason, it is convenient to use gloves. However, the material which the gloves are made, the recurrence of changing gloves or even the choice of light or dark gloves can influence the possible contamination of the surface of the parts.

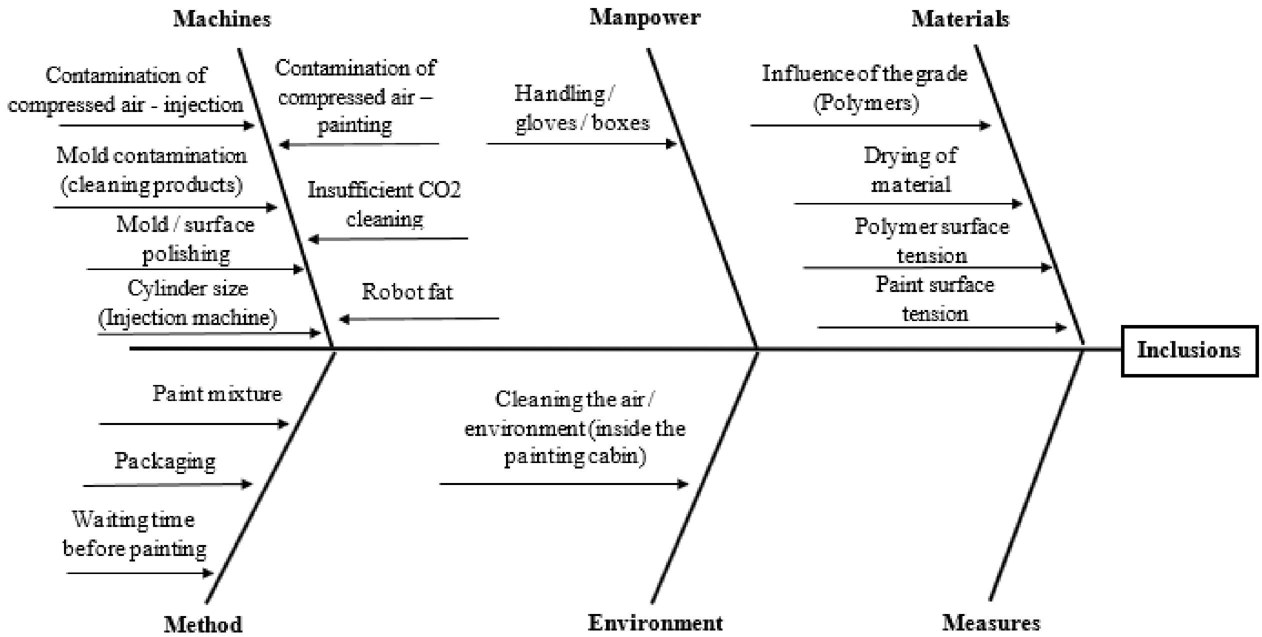

Figure 5 – Ishikawa diagram for the inclusion defect (Elaborated by the authors).

Table 1 – 5 Why´s for the inclusion efect (Elaborated by the authors).

Problem definition	**Why?**	**Why?**	**Why?**	**Why?**	**Why?**
Appearance of the inclusion defects	Contamination on the surface of the parts	Polymers has hight static electricity	Ionization system is not enough	The pieces gain static electricity again	Handling and packaging

In order to verify the possible influence of the hand's transpiration in the accumulation of fat in the parts, a test was made to 640 parts manipulated only with nitrile gloves. All the steps were completed just like normal production. Table 2 shows the number and type of defects after painting the parts.

Table 2 – Influence of the gloves used in handling the parts.

	Number of parts with inclusions	Number of parts with pits	Number of parts with "others"	% non-conforming parts
Use of nitrile gloves	72	21	364	71.4%

The percentage of non-compliant parts was 71.4%, well above the maximum percentage for this component. The main defect was defined by the sensor as "others". A close look at these parts identified that the defect appeared on the surface that the employee contacted when collecting the parts from the carpet in the injection moulding stage to proceed to the packaging.

Since the lot painted just before had a percentage of non-conforming parts below 25%, and did not contain any parts with this defect, it was concluded that the nitrile gloves mark the parts and hinder the adhesion of the paint to the surface of the parts. As a process improvement, gloves were changed, opting for white cloth gloves. Due to the colour of the gloves, the dirt is more visible, which makes changing gloves more frequently.

After the injection process, the parts go through an ionization system that aims to remove static electricity from the parts and reduce impurities, reducing the possibility of creating the inclusion defect. Subsequently, the parts are packed and remain in stock until they are painted.

In order to verify the influence of ionized air and packaging on the percentage of non-conforming parts, 3 tests were carried out. In the first test, 640 parts that did not pass through the ionized air system were packed in plastic bags. In the second test, other 640 parts that passed through the ionized air system were packed in plastic bags. In the last test, 640 parts that passed through the ionized air system were packed with anti-static plastic bags. Table 3 shows the results obtained in each test.

Table 3 – Influence of the ionization system and packaging on parts.

	Number of parts with inclusions	Number of parts with pits	Number of parts with "others"	% non-conforming parts
Parts without ionized air and anti-static bag	129	25	21	27.34%
Parts with ionized air and without anti-static bag	86	30	25	22.03%
Parts with ionized air and anti-static bag	74	2	7	12.97%

Over the course of the tests, the percentage of non-compliant parts decreased. The parts that passed through the ionized air system and packed with anti-static bags presented 12.97% of non-conforming parts, which is much less than the maximum percentage defined by the company.

Given these results, it was decided to realize a broader study, including the results obtained in December 2019. Therefore, throughout this month the packing of the parts between the injection and painting phase used only anti-static bags.

The last point to analyse and improve is related to the cleaning of parts with CO_2. Before painting the parts, it is necessary to ensure that the surface does not have any impurity created during its production. In the paint cabin, the parts are cleaned with CO_2 which leads to the contraction of the fat and dust and its further elimination. The CO_2 used in the painting phase is supplied through bottles with a capacity of 6 working hours. However, a variation on the number of defective parts during the use of the bottle was identified, therefore it is an important topic to be analysed.

A study was carried out in which the percentage of non-conforming parts was counted in a sample of 400 parts before changing the CO_2 bottle and 400 parts after changing the bottle. The study was realized on a day when the percentage of non-compliant parts did not exceed 22% and the only defects that appeared in the parts were pits, inclusions and lack of paint. Table 4 shows the results obtained in the study.

Table 4 – Impact of changing the CO_2 bottle on parts.

	Number of parts with inclusions	**Number of parts with pits**	**Number of parts with "others"**	**% non-conforming parts**
Before changing the CO_2 bottle	59	18	11	22%
After changing the CO_2 bottle	48	7	10	16.25%

After changing the CO_2 bottle the percentage of non-compliant parts was 16.25%. With this study it is concluded that the efficiency of the bottle is not constant throughout its use, specially at its end when low CO_2 level in the bottle is attained.

In order to solve this problem, the solution was to instal a cryogenic tank with high storage capacity, and above all, a constant gas flow during the entire use time. This way, it would not be necessary to change the CO_2 bottle daily and the parts could be cleaned throughout the entire production.

Control

In the previous phase, some causes for the appearance of inclusions in the parts were defined and solutions were found. However, to implement changes such as the construction of a CO_2 reservoir, becomes impossible in a short period of time. Therefore, only some improvements such as changing the gloves used in handling the parts and changing the packaging type to carry the parts could be adopted.

The evolution of non-conforming parts along 2019 is depicted in Figure 6. At the start of the project in September and thought most of the year, the percentage of non-conforming parts was very high. Upon identification of the cause, solutions were tested. By October upon implementing the changes in the procedures of handling and treating the sample before painting a significant reduction in the percentage of non-compliant parts was observed. In December, it was possible to reach the maximum percentage of non-conforming parts acceptable by the company for this component.

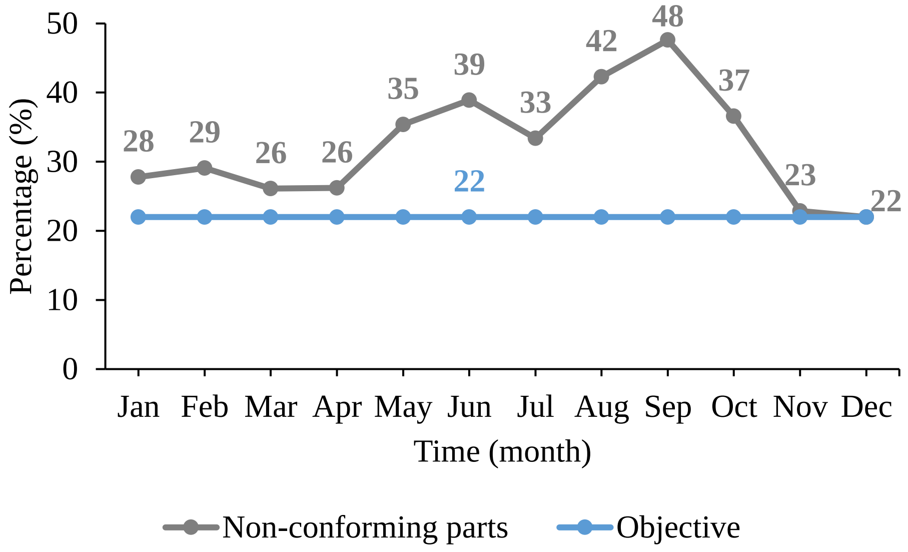

Figure 6 – Percentage of non-conforming parts in the High Gloss Blend component in 2019. Source: Internal data of Fehst Componentes, Lda, 2019.

CONCLUSIONS

The application of DMAIC methodology, teamwork and brainstorming were essential for achieving satisfactory results in a short period of time. The separate analysis of the possible causes that gave rise to the problem was carried to easily identify the changes needed. Through this methodology, it was possible to significantly reduce the percentage of non-conforming parts in the component under study. Although the implementation of the methodology was focused on the defect that occurred most frequently in the production process of the High Gloss Blend component, all the improvements implemented also reduced the appearance of other defects. The present case study proved that through the application of quality tools it was possible to significantly improve the company's production process.

In the future, it is suggested to implement the Six Sigma methodology in the company, in order to eliminate unproductive stage, develop and use the technology to drive improvements, both in new and existing projects.

ACKNOWLEDGMENTS

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Research on Quality Management and Sustainability

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ABSTRACT

Purpose - This article aims to ascertain the necessity for specific research on quality management approaches, bringing to the discussion some concerns and challenges to the quality movement, especially in development of new methodologies for supporting design in the digital area.

Design/methodology/approach - Firstly, papers were researched that had already studied the question of what research should carry out in response to the great scientific, technical, and social changes, specifically to support design activities for internet products and secondly we concluded what development is needed.

Findings - The increasing complexity of management and technology creates many situations of anxiety and distress, which often translate into abandonment of proven techniques and methodologies, leading to intuitive approaches. But complexity requires more techniques and methodologies not less. The quality movement faces a serious challenge: how to design in an ethical perspective these types of products.

Research limitations/implications - This research is limited to identify some needs, but future research should be done in characterizing existing answers and identifying what development is needed.

Practical implications - The above findings and reflections can help other researchers to focus on design, to find out practical solutions for sustainability in the innovation process of products and services.

Social implications - Finding out to design in an ethical perspective products and services for internet.

Originality/value - This research identified relevant challenges the quality management is facing, and it gives guidelines for defining research lines.

Keywords: Challenges, Research, Quality, Management, Sustainability**.**

Paper type: Conceptual paper**.**

1. INTRODUTION

The business environment is extremely focused on short term results, which impact negatively any management system in general terms and the quality ones specifically.

Quality management systems are not designed for unstable situations, which are now dominant. Business practices of low investment (ex.: short term, payback of 1 year) doesn´t fit well with planned and systematic actions.

The increasing complexity of management and technology creates many situations of anxiety and despair, which often translate into abandonment of proven techniques and methodologies, leading to intuitive approaches. We often find managers and managers asserting that quality is outdated, embedded in processes, and now it is about productivity, cost effectiveness, and business growth.

In this line of thought, there is also the position that structured approaches complicate, and therefore must be simplified. On the contrary, complexity requires more techniques and methodologies than less.

Thus, it is not difficult to understand the crisis that the quality movement is going through. Many studies in the area show very varied and sometimes contradictory results, so it is important to deepen the research, both to better understand the positive impacts of quality and its shortcomings.

Major technical, scientific, and social changes create new needs. The nature, size, and speed with which these changes must occur bring the need for adaptation of existing techniques and methodologies, but also the urgency of developing new ones.

Finally, social, political, and economic points of view are raising other issues mainly focused on the needs of vast areas of the planet, still as basic as fighting hunger and disease, for example.

Having no future vision, or being limited, we have not looked at these countries as future markets that should be developed, allowing investments to be monetized, but rather as non-existent markets.

The unbalanced development between rich and poor countries and within the rich countries, between regions and social classes, although recognized as long-term pernicious, concerns about the short-term have been crippling to even start moving to the solution.

Whereas the Quality Principles are the Customer focus, Leadership, Engagement of people, Process approach, Improvement, Evidence-based decision making and Relationship management and that the Business Principles are the Business results focus, Flexible/Intuitive, Engagement of qualified people, In instable environment, Innovation, Insight-based decision and Networks and co management, if we compare quality principles with similar ones at the management level, and we can see that there are worrying discrepancies. This situation is dangerous, and the quality movement needs to rethink approaches and positions at risk of continuing to deteriorate its credibility.

On the other hand, the social impact of media is consensually acknowledged. Some of the most relevant issues can be advanced:

- segment audiences do not contribute to building consensus.
- do not provide useful data and information, they give more disqualified information.
- instead of opening perspectives, they join those who think in the same way.
- presuppose and encourage the elimination of privacy aiming to sale products and services in exchange for access to content. What quality are we dealing with?
- “people have really gotten comfortable not only sharing more information and different kinds, but more openly and with more people. That social norm is just something that has evolved over time." (Mark Zuckerberg, Facebook, 5 years ago).
- Tim Cook from Apple took the opposite stance, while finger-wagging at both Google and Facebook, and said: “We believe that people have a fundamental right to privacy. The American people demand it, the constitution demands it, morality demands it.” (https://www.sas.com/pt_br/home.html).

Today the world has almost everything before the eyes, not filtered by scientific knowledge, moral or ethics, but by the tastes of the public (the basis of digital business models). Needs are not identified, but they are created. Companies experiment (in the digital world) and bet where receptivity arises and abandon products/services whenever there isn´t. The emphasis is on the short term (or even immediate) and continuous (and even permanent) development. This reality raises questions relevant to Quality.

However, many misconceptions continue to persist despite major dissemination and quality promotion initiatives: Quality is past (the fashion of quality has already been replaced by others); Quality is embedded in the processes (the quality function in organizations is no longer necessary); Quality is already guaranteed, now we need productivity; Quality is bureaucracy, we need to innovate (an easy way to quick solutions); The most important are soft competences (hard ones, like those of traditional quality, are less or not necessary at all); quality is rules (we don´t need rules, we need a quality culture); we need to do (we don´t need research and development); we don´t need statistic – only analytics - on time data).

Apart from these misconceptions are easy to take apart, some others are more difficult:

1. *Quality assumes intangible aspects, so important that they cannot be defined and therefore evaluated*. Contrary to this position we cannot speak of quality without defining and evaluating it. When we talk about identifying customer needs and expectations, or when we talk about customer satisfaction, we are not just talking about physical measures, but we cannot conclude that it is not possible to measure and objectify; We have to use other techniques and methods that are not typical of Quality Engineering.

2. *Quality is always associated with cost, so that better quality will necessarily have to cost more and / or make the production / service process more difficult*. If in some cases this is the case, in most situations it is possible to improve quality and lower costs simultaneously. The history of quality has been a permanent demonstration of this reality.

3. *Quality is synonymous with technology, so a quality system can only provide a quality product / service if it has the most sophisticated technology*. Technology is a necessary but not enough condition. Even with the most suitable technology, this does not mean that all its potential is being taken away from it. Even getting a top-quality product does not mean it was the first time, using minimal resources. Even if we have used technology properly and achieved the final product at the lowest cost, it does not mean that we can put it in the right time and place and in the conditions desired by customers.

4. *Quality is the qualification of professionals and has nothing to do with management methods and techniques*. This is a matter of frequent misunderstanding. When we talk about quality systems, we are not questioning the qualifications of technicians, but the organizational procedures that ensure that technical activities are not affected by deficiencies in management and support services.

In many cases, the assurance that quality is being achieved at minimum cost is essentially based on the qualifications of professionals.

These misinterpretations, although they result largely from ignorance, deserve reflection and understanding of their causes so that solutions can be devised.

For a better understanding of the appearance of the wrong messages, messenger identification may be relevant. Some of them are:

– Managers (misinformed or poorly trained managers who do not appreciate the planning and structuring of companies. Some of them also do not appreciate procedures that can give them responsibility and discipline).

- Political People (who only appreciate short-term results, who do not understand the technical components, and who are not concerned with public opinion - more sensitive to catastrophic failures than systematic approaches).
- Leaders of professional associations (more concerned with lobbying governments and legislators).
- Leaders of professional quality associations (those who are still in the past with bureaucratic visions and afraid of the future)

2. CHALLENGES OF THE QUALITY MOVEMENT: TECHNOLOGIES, SCIENCE, BIG DATA, AND INNOVATION

2.1. Internet Technologies: Internet of People (IoP), Internet of Things (IoT) and Internet of Emotions (IoE)

According to Porter (2001, p. 63) “some companies have been using internet technology to change the basis of competition away from quality, features and service, making it through price, and thereby making it harder for anyone in their industry to make a profit”.

We must not forget the two fundamental factors that determine profitability (universal and above any technology or type of activity):

1. the structure of economic activity (which determines the average profitability of the actors in their respective sectors of activity).
2. the sustainable competitive advantage (which allows to perform above the industry average).

Information and communication technologies have great potential to bring suppliers closer to customers. However, there seems to be a negative tendency to move away. Although online contacts are possible, in many cases they are difficult and in many others are unique (physical presence does not exist), causing dissatisfaction and distrust.

So, we fully agree with Porter when he finds that easy entry into market (or the illusion of easier entry), is destroying the sector competitiveness (Porter, 2001).

Another negative trend has to do with the platforms we call self-service (e.g. check in; banking, public services), where although they bring convenience and advantages to consumers, most of the advantages stay with suppliers (motivations are more focused on saving resources and increasing profits, and less on customer needs).

Transparency is another important issue. The traditional practices of hiding in the "small print" relevant exclusions and ambiguities are now enlarged, sometimes reaching clear swindle.

The Internet of People (IoP) (e.g. e-commerce, ERP, search application) were built to serve people and to accumulate specific types of data that we could analyse later. Internet of Things (IoT) is based on the interconnection of computing devices embedded in everyday objects, enabling them to send and receive data. The IoT enlarges Internet connectivity into physical devices and everyday objects. These devices can communicate and interact with others, and they can be remotely monitored and controlled. The concept of the IoT includes contributions of multiple technologies, such as real-time analytics, machine learning, commodity sensors, and embedded systems. The Table 1 presented de differences by Internet of people and Internet of things.

Table 1 – Internet of People versus Internet of Things

Internet of People (IoP)	Internet of Things (IoT)
- Metal-box type vendors - Set a problem to solve before start collecting data to analyse - Isolated logic - Data will support decision - Traditional analytics applies to processing after the data is stored	- Information vendors - Connect devices, collect data, learn from it and then figure out what to do Connected logic - Data will drive business insights. - Working with event data, when they are happening

Source: adapted from Evan (2011)

The "Industries that stand to gain the most are those that are able to extract the right business insights at the right time and the right place – edge or cloud – based on factors like cost and latency of the underlying business problem." (Kumar Balasubramanian, General Manager of Internet of Things Solutions at Intel. In https://www.sas.com/pt_br/home.html).

IoT will require partnerships among different types of vendors to keep everything working together. Privacy, security, and legal implications are significant challenges and risks along with unprecedented levels of security and complex infrastructures.

We know that many decisions are not rational, but emotional. We know many non-rational decisions, including mental buying mechanisms. The internet has a huge offer of information, shopping, entertainment, and interaction services.

The design of many of these new products assumes at the outset that they must be shocking and impressive, or to put it another way, they must trigger successive emotional states that lead to using, buying, playing, or interacting more, keeping the user eager to continue. The products are designed to have incentives to multiply the emotion of each instalment (news, television news, reporting ...) (Fukuda, 2011).

In addition to psychological and social problems, such as the loss of emotional learning ability (interactions are mostly via the internet), and easy access to information without intermediation (technology is used to create emotions and fabular), quality movement faces a serious challenge: how to design in an ethical perspective these type of products and which techniques and methodologies are available do support design activities and what development is needed (Dennis & Kappas, 2014).

To answer some questions, some contributions were attempted like the adaption of QFD (more in the name than in substance - Emotional Engineering, Affective Engineering) (Nagamachi, 2010).

Kansei methodology is coming from other point of view the user- centred design (Neto and Pires, 2019).

From the artificial intelligence side arises the term “HumanRithms” (Human Algorithms), transferring knowledge from neurosciences to computer sciences (Candamo et al, 2010).

Benski & Fisher (2014) state. “Most notably, research into online worlds (particularly games) finds that they provide immersive experiences which invoke a high level of emotional engagement and a strong sense of presence and intimacy” (Preface).

Küster & Kappas (2014) suggest 3 phases for researching: first, researchers can study large amounts of emotional content on the Internet. Second, they can ask individuals about their emotional experience online. Third, they can record bodily responses to measure emotions unobtrusively.

2.2. Technology Based Quality or Science Based Quality

Today, technology has always a scientific base (it was not true in the past). This is a good starting point for revisiting quality techniques and methodologies to strengthen and develop its scientific base. Some approaches have been developed based on the experience of quality professionals who have sacrificed scientific foundations over pragmatism. Acknowledging that the vast majority turns out to be useful, but their results show too much variability, depending on many variables (e.g. activity sector, dimension, culture, human development, economic development).

Particularly interesting is the observation of how to speak and write about topics on which education is poor (human resources, motivation, leadership, strategy, expectations, satisfaction, culture), as is the case of quality professionals.

Quality turns out to be a set of engineering techniques and methods framed by management concepts, which results in a mix that is very eclectic.

Technical and scientific developments, the average rise in purchasing power and education, and increased competition have led to a growing momentum in introducing new products and services, or significantly changed existing products.

In this way, innovation gained greater prominence even emerging as an alternative to quality. However, careful analysis of the product life cycle and particularly from its idealization allows us to conclude that quality stems from the organization's interface with the market, identifying the needs and expectations of market segments and their transposition to product and service requirements, ie innovation at this level.

Unfortunately, innovation is not a panacea for quick and easy solutions, but a complex process with many variables and interactions between areas of knowledge, technologies and functional areas of organizations. This process requires increasingly complex techniques and methodologies because failures at these stages of the life cycle have potentially devastating consequences.

The design process implies the progressive reduction of uncertainty, which can only be achieved with higher levels of knowledge (scientific and/or organizational). In other words, innovation implies risk, as the greater the degree of novelty, but also resources (human and financial).

Additionally, the entrepreneurship environments should be adequate.

In an innovative environment there is less interest on what we know and more interest on what we don´t know.

If we talk about Quality Management Systems (QMS) based on a procedure environment is difficult to innovate, which may justify the scepticism of many managers and researchers.

However, concerning science, some paradoxes arise that should not be expected to resolve. We must manage them in the best way.

Science is not democratic (it is not accessible and useful for all; few control their development). But science is essential for a democratic society (enabling broad access to information, technology and supporting many of the institutions of democracy in their functioning and in relations with citizens).

The public funds (R&D) will stop at the private companies (EUA, 2018). Public universities (and faculty) are evaluated by private rankings. States don´t provide services but should satisfy population needs.

The scientific community has never been so large and so influential, but the limits of science follow a centrifugal movement without sufficient synthesis efforts, which makes easy advances difficult (what is something new) as stated Araújo (2018): "No one can create new knowledge if it does not spend more than ten thousand hours on a subject." 1250 days and 3, 42 years. Who pays for it?

2.3. Big Data or Big Knowledge

We all know, feel, and live the increasing digitization amending labour relations, business organization, machines, and processes.

From the point of view of knowledge management and organizational learning, a practical scheme can help to understand and monitor (Figure 1).

Figure 1 - knowledge management and organizational learning

Data is not information, but can translated into information, through adequate treatment and interpretation, like tables, figures, models, equations.

Information is not knowledge. This comes from science or from experience and testing inside organizations allowing specific knowledge only available internally. If this specific knowledge can be generalized, we can talk about wisdom.

The availability of large amounts of data has aroused interest in their processing and has fostered the development of statistical techniques and methods, with the aim of obtaining information that supports decisions but also obtaining higher levels of knowledge (analytics - analytical intelligence).

Some authors call for cognitive capitalism (e.g. Rindermann, 2012) and Simbolic capitalism (e.g. Fuller & Tian, 2006).

Analytical Intelligence is a comprehensive, multidimensional field that uses mathematical, statistical, predictive modelling, and machine learning techniques to find meaningful patterns and knowledge in data.

With faster and more powerful computers, the opportunity for analytics and big data is plentiful. Examples and are:

- companies can find new ways to mitigate risk and increase profit.
- data scientists can explore their logical reasoning.
- business can improve predictive analytics.
- business can get insights at the right time and the right place – edge or cloud – based on factors like cost and latency of the underlying business problem.

The Table 2 presented a comparison between the Statistics and the Analytics.

Table 2 - Statistics Versus Analytics

Statistics	Analytics
Tendencies	On time values
Variation	So reduced, we don´t need to care
Capacity	We always can achieve
Correlations	Patterns, Fractals
Design of Experiments	Some variables at each time?
Metrology	Technology (auto calibration)
Hard Skills	Soft Skills
Quality of products	Control the decision process
Process control	Mental schemes of the decision-making process
Experientation	Emotional decisions (70% !?)
Testing	Emotional quality ? (Kansei, QFD…)

This comparison shows the basic statistics knowledge is the primary skill needed, but other issues are also relevant to deal with.

Other related issue is the concept of event stream processing. This is the process of quickly analysing time-based data as it is being created and before it is stored, even at the instant that it is streaming from one device to another - influencing a situation before it is over.

Whereas:

1. Event – An event is any occurrence that happens at a clearly defined time and is recorded in a collection of fields.
2. Stream – A data stream is a constant flow of data events, or a steady rush of data that flows into and around your business from thousands of connected devices and other sensored "things."
3. Processing – The act of analysing data.

Event stream processing can be viewed from three point of view (Tomasz, 2013):

- **At-the-edge analytics** (processed on the same device from which it is streaming) (Ex: thermostat, your iPhone or any single sensor with processing capabilities) - This type of analytics works with minimal context to the data, often confined to rudimentary rules and simple statistics like average or standard deviation.
- **In-stream analytics** (occur as data streams from one device to another, or from multiple sensors to an aggregation point) (Ex: analysing mobile phone use) - This type of analysis combines events of different types and alternate formats that are transmitting at varied rates.

- **At-rest analytics** (occurs when there is a historical repository of data). It is based on rich, historical context – the perspective required to create predictive analytical models and forecasts and to discover new patterns of interest.

Regarding this, term edge is also applied to devices. An edge device is any piece of hardware that controls data flow at the boundary between two networks. For instance, cloud computing and the internet of things (IoT) have enhanced the role of edge devices, fostering the need for more intelligence, computing power and advanced services at the network edge. The Table 3 presented the event processing.

Table 3 – Event processing

<table>
<tr><th colspan="2">Event stream processing</th></tr>
<tr><td>Traditional analytics
• Receive and store data.
• Prepare data.
• Process/analise data.
• Get results and share as needed.</td><td>Event stream processing
• Store queries/analysis.
• Receive data.
• Process data.
• Push results immediately (often to trigger a reaction).</td></tr>
<tr><td colspan="2">It can occur in three distinct phases:
- at the edge of the network
- in the stream,
- on data that’s at rest, out of the stream</td></tr>
</table>

Source: Bolen (2011)

Networks are starting to connect all sorts of things together and collect the data. With insights from this IoT data, many businesses are already boosting productivity and driving greater operational efficiencies (Ex: Predictive machine maintenance and performance optimization; Precision agriculture).

Streaming data from the IoT helps organizations understand their businesses better because it allows constant monitoring. The result is often a more customer-centric business model, allowing data to drive business insights. However, some disturbances and bad attitudes must be taken care of: withdrawal from customers and using the data in a partial and amateur way and in view of the complexity of the interpretation, only use intuition again - based on data intuition!

2.4. Product/Quality/ Innovation Cycle: Design for Emotions

Starting from the functional approach (the levels of satisfaction and importance of functions define quality) and its relationship with the costs that customers are willing to pay, we can now look at new digital products. Value is the relationship between quality and cost.

The internet (or the excess of technology) leads to massification (positive side), and to go through everything fast (trivial and profound) and obviously staying longer in what is easier to learn in an intuitive (or manipulated) way. Culture and traditional information are under pressure and seems to have difficulty for responding.

Here, too, the question of quality arises. Mass audiences want what the traditional media cannot provide. Are they failing to identify needs? Or are they unable to segment markets and consumers to offer each other dedicated products? Is it because of some kind of intellectual arrogance of the elites? (Chatfield, 2012).

Artificial intelligence can help to identify or create potential functions (see The Figure 2)

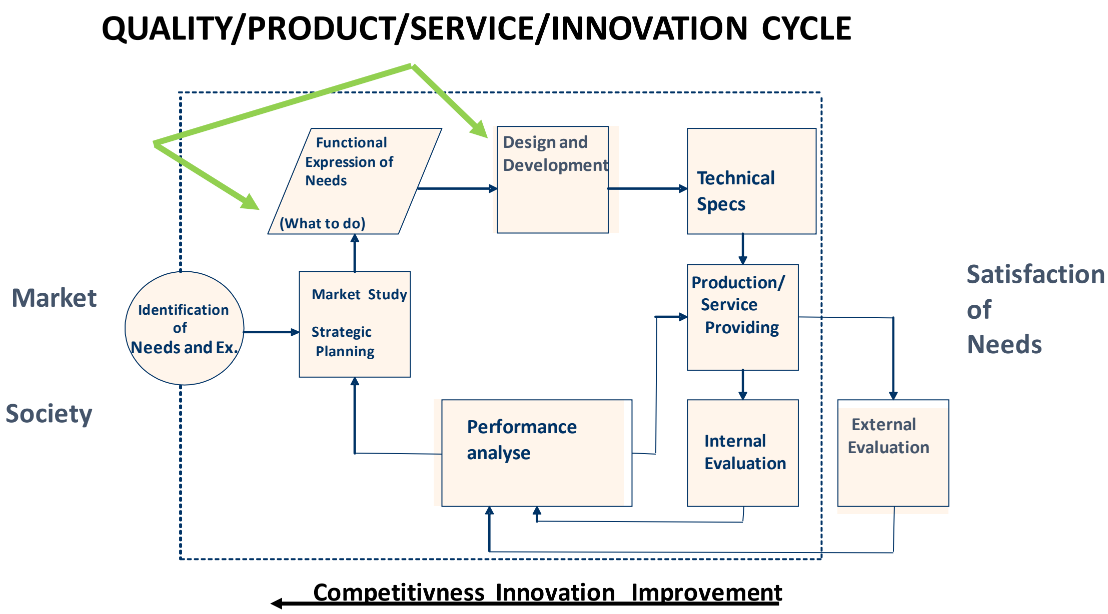

Figure 2 - Product/Quality/ Innovation Cycle

Source: Pires (2016)

As noted in the Figure 2, the critical activities for competitiveness lie in the early stages of the innovation cycle, where they are identified (or created) the needs and expectations and where they are translated into requirements for products and services.

The cyclical character of innovation is represented by the direction of the arrows. This cycle is to be run more often and faster, sometimes leading to dramatic changes in products, processes, technologies, marketing solutions and in the structural formats of organizations themselves.

Therefore, the question arises: How to design products for emotions ethically, since personal people's personal lives are being used without permission. How to design getting on time feedback and continuously improvement? we need to change paradigms and create new tools, co-creation, customer-centred design, emotional engineering can give some insights, but sure that we need multidisciplinary teams.

The early stages of the life cycle and particularly design is becoming increasingly important because the best sustainability solutions can be found here, considering all impacts on the life cycle. Reverse logistics complements the efforts made in design.

Lastly, we fully agree with Klöpffer (2002:133): "It is the duty of researchers and experts of different fields to develop and improve methods that can be used to operationalize the guiding principle of sustainability". The technical solutions must necessarily have scientific support, essential condition to minimize risks throughout the life cycle.

We can easily agree that the rise of digital is having huge impacts on business models and cultural perspectives. For instance, the time spent in digital environments (games ...) seems to be emotionally rewarding (perhaps even to "forget" real life). These are other needs that designers must consider: creating products for the real world and products for the virtual world.

However, there is a big misunderstanding: The power to create cultural and intellectual works is concentrated on those who control the infrastructure (where the works are disseminated). Instead of "democratization", we are witnessing concentration in the hands of very few. Moreover, these are not exactly talents in art, culture, politics…. And science! although the creation of niches is possible, the most relevant is the growth of an increasingly influential small group (Chatfield, 2012).

Can we talk about Post Neo Quality? Meaning that quality movement needs to update the scientific base of its approaches in the light of implementation experience and case studies research to generalizability and transferability. So, it is essential: analyse initial theory/approach; enhance this with new information in the form of theoretical contributions from multidiscipline; synthesize prior and new information to produce an updated theory (Dixon-Woods et al., 2011).

3. CHALLENGES FOR R&D AND FUTURE OF QUALITY MOVEMENT

3.1. Challenges for R&D

The following topics illustrate points of consensus and disagreement

- Client satisfaction. Customer satisfaction remains a key theme. However, the satisfaction construct has evolved to include positive experiences, expectations management and emotional relationships. ICTs are changing supplier-customer relationships, not always in the positive sense.

- Shareholders (more than direct client) is a practically not researched field, but with a great potential, since a networked society is being built.
- Society. The last goal of all economic activity spreads far beyond the quality of products and services, assuming political and philosophical dimensions.
- Impact of quality practices in performance and success. Quality practices should contribute to performance (at various levels), either individually or in some form of joint application. These themes have been investigated, generally with positive results, but also with negative results. Saraiva et al (2018) performed a critical analysis of the literature reviews, concluding that there were contradictory, controversial, or even conflicting results, suggesting that more variables should be included (e.g. sector of activity, company size, certification dimension, human development, scientific affiliation of researchers, economic development).
- Rhetoric of quality. For a long time, we have characterized the situation as the rhetoric of quality, meaning that the apologetic statements do not always correspond to reality (Pires, 2016).
- New tools (to deal with design for emotions respecting ethical principles and a bearing in mind a perspective of social responsibility).

Research on organizational design falls largely within the sphere of organizational theories, where quality has made little contribution. However, the drastic and rapid changes in products, services and processes raise the question of whether organizations' traditional structural formats can cope with increasing complexity. The traditional two dimensions of organizational charts are not enough to represent the multidimensional characteristics of today and emergent structural formats as networks, company chains and joint ventures. Without constituting a finished solution, the concept of multidimensional organization is landmark (Ackoff, 1999).

Much has been written about the importance of knowledge and its management. The popular expression of the knowledge economy is a recognition that science will play a more relevant role, without forgetting the knowledge acquired by organizations.

In a quick and simple perspective, we leave a summary reflection on possible approaches, which can range from countries that own, produce and maintain leadership in knowledge (north countries), even those that bet more on their valorisation (orient, global south).

Another point of view has to do with the language. Although English continues to be the dominant language, other languages emerge, reflecting the respective areas of influence:

Ibero american Portuguese Spanish	**Africa** Portuguese Spanish English French Native	**Asia** Chinese Japanese Korean	**USA, Canada, UK** English	**Global** North South

Some R&D results show controversial, conflicting, and even contradictory and /or non-consensual outcomes in different countries, which could suggest that dimensions are lacking. Specifically, an attempt was made to identify other issues that may explain the divergences, such as methodological issues, scientific affiliation of researchers, insufficient details in the design of the investigation, and in the collection and analysis of data, and in this way to outline guidelines for areas lacking theoretical deepening (Saraiva et al, 2018). So, we have concluded that more applied research is needed to support the quality movement.   Competitiveness moves rapidly from the areas of production/service delivery to those closest to the market, such as identifying needs and transposing them into products and services. Thus, quality must focus more on these areas, refining existing techniques and methodologies and creating new ones. Unfortunately, innovation is not a panacea for quick and easy solutions, but a complex process with many variables and interactions between areas of knowledge, technologies, and functional areas of organizations. In particular, the need to explore the interactions and interrelationships between quality practices is emphasized.

The quality movement needs to foster longitudinal studies, looking for universal laws, what can be done through multidisciplinary only.

3.2 Future of Quality Movement

The following topics illustrate some challenging issues to deal with by quality movement

- Focus on attractive quality: We usually think of ‘attractive’ in the same sentence as physical appearance. But deep down, what we really find most attractive is value, satisfaction, unexpected, surprising.
- Competition leads to similar products and services, which necessarily leads to major differentiation efforts.
- Emotions must be considered whether they arise from living needs or whether they are established in personal connections to products and services and their suppliers
- In this way, expressions such acceptable for attraction can included in the functional expression of needs.

- Emergence of new forms of citizen participation in service design, delivery, and evaluation processes. Examples are:
  - Systems interoperability.
  - Possibilities for greater individualization of services (at lower cost).
  - New service design approaches.
  - Co-production and co-creation (a user view as co-producer - and value in use).
- More research on interactions. Many studies have not considered possible interaction between quality practices (e.g. Nair, 2005; Dahlgaard-Park et al, 2012; Sousa & Voss, 2002). In fact, nowadays we should be more focused on interactions than actions, because most knowledge is based on actions and few attempts are done on interactions. Nair (2005) states there is evidence of complex cross relations among QM practices. This is one typical example of the mess (situations characterized by complex systems, where there are highly interactive problems) where researcher on quality issues was down.

In this regard, it is pertinent to quote Dahlgaard-Park et al (2012, pp. 421):

1. “Hence the challenges have been continuously: to adjust and modify the QM framework and at the same time to continuously develop better tools and techniques in order to fit with the needs of these new service and knowledge intensified organizations”.
2. “One of the critical challenges in the future can be for instance: to develop better tools and techniques which can be adopted for realization of value co-creation between customers and service providers in service contexts. Accordingly developing a way to better involve and empower customers in all processes will be a critical issue”.

According to Sousa & Voss (2002):

- Interaction effects and interrelationship might also exist among QM practices and between the various performance dimensions.
- These interaction effects: distinguish successful companies from others and being a promising avenue for future research.

Finally, this set of issues arise the question of the future of quality professionals. The issue of the future competences of quality professionals has been discussed and the perspective points out the extension of data processing (Analytical Intelligence). However, the scope of application remains essentially the same (monitoring of processes), leaving a large area uncovered, exactly those that are most critical (interface with market, design for emotions).

The traditional areas of support for quality control and management (Industrial Engineering and Management) are struggling to maintain leadership, with the main contributions being made by the computer sciences and marketing.

As an example of the difficulty in finding a solution, various names are given for new competencies and roles within organizations:

- Blogger-in-Chief
- Director of Emerging Technologies for Best Practices
- Insights Editor
- Principal Data Scientist (some are mathematicians, part computer scientists and part trend watchers)
- Chief analytics officer
- Data manager
- Insights accelerator
- improvement specialists

About the Future of Quality Associations, as the business world and societies are in deep transformation, the associative structures of quality professionals are in serious difficulty finding their way to social utility.

There are no known studies or investigations that have focused on services, technical and scientific skills. However, the accumulated knowledge shows that many are reduced to bureaucratic structures, and it is urgent to rethink the mission and redefine strategies that can respond to the needs of the people and companies of our time.

For example, it would be expected that the European Organization for Quality (EOQ) would intervene at the level of the European community and the European area, through projects, and close and intervening relationships with policy makers and regulators. In an information and knowledge society, EOQ should be the holder of qualified information and knowledge, developing collaborative networks with its members and with the technical and scientific community of Europe and the world. Instead, it has a marginal role and has no communication tool (e.g. a specialist magazine), no knowledge (e.g. book publishing), no studies and reflections about the future.

However, the potential exists, such as the network that its members constitute and the synergies that can be exploited. The confounding weaknesses can be turned into strengths by focusing on knowledge production and dissemination, using the potential of information and communication technologies.

EOQ Network! What for? EOQ and EOQ Members. Are they connected? Have they data scientists? What about analytics? What about quality practices? Which relationships with academia and research? Why not a Collaborative European Journal? (Technical or/and Scientific?)

These are some of the issues that urgently need an answer for Quality Associations to survive, so a paradigm shift is needed to meet the digital society.

4. FINAL COMMENTS

There seems to be no single, structured way to create theories, but neither do there seem to be many researchers interested in the task. In multidisciplinary areas, the difficulties increase, as only research groups can be successful. In any case, without pressure for theoretical development, quality management will fall into a secondary position and will be reduced to limited empirical studies.

However, it must be admitted that there are some paradoxical aspects. The objective of creating a comprehensive theory (using contributions from various areas of knowledge), while constituting a generous purpose, easily falls into the impossibility of considering all variables, being easily criticized, since some of them were not considered.

In terms of operationalizing the variables, it can also be concluded that the multidimensional approach to QM practices and the performance of organizations is a better choice than just one dimension. As for the effects of interactions and interrelationships between QM practices and between these and the various performance dimensions, it is also known that they exist, but less is known about the mechanisms through which they manifest themselves.

However, if the identified challenges for the quality movement reach positive answers, those contributions will be relevant for sustainability of organizations, allowing them to be successful in the actual business context in such a way that they will successful in the future also.

The most critical activities for competitiveness lie in the early stages of the innovation cycle, where they are identified (or created) the needs and expectations and where they are translated into requirements for products and services. These early stages and particularly design is becoming increasingly important because the best sustainability solutions can be found here, considering all impacts on the life cycle. Reverse logistics complements the efforts made in design. The technical solutions must necessarily have scientific support, essential condition to minimize risks throughout the life cycle.

Lastly, this paper agrees with Klöpffer (2002:133), quality researchers and experts of different fields must develop and improve methods to operationalize the guiding principle of sustainability.

Nevertheless, the rise of digital is having huge impacts on business models and cultural perspectives and consequently on design and sustainability.

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Comparing quality profiles in Human-Robot Collaboration: empirical evidence in the automotive sector

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STRUCTURED ABSTRACT

Purpose- Human-Robot Collaboration (HRC) is a paradigm that is gradually consolidating in the industrial field. The goal of this paradigm is to combine human and robot skills to make production more flexible. An effective implementation of HRC requires a careful analysis of its different aspects, related to both robots and humans. For this reason, the development of a tool able to consider all HRC aspects to evaluate the collaboration quality is a real practical need.

Design/methodology/approach- In a previous work, Gervasi et al. (2020) proposed a multidimensional framework to evaluate HRC quality. This framework has been tested on a real industrial HRC application in the automotive sector. Two different alternatives of the same assembly task were analyzed and compared on the quality reference framework.

Findings- The comparison between the two alternatives of the same assembly task highlighted the framework's ability to detect the effects of different configurations on the various HRC dimensions. This ability can be useful in decision making processes and in improving the collaboration quality.

Social implications- The framework considers the human aspects related to the interaction with robots, allowing to effectively monitor and improve the collaboration quality and operator satisfaction.

Originality/value- This paper extends and shows the use of the HRC evaluation framework proposed by Gervasi et al. (2020) on real industrial applications. In addition, an HRC application implemented in an important automotive company is described and analyzed in detail.

Keywords: Human-Robot Collaboration, HRC evaluation framework, Automotive industry.

Paper type: Research paper

INTRODUCTION AND LITERATURE REVIEW

The sharing of workspace and the physical interaction between humans and robots in manufacturing processes are no longer a futuristic utopia, but a reality that has been consolidating in recent years. Unlike traditional robotic systems, collaborative robots represent a promising solution to meet the needs arising from the increasingly pressing demand for production based on "mass customization" (Mateus et al., 2019; Pine, 1993).

Collaborative robots represent one of the fundamental elements of Industry 4.0, as enabling technologies of adaptive systems based on flexibility, reconfigurability and production efficiency (Cohen et al., 2019; Mateus et al., 2019). At the same time, they provide an important opportunity for technological development in many areas where robotics is almost unfamiliar (Huang et al., 2020; Wang et al., 2019).

The main idea of Human-Robot Collaboration (HRC) is combining the capabilities of humans with those of robots. On the one hand, humans have innate flexibility, intelligence, dexterity, and problem-solving skills; on the other hand, robots provide precision, power, and repeatability (ISO/TS 15066:2016, 2016). The implementation of HRC introduces several issues related mainly to safety (Robla-Gómez et al., 2017; Vicentini et al., 2020), robot programming (Argall et al., 2009; Huang et al., 2020), task organization (Raatz et al., 2020), and human-related aspects (Salm-Hoogstraeten and Müsseler, 2020).

For an effective implementation of collaborative robot systems it is necessary to consider all aspects concerning HRC (Franceschini et al., 2019; Gervasi et al., 2019; Goodrich and Schultz, 2007). The evaluation methods currently available in the literature focus only on certain HRC aspects (Beer et al., 2014; Bröhl et al., 2016; Vicentini et al., 2020) or on the analysis of specific tasks or situations (Gualtieri et al., 2020; Rabbani et al., 2020; Rifinski et al., 2020). However, the attempt to build a general evaluation framework for HRC, able to consider all its aspects, seems to be less explored.

In a previous work, Gervasi et al. (2020) proposed a multidimensional conceptual framework to evaluate HRC, with some preliminary metrics. The aim of this paper is to extend this framework to real industrial HRC applications, focusing on the automotive sector. With reference to a specific HRC application, the evaluation framework will be also used to compare different design alternatives.

The paper is organized as follows. In the next section, a short summary of the HRC evaluation framework proposed by Gervasi et al. (2020) is provided. Afterwards, the methodology for collecting information on the real industrial HRC application is described. The subsequent section contains an in-depth description and analysis of a real industrial HRC application in the automotive sector. Next, a hypothetical variant of the application is analyzed and compared with the original one. Afterwards, a discussion of the obtained results is presented. Finally, the concluding section explores limitations and future research directions.

HRC EVALUATION FRAMEWORK

Gervasi et al. (2020) proposed a reference framework to evaluate HRC applications considering several characterizing aspects, both related to humans and robots. The framework was developed to allow the comparison and analysis of different HRC applications. Moreover, it can support decision making, highlighting HRC aspects that need to be improved. Below follows a brief description of the latent dimensions and sub-dimensions of the HRC evaluation framework (Gervasi et al., 2020), also summarized in Table 1:

- *Autonomy* represents the robot capabilities of sensing the surroundings, planning and acting according to the environment and other entities. Note that, in the HRC context, higher robot autonomy enables more advanced and complex interactions (Goodrich and Schultz, 2007; Thrun, 2004).
- *Information Exchange* represents the way information is exchanged between robot and human. It is composed of two sub-dimensions, namely *Communication format* and *Communication medium*, which refer to the senses involved in the communication and how communication takes place, respectively.
- *Team Organization* considers the organization of the agents involved in the collaboration. It is composed of *Structure of the team,* which refers to the number of robots and humans in the team, and *Role of members*, which represents to the role of each team member.
- *Adaptivity and Training* latent dimension concerns robot adaptivity and instruction as well as human training, and it is characterized by three sub-dimensions. *Robot adaptivity* represents the ability to accomplish a given task despite unexpected situations. *Robot training method* refers to the methods for instructing the robot to perform a certain task. *Operator training* indicates the effort in training the operators involved in a collaborative task.
- *Task* dimension contains information on the task to be performed, and it is composed of five sub-dimensions. *Field of application* refers to the field in which the task takes place. *Task organization* refers to the assignation of individual operations to each team member. *Performance* refers to the evaluation of the outcome of the collaborative task. *Safety* concerns

the identification of the risks and hazards involved in the task and the related safety measures implemented.

- *Human Factors* dimension concerns the understanding of interactions among human and robot to optimize human well-being and overall system performance (ISO 26800:2011, 2011). It is composed of five sub-dimensions. *Workload* refers to the effort of the human operators during a task. *Trust* is the attitude that an agent will help to achieve an individual's goal in a situation characterized by uncertainty and vulnerability (Charalambous et al., 2015). *Robot morphology* refers to the evaluation of the morphology and design of the collaborative robot. *Physical ergonomics* addresses the anatomical, anthropometric, and biomechanical characteristics of humans in relation to physical activity. *Usability* sub-dimension represents the evaluation and design of the interaction between human and robot that is supposed to take place.
- *Ethics* represents the common understanding of the principles that constrain and guide human behavior (BS 8611:2016, 2016). *Social impact* refers to the consequences of introducing a collaborative robotic system within a community. *Social acceptance* indicates the perception of the collaborative robotic system within a community.
- *Cybersecurity* is the process of protecting information by preventing, detecting, and responding to attacks (NIST, 2018). It is composed of five sub-dimensions. *Identification* represents the actions related to the understanding of policies, cybersecurity risks, and priorities relevant for managing cybersecurity risks. *Protection* concerns activities related to the development and implementation of safeguards to protect infrastructure services and to train staff. *Detection* includes activities related to the development and deployment of appropriate detection activities to identify cybersecurity events. *Response* represents activities related to the development and implementation of appropriate plans to act regarding a detected cybersecurity event. *Recovery* involves activities related to the development and implementation of appropriate plans to recover from cybersecurity events.

Table 1 – Summary of HRC evaluation framework with latent dimensions, sub-dimensions, and evaluation methods (Gervasi et al., 2020).

Dimension	**Sub-dimension**	**Evaluation method**	**Scale levels**
Autonomy	-	LORA (Beer et al., 2014)	(L0) Manual – (L1) Teleoperation – (L2) Assisted Teleoperation – (L3) Batch Processing – (L4) Decision Support – (L5) Shared Control with Human Initiative – (L6) Shared Control with Robot Initiative – (L7) Executive Control – (L8) Supervisory Control – (L9) Full Autonomy
Information Exchange	Communication medium	4-level scale	(L0) No senses involved – (L1) A sense between between sigh, hearing, and touch involved– (L2) Two senses between sigh, hearing, and touch involved– (L3) Sight, hearing, and touch involved
	Communication format	4-level scale	(L0) No means – (L1) Only control panel/displays – (L2) A human-natural communication mean implemented – (L3) At least two human-natural communication means implemented
Team Organization	Team structure	Categorical scale	List of robots and humans involved.
	Member role	3-level scale	(L0) Executor – (L1) Assistant – (L2) Master
Adaptivity and Training	Robot adaptivity	4-level scale (Krüger et al., 2017)	(L0) No adaptivity – (L1) No flexible adaptivity – (L2) Adaptiity – (L3) Adaptivity with respect to human
	Robot training method	3-level scale	(L0) Only manual programming – (L1) Automatic programming are implemented – (L2) Automatic programming methods based on natural communication are implemented
	Operator training	4-level scale	(L0) Very Heavy – (L1) Heavy – (L2) Medium – (L3) Light
Task	Field of application	Categorical scale	Description of the application context.
	Task organitation	List of operations	-
	Performance	4-level scale	(L0) Low – (L1) Medium – (L2) High – (L3) Very High
	Safety	Risk Assessment (ISO 10218-2:2011, 2011; ISO/TR 14121-2:2012, 2012)	(L0) Low – (L1) Medium – (L2) High – (L3) Very High

Table 1 – (continued)

Dimension	**Sub-dimension**	**Evaluation method**	**Scale levels**
Human Factors	Workload	NASA-TLX (Hart and Staveland, 1988)	(L0) Very High – (L1) High – (L2) Medium – (L3) Low
	Trust	Trust Scale questionnaire (Charalambous et al., 2015)	(L0) Low – (L1) Medium – (L2) High – (L3) Very High
	Robot morphology	Categorical scale (Yanco and Drury, 2004)	Anthropomorphic – Zoomorphic – Functional
	Physical ergonomics	EAWS (Schaub et al., 2013)	(L0) Red – (L1) Yellow – (L2) Green
	Usability	SUS (Bangor et al., 2008; Brooke, 1996)	(L0) Not acceptable – (L1) Marginal – (L2) Acceptable
Ethics	Social impact	3-level scale	(L0) Heavy – (L1) Medium – (L2) Light
	Social acceptance	Brohl TAM (Bröhl et al., 2016)	(L0) Low – (L1) Medium – (L2) High – (L3) Very High
Cybersecurity	Identification	Dedeke framework (Dedeke, 2017)	(L0) Partial – (L1) Risk informed – (L2) Repeatable – (L3) Adaptive
	Protection		(L0) Partial – (L1) Risk informed – (L2) Repeatable – (L3) Adaptive
	Detection		(L0) Partial – (L1) Risk informed – (L2) Repeatable – (L3) Adaptive
	Response		(L0) Partial – (L1) Risk informed – (L2) Repeatable – (L3) Adaptive
	Recovery		(L0) Partial – (L1) Risk informed – (L2) Repeatable – (L3) Adaptive

DATA COLLECTION AND METHODOLOGY

The HRC evaluation framework has been used to analyze a real industrial HRC application, which will be discussed in next sections. Evaluations were carried out by a team of experts based on the information collected. Data were acquired through direct observations of the production process, semi-structured interviews with managers, and questionnaires administered to operators working with collaborative robots.

In order to evaluate the sub-dimensions *Workload*, *Trust*, *Usability*, and *Social acceptance*, a single questionnaire has been created summarizing the ones proposed in the HRC evaluation framework (Gervasi et al., 2020) (see Appendix A). Although this choice may have led to a light degradation of the evaluation for these sub-dimensions, it was necessary to administer a questionnaire easy to use, immediately understandable and not too intrusive for operators.

CASE STUDY: PARKING PAWL ASSEMBLY TASK

The industrial HRC application considered concerns an assembly task in an important automotive company. The task consists of assembling a mechanical component, called "parking pawl", in the gearbox for vehicles in the U.S. market.

The workstation is managed by three agents: a robotic system and two human operators. The robot and the operators share the same workspace without physical or virtual safety barriers.

The robot system is composed of a single-arm collaborative robot UR10/CB3 (Universal Robots, 2019) and three end devices installed on the robot flange: an electromagnetic gripper to take screws from a box, a vision system (SensoPart Visor V20 2D) and a collaborative gripper (Robotiq 2F-85).

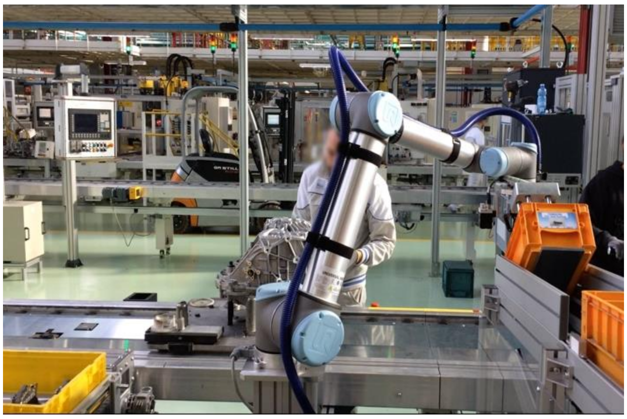
Table 2 shows the list of operations of the parking pawl assembly task, organized in four phases:

- First phase: a logistics staff operator sets up the workpieces in the appropriate boxes, also checking their correct position (Figure 1a).
- Second phase: the robot takes six screws from the workpiece box, through the electromagnetic gripper, and hands them to the operator (Figure 1b).
- Third phase: the robot takes with the gripper the parking pawl and hands it to the operator in an ergonomic position (Figure 1c).
- Fourth phase: the operator inserts the parking pawl into the gearbox and screws it in with a screwdriver (Figure 1d).

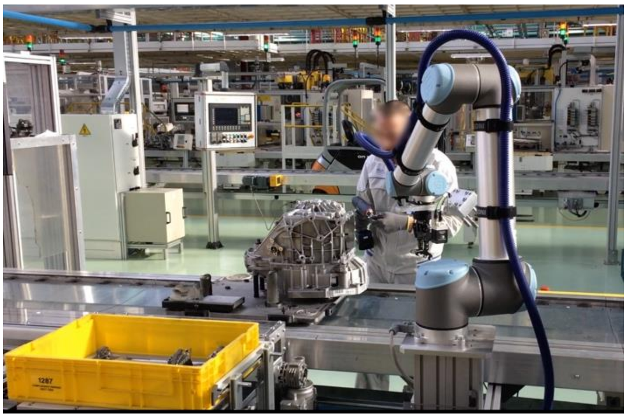
Table 2 – List, allocation and description of operations of the parking pawl assembly task.

Phase	Operation	Operation allocation	Description
0	**Parking pawl assembly** *1. Components setup* *2. Screws feeding* *3. Pawl feeding* *4. Pawl screwing*	**Humans - Robot** *Human (2)* *Human (1) - Robot* *Human (1) - Robot* *Human (1)*	Portion of gearbox assembly process performed by an operator in collaboration with a robot.
1.	*1. Components Setup* 1.1 Placing components into the box 1.2 Checking components in the box	*Human (2)* Human (2) Human (2)	Logistics staff sets up workpieces in the dedicated boxes, checking that they are correctly positioned.
2.	*2. Screws feeding* 2.1 Screws picking 2.2 Screws moving 2.3 Screw release	*Human (1) - Robot* Robot Robot Human (1) - Robot	The robot approaches the box containing the screws and picks them up via the dedicated gripper. The robot brings the screws closer to the operator, who extracts them.
3.	*3. Pawl feeding* 3.1 Pawl picking 3.2 Pawl moving 3.3 Pushbutton drive 3.4 Pawl releasing	*Human (1) - Robot* Robot Robot Human (1) Human (1) - Robot	The robot approaches the box containing the pawl and picks it up via the dedicated gripper. The robot brings the pawl closer to the operator. The operator presses the pushbutton to enable pawl release and extracts it.
4.	*4. Pawl screwing* 4.1 Pawl handling 4.2 Pawl insertion 4.3 Screwdriver load 4.4 Pawl tightening	*Human (1)* Human (1) Human (1) Human (1) Human (1)	The operator inserts the pawl into the appropriate seat. Afterwards, he sets each screw for insertion and tightens them with a screwdriver.

The following sub-sections describe the results of the analysis performed by a team of experts for each sub-dimension of the HRC evaluation framework. Table 3 provides a summary of the evaluations of the team of experts.



(a) (b)



(c) (d)

Figure 1 – Sequence of operations of the parking pawl assembly task: (a) Components setup; (b) Screws feeding; (c) Pawl feeding; (d) Pawl screwing.

Autonomy

Thanks to the vision system and the force sensor of the gripper, the robot is able to collect environmental data for the execution of the task and to support the operator in the execution of the planned task. The task planning is exclusive to the human. For these reasons, *Autonomy* was rated L3 ("Batch Processing") according to the evaluation scale based on LORA taxonomy (Beer et al., 2014; Gervasi et al., 2020).

Information Exchange

Communication between human and robot takes place through a teach pendant, displaying information about robot's status, and a button on the robot flange, used to order the robot to release workpieces. Since touch and sight senses are involved in communication, but no human-natural communication modality is implemented, *communication medium* and *communication format* were evaluated L2 and L1, respectively.

Team Organization

The *Team structure* is composed by 1 robot and 2 humans. The workstation is mainly composed of the robot and an operator, who carry out the assembly task; periodically, a second operator from the logistics area loads the workpieces into the appropriate boxes.

As for *Member roles*, the workstation operator is the master of process (L2), since he performs the assembly task and controls the task execution, the logistics staff operator is an assistant (L1), who provides support for task, and the robot is just an executor of the task instructions (L0).

Adaptivity and Training

The robot, thanks to the vision system, can identify the contour of objects to adjust its position and perform a correct grip. If the operation fails, the robot tries again three more times, after which it stops. Since the robot does not have the ability to learn from experience, but apply a fixed policy, *Robot adaptivity* was rated L1.

The robot was instructed using both offline programming and online programming via teach pendent. Since these methods are automatic programming methods, *Robot training method* was evaluated L1.

Operators involved in HRC task attended a training course organized by the robot manufacturer's academy. This course covered safety setting and teach pendant use. Thus, *Operator training* was evaluated L2 (Medium).

Task

Performance dimension was assessed L2 (High), based on information from interviews with managers and observations of the collaborative task.

Safety was evaluated through a risk-assessment based on a list of hazards contained in ISO 10218-2 standard (see Appendix B). The risk assessment was carried out considering the severity and probability of occurrence of harm, both evaluated on a 4-level scale. The assessment considered the risk reduction due to the implementation of protective measures, i.e. safety functions configured in the robot. These functions consisted of reducing the speed in the interaction zone and preventing unwanted movements or positions. This affected the probability of occurrence and the severity of harms. Regarding mechanical hazards, the most likely risks were "impact", "friction/abrasion" and "cutting/severing", due to the possibility of touching the robot and moving workpieces. However, the severity of harm of each of these risks was “Moderate” (L1), as the robot safety functions significantly reduced the damage and the possible contact regions were not vital organs. The other mechanical hazards (“entanglement”, “crushing”, “shearing”, “drawing-in/trapping”, “stabbing/puncture”) and hazards of other categories were evaluated with a “Serious” (L2) severity but “Remote” (L0) or

"Unlikely" (L1) probability of occurrence. Some hazards were assessed as "Not Available" (N/A) since potential harm was completely excluded. The final risk score obtained was 22/90, meaning that the *Safety* level is "Very High" (L3) according to the scale proposed in the HRC framework.

Human factors

Workload was rated "Medium" (L2), based on the results of the questionnaire and the adapted evaluation scale of the HRC framework (see Appendix A).

The responses collected by the operators revealed a high level of trust in the robot, with a final score of 19/20 (see Appendix A). Thus, *Trust* has been rated "Very High" (L3).

Physical ergonomics has been rated "Green" (L2), i.e. no risk or low risk for the operator. The task involves a low biomechanical load on the operator, as it requires the handling of low load objects and the application of low forces while maintaining a non-fatiguing posture. This is confirmed by the EAWS score of 15.5 (< 25), which indicates a low risk of biomechanical overload. For further details on the evaluation, see Appendix C.

Usability has been rated "Marginal" (L1). From the answers to the questionnaire (see Appendix A) the operators do not believe that the various functions of the robot are well integrated into the system.

Ethics

The implementation of the collaborative robot led to a significant reconfiguration of the assembly task. Previously, the assembly of the parking pawl was done in a dedicated off-line station. This operation was performed continuously and manually by one operator, on average for two shifts per day. Currently, this task has been integrated directly into the production line, resulting in a redeployment of personnel. Therefore, according to the scale proposed in the HRC framework (Gervasi et al., 2020), *Social impact* has been rated "Medium" (L1).

Social acceptance has been rated "High" (L2), based on the answers to the questionnaire (see Appendix A).

Cyber security

Identification, Protection, Detection, Response, and *Recovery* have been all evaluated "Risk informed" (L1) (Dedeke, 2017). The management of cybersecurity is part of the company's activities and is carried out by a specific and qualified personnel.

Table 5 – Evaluation summary of the parking pawl assembly task by the team of experts.

Dimension	Sub-dimension	Evaluation
Autonomy	-	L3 (Batch processing)
Information Exchange	Communication medium Communication format	L2 L1
Team Organization	Team structure Member role	2 Humans, 1 Robot Human (1) L2 (Master) Human (2) L1 (Assistant) Robot L0 (Executor)
Adaptivity and Training	Robot adaptivity Robot training method Operator training	L1 L1 L2 (Medium)
Task	Field of application Performance Safety	Manufacturing (automotive) L2 (High) L3 (Very High)
Human Factors	Workload Trust Robot morphology Physical ergonomics Usability	L2 (Medium) L3 (Very High) Functional (Single arm) L2 (Green) L1 (Marginal)
Ethics	Social impact Social acceptance	L1 (Medium) L2 (High)
Cybersecurity	Identification Protection Detection Response Recovery	L1 (Risk informed) L1 (Risk informed) L1 (Risk informed) L1 (Risk informed) L1 (Risk informed)

COMPARISON OF DESIGN ALTERNATIVES BY HRC FRAMEWORK

As pointed out in the introduction, the HRC evaluation framework (Gervasi et al., 2020) can also be used in the design phase as a tool to compare different alternatives of the same task. To show this use, a hypothetical alternative HRC scenario of the parking pawl assembly task was developed, evaluated, and compared with the original one by a team of experts.

As in the original HRC scenario, the workstation is managed by three agents: a robotic system and two human operators. The robotic system is equipped with an electromagnetic gripper, a vision system, and a collaborative screwdriver.

The operations of the hypothetical alternative HRC scenario are organized in four phases, which are the following:

- First phase: a logistics staff operator sets up the workpieces in the appropriate boxes.

- Second phase: the robot takes six screws from the workpiece box, through the electromagnetic gripper, and hands them to the operator.
- Third phase: the operator takes the parking pawl, inserts it into the gearbox and places the screws into the slots.
- Fourth phase: the robot performs the screwing with the collaborative screwdriver.

Figure 2 shows a comparison between the quality profiles of the original HRC application and the alternative one. *Autonomy*, *Information Exchange*, *Team Organization*, *Adaptivity and Training*, *Ethics*, and *Cybersecurity* have not undergone any changes compared to the original HRC scenario.

Regarding *Performance*, an increase from "High" (L2) to "Very High" (L3) has been hypothesized. Assigning the screwing operation to the robot could improve the quality of the product, reducing the risk of over-tightening and always having the correct tension, thanks to the robot precision and repeatability. *Safety* has been evaluated “High” (L2), suffering a decrease compared to the original HRC scenario. This is due to the presence of a screwdriver on the robot, which increases the risks of “crushing” and “stabbing/puncture”. *Workload* has been rated “High” (L1), since an increase in “frustration” is likely due to the new task allocation, although a slight decrease in “physical demand” is expected. The presence of a screwdriver as an end-effector may reduce the operator's trust, as well as the perception of safety, towards the robot. Therefore, *Trust* has been degraded from “Very High” (L3) to “High” (L2). Both *Physical ergonomics* and *Usability* have remained unchanged in the evaluations.

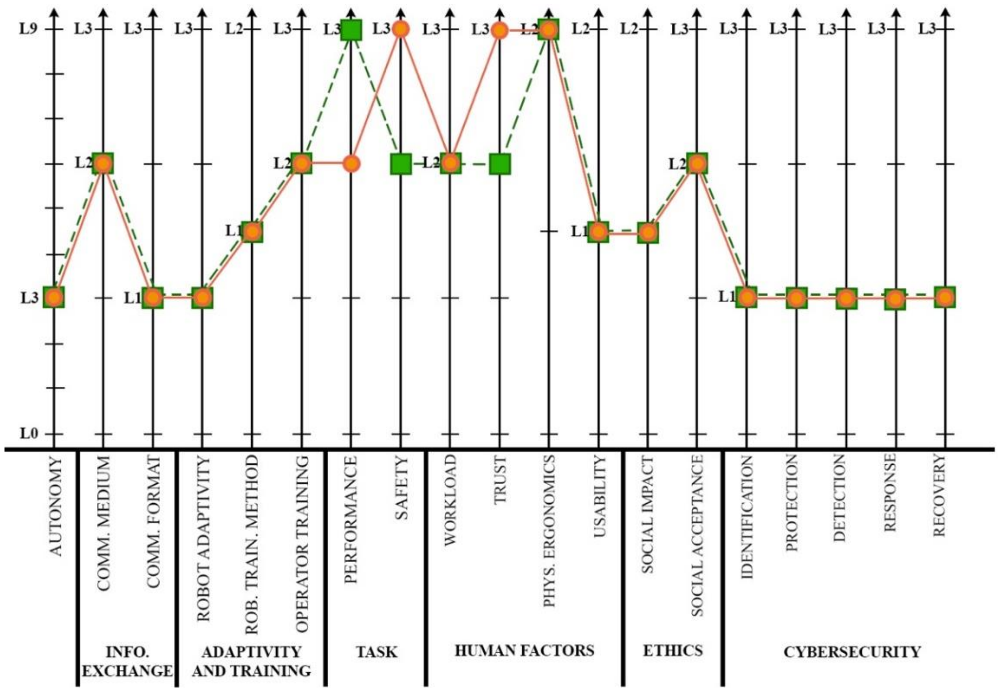


Figure 2 – Graphical comparison between the HRC quality profiles of the original parking pawl assembly task (orange) and the hypothetical alternative one (green).

DISCUSSION

The HRC reference framework proposed by Gervasi et al. (2020) , through the evaluation of each dimension, provides an extended and detailed representation of a collaborative task. This representation is focused on aspects related to each agent, their synergistic interaction, and the application context. Moreover, this representation allows to make considerations on the quality of the collaboration. For instance, in the industrial HRC application previously analyzed, it can be noted that the sub-dimensions *Safety*, *Trust*, and *Physical ergonomics* obtained quite high evaluations, indicating a good task design. However, *Autonomy* and *Communication format* were not particularly high, implying some limitation in the interaction.

Another use of the HRC evaluation framework consists in comparing different scenarios of the same application. For example, by varying the assignment of a task operation between operator and robot, a group of experts can understand which are the most suitable configurations. In order to show this possible exploitation, a hypothetical variant of the parking pawl assembly task was introduced. Once evaluated through the HRC framework, this variant was compared with the original HRC application. Looking at the evaluation profiles (Figure 2), it can be noted that the original HRC application outclasses the hypothetical one in almost all sub-dimensions. This result may suggest that the level of collaboration of the original HRC scenario is higher than that of the variant. Moreover, the comparison highlighted how changing certain aspects of a task can influence different HRC dimensions.

Further investigation to understand how to take advantage of the information provided by the HRC evaluation framework is needed. The creation of a global indicator that synthesizes the level of collaboration between human and robot is rather challenging, due to the heterogeneity of the aspects that influence it. However, one idea could be trying to identify benchmark profiles to define different collaboration levels. By examining a large sample of collaborative tasks and evaluating each of them through the HRC framework, it could be possible to cluster similar profiles. This process may lead to the identification of the most common collaboration profiles, which can constitute the benchmark levels of a potential HRC scale. However, during this operation, it has to be taken into account that the sub-dimensions of the HRC evaluation framework are not independent from each other (Gervasi et al., 2019).

CONCLUSIONS

A multidimensional HRC evaluation framework proposed by Gervasi et al. (2020) was examined and tested on an industrial HRC application in the automotive sector. Each framework dimension was evaluated by a team of experts supported by technical information provided by managers, process observations, and operators' feedback. By using the scales proposed in the reference framework, a structured description of the application with an evaluation profile was obtained.

A variant of the HRC application was also hypothesized and evaluated qualitatively. Some considerations were drawn from the comparison between the original HRC scenario and the alternative one. This procedure highlighted the framework's ability to detect the effects of different configurations on various HRC dimensions, which is useful in decision making processes and in improving the quality of collaboration and finished products.

Future investigations will concern the design of more agile questionnaires to evaluate some HRC dimensions (e.g., the possibility of using fuzzy scale rating to design questionnaire forms). Other future activities will focus on analyzing in depth the relationships between the different dimensions of the framework and on building benchmark profiles in order to create a unidimensional HRC scale.

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APPENDIX A - SYNTHETIC QUESTIONNAIRE

A synthetic questionnaire to evaluate *Workload*, *Trust*, *Usability*, and *Social acceptance* has been created. Table 4 shows the questionnaire items for each sub-dimension with their respective median scores for the parking pawl assembly task. Each item is evaluated on a five-point Likert scale, and, for each sub-dimension, the item scores are summed up to provide a final score. The final scores of each sub-dimension are interpreted using the respective evaluation scales proposed in the HRC evaluation framework, adapting them to the new scoring ranges.

Table 4 – Questionnaire to evaluate *Workload*, *Trust*, *Usability*, and *Social acceptance*. Negative items are indicated with " * " and scores are already correctly converted.

Dimension	**Item**	**Median Score (0 to 4)**	**Interquartile range**
Workload	How much mental and perceptual activity was required?	1	1
	How much physical activity was required?	2	2
	How irritated, stressed, and annoyed versus content, relaxed, and complacent did you feel during the task?	1	3
	How successful were you in performing the task? *	2	1
	Total	**6/16**	
Usability	I thought the system was easy to use	3	2
	I would imagine that most people would learn to use this system very quickly	3	1
	I found the system very cumbersome to use *	3	2
	I found the various functions in this system were well integrated	1	3
	Total	**10/16**	
Trust	The size of the robot did not intimidate me	4	1
	I was comfortable the robot would not hurt me	4	2
	I felt safe interacting with the robot	4	2
	The robot gripper did not look reliable *	3	3
	The way the robot moved made me uncomfortable *	4	2
	Total	**19/20**	
Social acceptance	People in my organization who use the robot have more prestige than those who do not	3	1
	I fear that I lose the contact to my colleagues because of the robot *	3	2
	I fear that I will lose my job because of the robot *	4	2
	Using the robot improves my performance in my job	2	3
	Total	**12/16**	

APPENDIX B - SAFETY DIMENSION EVALUATION

Safety has been evaluated through a risk-assessment based on a list of hazards contained in ISO 10218-2. Table 5 contains the evaluation results for the parking pawl assembly task, while Table 6 the risk matrix proposed in ISO/TR 14121-2 used for the evaluation.

Table 5 – Risk-assessment for the parking pawl assembly task

Type of risk	Risk	Probability	Severity	Risk indicator
Mechanical hazards	crushing	L0	L2	Low (1)
	shearing	L0	L2	Low (1)
	cutting or severing	L2	L1	Medium (2)
	entanglement	L1	L1	Low (1)
	drawing-in or trapping	L0	L2	Low (1)
	impact	L2	L1	Medium (2)
	stabbing or puncture	L0	L2	Low (1)
	friction, abrasion	L2	L1	Medium (2)
	high-pressure fluid/gas injection or ejection	N/A	N/A	N/A
Electrical hazards	electrocution	L0	L2	Low (1)
	shock	L0	L2	Low (1)
	burn	L0	L2	Low (1)
	projection of molten particles	N/A	N/A	N/A
Thermal hazards	burn (hot or cold)	L0	L2	Low (1)
	radiation injury	L0	L2	Low (1)
Noise hazards	loss of hearing	N/A	N/A	N/A
	loss of balance	N/A	N/A	N/A
	loss of awareness, disorientation	N/A	N/A	N/A
	any other	N/A	N/A	N/A
Vibration hazards	fatigue	L1	L1	Low (1)
	neurological demage	L0	L2	Low (1)
	vascular disorder	L0	L2	Low (1)
	impact	L0	L2	Low (1)
Radiation hazards	burn	N/A	N/A	N/A
	demage of eyes and skin	N/A	N/A	N/A
	releted illnesses	N/A	N/A	N/A
Material/substance hazard	sensitization	L0	L2	Low (1)
	fire	L0	L2	Low (1)
	chemical burn	L0	L2	Low (1)
	inhalation illness	N/A	N/A	N/A
Combinations of hazards	combinations of hazard	N/A	N/A	N/A

Table 6 – Risk matrix proposed in ISO/TR 14121-2.

	Severity of harm			
Probability of occurrence	(L3) Catastrophic	(L2) Serious	(L1) Moderate	(L0) Minor
(L3) Very likely	High (3)	High (3)	High (3)	Medium (2)
(L2) Likely	High (3)	High (3)	Medium (2)	Low (1)
(L1) Unlikely	Medium (2)	Medium (2)	Low (1)	Negligible (0)
(L0) Remote	Low (1)	Low (1)	Negligible (0)	Negligible (0)

APPENDIX C – PHYSICAL ERGONOMICS EVALUATION

EAWS (Schaub et al., 2013) has been used to evaluate *Physical ergonomics* sub-dimension. EAWS is divided in two macro-sections: Whole body and Upper limbs. The Whole-body macro-section is composed of four sections: Extra Points, Body Posture, Action forces and Manual material handling. The Upper limbs macro-section is composed of only one section, i.e. Upper limb load in repetitive tasks. Figures 3,4,5,6,7 and 8 show the evaluation of each EAWS section for the parking pawl assembly task.

<table>
<tr><th colspan="14">Extra points "Whole body" (per minute / shift)</th><th>Extra points</th></tr>
<tr><td rowspan="2">0a</td><td rowspan="2">Adverse effects by working on moving objects</td><td colspan="3">0</td><td colspan="3">3</td><td colspan="3">8</td><td colspan="3">15</td><td rowspan="2">Intensity
3</td></tr>
<tr><td colspan="3">none</td><td colspan="3">middle</td><td colspan="3">strong</td><td colspan="3">very strong</td></tr>
<tr><td rowspan="2">0b</td><td rowspan="2">Accessibility (e.g. entering motor or passenger compartment)</td><td colspan="3">0</td><td colspan="3">2</td><td colspan="3">5</td><td colspan="3">10</td><td rowspan="2">Status
/</td></tr>
<tr><td colspan="3">good</td><td colspan="3">complicated</td><td colspan="3">poor</td><td colspan="3">very poor</td></tr>
<tr><td rowspan="4">0c</td><td rowspan="4">Countershocks, impulses, vibrations</td><td colspan="3">0</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">5</td><td rowspan="4">Intensity × frequency
1 x 3 = 3</td></tr>
<tr><td colspan="3">light</td><td colspan="3">visible</td><td colspan="3">heavy</td><td colspan="3">very heavy</td></tr>
<tr><td colspan="2">0</td><td colspan="2">1</td><td colspan="2">2,5 3</td><td colspan="2">4</td><td colspan="2">6</td><td colspan="2">8</td></tr>
<tr><td colspan="2">[n]</td><td colspan="2">1 - 2</td><td colspan="2">4 - 5 6</td><td colspan="2">8 - 10</td><td colspan="2">18 - 20</td><td colspan="2">> 20</td></tr>
<tr><td rowspan="4">0d</td><td rowspan="4">Joint position (especially wrist)</td><td colspan="3">0</td><td colspan="3">1</td><td colspan="3">3</td><td colspan="3">5</td><td rowspan="4">Intensity × duration or frequency
/</td></tr>
<tr><td colspan="3">neutral</td><td colspan="3">~ 1/3 max</td><td colspan="3">~ 2/3 max</td><td colspan="3">maximal</td></tr>
<tr><td colspan="2">0</td><td colspan="2">2</td><td colspan="2">2,5</td><td colspan="2">4</td><td colspan="2">6</td><td colspan="2">8</td></tr>
<tr><td colspan="2">[s]
[n]
[%]</td><td colspan="2">3
1
5</td><td colspan="2">10
8
17</td><td colspan="2">20
11
33</td><td colspan="2">40
16
67</td><td colspan="2">60
20
100</td></tr>
<tr><td rowspan="2">0e</td><td rowspan="2">Other physical work load (please describe in detail)</td><td colspan="3">0</td><td colspan="3">5</td><td colspan="3">10</td><td colspan="3">15</td><td rowspan="2">Intensity
/</td></tr>
<tr><td colspan="3">none</td><td colspan="3">middle</td><td colspan="3">strong</td><td colspan="3">very strong</td></tr>
<tr><td></td><td>Extra = ∑ lines 0a – 0e</td><td colspan="6">Attention: Max. score = 40 (line 0c, 0d); Max. score = 15 (line 0a, 0e); Max. score = 10 (line 0b)</td><td colspan="6">Attention: correct evaluation, if duration of evaluation ≠ 60 s</td><td>= 6</td></tr>
<tr><td></td><td colspan="14">Lines 0a-b mainly relate to the Automotive Industry, for other sectors additional elements may be necessary. For details see the EAWS manual.</td></tr>
</table>

Figure 3 – Extra Points section of EAWS. Evaluations for the task are provided in red.

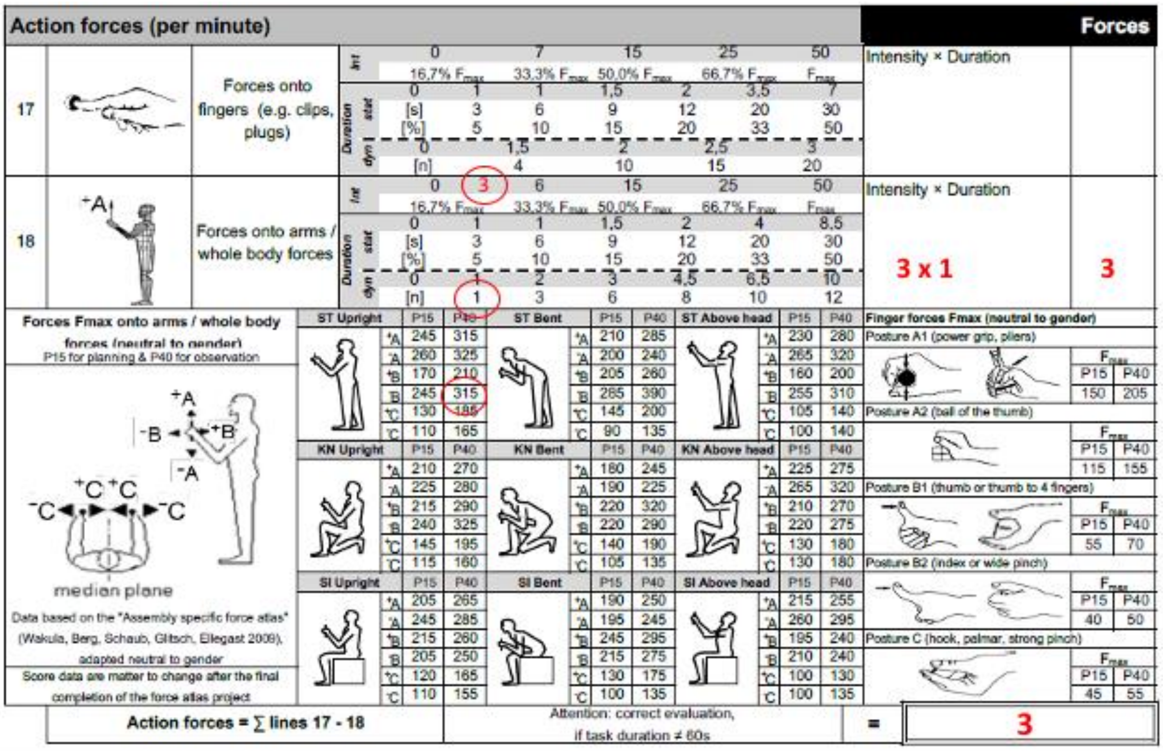
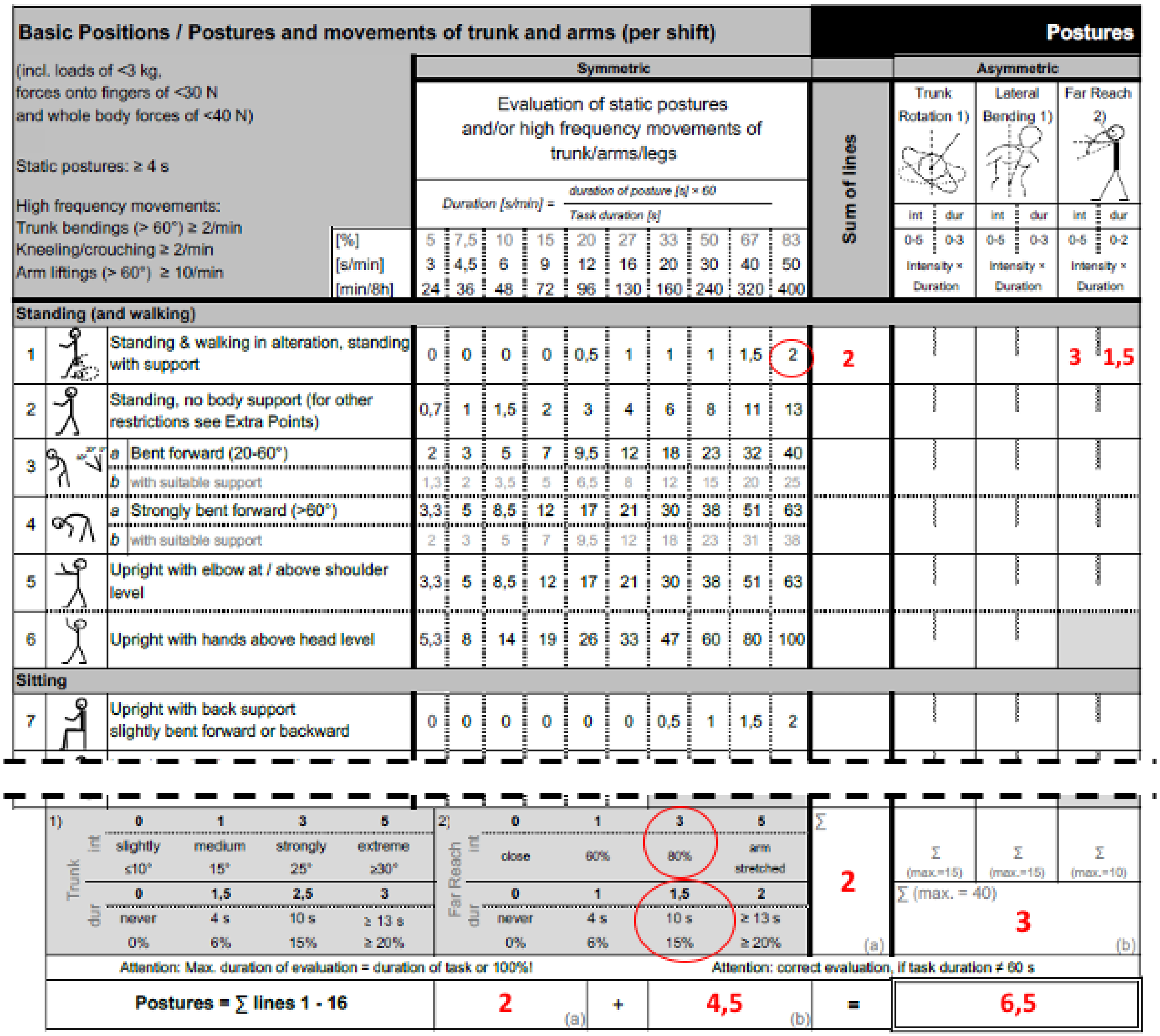


Figure 4 – Action forces section of EAWS. Evaluations for the task are provided in red.



Basic Positions / Postures and movements of trunk and arms (per shift)		Symmetric: Evaluation of static postures and/or high frequency movements of trunk/arms/legs. Duration [s/min] = duration of posture [s] × 60 / Task duration [s]										Sum of lines	Asymmetric: Trunk Rotation 1) (int 0-5, dur 0-3, Intensity × Duration)	Lateral Bending 1) (int 0-5, dur 0-3, Intensity × Duration)	Far Reach 2) (int 0-5, dur 0-2, Intensity × Duration)
(incl. loads of <3 kg, forces onto fingers of <30 N and whole body forces of <40 N) Static postures: ≥ 4 s High frequency movements: Trunk bendings (> 60°) ≥ 2/min Kneeling/crouching ≥ 2/min Arm liftings (> 60°) ≥ 10/min	[%]	5	7,5	10	15	20	27	33	50	67	83				
	[s/min]	3	4,5	6	9	12	16	20	30	40	50				
	[min/8h]	24	36	48	72	96	130	160	240	320	400				
Standing (and walking)															
1	Standing & walking in alteration, standing with support	0	0	0	0	0,5	1	1	1	1,5	2	2			3 1,5
2	Standing, no body support (for other restrictions see Extra Points)	0,7	1	1,5	2	3	4	6	8	11	13				
3	a Bent forward (20-60°)	2	3	5	7	9,5	12	18	23	32	40				
	b with suitable support	1,3	2	3,5	5	6,5	8	12	15	20	25				
4	a Strongly bent forward (>60°)	3,3	5	8,5	12	17	21	30	38	51	63				
	b with suitable support	2	3	5	7	9,5	12	18	23	31	38				
5	Upright with elbow at / above shoulder level	3,3	5	8,5	12	17	21	30	38	51	63				
6	Upright with hands above head level	5,3	8	14	19	26	33	47	60	80	100				
Sitting															
7	Upright with back support slightly bent forward or backward	0	0	0	0	0	0	0,5	1	1,5	2				

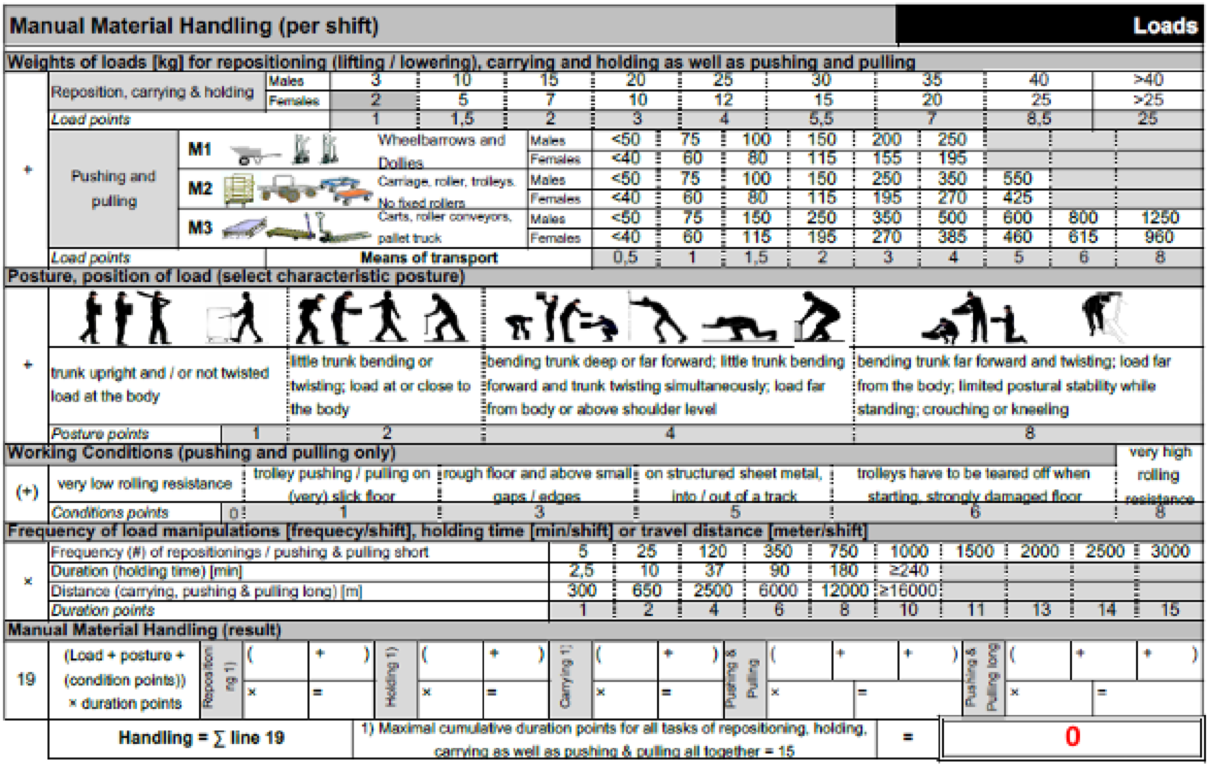
1) Trunk					2) Far Reach				
int	0	1	3	5	int	0	1	3	5
	slightly ≤10°	medium 15°	strongly 25°	extreme ≥30°		close	60%	80%	arm stretched
dur	0	1,5	2,5	3	dur	0	1	1,5	2
	never 0%	4 s 6%	10 s 15%	≥ 13 s ≥ 20%		never 0%	4 s 6%	10 s 15%	≥ 13 s ≥ 20%

Σ (a)	Σ (max.=15)	Σ (max.=15)	Σ (max.=10)
2	Σ (max. = 40) 3 (b)		

Attention: Max. duration of evaluation = duration of task or 100%! Attention: correct evaluation, if task duration ≠ 60 s

Postures = ∑ lines 1 - 16	2 (a)	+	4,5 (b)	=	6,5

Figure 5 – Body Postures section of EAWS. Evaluations for the task are provided in red.



Manual Material Handling (per shift) — **Loads**

Weights of loads [kg] for repositioning (lifting / lowering), carrying and holding as well as pushing and pulling

+	Reposition, carrying & holding	Males	3	10	15	20	25	30	35	40	>40
		Females	2	5	7	10	12	15	20	25	>25
	Load points		1	1,5	2	3	4	5,5	7	8,5	25

Pushing and pulling	M1 Wheelbarrows and Dollies	Males	<50	75	100	150	200	250			
		Females	<40	60	80	115	155	195			
	M2 Carriage, roller, trolleys. No fixed rollers	Males	<50	75	100	150	250	350	550		
		Females	<40	60	80	115	195	270	425		
	M3 Carts, roller conveyors, pallet truck	Males	<50	75	150	250	350	500	600	800	1250
		Females	<40	60	115	195	270	385	460	615	960
Load points	Means of transport		0,5	1	1,5	2	3	4	5	6	8

Posture, position of load (select characteristic posture)

+	trunk upright and / or not twisted load at the body	little trunk bending or twisting; load at or close to the body	bending trunk deep or far forward; little trunk bending forward and trunk twisting simultaneously; load far from body or above shoulder level	bending trunk far forward and twisting; load far from the body; limited postural stability while standing; crouching or kneeling
	Posture points 1	2	4	8

Working Conditions (pushing and pulling only)

(+)	very low rolling resistance	trolley pushing / pulling on (very) slick floor	rough floor and above small gaps / edges	on structured sheet metal, into / out of a track	trolleys have to be teared off when starting, strongly damaged floor	very high rolling resistance
Conditions points	0	1	3	5	6	8

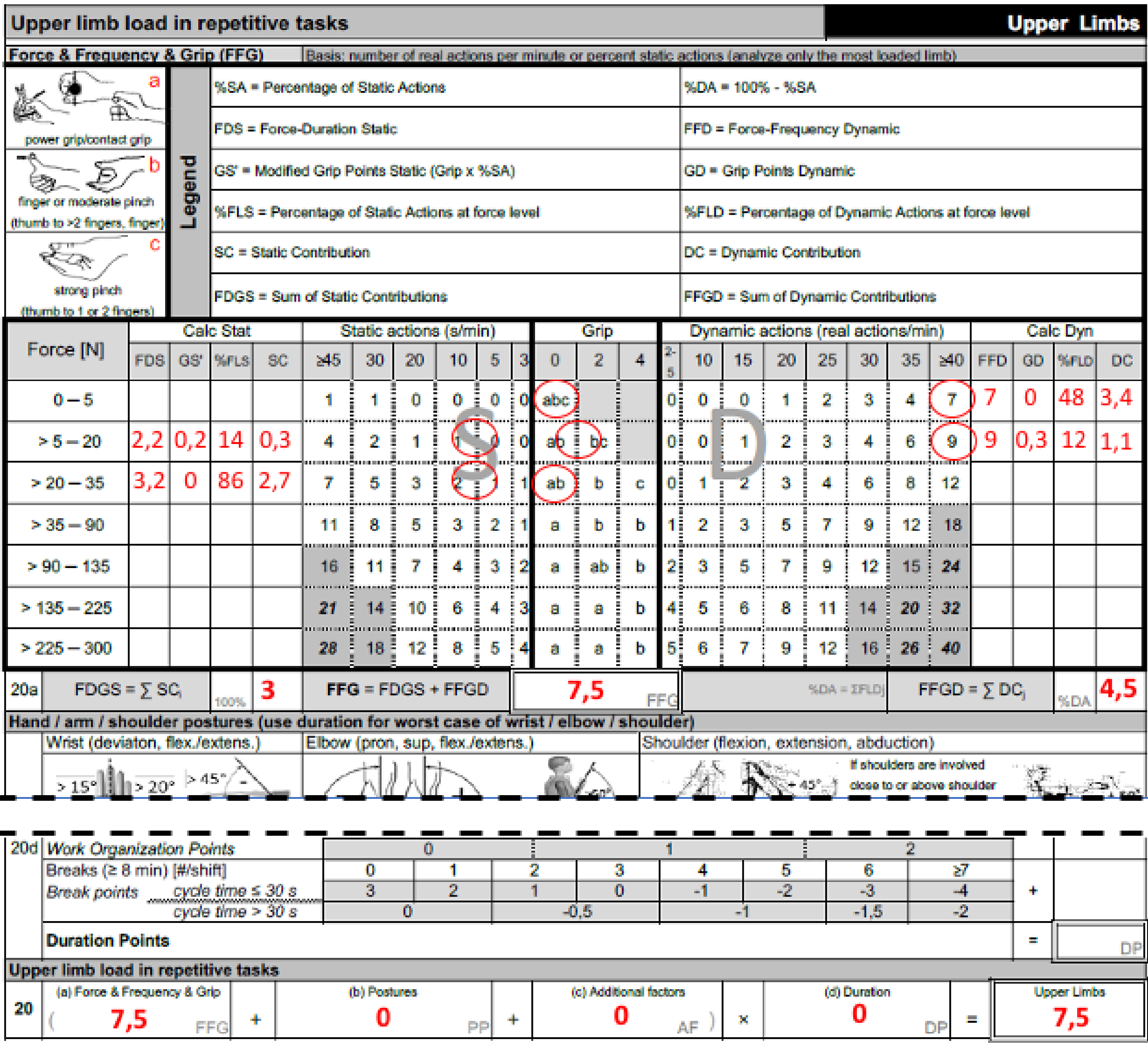
Frequency of load manipulations [frequecy/shift], holding time [min/shift] or travel distance [meter/shift]

×	Frequency (#) of repositionings / pushing & pulling short	5	25	120	350	750	1000	1500	2000	2500	3000
	Duration (holding time) [min]	2,5	10	37	90	180	≥240				
	Distance (carrying, pushing & pulling long) [m]	300	650	2500	6000	12000	≥16000				
	Duration points	1	2	4	6	8	10	11	13	14	15

Manual Material Handling (result)

19	(Load + posture + (condition points)) × duration points	Repositioning 1) (+) × =	Holding 1) (+) × =	Carrying 1) (+) × =	Pushing & Pulling (+ +) × =	Pushing & Pulling long (+ +) × =	
	Handling = ∑ line 19	1) Maximal cumulative duration points for all tasks of repositioning, holding, carrying as well as pushing & pulling all together = 15	=	0			

Figure 6 – Manual materials handling section of EAWS. Evaluations for the task are provided in red.



Upper limb load in repetitive tasks — **Upper Limbs**

Force & Frequency & Grip (FFG) — Basis: number of real actions per minute or percent static actions (analyze only the most loaded limb)

a: power grip/contact grip
b: finger or moderate pinch (thumb to >2 fingers, finger)
c: strong pinch (thumb to 1 or 2 fingers)

Legend

%SA = Percentage of Static Actions	%DA = 100% - %SA
FDS = Force-Duration Static	FFD = Force-Frequency Dynamic
GS' = Modified Grip Points Static (Grip x %SA)	GD = Grip Points Dynamic
%FLS = Percentage of Static Actions at force level	%FLD = Percentage of Dynamic Actions at force level
SC = Static Contribution	DC = Dynamic Contribution
FDGS = Sum of Static Contributions	FFGD = Sum of Dynamic Contributions

Force [N]	Calc Stat				Static actions (s/min)						Grip			Dynamic actions (real actions/min)								Calc Dyn			
	FDS	GS'	%FLS	SC	≥45	30	20	10	5	3	0	2	4	2-5	10	15	20	25	30	35	≥40	FFD	GD	%FLD	DC
0 – 5					1	1	0	0	0	0	abc			0	0	0	1	2	3	4	7	7	0	48	3,4
> 5 – 20	2,2	0,2	14	0,3	4	2	1	1	0	0	ab	bc		0	0	1	2	3	4	6	9	9	0,3	12	1,1
> 20 – 35	3,2	0	86	2,7	7	5	3	2	1	1	ab	b	c	0	1	2	3	4	6	8	12				
> 35 – 90					11	8	5	3	2	1	a	b	b	1	2	3	5	7	9	12	18				
> 90 – 135					16	11	7	4	3	2	a	ab	b	2	3	5	7	9	12	15	24				
> 135 – 225					21	14	10	6	4	3	a	a	b	4	5	6	8	11	14	20	32				
> 225 – 300					28	18	12	8	5	4	a	a	b	5	6	7	9	12	16	26	40				

S D

20a FDGS = ∑ SC$_i$ 100% **3** | FFG = FDGS + FFGD **7,5** FFG | %DA = ∑FLD$_i$ FFGD = ∑ DC$_i$ %DA **4,5**

Hand / arm / shoulder postures (use duration for worst case of wrist / elbow / shoulder)

Wrist (deviaton, flex./extens.): > 15° > 20° > 45° | Elbow (pron, sup, flex./extens.) | Shoulder (flexion, extension, abduction): 45° If shoulders are involved close to or above shoulder

20d Work Organization Points	0			1			2		
Breaks (≥ 8 min) [#/shift]	0	1	2	3	4	5	6	≥7	
Break points cycle time ≤ 30 s	3	2	1	0	-1	-2	-3	-4	+
cycle time > 30 s	0		-0,5		-1		-1,5	-2	
Duration Points									= DP

Upper limb load in repetitive tasks

20	(a) Force & Frequency & Grip		(b) Postures		(c) Additional factors		(d) Duration		Upper Limbs
	(7,5 FFG	+	0 PP	+	0 AF)	×	0 DP	=	7,5

Figure 7 – Manual materials handling section of EAWS. The evaluations for the task are provided in red.

Result of overall evaluation:

☑ green ☐ yellow ☐ red	WHOLE BODY	=	Postures	+	Forces	+	Manual handling	+	Extra	UPPER LIMBS
	15,5	=	6,5	+	3	+	0	+	6	7,5

EAWS evaluation		
0-25 Points	green	Low risk: - recommended; no action is needed
26-50 Points	yellow	Possible risk: – not recommended; redesign if possible, otherwise take other measures to control the risk
>50 Points	red	High risk:– to be avoided; action to lower the risk is necessary

Figure 8 – Overall score of EAWS. The evaluations for the task are provided in red.

Defect prediction model for wrapping machines assembly

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STRUCTURED ABSTRACT

Purpose – Development of a defect prediction model for the assembly of wrapping machines.

Design/methodology/approach – The assembly process of wrapping machines is firstly decomposed into several steps, called workstations, each one potentially critical in generating defects. According to previous studies, two assembly complexity factors related to the process and the design are evaluated. Experimental defect rates in each workstation are collected and a bivariate prediction model is developed.

Findings – Defects occurring in low-volume production, such as those of wrapping machines, may be predicted by exploiting the complexity based on the process and the design of the assembly.

Research limitations/implications – Although the defect prediction model is designed for the assembly of wrapping machines, the research approach can provide a framework for future investigation on other low-volume productions of similar electromechanical and mechanical products.

Practical implications – The defect prediction model is a powerful tool for quantitatively estimating defects of newly developed wrapping machines and supporting decisions for assembly quality-oriented design and optimisation.

Originality/value – The proposed model is one of the first attempts to predict defects in low-volume production, where the limited historical data available and the inadequacy of traditional statistical approaches make the quality control extremely challenging.

Keywords: Defect prediction, Assembly, Low-volume production, Wrapping machines.

Paper type: Research paper

INTRODUCTION

Defects occurring during the manufacturing process represent a huge issue for a wide range of industrial processes due to the dramatic impact they can cause, both in terms of quality and costs. The development and identification of appropriate models of defects predictions have long been a question of great interest in a wide range of manufacturing processes, including assembly. In the past years, a considerable literature has grown up around the theme of assembly defects, i.e. improper design, defective part, variance in assembly system and operator mistake. To this aim, traditional assembly quality control technologies and management approaches have been extensively exploited to evaluate, improve and control the assembly quality, such as design for assembly (DFA), Design of Experiments (DoE), Design Failure Modes and Effects Analysis (DFMEA), Statistical Process Control (SPC), data mining and sensor-based monitoring (Boothroyd and Alting, 1992; Shin et al., 2006; Zhang and Luk, 2007). Recently, some investigations have focused on assembly defects caused by operator errors, focusing on the close relationship between them and the product assembly complexity (Antani, 2014; Falck et al., 2017; Hinckley, 1994; Krugh et al., 2016; Shibata, 2002; Su et al., 2010). Although extensive research has been carried out on the prediction of operator-induced assembly defects, it has been mostly restricted to mass productions, involving millions of parts and assembly operations. To date, only a limited number of studies is directed to the investigation of defects occurring in low-volume assembly processes. Under these considerations, taking the wrapping machines assembly as an example, the mechanisms of the operator error-induced assembly defect are explored systematically in this paper. The specific objective of this study is to investigate the effect of assembly complexity on the defects occurring in low-volume assembly processes. Specifically, the Research Question (RQ) addressed in this paper is the following:

RQ: *As for mass productions, can defects in the assembly processes of wrapping machines be predicted by assembly complexity?*

In order to answer this question, the assembly process of wrapping machines is firstly decomposed into several steps, called workstations, and into elementary operations. Then, according to previous studies referring to mass productions, two assembly complexity factors related to the process and the design are obtained for each workstation. Experimental defect rates are collected, and the defect prediction model is developed. This study provides new insights into the prediction of defects in low-volume production, where the limited historical data available and the inadequacy of traditional statistical approaches make quality control extremely challenging. The defect prediction model developed is a powerful tool that designers can use to estimate defects of newly developed wrapping machines quantitatively and to design and optimise the assembly process of quality-oriented wrapping machines. The findings of the present research should make an essential contribution to the field of low-volume assembly processes because, although the defect prediction model is specifically designed for the assembly of wrapping machines, the research approach can provide a general framework for future investigation on other low-volume productions, especially in electromechanical and mechanical fields.

The paper is arranged as follows. In "Assembly modelling of wrapping machines" section, the assembly process of wrapping machine, specifically that of the pre-stretching device, is modelled. Then, in "Assembly complexity factors" section, the two complexity factors related to the process and the design are introduced and analysed. The defects prediction model is discussed in "Defect prediction model" section. Finally, "Conclusions" section summarises the main findings of the paper, the limitation of the prediction model and the future research topics.

ASSEMBLY MODELLING OF WRAPPING MACHINES

Wrapping machines are electromechanical machines exploited at the end of production lines to pack palletised loads with a stretch plastic film. Three main categories of machines are typically available: (i) turn table, (ii) rotating arm and (iii) rotating ring wrapping machines (see Figure 1).

(i) (ii) (iii)

Figure 1 – Illustration of the three main categories of wrapping machines: (i) turn table, (ii) rotating arm and (iii) rotating ring.

This work focuses on the last category, i.e. the rotating wrapping machines produced in particular by the company Tosa Group S.p.A. (Italy). The total number of machines produced each year is of about 50 units. Accordingly, this production can be considered a low-volume manufacturing process. Furthermore, each assembled machine is highly customised, making it almost a unique piece.

Rotating wrapping machines consist of three main units: (i) mechanical unit, (ii) electrical and electronic unit and (iii) software unit. The mechanical unit (see Figure 2) is composed of two parts: one fixed and the other mobile. The fixed part is made up of:

1. the frame, i.e. the load-bearing structure, dimensioned to guarantee strength and durability, made up of boxes and profiles in high-strength sheet steel;
2. the cutting-hooking-welding unit that automatically cuts the plastic film employing a heated metal wire and heat-seals the last tail to the load with a special plate;
3. the pantograph presser, which stabilises the palletised load, exerting pressure on its top during the wrapping process.

Besides, the mobile part is made up of a trolley consisting of:

4. a rotating ring, built with a calendered steel profile, light but very resistant and therefore suitable for high speeds. It is moved by a special belt connected to an electric motor. The rotation of the ring around the palletised load is combined, during the winding cycle, with the vertical sliding of the rotating ring to which the pre-stretching unit is fixed;
5. the pre-stretching device, which is an electromechanical device, allowing: (i) the pulling/unwinding, (ii) the pre-stretch and positioning of the plastic film, (iii) the wrapping of the pallet with the required number of windings.

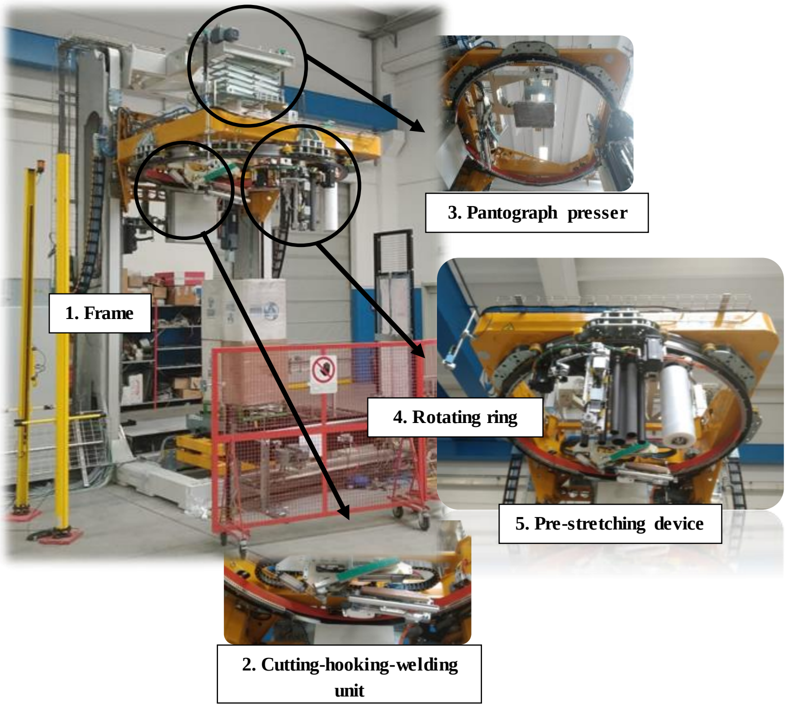


Figure 2 – Illustration of the main components of the mechanical group of a rotating ring wrapping machine of the company Tosa Group S.p.A. (Italy).

The electrical and electronic unit includes all the wiring of the various components, sensors and motors onboard the machine and the general electrical panel. The software unit is designed for the control of the machine, as well as for communication with the operator, whose programming and configuration is entrusted to a specialised external supplier.

During a typical working cycle, the palletised load is carried utilising a roller or belt conveyor system within the area delimited by the trolley. Then, the pantograph presser goes down by pressing on the top of the palletised load to ensure its stability during the film wrapping phase. The trolley goes down, the ring starts to rotate, and at the same time, the plastic film passes through the pre-stretching unit and is distributed around the load. After a variable number of wrappings according to the palletised load, the wrapping cycle ends: the cutting-hooking-welding unit provides to detach the plastic film tail, and the load is left free to be transported to the next station. Then a new pallet enters the perimeter of the machine ring and the cycle is repeated.

Given the complexity and the high number of components of the wrapping machine, this paper focuses on the assembly of the single pre-stretching device. The main reason is that, although each machine differs from the others in some details, this device is common to all rotating ring wrapping machines. Nevertheless, the proposed approach can be extended and implemented to the overall wrapping machine.

The pre-stretching device (see Figure 3) is installed on a support structure called frame plate. The stretch film runs through two rubber rollers, each one connected by a belt drive system to a brushless motor: the speeds of the two rollers are therefore independent of each other. By coming into contact with the surface of the two rollers, the film is stretched in quantity proportional to this speed difference, thus determining a significant increase in the length of the film that is wrapped on the load. The electronic system measures the speed using special sensors and keeps the tension of the film constant during its application on the entire surface of the pallet. Besides, the pre-stretching device may be equipped with a patent spindle which automatically replaces the empty film reel.

The assembly of the pre-stretch device may be subdivided into 29 workstations, as illustrated in Figure 4. According to previous studies, the workstations are assembly steps defined within operation standards, i.e. instruction sheets for work procedure (Shibata, 2002; Su et al., 2010). As evidenced in Figure 4, each of the pre-stretching device subassemblies is first assembled on the bench by an operator and then assembled on the frame plate. Each workstation can be decomposed in turn into job elements, defined as elementary operations that have definite start and end points (Shibata, 2002). These should have easily identifiable starting and stopping points and be repeatable regularly throughout the working day (Aft, 2000). The number of job elements in each workstation is also reported in Figure 4.

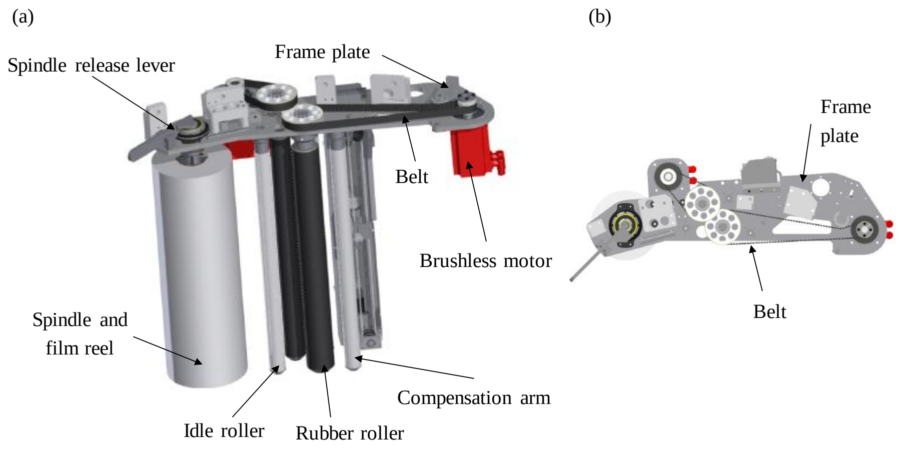


Figure 3 – 3D CAD model of the pre-stretching device: (a) front view and (b) top view, with indication of the main components.

BENCH ASSEMBLY

No. WS	WS Description	N_a
1	Motor no. 1 bench assembly	6
2	Motor no. 2 bench assembly	6
3	Support plate of motor no. 2 bench assembly	3
4	Spindle bench assembly	3
5	Rubber tyres bench assembly	12
6	Idle rolls bench assembly	12
7	Rubberized pads bench assembly	3
8	Belt tensioner device bench assembly	3
9	Driven wheels of transmission system bench assembly	2

ASSEMBLY ON THE FRAME PLATE

No. WS	WS Description	N_a
10	Pre-stretch frame plate preparation	3
11	Rubber rollers on pre-stretch frame plate assembly	4
12	Idle rollers on pre-stretch frame plate assembly	6
13	Motor no. 1 on frame plate assembly	1
14	Transmission system of motor no. 1 assembly	2
15	Motor no. 2 on frame plate assembly	4
16	Transmission system of motor no. 2 assembly	2
17	Motor no. 1 bracket on pre-stretch frame plate assembly	1
18	Belt tensioner on pre-stretch frame plate assembly	2
19	Transmission system of motor no. 1 calibration	2
20	Transmission system of motor no. 2 calibration	2
21	Spindle preparation for assembly on pre-stretch frame plate	2
22	Spindle group on pre-stretch frame plate assembly	6
23	Rubber pads on pre-stretch frame plate assembly	2
24	Motor assembly no. 1 final steps	1
25	Motor assembly no. 2 final steps	1
26	Spindle release lever bench assembly	1
27	Spindle release lever on pre-stretch frame plate assembly	3
28	Compensation arm bench assembly	9
29	Compensation arm on pre-stretch frame plate assembly	3

Figure 4 – Subdivision of the assembly process of the pre-stretching device into workstations (WS). For each WS, the number of job elements (N_a) is evidenced (3rd column).

ASSEMBLY COMPLEXITY FACTORS

In this Section, the two predictors of the defect model used to estimate defects occurring in each workstation (process-based and design-based complexity factors) are described and analysed.

Process-based complexity factor

According to Shibata (2002), the Defects Per Unit occurring in each i-th workstation (DPU_i) may be predicted by exploiting the assembly times and the number of job elements in each i-th workstation, by defining a process-based complexity factor for each i-th workstation, called $Cf_{P,i}$, as follows:

$$Cf_{P,i} = \sum_{j=1}^{Na_i} SST_{ij} - t_0 \cdot N_{a,i} = TAT_i - t_0 \cdot N_{a,i} \qquad (1)$$

where $N_{a,i}$ is the number of job elements in the workstation i, SST_{ij} is the Sony Standard Time spent on the job element j in the workstation i, TAT_i is the total assembly time related to the workstation i, and t_0 is the threshold assembly time, i.e. the time required to perform the simplest assembly operation (Shibata, 2002).

In this work, instead of using Sony Standard Time (typical of Sony's home audio products), the times of each job element were evaluated by considering the average value of 3 measurements of the assembly times. The threshold assembly time t_0 was set at 0.04 min (specifically 2.33 s), which corresponds to the time required to perform the least complex job element. In Table 5, the obtained total assembly time TAT_i, and the final values of the first predictor $Cf_{P,i}$, for each i-th workstation, are listed.

Design-based complexity factor

As evidenced by Shibata (2002), the time-related measures, and therefore the $Cf_{P,i}$, may not capture all the sources of defects. For this reason, a design-based assembly complexity factor was introduced in his work (Shibata, 2002). Specifically, such design complexity factor was defined as the ratio between a calibration coefficient and the ease of assembly (EOA) coefficient of the corresponding workstation estimated through the assembly/disassembly cost-effectiveness (DAC) method developed in Sony Corporation (Yamagiwa, 1988). In a later study, Su et al. (2010) remarked that the DAC method was developed specifically for Sony electronic products; therefore it may not be directly suitable for other types of products, such as electromechanical products (copiers in particular). Accordingly, a different method for evaluating the design-based assembly complexity factor was proposed (Su et al., 2010). In this paper, since a wrapping machine is substantially an electrotechnical equipment, the design-based complexity factor of Su et al. (2010) was used as a second predictor.

The methodology adopted to evaluate the design-based complexity factor ($Cf_{P,i}$) is based on the approach developed by Ben-Arieh for evaluating the degree of difficulty of assembly operations (Ben-Arieh, 1994). According to Ben-Arieh (1994), assembly operations can be specified by parameters related to the parts' geometry (geometry-based parameters) and ones related to the type of contact between the components (non-geometrical parameters), see Table 1.

Table 1 - Parameters of assembly operations (Ben-Arieh, 1994).

	Geometry-based parameters		**Non-geometrical parameters**
(a)	Shape	(n)	Position contact
(b)	Force required	(o)	Snap contact
(c)	Mating direction	(p)	Spring contact
(d)	Alignment of components	(q)	Gear contact
(e)	Mating component's length	(r)	Clamp fit
(f)	Length of components intersection	(s)	Belt contact
(g)	Ratio of length to width (diameter) of the mating component		
(h)	Ratio of the mating component's weight to the mated one		
(i)	Stability of the resultant assembly		
(l)	Amount of support required for the assembly operation		
(m)	Interference (reachability) to the assembled component		

Depending on the characteristics of the products to be assembled, a number l of parameters should be selected as criteria for evaluating the design-based assembly complexity. In this work, $l = 11$ parameters were selected (see Table 2), adapting Ben Arieh's approach to the case of wrapping machines. Then, to obtain an integrated index, the weights of the l criteria are allocated using the Analytic Hierarchy Process (AHP) approach (Ben-Arieh, 1994; Saaty, 1980; Wei et al., 2005). In detail, e evaluators, 2 engineers and 4 assembly operators in this specific study, are asked to compare the relative importance of each parameter in determining the difficulty of inserting a part into a product. The evaluation scale used for the relative importance between each pair of parameters ranges from a minimum of 1, which indicates equal importance of the two parameters, to a maximum of 9, which represents the dominant importance of the considered parameter with respect to the other. The result of this first interview produced a total of 6 paired comparison matrices, whose individual evaluations were then aggregated into a single paired comparison matrix representative of the group judgment by using the geometric mean, as suggested by Dong and Saaty (2014). From the paired comparison matrix reported in Table 3, the weights w_q of the l parameters were derived, according to Eq. (2), and are listed in Table 2:

$$w_q = (\prod_{r=1}^{l} a_{qr})^{1/l} / \sum_{q=1}^{l} (\prod_{r=1}^{l} a_{qr})^{1/l} \qquad (q=1,\dots,l) \tag{2}$$

where:

- a_{qr} is the relative importance of parameter q over parameter r (r =1,…,l);
- l is the number of parameters (here l=11);
- w_q is the weight of parameter q, as listed in Table 2.

For instance, taking parameter P1 as an example, the corresponding weight w_q (q=1) is:

$$w_1 = \frac{1.761}{12.693} = 0.139$$

Table 2 - Parameters chosen from those in Table 1 for evaluating the design-based complexity factor and their weights.

Parameter	**Ref. Table 1**	**Parameter description**	**Weight**
P1	(a)	Shape of mating objects	0.139
P2	(b)	Force required	0.120
P3	(d)	Alignment of components	0.150
P4	(c)	Mating direction	0.169
P5	(h)	Ratio of the mating component's weight to the mated one	0.094
P6	(g)	Ratio of length to width (diameter) of the mating component	0.091
P7	(m)	Reachability to the assembled component	0.056
P8	(e)	Mating component's length	0.064
P9	(l)	Amount of support required for the assembly	0.037
P10	(i)	Stability of the resultant assembly	0.041
P11	(f)	Length of components intersection	0.038

Table 3 - Paired comparison matrix of parameters for evaluating the design-based assembly complexity.

Parameter	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	$(\prod_{r=1}^{l} a_{qr})^{\frac{1}{l}}$
P1	1.00	1.32	1.96	0.78	0.60	2.59	5.58	2.72	2.93	1.53	2.38	1.761
P2	0.76	1.00	3.05	0.83	1.26	0.79	1.67	3.63	2.51	1.27	2.89	1.529
P3	0.51	0.33	1.00	1.26	3.04	1.26	3.80	2.12	5.10	4.93	7.41	1.907
P4	1.29	1.21	0.79	1.00	2.74	4.39	3.53	1.36	3.37	5.13	3.69	2.151
P5	1.66	0.79	0.33	0.53	1.00	1.47	1.02	1.10	3.45	5.44	0.97	1.192
P6	0.39	1.26	0.79	0.23	0.68	1.00	3.52	1.41	5.38	2.67	1.21	1.161
P7	0.18	0.60	0.26	0.28	0.98	0.28	1.00	1.28	1.76	1.31	3.69	0.714
P8	0.37	0.28	0.47	0.73	0.91	0.71	0.78	1.00	2.00	1.51	1.85	0.810
P9	0.34	0.40	0.20	0.30	0.29	0.19	0.57	0.50	1.00	1.51	1.24	0.466
P10	0.66	0.79	0.20	0.20	0.18	0.37	0.76	0.66	0.66	1.00	1.69	0.523
P11	0.42	0.35	0.13	0.27	1.03	0.82	0.27	0.54	0.81	0.59	1.00	0.480
										$\sum_{q=1}^{l}(\prod_{r=1}^{l} a_{qr})^{1/l}$		12.693

Furthermore, the *e* evaluators were asked to express an evaluation on the degree of difficulty of each parameter in each workstation. Specifically, the evaluation of the parameter *q*-th in the workstation *i*-th estimated by the evaluator *k*-th is denoted as A_{kqi}. Such evaluations are rated by scores between 0 and 10. The question asked to the evaluators was the following: *"How much does the q-th parameter affect the assembly difficulty in the i-th workstation on a scale from 0 to 10, where 0 corresponds to no difficulty and 10 corresponds to maximum difficulty?"*

In order to align the assessment scales, the framework provided in Figure 5 was explained to each evaluator. This tool allowed the evaluators to use the same scale of judgement by creating conventional alignment metrics.

In this specific case, 6 matrices were obtained, one for each evaluator. Then, by averaging the evaluations of the *e* evaluators, for each *q*-th parameter in each *i*-th workstation, the matrix of the degrees of difficulty was derived (see Table 4).

Table 4 – Degrees of difficulty matrix for evaluating the design-based assembly complexity.

	Parameter										
Workstation	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
1	4.00	4.17	4.17	4.50	5.17	3.67	4.33	3.17	6.00	5.83	5.50
2	4.33	4.33	4.17	4.50	5.17	3.67	5.67	3.33	6.00	5.83	6.33
3	5.83	6.50	5.50	4.33	4.00	3.50	5.00	4.00	6.50	5.00	6.00
4	3.67	4.00	3.50	3.33	4.83	3.83	6.00	5.17	6.00	6.83	6.67
5	4.17	7.33	4.83	5.33	4.67	6.33	5.83	6.67	7.83	6.50	7.33
6	3.83	5.67	4.83	3.50	4.00	5.83	5.00	6.50	6.33	6.50	6.67
7	2.83	3.50	3.00	2.67	1.50	2.00	2.67	1.67	3.00	4.00	4.83
8	3.83	4.17	4.17	3.17	2.33	1.83	3.50	1.83	4.67	5.00	5.50
9	5.00	2.83	6.00	2.83	2.33	2.67	2.83	2.33	1.17	6.17	5.17
10	4.17	3.50	5.00	2.00	6.17	5.33	2.67	4.33	5.67	5.83	4.83
11	4.00	4.67	6.17	3.67	6.33	7.17	4.50	7.67	5.33	6.83	5.67
12	4.00	4.00	6.00	3.67	6.00	6.83	4.50	7.17	5.00	7.17	5.33
13	3.83	5.17	6.67	4.83	5.83	4.83	3.50	5.00	5.50	5.33	5.00
14	6.17	5.00	6.67	6.33	3.17	4.00	6.00	3.83	3.17	6.67	6.17
15	4.17	5.00	6.50	4.50	5.17	5.00	4.17	4.83	5.17	5.00	3.67
16	5.50	4.83	5.83	6.00	2.67	3.67	6.00	3.00	2.83	6.17	6.17
17	3.17	3.67	6.33	5.00	4.00	3.33	3.33	3.17	3.17	4.83	4.00
18	3.67	3.67	6.50	5.17	3.00	3.33	4.00	2.83	3.00	6.33	2.67
19	4.33	5.17	7.33	5.67	3.50	5.00	5.83	3.00	3.83	6.83	4.67
20	4.33	5.17	7.33	5.67	3.50	4.50	5.50	3.83	3.83	6.67	5.67
21	3.50	4.17	6.17	4.83	6.33	7.00	4.50	7.17	4.33	4.50	4.67
22	5.50	5.67	5.33	5.17	5.67	6.50	6.33	6.83	5.17	4.50	4.67
23	3.50	4.67	4.67	4.00	3.50	3.17	4.33	3.67	3.67	5.83	6.17
24	3.17	3.17	5.17	5.33	3.83	3.00	4.67	2.67	3.17	5.00	4.83
25	3.33	3.33	5.67	5.50	3.83	3.17	4.50	3.17	3.00	5.00	4.83
26	4.00	2.83	5.50	5.00	2.50	3.33	3.67	4.00	2.83	5.00	4.83
27	4.33	4.67	5.83	5.00	4.17	3.50	4.50	4.83	3.33	6.00	5.17
28	4.83	4.33	6.33	5.17	5.17	6.17	5.17	7.33	5.33	6.83	6.33
29	3.83	4.50	5.83	5.83	3.33	5.00	4.67	6.00	3.00	5.83	6.83

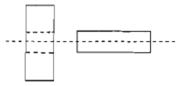
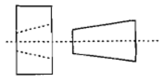
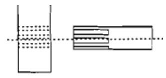
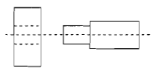
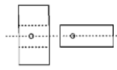
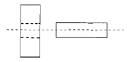
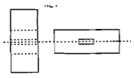
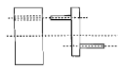
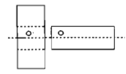
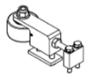
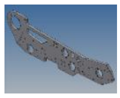
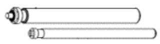
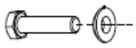
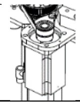
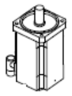
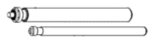
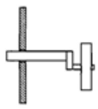
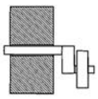
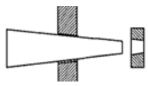
Parameter	Parameter description	Degree of difficulty 0-3	Degree of difficulty 3-6	Degree of difficulty 6-10
P1	Shape of mating objects			
P2	Force required	Simple coupling (no manual tool required)	Forced coupling (manual tool required)	Coupling with hydraulic press (20000 kg)
P3	Alignment of components	Mechanical stop 	Stop with reference 	No reference stop 
P4	Mating direction	Axial 	Eccentric axial 	Eccentric radial 
P5	Ratio of the mating component's weight to the mated one	Bearing lift (approx. 1 kg)	Idle roller lift (approx. 4 kg)	Frame plate lift (approx. 7 kg)
P6	Ratio of length to width (diameter) of the mating component	Belt tensioner device 	Frame plate 	Roller 
P7	Reachability to the assembled component	Simple coupling 	Medium complexity coupling	Complex coupling 
P8	Mating component's length	Flanged sleeve 	Brushless motor 	Roller 
P9	Amount of support required for the assembly	No support 	Medium stable support 	Very stable support 
P10	Stability of the resultant assembly	Very stable resultant assembly	Medium stable resultant assembly	Poorly stable resulting assembly
P11	Length of components intersection	Low component coupling length	Medium component coupling length	High component coupling length

Figure 5 - List of parameters used to evaluate the design-based assembly complexity, with examples of the degrees of difficulty to be assigned during the assessment.

To clarify the evaluations listed in Table 4, a single workstation is analysed in detail: the workstation no. 22, i.e. the spindle group on pre-stretch frame plate assembly. In such workstation, 6 elementary operations are performed:

1) pre-tightening the spindle on a pre-stretch frame plate, repeated 12 times;
2) spindle clamping on pre-stretch frame plate, repeated 12 times;
3) tightening the screws on the intermediate spindle ring, repeated 3 times;
4) tightening the screws on the spindle brake support plate, repeated 4 times;
5) tightening the first spindle ring nut;
6) tightening the second spindle ring nut.

The elementary operations are carried out by the assembly operator using, in addition to his hands, simple equipment including a wrench and a torque wrench. The assembled spindle group on the pre-stretch frame plate is shown in Figure 6.

Figure 6 – Workstation no. 22: spindle group on pre-stretch frame plate assembly.

As can be seen in Table 4 for workstation 22, the degrees of difficulty range from a minimum of 4.50 to a maximum of 6.83. These values are within the intermediate difficulty range (fourth column of Figure 5) since the operations performed are mainly screw tightening activities on the spindle, requiring manual equipment and medium-complex couplings. Accordingly, they do not involve any particular assembly difficulties. The only exception is for parameter P8, whose degree of difficulty is almost 7, due to the high coupling length of the components to be assembled.

The design-based complexity factor, for each workstation, can be obtained by combining the weights of the parameters, see Table 2, and the degrees of difficulty matrix, see Table 4, as shown in Eq. (3):

$$Cf_{D,i} = \sum_{q=1}^{l} \left(w_q \cdot \frac{1}{e} \cdot \sum_{k=1}^{e} A_{kqi} \right) \qquad (3)$$

Table 5 shows the values of the obtained design-based complexity factors in each *i*-th workstation.

DEFECT PREDICTION MODEL

The experimental *DPU* (Defects Per Unit) values that occurred under stationary process conditions in each *i*-th workstation of the pre-stretching device are listed in Table 5. Such values were obtained by combining the historical data of the company. Hence, they can be considered as the reference values of the average defectiveness rate of the assembly process of the pre-stretching device of wrapping machines in normal working conditions. As evidenced by Figure 7, where experimental DPU_i vs $Cf_{P,i}$ and $Cf_{D,i}$ are plotted, there is a clear power-law relationship between defects per unit and the two predictors. Previous investigations carried out on different assembled products belonging to different industrial context, including automobile, hard disk drive, semiconductor, audio equipment and copier companies, also demonstrated such power-law behaviour of *DPU* (Galetto, Verna and Genta, 2020; Hinckley, 1994; Hinckley and Barkan, 1995; Shibata, 2002; Shibata et al., 2003; Su et al., 2010). Accordingly, experimental data were analysed using a power-law regression model by *MATLAB*®:

$$DPU_i = \mathrm{a} \cdot (Cf_{P,i})^{\mathrm{b}} \cdot (Cf_{D,i})^{c} \tag{4}$$

It should be noted that, although Eq. (4) is linearisable, a recent study has shown that it is preferable using a nonlinear regression model in the case of few non-repeated data, affected by high variability, as highlighted by the well-known problem of the retransformation bias (Galetto, Verna and Genta, 2020). The defect prediction model obtained is the following (see also Figure 7):

$$DPU_i = 5.04 \cdot 10^{-5} \cdot (Cf_{P,i})^{0.77} \cdot (Cf_{D,i})^{3.08} \tag{5}$$

The *DPU* predicted using Eq. (5) are listed in Table 5. Finally, as shown in Figure 7 (b)-(e), the analysis of the residuals between experimental *DPU* and predicted *DPU* suggests that the power-law model describes well the trend of the *DPU* as a function of the assembly complexity. The Normal Probability Plot (NPP) indicates that the residuals are normally distributed, even though a slight hypernormality is evidenced, indicating a higher concentration of residuals around the central value. Furthermore, by performing the Anderson-Darling test, the null hypothesis that the residuals follow a normal distribution cannot be rejected with a *p*-value of 0.51 (Devore, 2011). The plot of residuals versus order shows a horizontal band around the residual line (value 0) and no systematic effects in the data due to time or data collection order are present. The *S* value, known both as the standard error of the regression and as the standard error of the estimate, is a measure of goodness of fit of the model to be used instead of R^2 for nonlinear models (Bates and Watts, 1988; Spiess and Neumeyer, 2010), is 0.024. It indicates that the experimental values of *DPU* fall a standard distance (roughly an average absolute distance) of 0.024 units from the *DPU* values predicted by Eq. (5). It should be noted that *S* value is of the same order of magnitude of predicted *DPU*s. This can be attributed to the intrinsic variability of data and to the lack of replications (Galetto, Verna and Genta, 2020). As has already been investigated in a recent study, such defect prediction models could be exploited to identify the workstations whose defectiveness deviates, at a certain confidence level, from the predicted average value (Verna et al., 2020a). Consequently, appropriate corrective actions may be promptly undertaken to improve the process (Verna et al., 2020a). Besides, the defect prediction models can be adopted to obtain reliable predictions of defects probabilities. This information can be used in the design of appropriate quality-inspection strategies (Franceschini et al., 2018; Galetto, Genta, Maculotti, et al., 2020; Galetto, Verna, Genta, et al., 2020; Genta et al., 2018, 2020; Verna et al., 2020b, 2020c). Indeed, by combining these probabilities with different inspection parameters, the effectiveness and cost of alternative inspection strategies may be assessed and, accordingly, the most suitable quality-inspection may be selected by inspection designers.

Table 5 - Decomposition of the assembly of the pre-stretching device into 29 workstations (WS) with indication of the assembly complexity factors, $Cf_{P,i}$ and $Cf_{D,i}$ (see Eq. (1) and (3)), experimental DPU_i and predicted DPU_i (see Eq. (5)).

No. WS	TAT_i [min]	$Cf_{P,i}$ [min]	$Cf_{D,i}$	Experimental DPU_i	Predicted DPU_i
1	7.30	7.1	4.4	0.0364	0.0214
2	7.61	7.4	4.6	0.0364	0.0250
3	5.96	5.8	5.1	0.0182	0.0287
4	3.92	3.8	4.3	0.0000	0.0126
5	12.37	11.9	5.7	0.1091	0.0715
6	8.16	7.7	4.9	0.0545	0.0320
7	3.64	3.5	2.8	0.0000	0.0030
8	2.47	2.4	3.5	0.0364	0.0045
9	0.41	0.3	3.7	0.0000	0.0012
10	4.96	4.8	4.2	0.0182	0.0142
11	5.34	5.2	5.3	0.0182	0.0312
12	5.96	5.7	5.1	0.0182	0.0298
13	3.70	3.7	5.1	0.0000	0.0205
14	0.97	0.9	5.4	0.0000	0.0084
15	8.63	8.5	4.9	0.0182	0.0355
16	0.89	0.8	4.9	0.0364	0.0060
17	0.98	0.9	4.2	0.0000	0.0041
18	1.82	1.7	4.3	0.0364	0.0067
19	5.79	5.7	5.2	0.0364	0.0306
20	6.33	6.3	5.2	0.0364	0.0332
21	2.24	2.2	5.2	0.0000	0.0147
22	13.59	13.4	5.6	0.0364	0.0738
23	2.36	2.3	4.1	0.0000	0.0075
24	1.15	1.1	4.1	0.0545	0.0041

25	1.20	1.2	4.3	0.0545	0.0049
26	1.19	1.2	4.1	0.0000	0.0042
27	8.00	7.9	4.7	0.0000	0.0293
28	12.58	12.2	5.5	0.0909	0.0672
29	5.56	5.4	5.0	0.0000	0.0257

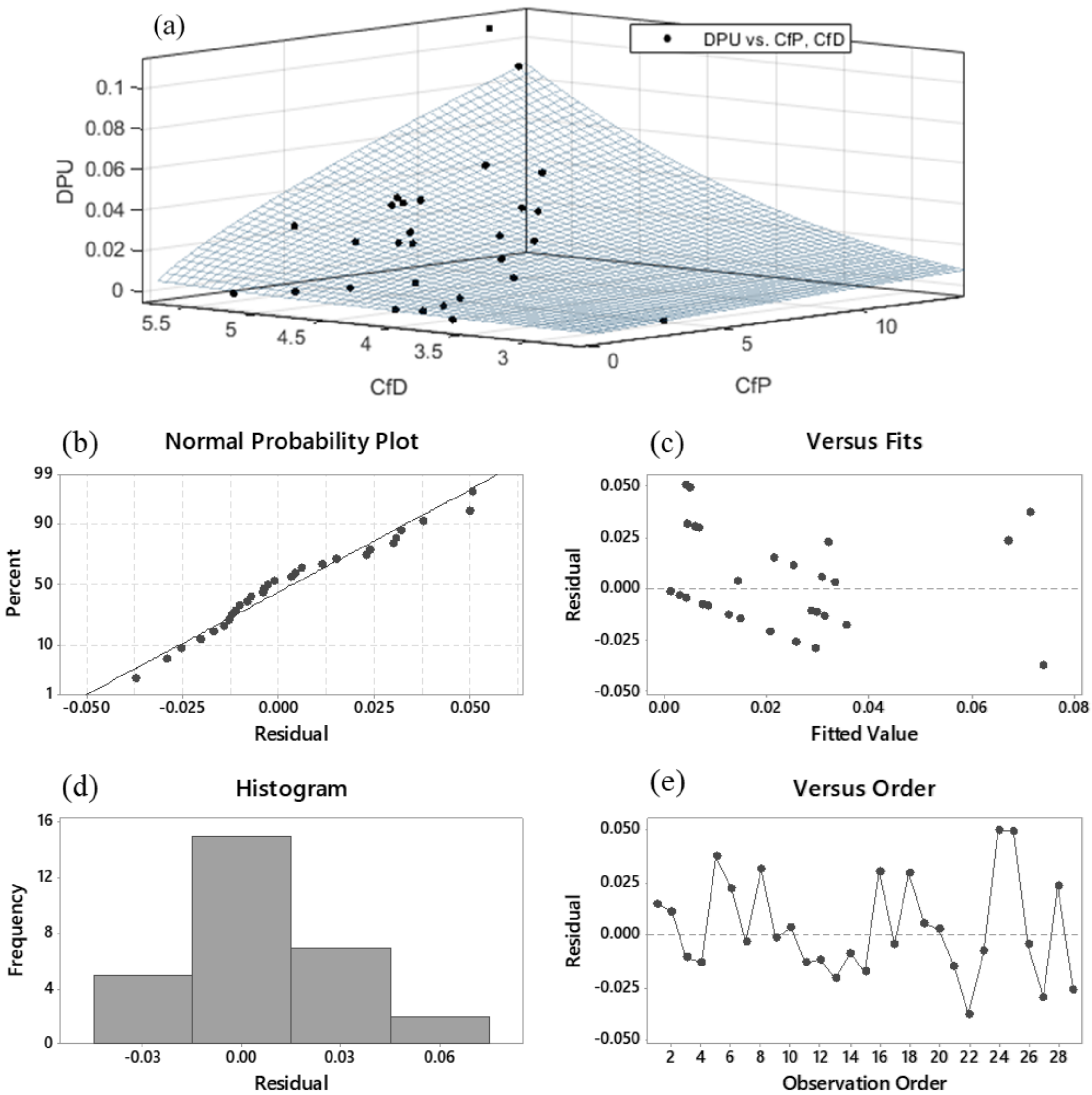


Figure 7 - (a) *DPU* vs Cf_P and Cf_D: defect prediction model, see Eq. (5), and experimental data; Plots of residuals between nominal *DPU* and predicted *DPU*: (b) Normal Probability Plot, (c) Residuals vs Fitted values, (d) Histogram and (e) Residuals vs Order.

CONCLUSIONS

The production of wrapping machines can be considered a low-volume assembly process because of the low production rate (about 50 machines assembled each year). Besides, each assembled machine is highly customised and therefore a unique exemplary. In this situation, applying traditional statistical methods is extremely difficult due to the limited historical data available. The present research aimed to examine the assembly process of wrapping machines in order to develop a model for predicting defects occurring during the production process. The assembly process was firstly modelled by decomposing it into workstations (process steps) and job elements (elementary operations). Then, according to previous studies, two assembly complexity factors were defined: (i) the process-based complexity factor and (ii) the design-based complexity factor. The first one was obtained by exploiting the assembly times to perform the workstations and the number of elementary operations. The second one was derived by combining Ben-Arieh's method with the AHP method. These assembly complexity factors were considered the two predictors of the model adopted to estimate the Defects Per Unit (*DPU*) occurring in each workstation. In accordance with existing studies in the literature, the power-law model was selected as the most accurate fitting function in the *DPU* prediction. The obtained model, although specifically designed for wrapping machines assembly, can be used in other similar industrial contexts to predict defects in low-volume productions. Besides, the research approach can provide a framework for future explorations on other products, particularly for electromechanical and mechanical products. The proposed model can act both as a tool for quantitatively estimating defects of newly developed wrapping machines and as a decision support tool for the assembly quality-oriented wrapping machine design and optimisation. In particular, this defect prediction model can provide a useful tool to suggest engineers the appropriate strategy for assembly quality improvement. Generally, according to the values of the two complexity factors, a point on the prediction model corresponding to the current assembly quality level can be identified. At this point, based on cost and technical criteria, engineers can decide which of the two complexity factors should be reduced first, or whether to reduce them both simultaneously, to achieve the target quality level.

Further research need to examine alternative models involving different predictors for evaluating the overall product complexity. To this aim, authors have recently investigated the adoption of the complexity paradigm proposed by Alkan (2019) and Sinha (2014), which is based on product structural properties associated with handling and insertion of assembly parts, and their architectural structure (Verna et al., 2020d). Furthermore, authors are planning to expand the research approach by moving the perspective from product complexity to production process or production system complexity. This research progress entails combining the models of defect prediction with inspection variables to support the design of quality-inspection strategies in low-volume assembly processes.

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Identifying car-sharing quality determinants: a data-driven approach to improve engineering design

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STRUCTURED ABSTRACT

Purpose - This study aims at identifying the quality determinants of car-sharing services, analyzing unstructured User-Generated Contents (UGCs) and, more specifically, online reviews generated by users of the same car-sharing service. Moreover, this paper discusses the implication of the proposed data-driven approach on engineering design.

Methodology - A large dataset of car-sharing users' online reviews was analyzed by means of the Structural Topic Model (STM), i.e. a variant of Latent Dirichlet Allocation (LDA) technique which discovers underlying topics in a collection of documents also using document-level covariate information.

Findings - This paper reports an analysis of UGCs related to different car-sharing services. The analysis unveils 20 determinants of car-sharing quality: *customer service (physical office); accident & damages management; registration process; charges & fees; parking areas; app reliability; end trip issues; car condition; convenience; use rates; car proximity; car availability; efficacy; sharing benefits; customer service responsiveness; intermodal transportation; car start-up issues; customer service courtesy; billing and membership; car reservation.*

Originality – This paper proposes a novel approach to identify quality determinants by analyzing UGCs. The study of the quality determinants of a car-sharing service is a scarcely discussed field of research although the car-sharing sector is an increasingly important part of the transport economy.

Keywords: Car-sharing, Quality determinants, User-Generated Contents, Topic modelling.

Paper type: Research paper

INTRODUTION

Business models combining the offering of products and services are becoming considerably more widespread (Mastrogiacomo et al., 2019; L. Mastrogiacomo et al., 2020; Luca Mastrogiacomo et al., 2020). In this context, car sharing, a form of shared mobility, has gained increasing popularity in recent years (Shaheen and Cohen, 2007). Given its promise to reduce traffic congestion, parking demands and pollution, this mode of shared transportation has spread especially in urban contexts, so much so that several new competitors are recently entering this market designing and proposing new service solutions (Shaheen and Cohen, 2013). The number of users of carsharing services is growing rapidly: 15 million people in Europe (about 2% of the population) are expected to use carsharing services in 2020, compared to 7 million in 2015 (Frost & Sullivan, 2016). This increase of users is expected to increase profits from approximately $1 billion in 2013 to $10.8 billion by 2025 (Prescient & Strategic Intelligence, 2019). Generally, carsharing schemes can fall into one of four models:

- *one-way*, when members are allowed to begin and end their trip at different locations, through free-floating zones or station-based models with designated parking locations;
- *roundtrip*, when members are required to begin and end their trip at the same location;
- *peer-to-peer*, when the vehicles are typically privately owned or leased with the sharing system operated by a third-party;
- *fractional*, if the users to co-own a vehicle and share its costs and use.

Among others, the most successful model in terms of users over time is the "one-way" model in both free-floating and station-based configuration (Boyaci et al., 2015).

Despite the emerging importance of this type of mobility, to the best of authors' knowledge, no structured analysis has been performed to understand the most critical determinants of the quality of a car-sharing service by means of UGCs (Illgen and Höck, 2019). Apart from traditional approaches to assess quality of car-sharing, e.g. questions/focus groups/interviews (Möhlmann, 2015), there are a couple of interesting works on the subject which relies on the use of UGCs. Guglielmetti Mugion et al. (Guglielmetti Mugion et al., 2019) discusses the antecedents of the use of car-sharing through an analysis of UGCs limited to service users in the city of Rome. Jeong et al. (Jeong et al., 2019), only investigates online car-sharing reviews on the google play website, which is designed to collect users' opinions mainly related to the application of the service.

The focus of this study is to extend previous analysis to the evaluation of the quality determinants (i.e. the most significant characteristics that influence perceived quality) of one-way and roundtrip car-sharing using information available online in the form of user reviews. A recent approach to determine the quality determinants is the analysis of UGCs and, more specifically, of online reviews which can offer a low-cost source of information for understanding customer's expectations and requirements. The identification of quality determinants is based on the in-depth analysis of such data, leveraging text mining approaches capable of obtaining information through text documents written in a natural language (Aggarwal and Zhai, 2012). To this end, topic modelling approaches are used. Such approaches are based on unsupervised machine-learning algorithms that can detect latent topics running through a collection of unstructured documents (Müller et al., 2016). Given a big set of documents, topic modelling algorithms deals with the problems of: (i) identifying a set of topics that describe a text corpus (i.e. a collection of text document from a variety of sources); (ii) associating a set of keywords to each topic and (iii) defining a specific mixture of these topics for each document (Blei et al., 2003).

The logic of these approaches is that if a topic is discussed (within the UGCs), then it is critical to the definition of the quality of the object (product, service or product-service system) under investigation.

In this study, we use a probabilistic topic modelling method, named as Structural Topic Model (STM), an extension of well-established probabilistic topic models, such as Latent Dirichlet Allocation (LDA) (Blei et al., 2003) or Correlated Topic Models (CTP) (Blei and Lafferty, 2007). A significant advantage of STM is that it allows the connection of arbitrary information, in the form of covariates (such as customer ratings, date and place of publication of the review, service provider, etc.), with the degree of association of a document with a topic (topic prevalence) as well as the degree of association of a word with a topic (content prevalence). Roberts et al. (Roberts et al., 2014, 2019) provide a good overviews of the STM algorithm.

This paper has been organized in three sections. The first section deals with the methodology applied to identify car-sharing quality determinants, with particular reference to how the experimental dataset was obtained and processed. The second section highlights the preliminary results of the analysis. Implications for engineering design are discussed in the third section. Finally, the concluding section explores the limitations and future directions of this research.

METODOLOGHY

The analysis herein presented has been carried out using the Structured Topic Modelling (STM) package of R software (R Core Team, 2017). Its application consists of the five steps, described by the following sections (see Figure 7):

(i) dataset extraction;

(ii) pre-processing;

(iii) identification of the optimal number of topics:

(iv) labelling;

(v) validation of results (see Figure 7).

Figure 7 – Activity flow of the methodology.

Dataset extraction

Analyzed data are reviews and relevant metadata (car-sharing providers, nationality, rating, date, source) retrieved in December 2019 from different review aggregators: Yelp, Google, Trustpilot, Facebook and Playstore. Reviews were published from January 2010 to December 2019. Only English-language reviews were selected, with a total of almost 17,000 reviews from 22 carsharing providers (Car2go, DriveNow, Maven, Zipcar, Goget, etc.), distributed in 3 countries (US, Canada and UK). Each provider was related to the type of car sharing (station-based or free-floating). The average length of the obtained reviews is about 500 characters.

The information concerning review ratings, types of carsharing (station-based or free-floating) and countries was used to define the topic prevalence in the STM model, i.e. the overall frequencies of words associated to each topic.

Pre-processing

According to previous approaches (Meyer *et al.*, 2008; Guo *et al.*, 2017), the text corpus was pre-processed and unified in order to improve the efficiency of the topic modelling algorithm. In detail, the text corpus was pre-processed as follows:

- the text was converted to lowercase in order to eliminate ambiguity with uppercase words;
- punctuation and numbers were removed since adding little topical content;
- English stop words (e.g. “the”, “and”, “when”, “is”, “at”, “which”, “on”, etc.) were removed;
- words shorter than 2 or longer than 15 characters were removed;
- words with an extremely low frequency (less than 15 occurrences in the whole text corpus) were excluded from the text corpus since their inclusion would confound results or would not

be representative of any specific topics.

- the text was normalized using Porter stemmer (or 'Porter stemming') to reduce similar words to a unique term. Stemming removes the commoner morphological and inflexional endings from words in English (Jivani, 2011). For example, the words "likes", "liked", "likely" and "liking" were reduce to the stem "like";
- words generally not related to topical content (such as: "another", "mean", "etc", "problem", "review", "made") were removed;
- All the n-grams, i.e. contiguous sequences of n items from a given sequence of text were replaced by a single term. For example, the n-grams "customer service" were replaced by the term "customerservice".

Identification of the optimal number of topics

An essential parameter for the STM method is *T*, i.e. the number of topics able to describe the analyzed text corpus. The literature discusses a number of possible alternatives to define T (Wallach *et al.*, 2009). To the purpose of this analysis, the held-out likelihood has been selected as measure of performance of the topic model. The held-out likelihood evaluates how well the trained model explains the held-out data (i.e. a portion of data not used to develop the topic model). It can be seen as a measure of how the developed topic model is able to explain the overall variability in the text corpus (Scott and Baldridge, 2013; Roberts *et al.*, 2014). In the proposed application, only the 90% of available UGCs was used to train the topic model and the remaining 10% was used to test the developed topic model. Held-out likelihood (L) is formally defined as le the log probability (p) of the held-out data ($W_{held-out}$) given the trained model ($M_{trained}$):

$$L = \log p(W_{held-out} | M_{trained}) \tag{1}$$

The graph in

Figure 8 show the values of the Held-out likelihood as a function of T (from 5 to 100).

From the graph, we can observe that starting from the value of T equal to 20 there is an almost stationary Held-out Likelihood. Considering this, an optimal number of T = 20 topics was identified.

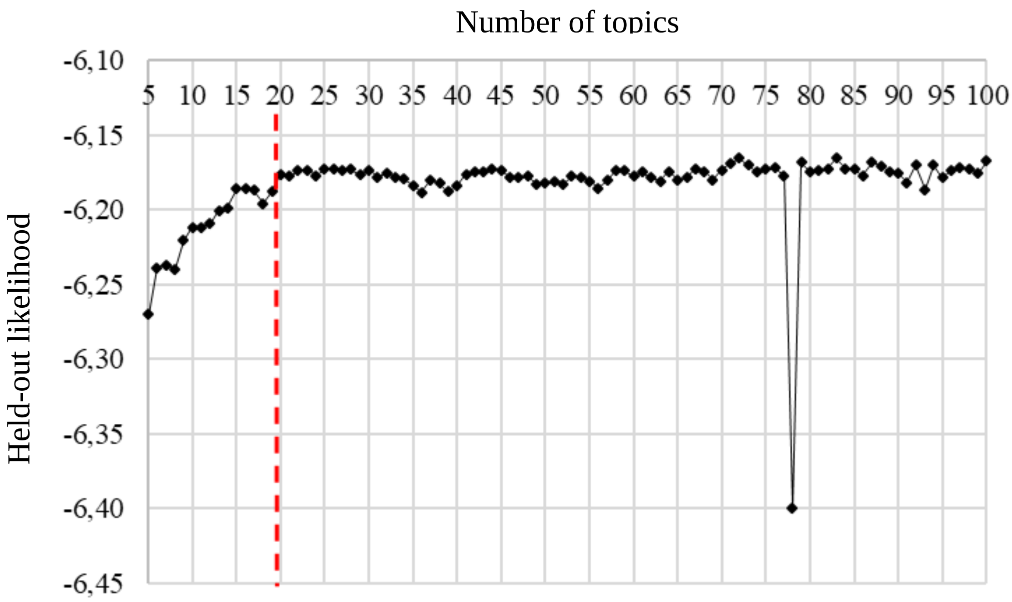

Figure 8 – Held-out likelihood by number of topics [5-100].

Labelling

For each topic, the STM approach identifies the most relevant keywords, however to generate a relevant semantic label the method still requires some human input (Blei, 2012). To date, no automatic labelling techniques have yet been developed. Table 6 shows the identified labels and the relevant lists of keywords as defined by the authors. After a first phase of independent analysis, which led to partially different labels, a joint brainstorming allowed to settle the differences and obtain the final list of labels listed in Table 6. Finally, to test their reliability, the defined topic labels were submitted for confirmation to an external panel familiar with quality research and practice.

Table 6 – Top keywords and related semantic labels of the identified topics.

Number of topic	Keywords (Highest probability)	Topic label
1	help, phone, call, person, office, answer, number	Customer service (physical office)
2	damage, report, accident, fault, member, enterprise, claim,	Accident & damages management
3	sign, process, website, license, drive, driver, registration	Registration process
4	charge, fee, late, return, time, pay, hour	Charges & fees
5	park, lot, spot, find, ticket, street, space	Parking areas
6	app, work, update, book, map, reserve, time	App reliability
7	trip, end, time, make, actual, take, system	End trip issues
8	gas, dirty, rent, clean, tank, card, tire	Car condition
9	need, convenient, quick, recommend, awesome, clean, perfect	Convenience
10	hour, price, rate, cost, expense, mile, cheaper	Use rates
11	minute, reservation, walk, wait, home, time, away	Car proximity
12	car, available, location, vehicle, area, change, time	Car availability
13	use, time, now, far, user, review, star	Efficacy
14	city, year, insurance, member, gas, need, month	Sharing benefits
15	service, custom, issue, company, terrible, problem, experience	Customer service responsiveness
16	way, drive, little, take, get, town, bus	Intermodal transportation
17	time, start, location, turn, lock, pick, key	Car start-up issues
18	call, member, cancel, ask, rep, refund, manage	Customer service courtesy
19	account, card, email, credit, month, day, membership,	Billing and membership
20	reservation, plan, time, need, book, cancel, advance	Car reservation

Data Verification

Obtained results were verified by comparing the assigned topic of a randomly selected sample composed of 100 reviews with a manual topic assignment performed by the authors. For each of the 100 reviews, the authors were requested to agree in the association of one or more of the 20 topics identified by STM. The so-defined topic assignment was then considered as reference and compared to that obtained by STM. For each review and topic, the following four cases can occur (see examples in Table 7):

- True Positive (*tp*), i.e. agreement between authors and algorithm in the assignment of a review to a topic.
- True Negative (*tn*), i.e. agreement between authors and algorithm not to assign a review to a topic.
- False Positive (*fp*), i.e. misalignment between the assignment of the review to a topic by STM and the non-assignment by the authors (type I error).
- False Negative (*fn*): i.e. misalignment between the assignment of the review to a topic by the authors and the non-assignment by STM (type II error).

Table 7 – Examples of verification procedures. Total number of topics equal to 20.

	STM topic assignment	Manual topic assignment	True Positive	True Negative	False Positive	False Negative
Review 1	20 - 11	20 - 4	1	17	1	1
Review 2	7	7	1	19	0	0
Review 3	5 – 8 - 7	5 - 8	2	17	1	0
Review 4	14 - 16	11 – 14 - 16	2	17	0	1

According to Costa et al. (Costa *et al.*, 2007), three verification indicators have been calculated (see Table 8). *Accuracy* is the most intuitive performance measure and it is equal to the ratio of correctly predicted observation to the total observations. It measures how often the algorithm produce a correct topic assignment. Accuracy assumes equal costs for both kinds of errors. Further metrics should be calculated in order to evaluate more accurately the performance of the applied method. To fully evaluate the effectiveness of a topic modeling algorithm, two indicators should also be considered: Recall and Precision. *Recall*, also known as sensitivity or true positive rate, can be defined as the ratio of the total number of correctly predicted observation (true positive) with the sum of true positive and false negative observations. Recall metric answers to the questions: “If a topic is present in a review, how often is the algorithm able to detect it??”. *Precision*, also known as positive predictive value, is equal to the ratio between the total number of correctly classified positive examples by the total number of predicted positive prediction (true positive + false positive). This metric answers to the question: "What proportion of positive topic assignments was actually correct?".

These three metrics show a generally good correspondence between the assignment produced by STM and the authors. The accuracy of 94% proves good effectiveness of the method to predict the content of the reviews, correctly identifying true positive and true negative. According to Nassirtoussi et al. (Nassirtoussi *et al.*, 2014), accuracy values above 55% can be accepted as "report-worthy". According to Zaki and McColl-Kennedy (Zaki and McColl-Kennedy, 2020), in most cases, accuracy is between 50% and 80%. The Recall and Precision indicators, respectively equal to 73% and 65%, show that the method performs well in terms identification of the topics (true positive).

Table 8 – Verification indicators (Costa et al., 2007).

Indicator	Definition	Value
Accuracy	$A = (tp + tn)/(tp + tn + fp + fb)$	0.94
Recall	$R = tp / (tp + fn)$	0.73
Precision	$P = tp / (tp + fp)$	0.65

PRELIMINARY RESULTS

Figure 9 shows the proportion (i.e. the average weight) of the 20 identified topics in the analyzed reviews. The most discussed topics are topic 6, concerning the reliability of the mobile application, topic 9, related to service convenience, and topic 15, related to the responsiveness of the customer service. The less discussed topics are those related to the tangible component of the carsharing service: topic 2, relating to the management of accidents and damage to vehicles, and topic 8, relating to the internal condition of vehicles. Note that this does not mean these topics are more "critical to quality" than others. The difference in proportions may depend on a number of factors, including the review aggregators used for the analysis, which may be more (or less) oriented towards collecting specific information on certain topics. For example, the Playstore commonly collects information related to the user experience with respect to the applications.

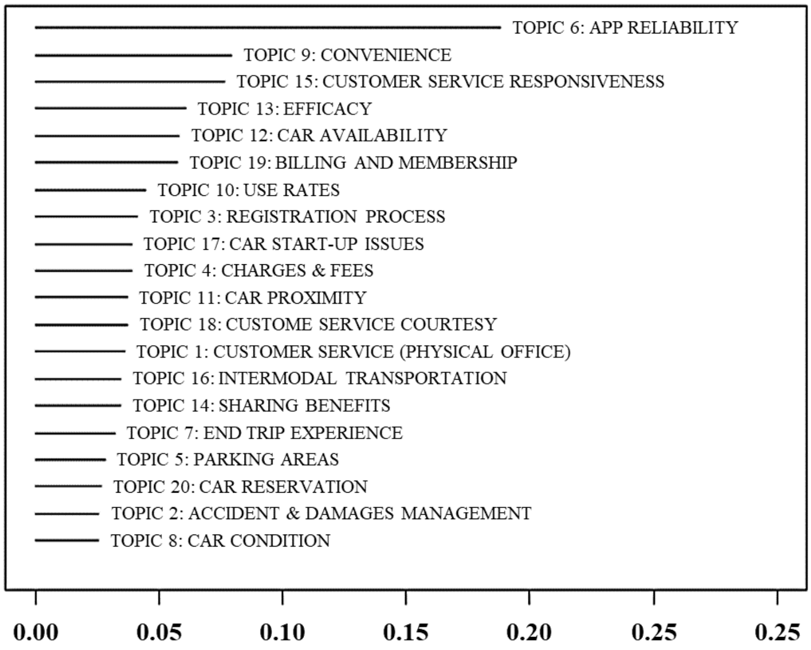

Figure 9 – Topic proportions.

Topics vs. Car sharing scheme

Figure 10 shows the association between identified topics and the scheme of car sharing (station-based or free-floating). In detail, the figure shows the marginal effects in the change of expected proportions of topic prevalence: dots on the chart depict expected difference in topic proportions, while the horizontal bars represent uncertainty ($\alpha = 95\%$) in these estimates. As an example, see how topic 14 (sharing benefits) is more discussed (by about 4%) for station-based than for free-floating car-sharing services.

The following considerations can be made by analyzing the figure:

- topic 12 (car availability) and 17 (car start-up issues) do not seem to be influenced by the type of car-sharing scheme;
- reviews related to topic 3 (registration process), 5 (parking areas), 6 (app reliability), 7 (end trip issues), 11 (car proximity), 13 (efficacy) and 16 (intermodal transportation) are prevalent for free-floating scheme. It is noteworthy how topic 6 has an important prevalence of 15%.
- topic 1 (customer service – physical office), 2 (accident and damages management), 4 (charges and fees), 8 (car condition), 9 (convenience), 10 (use rates), 14 (sharing benefits), 15 (customer service responsiveness), 18 (customer service courtesy), 19 (billing and membership) and 20 (car reservation) are mainly discussed for station-based car-sharing scheme.

Despite the differences highlighted, it is possible to state that all the topics identified are associated with both types of car-sharing.

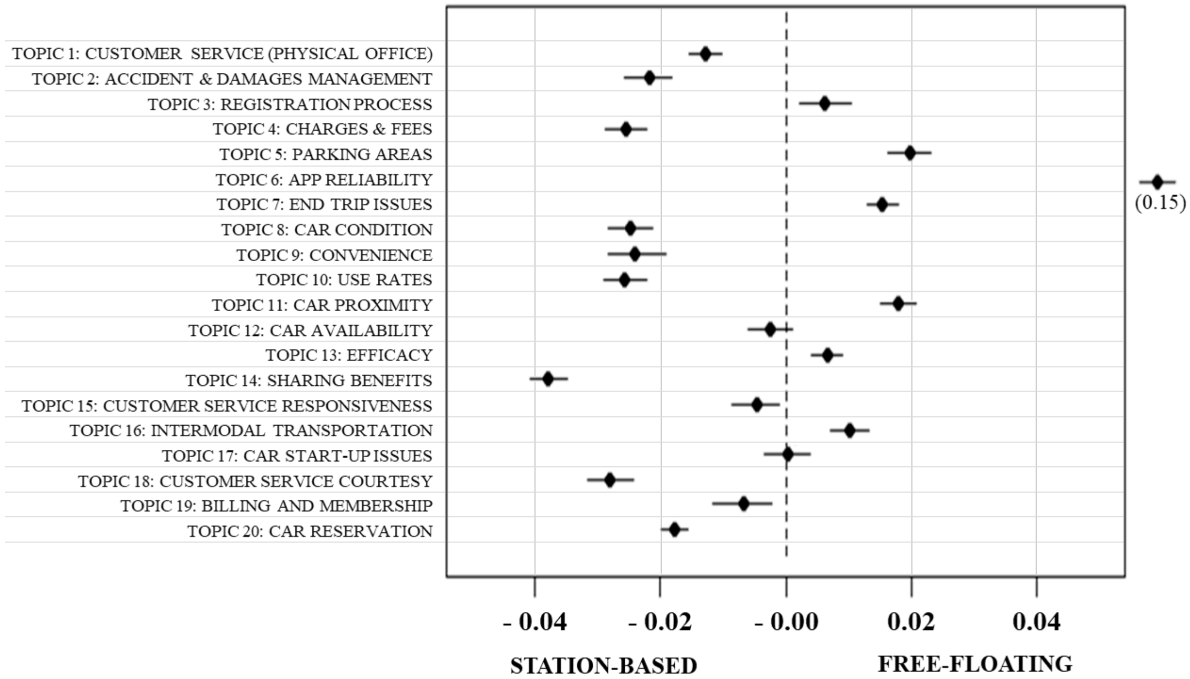

Figure 10 – Marginal effects in the change of expected proportions of topic prevalence based on the scheme of car-sharing. The dotted line represents the zero effect.

Topics vs. Ratings

Figure 11 shows the marginal effects in the change of the expected proportion of topic prevalence based on low (1 and 2) and high (4 and 5) review ratings. As the distance from the dashed axis increases, the probability of specific topics becomes more dominant. Three different cluster of topics can be qualitatively identified:

- topic 1 (customer service – physical office), 8 (car condition), 17 (car start-up issues) and 20 (car reservation) are “neutral” with respect to the review rating;
- topic 5 (parking areas), 6 (app reliability), 7 (end trip issues), 9 (convenience), 10 (use rates), 11(car proximity), 12 (car availability), 13 (efficacy), 14 (sharing benefits) and 16 (intermodal transportation), seem to be driver of high ratings as the topic are becoming dominant for satisfied customers;
- topic 2 (accident & damages management), 3 (registration process), 4 (charges & fees), 15 (customer service responsiveness), 18 (customer service courtesy) and 19 (billing and membership) are critical factors that lead to customer dissatisfaction when occurring and if not appropriately addressed.

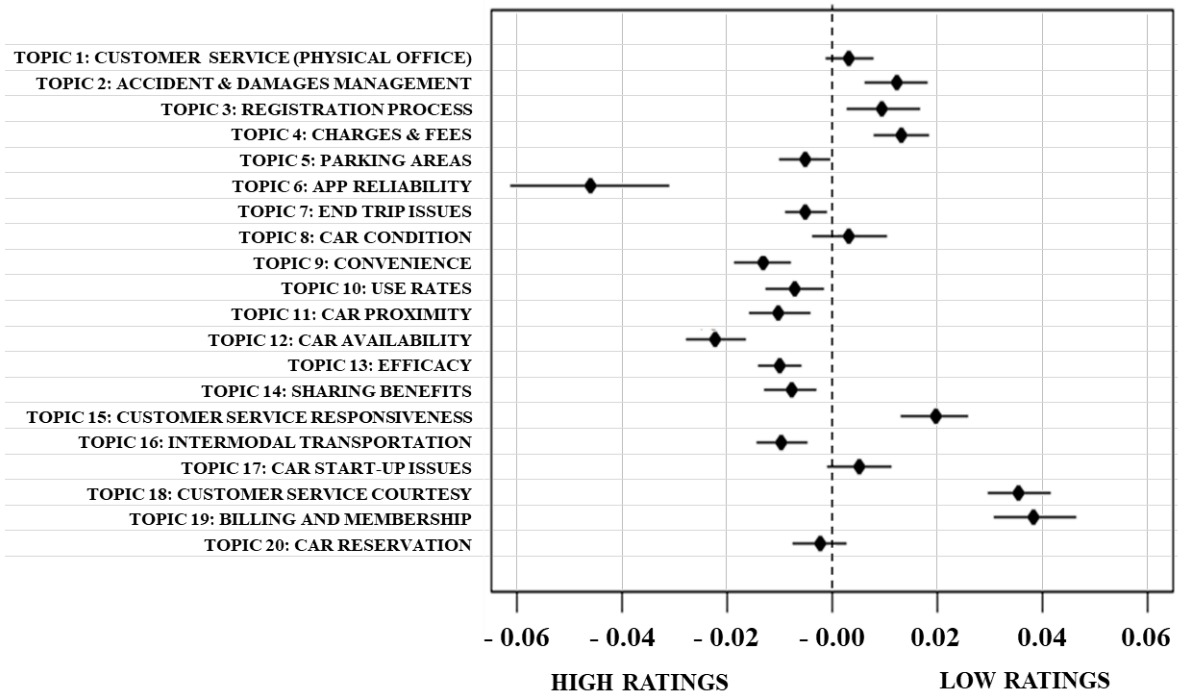

Figure 11 – Marginal effects in the change of expected proportions of topic prevalence based on low and high review ratings. The dotted line represents the zero effect.

IMPLICATIONS FOR ENGINEERING DESIGN

The findings of this article, while preliminary, highlights the potentialities that data-driven methodologies may have in quality management and engineering design. Understanding the quality determinants of a product, service or product-service system provides some support for their engineering design. In particular, several steps of the design process may be influenced by the results gathered by the application of proposed data-driven methodology, including:

(i) *Identification of design challenges*: the study of latent quality determinants can help designers in identifying new design challenges for the development of innovative products, services or product-service systems.

(ii) *Comparison of existing approaches*: the examination of the prevalence of quality determinants (see for example section "Topics vs. Car sharing scheme") can help designers to group different types of existing products, services or product-service systems into homogeneous families. In this way, the comparison of different existing approaches can be performed by directly considering customers' perceptions. In addition, the analysis of the evolution of the prevalence of quality determinants may also allow to identify potential emerging markets.

(iii) *Identification of customer needs*: as can be seen from the discussion of the proposed results, a comprehensive and detailed overview of the quality determinants of a product, service or product-service system can be obtained by analysing UGCs. In this consideration, UGCs may serve as primary source for the identification of customer needs. Moreover, using a large amount of UGCs produced over several years, it is possible to analyse the temporal dynamics of the quality determinants, eventually predicting patterns and anticipating customer needs.

CONCLUSIONS

This paper reports an analysis of User-Generated Contents related to different car-sharing services. The analysis unveils 20 determinants of car-sharing quality: *customer service (physical office); accident & damages management; registration process; charges & fees; parking areas; app reliability; end trip issues; car condition; convenience; use rates; car proximity; car availability; efficacy; sharing benefits; customer service responsiveness; intermodal transportation; car start-up issues; customer service courtesy; billing and membership; car reservation.*

This analysis presents a number of novel aspects, including: (i) it is one of the first attempts to identify quality determinants by analyzing UGCs, (ii) the study of the quality determinants of a car-sharing service is a scarcely discussed field of research although the car-sharing sector is an increasingly important part of the transport economy.

Results of the proposed approach may have significant implications in engineering design, with particular reference to: (i) the identification of design challenges; (ii) the comparison of existing approaches and (iii) the identification of customer needs.

Despite producing multi-faceted insights, the adopted method uses UGCs, i.e. textual information produced spontaneously by users that can potentially be distorted as generated by an uncontrolled sample of individuals. Moreover, the analysis introduces elements of subjectivity (e.g. in the labelling operation). Future developments will be directed to the solution of the above-mentioned limitations as well as to the use of similar approaches for the study of the quality in different contexts.

ACKNOWLEDGEMENTS

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Bibliometric analysis of quality function deployment with fuzzy systems

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ABSTRACT

Research on quality function deployment (QFD) with fuzzy systems has increased since the 2000s. The growing number of QFD applications with fuzzy systems indicates worldwide attention on this field of research. Then, two research questions arise: Are there some trends? And, are there some research gaps? This paper presents bibliometric analysis to answer those questions, performed on data from Scopus database, in a total output of 598 documents. Only articles and reviews were searched. China is the leading country in publication and international collaboration (207 published documents, more than a third of total). The main finding of analysis is the trend of QFD integration with fuzzy and multi-criteria decision-making (MCDM) methods. This could be observed with different applications as new product development, quality management, service quality, and supply chain management, to name a few.

Keywords: Bibliometrics, fuzzy systems, quality function deployment, Scopus.

INTRODUTION

Quality function deployment (QFD) is a method to translate, in an efficient way, needs of customers into development of new products or improvements in current ones (Kwong and Bai, 2002). However, a few proposals have been presented to enhance the performance of the original QFD method (Carnevalli and Miguel, 2008; Sivasamy et al, 2016).

Fuzzy systems have been successfully applied to deal with imperfect, vague, and imprecise information, often found in decision problems, including the QFD method (Rodriguez et al, 2016). In one of the first applications, a method of a robust design was developed for Kraslawski et al (1993). Fuzzy systems were applied in the “House of Quality”: The main idea was to minimize the variability of product quality under fuzzy technological and economic constraints. Also, in early 1990’s, fuzzy linear regressions equations were applied in QFD to estimate relationships among variables with limited and uncertain data (Moskowitz and Kim, 1993).

Fuzzy systems have also been applied to determine weights for customers’ requirements (Akao, 2004; Kwong and Bai, 2003; Li et al, 2014). These applications include multi-criteria decision making (MCDM) methods, as the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Afterwards, developments in fuzzy systems, including intuitionistic fuzzy sets were integrated to MCDM for QFD (Jian et al, 2016; Onar et al, 2016; Osiro et al, 2018; Wang et al, 2017; Wu et al, 2017).

The growing number of QFD applications with fuzzy systems indicates worldwide attention on this field of research. Then, two questions arise: Are there some trends? And, are there some research gaps? This paper presents a bibliometric analysis which aims to answer those questions. Therefore, this is a literature review paper. Methodologically, it was performed a bibliometric study (Yataganbaba and Kurtbas, 2016; Zyoud and Fuchs-Hanusch, 2017). Section 2 presents a literature review on QFD and fuzzy systems. Section 3 presents methodological subjects. Section 4 points out bibliometric results. Section 5 presents contents analysis, and Section 6 the Conclusions.

LITERATURE REVIEW

Quality Function Deployment

QFD was developed by Dr. Yoji Akao and Dr. Shigeru Mizuno (Akao, 2004). Then, many researchers and professionals have proposed adaptations and improvements in the original QFD. Although QFD has been originally developed for product development planning, its applications have extended to different processes such as costs analysis, managerial decision making, process planning, engineering, and teamwork, to name a few (Chan and Wu, 2002).

A complete QFD application consists of several relationship matrices. House of Quality (HOQ) is the first matrix, which translates customers' needs into technical characteristics of the product (Kahraman et al, 2006). Customers' requirements (CR) are obtained through surveys or direct questions to the customers. To develop a new product, CR must be translated into engineering characteristics (EC) (Chen et al, 2014).

HOQ has been used to determine the relationship between customers' needs, or CR, and quality characteristics or EC (Govers, 2001). Moreover, there are benchmark data (marketing and technical) which individually represent the competitive analysis upon customers and technology (Chen et al, 2014).

In the traditional QFD, the relationship between CR and EC is determined by a project team using linguistic expressions, such as: "very low", "low", "medium", "high" and "very high", with values that range from 1 to 5 being assigned to them (Chen et al, 2014). In addition, some QFD applications combine the method with MCDM techniques such as AHP or TOPSIS and fuzzy systems, to deal with the subjectivity and uncertainty of quality matrices analyses (Carnevalli and Miguel, 2008; Chan and Wu, 2002).

Fuzzy Systems

Fuzzy Sets Theory (FST) was introduced to deal with the uncertainty due to imprecision and vagueness (Tong and Bonissone, 1980). A fuzzy set X is characterized by a membership function μ, which assigns to each element x in the set a grade of membership ranging from zero to one (Zadeh, 1965). That is, each element in a fuzzy set is associated with a value indicating to what degree the element is a member of the set (Bevilacqua et al, 2006). A major contribution of FST is the capability of representing vague data (Buyukozkan et al, 2004).

Despite that, when handling vague and imprecise information whereby two or more sources of vagueness arise concurrently, the modeling tools of ordinary fuzzy sets have limitations. Hence, different generalizations and extensions of fuzzy sets have been introduced (Rodriguez et al, 2012).

Figure 1 presents an evolution of FST (Kahraman et al, 2016): from original type-1 fuzzy sets (Yataganbaba and Kurtbas, 2016), through type-n fuzzy sets (Zadeh, 1975) and interval-valued fuzzy sets (Zadeh, 1975; Grattan-Guiness, 1976), following by intuitionistic fuzzy sets (Atanassov, 1986), fuzzy multisets (Yager, 1986), nonstationary fuzzy sets (Garibaldi and Ozen, 2007) and, finally, hesitant fuzzy sets (Torra, 2010).

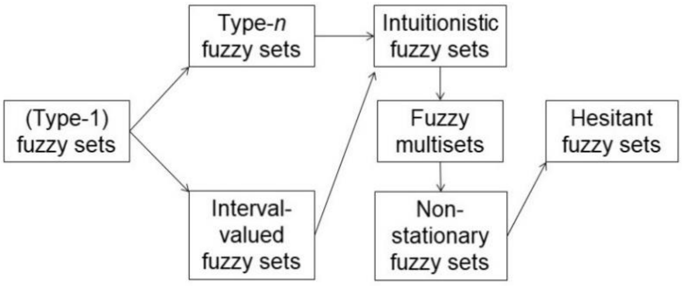

Figure 2 – Evolution of fuzzy sets theory (Kahraman and Onar, 2016).

Type-2 fuzzy sets and type-n fuzzy sets incorporate uncertainty about the membership function in their definition (Rodriguez et al, 2012). Membership function of type-2 fuzzy sets ranges over a type-1 fuzzy set. Generalizing, membership function of a type-n fuzzy set (n = 2, 3, 4...) ranges over a type-n-1 fuzzy set (Zadeh, 1975; Melin et al, 2013).

Nonstationary fuzzy sets introduce into the membership functions a connection that expresses a slight variation on them (Rodriguez et al, 2012).

Intuitionistic fuzzy sets extend fuzzy sets by an additional degree: the degree of uncertainty (Rodriguez et al, 2012). Intuitionistic fuzzy sets also incorporate a degree of hesitation, defined as 1 minus the sum of membership μ and non-membership ν degrees (Kahraman et al, 2018).

Fuzzy multisets based on multisets allow repeated elements in the set (Rodriguez et al, 2012). They are based on the concept of bags (Yager, 1986). A bag is a set with repeated elements.

Hesitant fuzzy set (HFS) is the most recently introduced extension of fuzzy sets. An HFS allows the modeling of uncertainty originated by the hesitation arisen in the assignment of membership degrees of the elements to a fuzzy set (Torra, 2010).

RESEARCH METODOLOGHY

Usually, bibliometric analyses are performed in one of four databases: Google Scholar, PubMed, Scopus, or Web of Science (Falagas et al, 2008). This paper presents a Scopus-based bibliometric analysis. Scopus was preferred because of the greater number of journals it contains (Zyoud and Fuchs-Hanusch, 2017). Scopus provides flexible review for several fields of science (Kulkarni et al, 2009). It allows the collected data to be analyzed without the need to separate the different sections (Yataganbaba and Kurtbas, 2016).

Scopus database was first searched for QFD with fuzzy systems in general. For this, the search bars of *abstract, keywords* and *title* on Scopus database were first filled with “fuzzy”, “house of quality”, “QFD”, and “quality function deployment”. Both Boolean operators “and” and “or” were searched. The query was it as follows: TITLE-ABS-KEY(QFD) OR TITLE-ABS-KEY (“quality function deployment”) OR TITLE-ABS-KEY (“house of quality”) AND TITLE-ABS-KEY (fuzzy) AND PUBYEAR < 2020. Only articles and reviews were searched.

Besides authorship, details such as citation, country, document type, impact factor (IF), institution, journal name and prevalent interest area were considered.

Citations were counted considering h-index. This indicator includes measures of quantity (amount of publications) and quality (citation rates) (Egghe., 2006). On Scopus, journals can be sorted with three indicators: Cite Score, SCImago Journal Rank (SJR) and Source Normalized Impact per Paper (SNIP). Cite Score measures average citations received per document published in the journal. SJR measures weighted citations received by the journal. Citation weighting depends on subject field and prestige of the citing journal. SNIP measures actual citations received in comparison to the citations expected for the journal’s subject field.

For each considered journal, IF was extracted from the Journal Citation Reports (Clarivate Analytics, 2018) and word frequencies were used in content analysis (Wang et al, 2017). Keywords have a great potential to reflect the focus of research. According to Tan et al (2014) the core words indicate the core literature within a specific field of research.

Co-occurrence analysis of keywords was performed with VOSviewer. This software builds maps of networks and uses “visualization of similarities” techniques of clustering, which are widely used in bibliometric analysis (Van Eck and Waltman, 2010).

After bibliometric analysis about QFD on the fuzzy environment, new searches were performed inserting, separately, those new expressions: “hesitant”, “intuitionistic”, “nonstationary”, “type-2” and “multiset”. The objective in the second search was to verify if there was any publication about QFD in other extensions of fuzzy environment

For the QFD method on Hesitant fuzzy environment, for example, the query was as follows: TITLE-ABS-KEY(QFD) OR TITLE-ABS-KEY ("quality function deployment") OR TITLE-ABS-KEY ("house of quality") AND TITLE-ABS-KEY (fuzzy) AND TITLE-ABS-KEY (Hesitant) AND PUBYEAR < 2020. Only articles and reviews were searched.

RESULTS

Ranks of Publications

The research performed, as described in Section 3, resulted in 598 documents: 588 articles and 11 reviews. That is, the overwhelming majority of publication is from articles, or else, original findings. Then, there is a lack on reviews in the QFD and fuzzy systems literature. Presenting a literature review, this paper contributes to the diversification of the literature of the researched field. The yearly average of publications is 22.

A gradual increase is observed, with a steep rise and breakthrough, in 2007. More than 79% of documents were published after 2007 (Figure 2). The years of 2009 and 2019 were outliers with more than 50 documents published. From 2010 to 2018, documents per year average 39. China is the leading country in published documents on QFD and fuzzy systems (Table 1). The 207 documents published by China are more than a third of the total. This result is even more impressive considering that Scopus counts China, Hong Kong and Taiwan, independently.

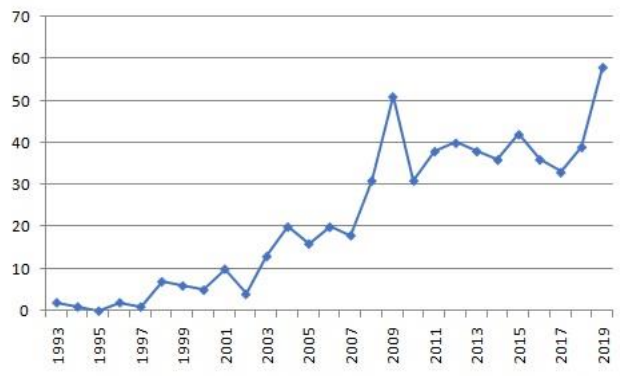

Figure 2 – Publication by year

Table 1 - Publications by country

Rank	Country	Documents	h-index	Citations
1	China (CHN)	207	26	3,104
2	Taiwan (TWN)	108	30	2,738
3	Turkey (TUR)	63	26	2,452
4	Iran (URN)	53	15	674
5	India (IND)	51	15	571
6	United States (USA)	34	17	1,442
7	Hong Kong (HK)	33	22	2,622
8	United Kingdom (UK)	22	14	1,038
9	Singapore (SGP)	19	14	933
10	Canada (CAN)	12	7	313

The average h-index for the top ten countries is 18 and the average of citations is greater than 2,500 citations per document. The 598 resulting documents received more than 15,000 citations. China keeps leading the rank considering the international collaboration (Table 2), besides of the moves in lower positions. Researches from Hong Kong and from the United States result from collaborations with more countries. However, China is the most collaborative country in the top ten.

Table 2 - Publications by international collaboration

Rank	**Country**	**Documents**	**Collab. Countries**	**Top country**
1	CHN	51	12	HK
2	HK	31	8	CHN
3	USA	24	10	TUR
4	UK	21	13	CHN
5	IRN	17	9	USA
6	TWN	16	6	CHN
7	TUR	15	7	USA
8	SGP	11	6	China
9	CAN	7	4	China
10	IND	2	2	Ethiopia

The institution with more documents published by first authors is *Galatasaray Universitesi*, from Turkey (Table 3), with 28 documents. The publication is worldwide spread in a hundred institutions. China has eleven institutions ranked in the top 20. This is a result of the active participation of China in this field of research. The most prolific author is Jiafu Tang, from Dongbei University of Finance and Economics, China. Dr. Tang published 26 documents (Table 4). Publishing 30 documents, Expert Systems with Applications (ESWA) is the leading journal (Table 5). ESWA is the second journal on Cite Score and IF (Table 6), leaded by Journal of Cleaner Production (JCP). On SJR, European Journal of Operational Research ranks first, followed by JCP, International Journal of Production Research, Journal of Intelligent Manufacturing and Computers and Industrial Engineering. ESWA leads on SNIP.

Engineering and Computer Science are the leading interest areas (Table 7). ESWA is the top journal in both areas. China is the top country in almost all areas, except Business, Management and Accounting, and Social Sciences. Three top authors, Kahraman, Ertay and Buyukozkan, co-authored the most cited document (Kahraman et al, 2006), which is cited 454 times (Table 8).

Table 3 - Publications by Institution

Rank	Institution	Country	Documents
1	Galatasaray Universitesi	TUR	28
	Northeastern University, China	CHN	28
3	Shanghai University	CHN	18
4	Hong Kong Polytechnic University	CHN	17
	City University of Hong Kong	CHN	17
6	National Institute of Technology, Tiruchirappalli	IND	16
	Southwest Jiaotong University	CHN	16
	National Cheng Kung University	TWN	16
9	National Chin-Yi University of Technology Taiwan	TWN	13
10	National Taiwan Ocean University	TWN	12
	The International Joint Research Laboratory of Integrated Automation	CHN	12
12	Zhejiang University	CHN	11
	Istanbul Teknik Universitesi	TUR	11
	Kun Shan University	TWN	11
15	Nanyang Technological University	SGP	10
	Shanghai Jiao Tong University	CHN	10
	Tsinghua University	CHN	10
18	Chang Jung Christian University	TWN	9
19	University of Shanghai for Science and Technology	CHN	8
	Beihang University	CHN	8

Table 4 - Publications by First Author

Rank	First Author	Country	Documents
1	J. Tang	CHN	26
2	Y. Chen	CHN	17
3	Y. L. Li	CHN	16
4	G. Buyukozkan	TUR	12
	R.Y.K. Fung	HK	12
	E.E. Karsak	TUR	12
7	C. K. Kwong	CHN	11
	Y. Pu	CHN	11
9	L. H. Chen	TWN	10
	W. C. Ko	TWN	10
	S. Vinodh	IND	10
12	J. F. Ding	TWN	8
	C. Kahraman	TUR	8
	G. S. Liang	TWN	8
15	X. Geng	CHN	7
	L. P. Khoo	SGP	7
	L. Z. Lin	TWN	7
18	X. Chu	CHN	5
	T. Ertay	TUR	5
	A. Liu	CHN	5

Table 5 - Publications by Journal

Rank	Journal	Documents
1	Expert Systems with Applications (ESWA)	30
2	International Journal of Production Research (IJPR)	29
3	Jisuanji Jicheng Zhizao Xitong (Computer Integrated Manufacturing Systems, CIMS)	27
4	Computers and Industrial Engineering (CAIE)	21
5	Total Quality Management and Business Excellence (TQMBE)	13
6	International Journal of Advanced Manufacturing Technology (IJAMT)	12
7	European Journal of Operational Research (EJOR)	11
	Journal of Intelligent Manufacturing (JIM)	11
9	Applied Soft Computing Journal (ASCJ)	10
	Journal of Cleaner Production (JCP)	10
11	Jixie Gongcheng Xuebao (Chinese Journal Of Mechanical Engineering, CJME)	9
	Quality and Quantity (QQ)	9
	Zhongguo Jixie Gongcheng (China Mechanical Engineering, CME)	9
14	Journal of Intelligent and Fuzzy Systems (JIFS)	8
15	Sustainability Switzerland (SS)	7
16	Computers in Industry (CII)	6
	International Journal of Logistics Systems and Management (IJLSM)	6
	International Journal of Productivity and Quality Management (IJPQM)	6
19	Applied Mathematical Modelling (AMM)	5
	Concurrent Engineering Research and Applications (CERA)	5

Table 6 - Citations by Journal

Rank	Journal	Cite Score	SJR (2018)	SNIP (2018)	IF
1	ESWA	6.36	1.190	2.696	5.71
2	IJPR	4.34	1.585	1.720	3.93
3	CIMS	0.84	0.299	0.591	-
4	CAIE	4.68	1.334	1.755	3.30
5	TQMBE	2.44	0.776	1.425	-
6	IJAMT	3.04	0.987	1.596	2.69
7	EJOR	4.98	2.205	2.455	3.03
8	JIM	4.20	1.389	1.921	2.32
9	ASCJ	6.27	1.216	2.369	2.21
10	JCP	7.32	1.620	2.308	2.35
11	CJME	1.10	0.435	0.927	1.00
12	QQ	1.40	0.421	0.886	-
13	CME	0.38	0.217	0.428	1.37
14	JIFS	1.96	0.412	0.818	-
15	SS	3.01	0.549	1.169	-
16	CII	6.05	1.242	2.395	-
17	IJLSM	1.31	0.330	0.758	-
18	IJPQM	1.33	0.345	0.736	-
19	AMM	3.36	0.873	1.495	-
20	CERA	1.79	0.549	1.225	-

Table 7 - Publications by Interest Area

Rank	Area	Documents	Journal	Country
1	Engineering	367 (61.37)	ESWA	CHN
2	Computer Science	267 (44.65)	ESWA	CHN
3	Business, Management and Accounting	141 (23.58)	IJPR	TWN
4	Decision Sciences	110 (18.39)	IJPR	CHN
5	Mathematics	109 (18.23)	EJOR	CHN
6	Social Sciences	37 (6.19)	QQ	TWN
7	Environmental Science	32 (5.35)	JCP	CHN
8	Energy	24 (4.01)	JCP	CHN
9	Multidisciplinary	14 (2.34)	Tongji Daxue Xuebao	CHN
10	Materials Science	12 (2.01)	JTE	CHN

Table 8 - Most Cited Documents

Rank	Document	Citations	Rank	Document	Citations
1	Kahraman et al (2006)	454	11	Bottani & Rizzi (2006)	158
2	Kwong & Bai (2002)	301	12	Fung et al. (1998)	156
3	Kwong & Bai (2003)	299	13	Vanegas & Labib (2001)	149
4	Chan & Wu (2005)	274	14	Bayou & de Korvin (2008)	146
5	Bevilacqua et al. (2006)	266	15	Chen & Weng (2006)	145
6	Kim et al. (2000)	220	16	Tang et al. (2002)	144
7	Chan et al. (1999)	217	17	Bouchereau & Rowlands (2000)	142
8	Khoo & Hot (1996)	198	18	Büyüközkan et al, (2004)	138
9	Temponi et al. (1999)	170	19	Chen et al. (2006)	135
10	Wang (1999)	169	20	Karsak (2004)	125

Contents Analysis

The analysis of the word frequency in published research has been a widely used tool to examine the content analysis of research (Wang et al 2017). The author keywords have a great potential to reflect the focus of research because the core words indicate the core literature within a specific field of research. It also helps identify the central topics and hot spots that will continue to be vital in the examined field of research, besides helping suggest new directions for science in the future (Tan et al, 2014; Zyoud and Fuchs-Hanusch, 2017).

Analysis of the co-occurrence of keywords of published research to examine the hot research areas was conducted by VOSviewer software. This software builds visualization maps relied on data of networks and uses the "visualization of similarities" mapping and techniques of clustering, which are widely used in the analysis of bibliometric networks (Van Eck and Waltman, 2010; Zyoud and Fuchs-Hanusch, 2017).

In the resulting 598 documents there were a total of 1,432 keywords. There were 69 keywords that appeared at least in five different documents. Figure 3 presents a network map obtained with Software VOSviewer. Figure 4 displays the density visualization map-item density in association with published research that utilized QFD method on fuzzy environment. The central keywords are in the darkest areas (from red to blue)

For the same concept, different authors used different keywords. As a limitation of VOSviewer, in this case, keywords were counted apart. That is, "Quality function deployment", "QFD" and "Quality function deployment (QFD)" were counted as different keywords. Given this, eight keywords clusters were identified (Table 9).

The keyword analysis shows that there is a trend to apply hybrid methods, combining fuzzy systems, MCDM and QFD. The most used MCDM methods are AHP, ANP (Analytic network process), TOPSIS and GRA (Grey Relational Analysis). In addition, some authors use more than one MCDM method simultaneously. Advances in fuzzy systems application in MCDM are not independent of fuzzy systems application in QFD.

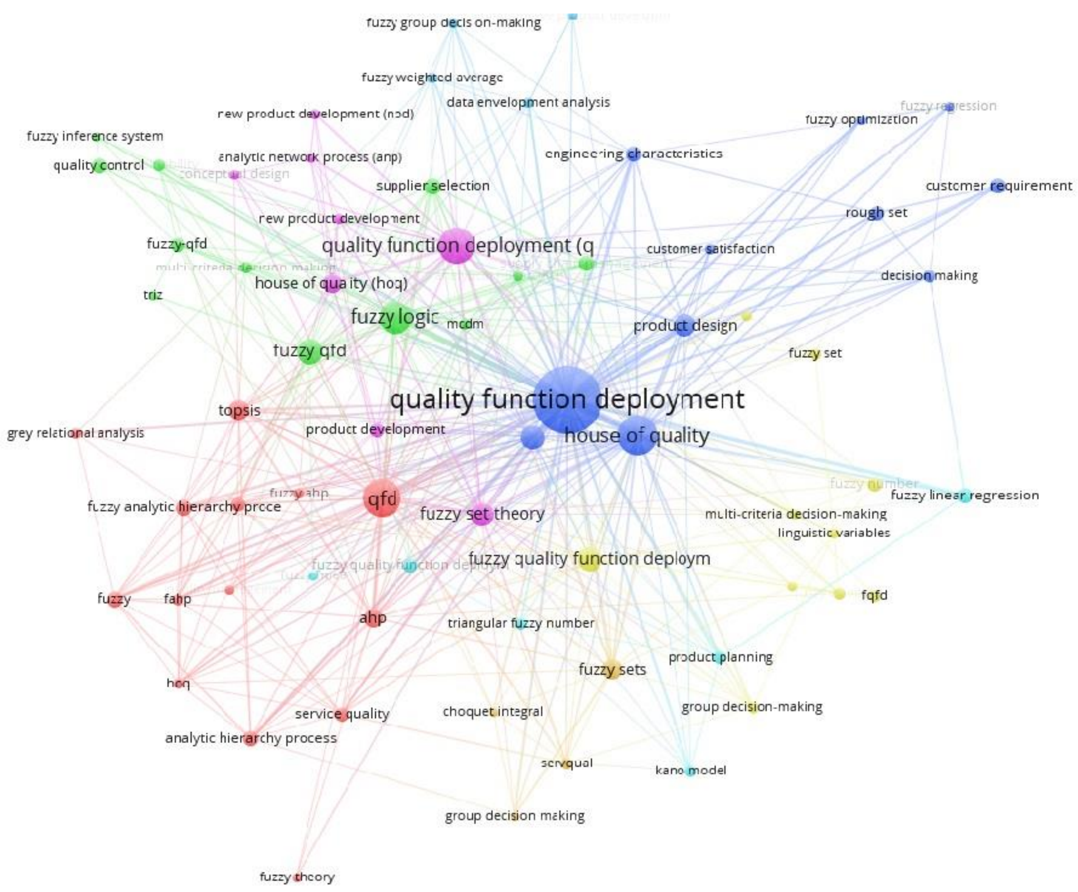

Figure 3 – Network of Keywords

Table 9 - Clusters of keywords

Clusters	Keywords
1	"AHP", "Analytic Hierarchy Process", "FAHP", "Fuzzy", "Fuzzy AHP", "Fuzzy Analytic Hierarchy process", "Fuzzy Theory", "Fuzzy TOPSIS", "GREY relational analysis", "HOQ", "QFD", "Quality management", "service quality", "TOPSIS"
2	"Analytical Hierarchy Process", "Fuzzy inference system", "fuzzy logic", "fuzzy QFD", "fuzzy-QFD", "MCDM", "multi-criteria decision making", "quality control", "supplier selection", "supply chain management", "sustainability", "triz"
3	"Customer requirement", "Customer requirements", "Customer satisfaction", "decision making", "engineering characteristic", "fuzzy optimization", "fuzzy regression", "house of quality", "product design", "quality function deployment", "rough set"
4	"Decision-making", "FQFD", "Fuzzy Goal programming", "fuzzy number", "fuzzy numbers", "fuzzy quality function deployment", "fuzzy set", "group decision-making", "linguistic variable", "multi-criteria decision-making"
5	"Analytic network process (ANP)", "conceptual design", "fuzzy set theory", "house of quality (HOQ)", "new product development", "new product development (npd)", "quality function deployment (QFD)"
6	"Fuzzy FMEA", "Fuzzy linear regression", "fuzzy quality function deployment (FQFD)", "Kano Model", "product planning", "triangular fuzzy number"
7	"Collaborative product development", "data envelopment analysis", "fuzzy group decision-making", "fuzzy weighted average".
8	"Choquet integral", "fuzzy sets", "group decision making", "SERVQUAL"

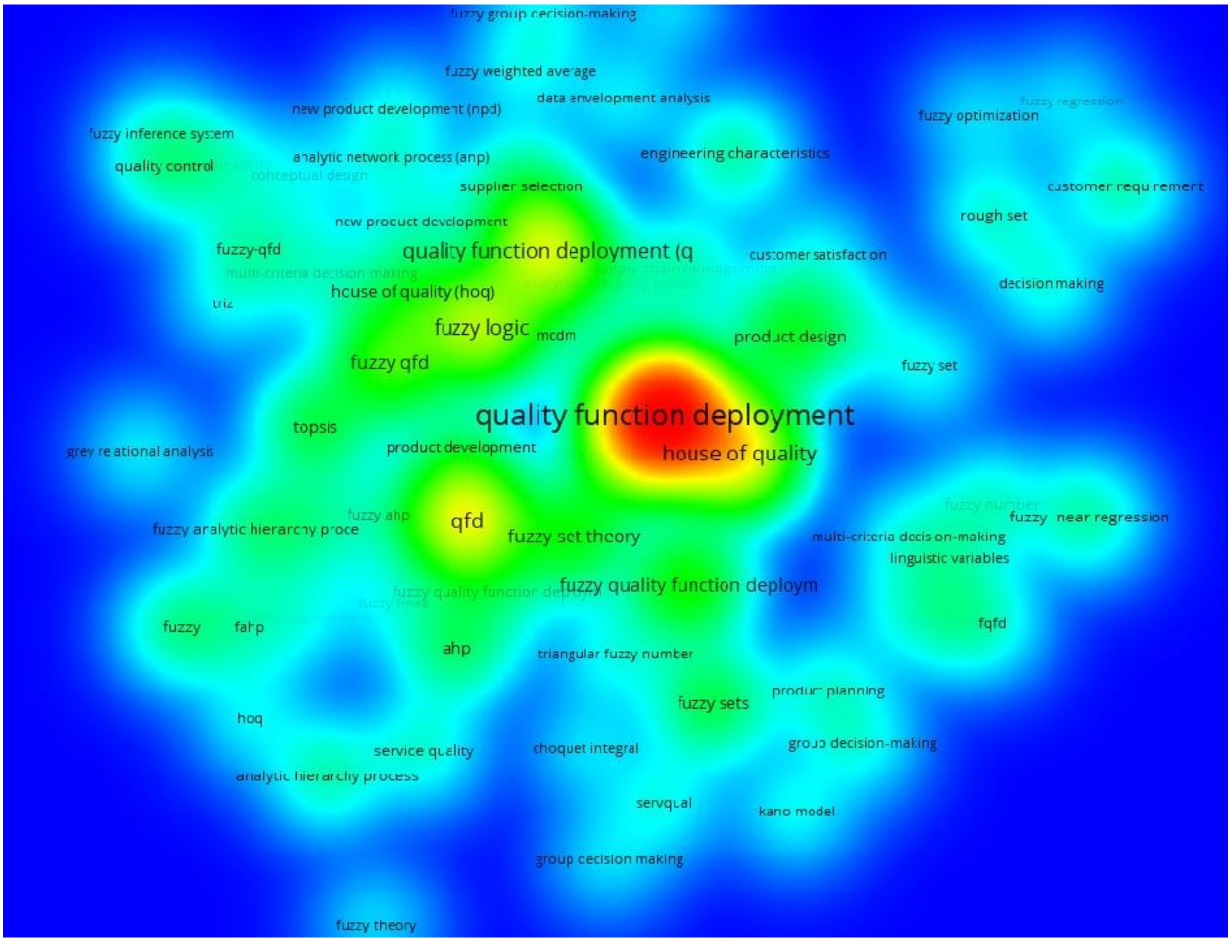

Figure 4 – Map-item density of keywords

Therefore, this is the hot topic of research on QFD and fuzzy systems: their integration with MCDM. Different applications were observed, including: "multi-criteria decision making", "Quality management", "service quality", "quality control", "supplier selection", "supply chain management", "sustainability", "Customer satisfaction", "product design", "conceptual design", "new product development", "product planning", and "Collaborative product development", to name a few. Moreover, "Choquet integral" was used in "group decision making" problems, such as determining a correlation among customer requirements (Yu et al, 2018).

Other topics of investigation include the Kano Model, FMEA and SERVQUAL, and “fuzzy goal programming”, “fuzzy linear regression”, “fuzzy optimization”, “fuzzy regression” and DEA (Data Envelopment Analysis) among others. The use of different types of fuzzy systems is a promising topic of research.

Map-item density also shows that there is a trend to use MCDM methods, such as AHP and TOPSIS, for example, with QFD method on fuzzy environment, forming new hybrid MCDM methods for solving decision problems.

Different generalizations and extensions of fuzzy sets have been introduced in MCDM methods, such as in AHP and TOPSIS, for example, that had already been used with QFD method. Therefore, it is assumed that new hybrid MCDM methods will be created using QFD in their composition on other extension of fuzzy environment.

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CONCLUSIONS

This paper presents a bibliometric analysis on fuzzy systems applied to QFD. The first quantitative result is the growing number of publications observed since 2008. The second result is the leading position of China, both in publication and international collaborations.

A qualitative result from the research is the widely spread publications in terms of authorship, interest area and journals. However, Computer Science and Engineering are the leading areas, with far more publications than other areas. Therefore, Expert Systems with Applications is the journal which published more documents on QFD with fuzzy systems. Two groups of researchers have outstanding publication productivity. A group led by Dr. Kahraman, in Turkey, and another led by Dr. Y. Chen, in China.

A strong relationship between MCDM and QFD with fuzzy systems could be identified as the highest studied topic. Innovations in fuzzy systems theory have also been applied to QFD, as the intuitionistic fuzzy systems and the hesitant fuzzy systems. However, no publication on type-2 fuzzy set, fuzzy multisets and nonstationary fuzzy sets were found despite having been successfully applied in multicriteria decision methods. A study on the advantage of applying these fuzzy extensions in the QFD method would be a research gap to be addressed by researchers.

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Applying Lean Six Sigma Methodologies for Quality Improvement in a Powder Coatings Industry

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STRUCTURED ABSTRACT

Purpose - This article presents a case of application of the Lean Six Sigma methodology in a powder coatings industrial company. The project had the goal to ensure reproducibility between a quality control step and an extruder machine in order to avoid machine downtime to validate product quality.

Design/methodology/approach - The DMAIC (Define–Measure–Analyse–Improve–Control) approach was followed to increase by approximately 30% the percentage of productions that do not stop for quality control approval and to consequently increase 5 percentage points (pp) of the Overall Equipment Effectiveness. Throughout this five-stage cycle, a set of analytical tools was systematically applied for a correct characterisation of the problem, definition of the input variables and their effect on the response variable, investigation of the cause and effect relationships, selection of the improvements according to their impact and effort, definition of an action plan and continuous evaluation of their effectiveness, culminating in a monitoring and control plan.

Findings - By performing tests throughout the several stages of the process, it was identified that the lack of reproducibility was mainly associated with the incorrect parameterisation and the lack of standardisation. As a result of this project, the percentage of products that do not require the extruder to stop for quality control rose by 40%, with the effect of a 9 pp increase in OEE. The financial return was estimated at 4.8% of the company's fixed manufacturing costs, in addition to the culture of continuous improvement established in the company. Since this is only the work of a pilot line, the benefits, not only for this project but for others resulting from this new mindset, are expected to be high.

Practical implications - The case study exposes a Lean Six Sigma project carried out in a small and medium-sized Portuguese company, serving as an example of the cross-cutting methodology and the benefits incurred from its use. The respective operational and financial benefits are also presented.

Originality/value - There are very few cases of the application of the Lean Six Sigma methodology in Portugal, applied to small and medium-sized companies. In addition to the fact that they are not reported in the literature, there are no mentioned case studies in this industry: powder coatings. In this sense, this paper, besides being of great importance for similar companies, its application may be generalized to other companies that intend to adopt structured methodologies to improve the quality of their products and the efficiency of their processes.

Keywords: Lean Six Sigma, DMAIC, Design of Experiments (DOE), Powder Coatings.

Paper type: Case Study

INTRODUCTION

Powder coating is one of the most advanced painting techniques, creating an effective and high-quality layer on a wide range of products (Du et al., 2016). The powder coatings industry began its strong development during the mid-20th century and has been increasing its growth ever since. While there is a myriad of possible applications in different products/industries, its use is particularly significant in the automotive and architecture industry (Dudek et al., 2018).

This case study is part of a larger continuous improvement project that took place at a powder coatings company in Portugal, CIN Industrial Coatings. Frequent production stoppages, causing a low Overall Equipment Effectiveness (OEE), was a major concern for the company and it urgently needed attention. Thus, to achieve the stabilisation of the production process, it is imperative to define parameters that ensure the minimisation of variability as well as the reduction of stoppages for quality control in the process. The problem-solving model DMAIC was used to address the problem at hand. Once the objectives were defined, the team agreed to address the following research questions:

1. Which variables must be studied in order to guarantee the reproducibility between raw materials approval (RMA) phase and extrusion? Which values must be parameterised?
2. What should be the strategy to improve control of the other most critical quality factors?
3. How to provide the production and quality teams with problem-solving techniques, so that the causes of the problem are dealt directly at the root and with in-house knowledge?

The following paper is organised as follows: the next section presents the theoretical background that supports the research carried. Then, section III details the case study and section IV discusses the main conclusions concerning the results achieved and their impact.

THEORETICAL BACKGROUND

In order to obtain quality, all variability in the process must be reduced. According to Shewhart (1931), these two concepts are antagonistic, that is, when quality is the desired parameter, variability creates different actions for the same causes.

There are several continuous improvement methodologies that are used repeatedly by organisations to raise their quality parameters. Regardless of the method followed, they have a universal character, being generally divided into two major phases: diagnosis and resolution (Juran and Godfrey, 1999a).

According to Jacobs et al. (2011), Six Sigma refers to a philosophy that aims to eliminate defects in products and processes, in which the defect represents any component that does not fit the customer's specifications. This methodology is based on a framework known by the acronym DMAIC (Define, Measure, Analyse, Improve and Control), used for process improvement (De Mast and Lokkerbol, 2012), focusing on product quality (Pande et al., 2001). Kwak and Anbari (2006) describe it as a closed circuit that links a set of statistical methods and tools for the study of process variability, seeking to eliminate non-productive stages. Based on the PDCA cycle (Plan, Do, Check, Act), once the opportunities are identified and studied, actions are planned and implemented, generally with significant benefits for the organisation's results (Linderman et al., 2003).

Alexander et al. (2019) refers that, although Six Sigma has been well implemented in large organisations, there are still many gaps in the literature concerning SMEs, thus further research is needed to address these. Searching for increasingly high-quality standards, companies point to Lean Manufacturing and Six Sigma methodologies as critical factors for their success. The lean philosophy's main principle is to increase productivity by reducing waste and improving workflow. By improving process performance, it enhances consumer and bottom-line satisfaction (Snee, 2010). On the other hand, Six Sigma presents an approach with a greater focus on quality and on reducing process variation, involving, due to its quantitative nature and the requirement for advanced statistical knowledge, a smaller number of people. Thus, Lean Six Sigma can offer better results than conducting the two independent programs (Arnheiter and Maleyeff, 2005). This view is corroborated by Mi Dahlgaard-Park et al. (2006), who found that both have in common objective proposals for the pursuit of operational excellence.

The Lean Six Sigma methodology has proven to be an effective problem-solving approach, with successful implementations in terms of quality, cost, delivery, lead time and customer satisfaction (Mandahawi et al., 2012). An example of this is its impact on Overall Equipment Efectiveness (OEE), a key performance indicator focusing on equipment availability, performance and quality yield (Dal et al., 2000). Gibbons (2010) pointed out that increasing the OEE, the strategy for productivity improvement in manufacturing, can be achieved by following a Lean Six Sigma methodology. Mandahawi et al. (2012) proved, in a paper production company, that OEE improved by 35%, applying this methodology. Other successful case studies have been reported, suggesting a symbiosis synergy between Total Productive Maintenance (TPM), where OEE is the main performance indicator, and Lean Six Sigma. Also, the TPM is considered a quality management tool in order to achieve operational excellence (Sahu and Sridhar, 2013).

According to Burghall et al. (2014), the key to Lean Six Sigma thinking must be in the customer. Its characteristics involve a strong emphasis on defining the project, especially in internalising the customers' perceptions of value and their requirements for quality characteristics. In addition, creating forms of control to maintain improvements and a continuous effort for change are other attributes of this philosophy. In order to maximise the benefits of Lean Six Sigma, companies must invest in training and change in organisational culture and infrastructure. Standardisation is an important pillar for securing repeatability and solid results (Sokovic et al., 2010). The advantage of this principle is also the rapid identification of deviations and the elimination of waste and time, making the process more transparent (Branco, 2009).

Ulrich (1993) mentions that in every coatings industry all powder coatings are formulated individually in order to achieve very specific needs for each client. For most industries, it is difficult to produce products that always meet these same characteristics. However, if this difference between products is insignificant, it may not have any impact on the customer (Juran and Godfrey, 1999b). Utech (2002) describes that the performance of the powders depends on a variety of factors, especially the quality and formulation of the materials, the condition of the equipment applying the powder and the operator applying the paint.

Although there are different strategies for improving product and service quality, the application of formal continuous improvement methodologies in the powder coatings industry is not as advanced as those used in other industries, and there are still no references concerning the use of the most widely used quality improvement methodologies, e.g. Six Sigma and Lean Six Sigma in this context.

CASE STUDY

In order to comprehend a problem and define its boundaries, it is fundamental to fully understand the production process.

Powder coatings consist of resins, pigments and additives, whose mixture gives the paint certain characteristics, depending on the desired output. The powder coatings manufacturing process is divided into 3 major steps: weighing/premixing, extrusion and micronisation (grinding).

1. Weighing/Premixing

The powder coatings consist in a mixture of resins, hardeners, fillers, pigments and additives which are weighed according to the manufacturing order launched for the factory. The 100% solid raw materials are weighed separately and then introduced in a container for being homogenised in a machine called premixer. At this stage, it is important to ensure all raw materials are properly mixed, in order to prevent quality problems further in the process, hard to correct. Due to the importance of this operation, the company has set up an internal method of quality approval of raw materials named RMA, where, before all the mixture continues to the subsequent stages of the production process, a sample of the mixture is tested in an offline process. This internal method was developed to approve the premix without the need to stop the extruder for quality control of the chip, name given to the material that results from the crushing of the raw material by the extruders. In this control, samples must be taken by operators up to four hours before production starts, so that, in case of any deviations from the specified requirements, there is enough time to perform the necessary adjustments until the product's compliance.

The samples are sent to the Laboratory Quality Control (LQC) and the paint characteristics are analysed. The booth chosen to apply the paint is selected according to the characteristics of the product under analysis, after the grinding stage is performed. There are booths suitable for textured whites, smooth whites, smooth dark paint and textured dark paint. The application of the paint is controlled given the proper thickness of the paint on the test panel, conditioning the measurement of gloss and colour. After that, the plate is placed in an oven at a certain temperature for a determined period. The colour is analysed in an equipment designated by spectrophotometer, according to the three-dimensional spacing system, the International Commission on Illumination (CIE) L*a*b* system. The L* axis indicates the lightness of the colour, varying from light on top to dark on the bottom (Gundlach, 2015). The lightness value, L*, represents the darkest black at L* = 0, and the brightest white at L* = 100. The coordinate +a* represents red, -a* represents green, +b* represents yellow and -b* represents blue. As soon as the colour of a new paint is created, its CIE L*a*b* coordinates are recorded in spectrophotometer database. So, when a new batch is manufactured, its

CIE L*a*b* values are compared to the standard stored and the colour difference is evaluated in terms of ΔE, given by Equation 1:

$$\Delta E = \sqrt{(L*_2 - L*_1)^2 + (a*_2 - a*_1)^2 + (b*_2 - b*_1)^2} \quad (1)$$

If the LQC approves the mixture, then the container with the raw materials is authorised to proceed to the extruder. If not, the premix must be adjusted by adding ingredients, until the product specifications are met.

Thus, the RMA phase comprises the introduction of a product in a mini extruder that simulates the behaviour of the extruder, until the product is validated in the laboratory.

2. Extrusion

The premix is fed to the extruder in a continuous process, being subjected to high temperatures and high shear stress to promote a high dispersion of the product.

The finished product at this stage is a homogeneous paste in which the polymeric resin aggregates all the components of the paint. As the temperature of extrusion is not high enough to trigger chemical reactions, this process is performed in the thermoplastic phase and the curing (polymerization reaction) does not happen at this stage.

This mixture is pressed and extended along a cooling belt, that in the end it has a crusher for breaking the material into smaller dimensions (chip).

3. Micronisation (Grinding)

The chips coming from extruder proceed to grinding, where the size of the particles is reduced to a few microns in diameter – micronisation. The paint acquires the form of a fine powder and the manufacturing process is finished. This step also consists of a continuous process.

The grinding system has components that will grind the chip by mechanical impact and to classify the product, in order to get a specific particle size distribution, that can be adjusted according to product specifications.

As it happens with the extruder, the mill also stops for quality control, a stoppage that is mandatory regardless of the product under production. If there is any defect in the quality characteristics, actions can be performed in order to adjust parameters; otherwise, the product is designated as a non-compliant product (NCP) and will wait until further quality control tests are done.

After the individual extrusion and micronisation operations, a cleaning operation is performed in order to remove traces of product that could lead to contamination of the next product. To support the type of cleaning to be applied, a compatibility matrix is used.

A visual diagram of the process is depicted in Figure 12.

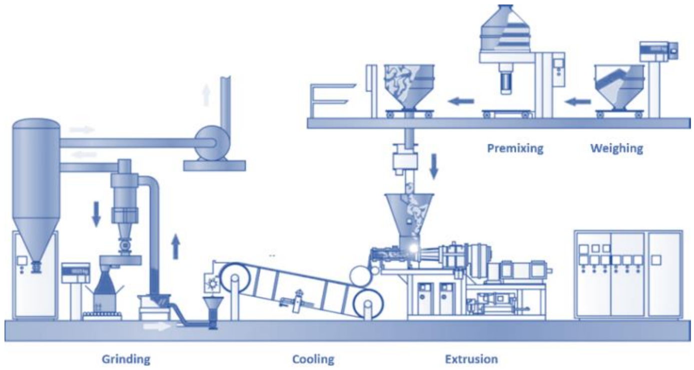

Figure 12 - Productive process scheme (FreiLacke, accessed 10 january 2020)

To structure the problem analysis, the Define, Measure, Analyse, Improve and Control steps of the DMAIC model were used. For confidentiality reasons, a different nomenclature was used for product's names, lines and combinations under study.

A. Define

In this section, a detailed analysis of the production process, the problem and the study object are presented, essential requirements for a better understanding of the project with direct impact on the solutions design.

The company under analysis had a history of having a low OEE due to the occurrence of long setups and frequent production stops, causing a decrease in productivity, as well as a high lead time. The frequent stops in the extruder machine caused by the products that require a quality control check before undergoing subsequent process steps, can occur for three reasons: 1) the product did not have time to go through the RMA phase, 2) the customers require a specific product to stop at this stage of the process or 3) a precedent has been set, never questioned before. In order to eliminate these stoppages, reproducibility between the RMA method and the extruder are required.

In order to measure the percentage of products that do not require the extruder to stop for quality control, an indicator was created, designated as NSY (Non-Stop Yield) - Equation 2.

$$\mathrm{NSY}\ (\%) = \frac{\text{Number of manufacturing orders that do not stop during production}}{\text{Number of manufacturing orders}} \times 100\% \qquad (2)$$

The company has dedicated lines to produce different products, such as textured and smooth paints, two categories of powder coatings. Line C was chosen as the pilot line, dedicated to the production of smooth paints, since it represents almost 20% of the annual production. The history of the year preceding the study, with a value of NSY for the extruder of 64%, set the baseline value. Later, this line will serve as the foundation model for the other lines in the unit.

Analysing Figure 13, it is possible to infer that the substantial corrections, after the quality control step, are at the level of colour (60.7%) and gloss (17.8%). Products A and B were selected because they represent two product families that often force extruder to stop, because they are made using delicate compounds more prone to problems. Product A is based on a polyester resin, representing the products whose variable of interest is the colour. In the product B, equipped with resin and epoxy-polyester, the response variable is the gloss.

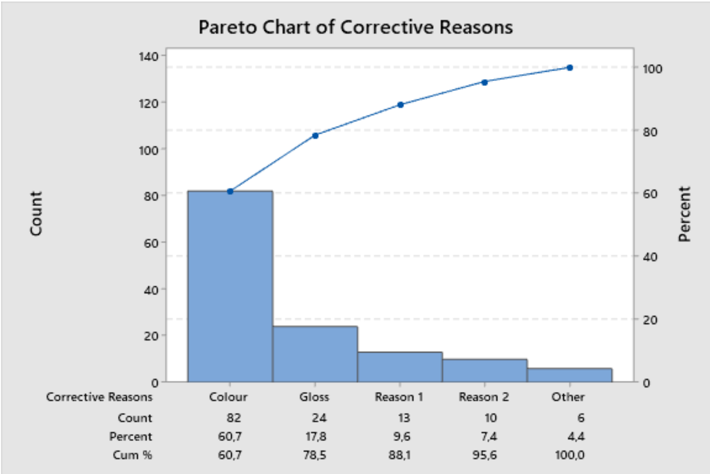

Figure 13 – Pareto chart of corrective reasons

To quantify the problem and measure the attained results, it was set as the main goal to reach a 30% increase in non-stop production for quality control purposes in this pilot production line. Resulting from the implementation of all the identified improvements that seek to achieve the proposed objectives, it was estimated an increase of approximately 5 percentage points (pp) of the productivity indicator (i.e. OEE), if the goal of a NSY of 85% for the extruder, is achieved. It should be noted that the OEE is obtained by multiplying three factors: availability, performance, and quality, where the increase in NSY is impacting on the first and third factors.

The reduction of time spent in quality control during production represents a possibility to increase the productivity of the company with a return on investment, due to a substantial reduction in fixed manufacturing costs. The return on investment is calculated considering the current OEE of the line, the nominal debit, the number of products that stopped the machine during the year, as well as the time used for quality control procedures.

To conduct the sessions, the work team was composed of multidisciplinary elements, meeting weekly in a workshop, with daily follow-ups, if applicable.

B. Measure

According to Burdick et al. (2005), to correctly monitor a manufacturing process, it is necessary to measure the attributes of the process output. Hence, an evaluation of the adequacy of the measurement system used for collecting data in the process is mandatory. In this section, a measurement system analysis (MSA) (e.g. R&R study) and an exploratory analysis of the problem are carried out.

Study of the Measurement System

To evaluate the variability of the measurement system, and thus its capability, a type I gage study was carried out. According the Flynn (2008), this study evaluates the combined effects of bias and repeatability based on multiple measurements from a single instrument, assuming that a reference value exists.

Since all quality control tests are conducted in the laboratory, it is necessary to understand if the equipment’s responsible for measuring colour and gloss can measure these variables in a consistent and precise way. To evaluate the colour measurement performed by a spectrophotometer, the L* coordinate was chosen (Equation 1), with a tolerance range of 1.

According to Cano et al. (2012), the Run Chart is a two-dimensional chart that can show patterns (cycles, changes or fashions) that are indicative of process changes. In this case, a target value of 93.61 was defined based on a standard sample, representing this central line the reference value of the L* coordinate. Analysing Figure 14, no patterns or clusters are observed, which means that the variation is random. It is verified that the values of the L* coordinate are within the defined limits by ±10% of the tolerance, showing that there are no problems in the measurement system.

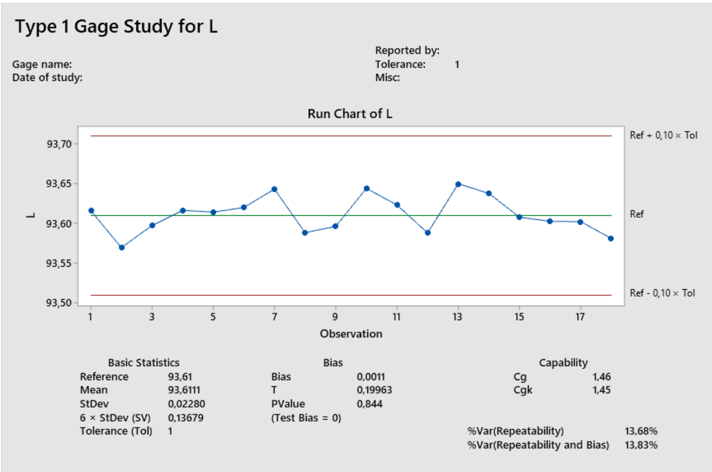

Figure 14 - Results of Type 1 Gage Study for L*coordinate of a sample of product B

As p-value ≥ 0.05, the null hypothesis is rejected, thus concluding that the bias of the measurement system is not statistically significant. This result is in accordance with the values of both capability indices, C_g and C_{gk}, clearly above the benchmark of 1.33, measuring the samples consistently. The capability index C_g compares the tolerance range with the variation of the system measurement and C_{gk} compares the tolerance range with the total bias and the variation of the measurement system. The same methodology was applied for the measurement of gloss and the same conclusions were reached.

As type 1 gage study only considers the inherent variation of the measurement system and does not assess the variability of the analysts, R&R tests were then conducted. Two components of the variability of measurement systems are identified in these studies: repeatability and reproducibility. Repeatability represents the variability measured when it is used to measure the same unit (with the same person, over the same time period). Reproducibility analyses how much variability in the measurement system is caused by differences between persons.

Three operators measure the L* coordinate of two samples, three times per part, in a random order. Then, it was performed a crossed gage R&R study. In these results, the variation from Part-To-Part is 96.64, which is much larger than Total Gage R&R - 3.36%. According to the Automotive Industry Action Group (AIAG), a good value of % Contribution from R&R is <10%. Thus, much of the variation is due to differences between parts and not caused by the measurement system.

In synthesis, these MSA analysis enable the researchers to conclude that the variability present in the system is solely due to the inherent differences between parts and that the measurement system performs correctly.

Exploratory Analysis

In the RMA phase, the equipment that simulates the extruder behaviour has associated a set of input variables (X, Y, Z) that the operator can manipulate, with a direct intervention in its parameterisation. In order to investigate the impact of these variables on the response variable, the mean and extreme values were selected, where V, W and U represent the current values used by the company:

- Factor X: 0.83V; V; 1.33V
- Factor Y: 0.6W; W
- Factor Z: 0.52U; U; 1.73U

The factor Z, however, changed only two times, since the change of its parameterisation resulted in problems in the operation of the equipment. In all other combinations, the U level was used.

According to Table 9, it is possible to observe all combinations for variance analysis.

Table 9 - Factors X, Y and Z combinations used

Combinations
V-W-U
1.33V-0.6W-U
1.33V-W-U
V-0.6W-U
0.83V-0.6W-U
0.83V-W-U
V-W-1.73U
V-W-0.52U

For product A, the critical quality parameter is colour, evaluated by the ΔE parameter, and for product B it is gloss, evaluated by gloss units (GU). Considering that product A has a ΔE = 0.8, the maximum variation allowed between the paint which was approved by the client and the paint obtained as a final product, must not overcome this value. The product B has a range gloss between 47 and 53 UG. Overcoming this interval is considered a non-conformity.

Product A

For each combination of factors, 6 samples were extracted to be applied later in RMA, resulting in a total of 48 samples. In addition, 4 premix samples were taken from different locations in the container, as well as 6 chip samples, resulting from the production in the extruder, taken every 5 minutes.

Table 10 provides information for the totality of the samples. Comparing with the Table 11 (which represents the descriptive statistics of the samples obtained in the extruder), it is possible to conclude that the coordinates a* and L* are not affected by the variation of X, Y and Z. On the other hand, the b* coordinate is the one most affected by the variation of the combinations, as can be deduced from the coefficient of variation. It should be noted that the existing differences in gloss (2 GU) are within the acceptable range for the customer and do not constitute a study factor. It should also be noted that, as product A is composed by a resin that is a polyester, the gloss is not affected by the X and Y factors. It is important to recall that for this product the critical quality feature is ΔE.

Table 10 - Descriptive statistics of the samples obtained by the RMA of the product A

	L*	a*	b*	Gloss
Mean (μ)	88.984	-1.285	1.012	60.145
Standard Deviation (σ)	0.096	0.013	0.083	3.602
Coefficient of Variation (CV)	0%	-1%	8%	6%

Table 11 - Descriptive statistics of the samples obtained by the extruder of the product A

	L*	**a***	**b***	**Gloss**
μ	89.064	-1.282	0.851	58.000
σ	0.102	0.012	0.058	3.162
CV	0%	-1%	7%	5%

The differences between the ΔE measures of the product that was produced in the extruder and the product obtained in the RMA phase for each combination of values were calculated (Figure 15). A combination with the value of 0 represents perfect reproducibility. In that sense, the best combinations, which presents the lowest ΔE, are represented by 1.33V-0.6W-U and 0.83V-0.6W-U (highlighted with different colours in Figure 15).

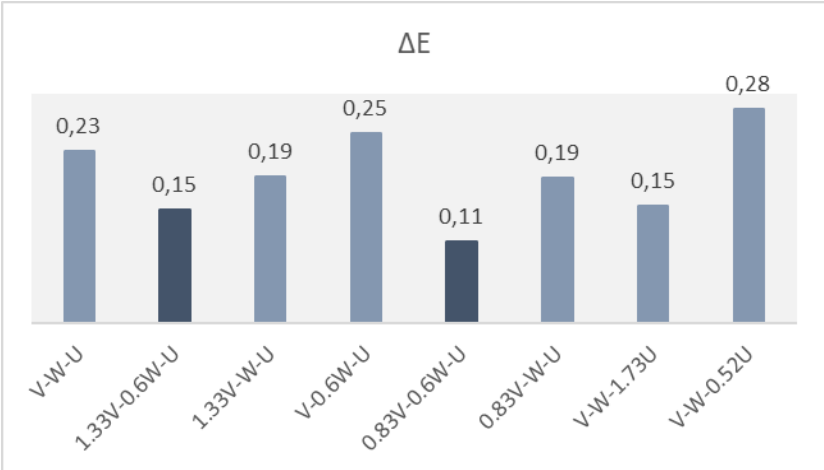

Figure 15 – Differences of ΔE between extruder and each combination

To facilitate the comparison, Figure 16 shows the values of the b* coordinate depending on the combination used. The distance of the b* coordinate between practically all the samples taken and the value of the b* coordinate obtained in the extruder is evident. Through the arrangement of the medians, the combination which the extruder best reproduces is 1.33V-0.6W-U.

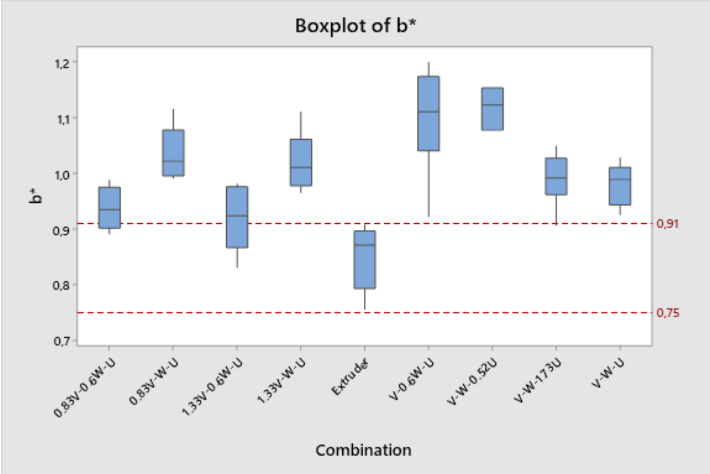

Figure 16 - Boxplot of b* coordinate for product A

To further assess if there are significant differences between combinations, a one-factor ANOVA test was performed, being the factor under study the b* coordinate (Table 12). As the p-value is smaller than expected, there is strong evidence to conclude that H_0 is not true and that the combination used has an impact on the b* coordinate.

Table 12 - ANOVA response variable: b* coordinate

	Df	Sum Sq	Mean Sq	F-value	P-value
Factor	8	0.349	0.043	14.341	3.9e-10
Residuals	45	0.137	0.003		

After checking that the residuals follow a normal distribution with the Shapiro test (p-value = 0.162) and that the homogeneity of the variances is confirmed through the Bartlett test (p-value = 0.428), the Tukey method is therefore applied. The results are presented in Table 13. It is noted that the extruder group is shared with only two combinations, indicated by 1.33V-0.6W-U and 0.83V-0.6W-U. Given the greater approximation to the average, it is observed that the combination which best follows the extruder is combination 1.33V-0.6W-U.

Table 13 - Tukey pairwise comparisons product A

Combination	N	Mean	Grouping
V-W-0.52U	6	1.118	A
V-0.6W-U	6	1.098	A
0.83V-W-U	6	1.036	AB
1.33V-W-U	6	1.021	ABC
V-W-1.73U	6	0.990	BC
V-W-U	6	0.981	BC
0.83V-0.6W-U	6	0.938	BCD
1.33V-0.6W-U	6	0.919	CD
Extruder	6	0.851	D

A multiple regression test was performed, and it was identified that the variables X, Y and Z are statistically significant, with p-values below 0.05. However, changing the current parameterization of factor Z (U) was proved to be impossible, given the short-term problems expected from process constraints, as well as the additional lead time that is charged to the machine cleaning operation, consequence of poor operating conditions.

For the purpose of investigating the influence of the sampling location on the variable colour, different samples were extracted from different locations of the premix container. The central locations corresponding to the sample taken were analysed (i) on the container surface; (ii) 15 cm below the container surface; (iii) in the middle of the container; and (iv) at the bottom of the container. It can be verified that, whatever the location, all samples have a b* coordinate value higher than the one that should be present in the extruder ($\mu=0.85$). It is also observed that the L* and a* coordinates are in accordance with what was obtained in the extruder. It should be noted that all these samples were taken under the company's standard combination, V-W-U, reinforcing the challenge of achieving reproducibility between these two stages.

Product B

The method of studying product B was similar to the one used with product A, taking into account that right now the critical quality characteristic under analysis is the gloss. Observing Table 14 with the description of every combination after the RMA test, it is possible to observe that even though the gloss has an average of 47.4, the extruder (Table 15) showed a value of 49.4 for the same variable. It has assumed that there is no relevance in studying the colour, because the product has a ΔE within specifications.

Table 14 - Descriptive Statistics of the samples obtained by the RMA of the product B

	L*	a*	b*	Gloss
μ	93.600	-0.299	4.028	47.375
σ	0.065	0.063	0.097	1.863
CV	0%	-21%	2%	4%

Table 15 - Descriptive statistics of the extruder for product B

	L*	a*	b*	Gloss
μ	93.602	-0.281	4.170	49.400
σ	0.060	0.049	0.083	2.607
CV	0%	-18%	2%	5%

The boxplot chart in Figure 17 allows us to deduce that there are several combinations that exceed the minimum mandatory value of gloss for this product (47), but no combination exceeds the maximum (53). It was confirmed that the combination used by the company has values that are below the specification limits.

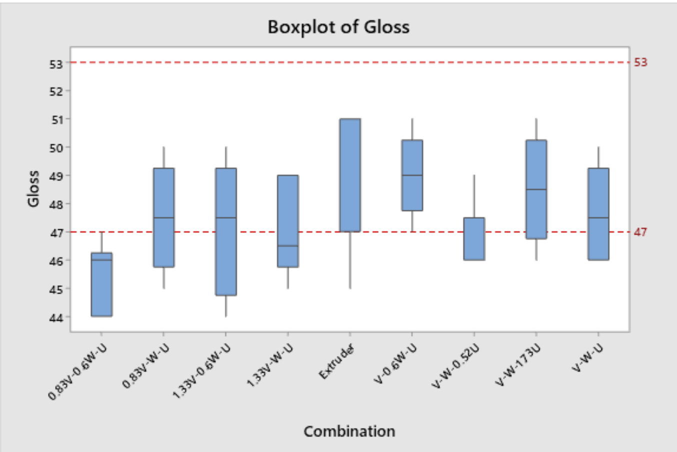

Figure 17 - Boxplot of gloss for product B according to combinations

In order to assess if the location from where the sample is collected from the premix container affects the variable colour, a similar analysis as the one conducted for product A was performed for product B.

For product B, colour and gloss analyses need to be performed, because although the critical parameter is the gloss, it must be confirmed that the new conditions will not influence the colour.

The results of the one factor ANOVA, where the response variable is the gloss of product B are shown in Table 16. The p-value of 0.019, allow us to conclude that at least one treatment has a different expected value.

Table 16 - ANOVA response variable: gloss

	Df	Sum Sq	Mean Sq	F-value	P-value
Factor	8	67.819	8.477	2.641	0.019
Residuals	44	141.200	3.209		

After confirmation of the normality of the residuals (p-value = 0.273) and the homogeneity of the residuals (p-value = 0.771), a Tukey test is conducted for comparing the different expected values of the underlying populations (Table 17). The group A of the extruder is shared with all the combinations, except for the combination 0.83V-0.6W-U. The one whose average is closest to the extruder is the combination defined by V-0.6W-U.

Table 17 - Tukey pairwise comparisons product B

Combination	N	Mean	Grouping
Extruder	6	49.400	A
V-0.6W-U	6	49.000	A
V-W-1.73U	6	48.500	AB
V-W-U	6	47.667	AB
0.83V-W-U	6	47.500	AB
1.33V-0.6W-U	6	47.167	AB
1.33V-W-U	6	47.000	AB
V-W-0.52U	6	46.667	AB
0.83V-0.6W-U	6	45.500	B

The same study had to be carried out to confirm that the best combination applied to gloss did not change the colour. Therefore, in order to have greater confidence in the results, the ANOVA was performed once more, with the b* coordinate response as the response variable. It is confirmed that the combination used for the gloss is not statistically different from the one obtained for the colour.

For this product, a multiple regression test was also conducted, having the three variables a p-value greater than 0.05 (factor X, Y and Z with a p-value of 0.758, 0.754 and 0.089, respectively). From this analysis and the value of the coefficient of determination (7%), it is possible to conclude that changes in the parameterisation of equipment are not statistically significant for the problem identified by the company, so the root causes need to be ascertained.

The four samples taken from the different locations in the container are within the allowed limit for this product and the differences are not statistically significant, in addition to approaching the average obtained by the extruder, concluding that the location where the sample is taken has no influence on the gloss units obtained. However, it has been shown that there are statistically significant variations in the gloss units of the samples collected over time (p-value = 0.031).

After this phase of DMAIC, a preliminary conclusion has been reached that these parameters have an impact and it is required to explore these variables and other potential causes.

C. Analyse

The problem of reproducibility between the RMA phase and extrusion is not exclusively due to the lack of standardisation of the process and the use of the wrong levels in the respective equipment. In order to uncover other potential causes of the problem, an Ishikawa diagram (Figure 18) was constructed. This exercise was conducted through a brainstorming session with the team, integrating the most critical elements of the operation concerned. The majority of the identified causes were addressed, as most of them were easy to implement, reaping immediate benefits.

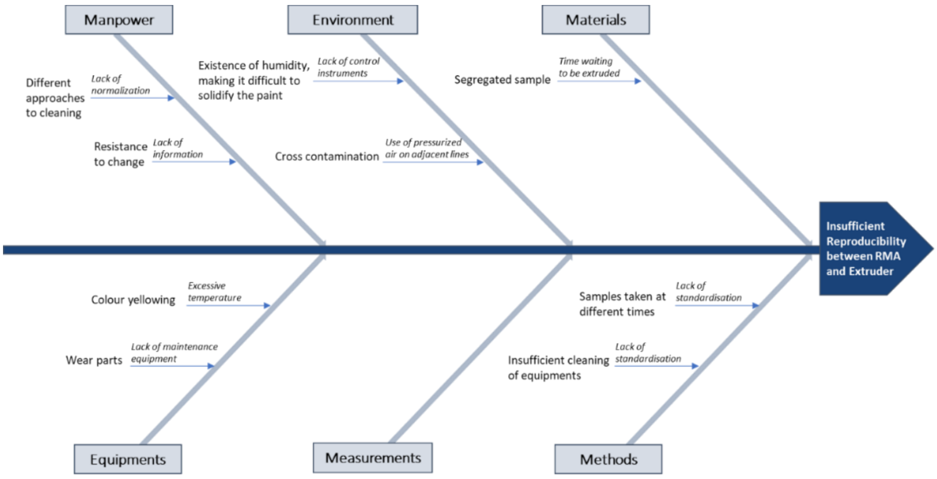

Figure 18 - Ishikawa Diagram to analyse the insufficient reproducibility between RMA and extruder

D. Improve

In this section, the main improvement actions implemented are described, addressing the root causes previously identified.

After the variance analysis, an experiment design (DOE) for product A has been performed. Through this tool, it is intended to determine the influence of each variation factor on the quality characteristic of the product under analysis - b* coordinate, identifying the optimal combination of factors and at which levels it is most recommended to operate (Montgomery, 2017). Via a general full factorial design, two factors were set (X and Y) with three and two levels, respectively, having each combination 6 replicates.

Product A

The main effects plot and the factorial plot or these experimental design are represented in Figure 19 and Figure 20. Previously, the ANOVA test applied to Product A enabled us to conclude that there are significant differences between the different combinations and the b* coordinate. Thus, and from the analysis of the results of the DOE, in order to get a b* coordinate level which reproduces the value obtained in the extruder, it is recommended to use the level 1.33V for the X factor and 0.6W for the Y factor. However, the use of the X factor of 0.83V could also be utilised instead of the 1.33V with minimum differences.

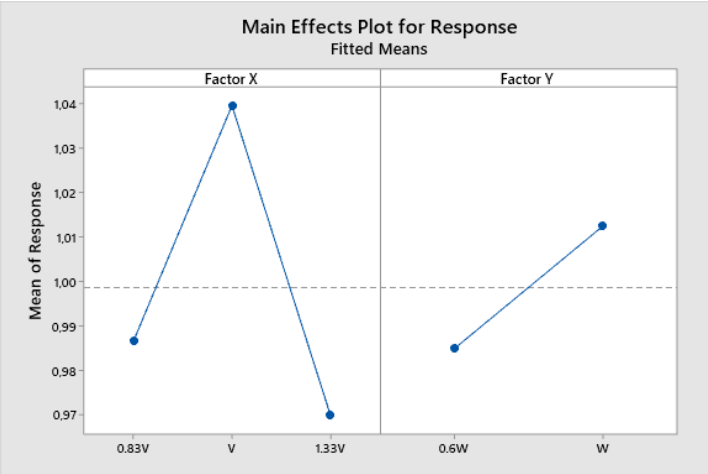

Figure 19 - Main effects plot product A

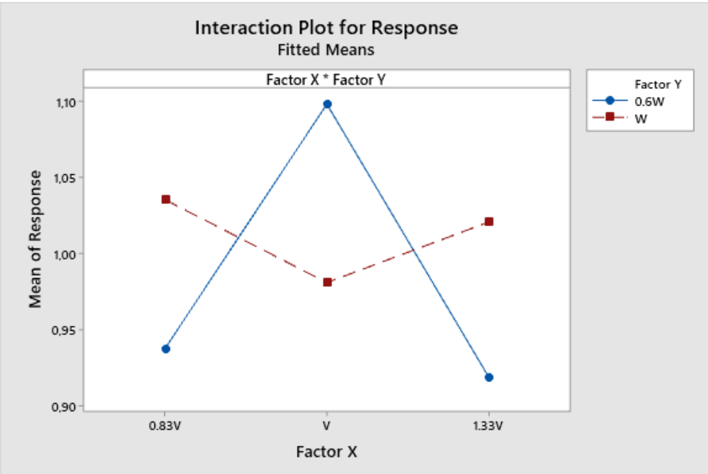

Figure 20 - Factorial plot product A

Global

After identifying the correct values to be used in the RMA equipment, one-point lessons (OPLs) were created with the new work standards. Thus, for products that showed differences in colour, the combination 1.33V-0.6W-U was applied. In the case of gloss, although the variables were not significant, the combination that best approximated the values seen in the extruder is the V-0.6W-U, being the one that was selected.

Due to the setups, it is critical to determine the time and the location in the extruder in which a sample must be taken from the product. In that sense, these moments were also standardised.

In view of the high risk of contamination, the cleaning procedures in RMA, extrusion and mill were also typified and standardised. At the same time, setup preparation records were implemented as a standard procedure. In these sheets, the operator must specify the name of the product, the production order, the type of cleaning that should be performed, as well as information concerning non-conformities, should they occur. In order to ensure the knowledge of the cleaning type and quality control is well disseminated between all the workers, a decision support tool has been developed, based on the sequence of products and the respective contamination risk.

Given the criticality of all the equipment in the process, a checklist for controlling the extruder and the mill was also created. Depending on the parameters to be analysed, a daily, weekly and monthly monitoring was established, to be carried out by the operators.

In order to guarantee and enhance the results obtained through the actions listed above, some support initiatives were implemented. The first step was the restructuring of the teams by Value Stream (called flows), unlike the initial organisation by sections, which allowed greater control and visibility of the entire production flow. In order to implement and sustain all improvements, the first 3 levels of Daily KAIZEN^{TM} were also implemented, which strongly contributed to the creation of a culture of continuous improvement and alignment of teams with the goals of the organisation. Level 1 - Work Teams Organisation - allowed daily monitoring of performance indicators and acting on deviations with immediate countermeasures, thus facilitating the help chain, improvement in communication channels and collaborators involvement. Level 2 ensured the workspace organisation and the reduction of some micro-stops due to lack of material/tools and Level 3 the team's competences, improving the work efficiency and levelling the knowledge.

A Mission Control Room (MCR) has been created to control and monitor initiatives and projects, where weekly meetings (board, flow and department leaders) and quarterly meetings (steering committee) are held. It should be noted that in these meetings the main indicators are discussed, one of them the NSY (extruder and mill), and the action plan resulting from the deviations identified in the indicators and improvement actions.

As a deliverable, a statistical training was also carried out to use the applied techniques, in order to ensure that the company has the knowledge to develop, autonomously, the rollout of this project for all lines.

E. Control

At this stage, the gains obtained in the previous phases should be monitored and the new process conditions documented. In addition, the stability of the new process must be guaranteed.

Monitoring Mechanisms

Considering that the b* coordinate is one of the critical characteristics to quality, it was possible to conduct a control over the products which were analysed in RMA, comparing the results with the ones from the extruder. After four weeks of study, it was concluded that the combination obtained with the experiment design effectively reproduced 71% of the products analysed, with an average difference of 2% between the extruder and RMA. The remaining products are industrial trials and products whose critical quality parameter is gloss. Subsequently, the new combination was introduced to the product family represented by product B.

It should be noted that there are products where ΔE is less than 0.4 and, at the customer's request, the extruder stops production for quality control purposes, even if in RMA the product does not show any colour problems.

To ensure the sustainability of the main countermeasures defined, a program of Kamishibai audits and Gemba Walks has been developed internally for control, maintenance of standards and work improvement. These are executed at all levels of the company - from the flow leader to the Industrial Unit Director. The results are analysed in the weekly meetings; however, feedback is given immediately to the collaborator(s) assigned to the respective task.

Results Obtained

In terms of benefits quantification, the project goal has been achieved with a 40% increase in NSY in the pilot line extruder - Figure 21.

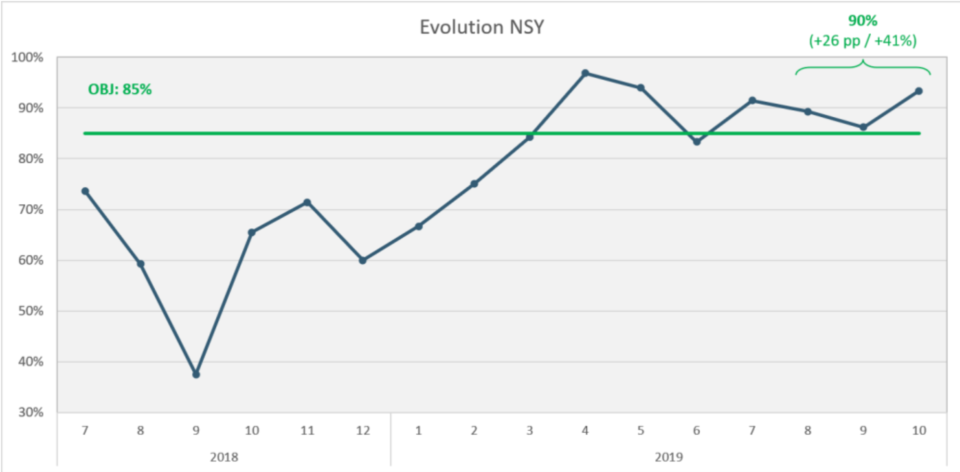

Figure 21 - Line C NSY evolution (2018 - 2019)

In addition, there was an increase in the NSY from 0% to 64% in the mill.

This combined effort of the team in implementing the actions allowed for a 9 pp improvement in the OEE indicator (Figure 22) in the value stream to which this line belongs and the achievement of a level of excellence regarding the quality of the CIN products. The financial return is reflected in 4.8% of the company's fixed manufacturing costs.

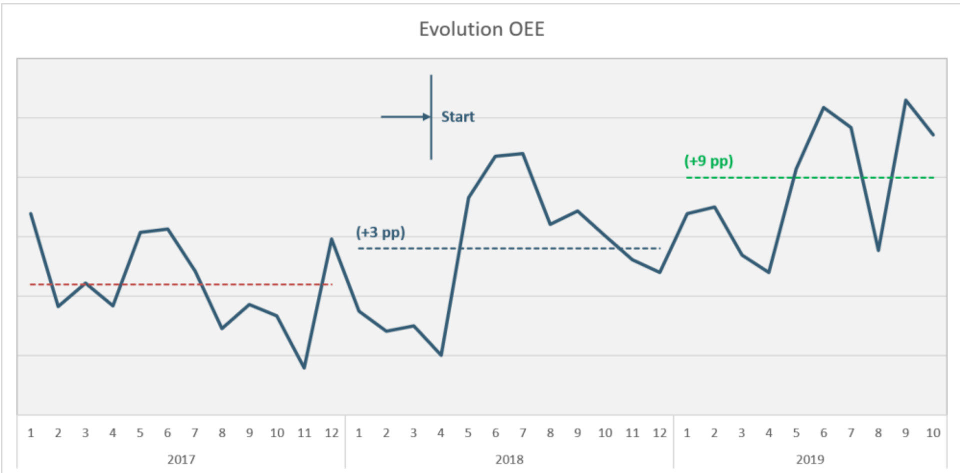

Figure 22 – OEE evolution (2017 - 2019)

Once the respective goals have been achieved, a schedule was defined for the deployment process, using the same approach for the remaining lines. After rollout, a more significant increase in the value of the OEE is expected, as more production lines are considered.

CONCLUSIONS

The current article intended to perform a detailed analysis on the variability existing in the current process, as well as an analysis to the critical factors to quality of the powder coating process, in order to identify which levels influence the correct reproducibility between the stages of RMA and the extrusion.

Despite being out of the scope of the study initially established, the main focus of contamination of the mill was also analysed with the goal of eliminating the mandatory stopping rule that was the standard practice in the company, at this stage. In parallel, the product compatibility matrix was reviewed, and the list of mandatory stop products was sorted.

In the end, this paper can state that most of the project’s goals were successfully achieved and that the research questions initially outlined for the project were dealt. The tools used throughout the project have proven to be suitable for reducing process variability and improving daily management.

Through a rigorous control, it is proven that it is possible to obtain a product in accordance with the established parameters, meeting the expectations and quality expected by the customer. In the final stage, Lean Six Sigma has also ensured that it is a crucial methodology in this project and has stood out in:

- Monitoring the process to ensure that quality requirements are being met. If any cause of abnormal variation arises, it will be identified and characterised and measures will be taken to restore the process to normal conditions;
- Incorporation of a change culture and breaking of many paradigms - crucial for the reflection of the problems' causes. Although it was not possible to quantify it, its effect was perceived and reflected in the results.

Regardless of the size of the organisation, the results obtained prove the effectiveness of this methodology as the key tool in the search for better operational performance, rewarding all the effort invested in fighting waste and seeking excellence.

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Towards Digital Lean Manufacturing: A Brazilian Case

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ABSTRACT

Purpose – The purpose of this paper is to present a case study to describe the contact points between industry 4.0 technologies and lean manufacturing practices, that characterize the concept of digital lean manufacturing.

Design/methodology/approach – After building a research framework extracted from the literature review, a single and in-depth case study was carried out in a Brazilian factory to understand the implementation of the digital lean manufacturing. The data were analyzed using descriptive statistics and content analysis, and resulted in the development of a conceptual map.

Findings - The results revealed characteristics regarding six contact points implemented in the organization investigated. Also, it was observed that the results with the digitization of lean practices are consistent with the traditional literature, as they are aimed at reducing operating costs, eliminating waste, increasing quality, reducing lead time and real-time information.

Research limitations/implications - The results of the research are based on a single case study and cannot be generalized. Therefore, the application of the same research framework will be conducted in other companies.

Practical implications - Understanding the requirements for implementing the contact points illustrated in this case can help lean practitioners in the process of converting to the digital lean manufacturing model. However, it is understood that the implementation of DLM requires investments in technology and organizational culture aligned to the digital transformation.

Originality/value – This work represents the first attempt to verify the adequacy of a research framework for the characterization of digital lean manufacturing practices.

Keywords: Lean Manufacturing, Industry 4.0, Digital Lean Manufacturing.

Paper type: Case study.

INTRODUCTION

Several industrial sectors have adopted operational excellence strategies to achieve better performance in terms of quality, cost, and delivery. From this perspective, the Lean Manufacturing (LM) represents a fundamental approach able to accelerate the manufacturing processes and eliminate waste. Either, the paradigm of the fourth industrial revolution, also known as "Industry 4.0" (I4.0), has become part of the business agenda to develop strategies to convert the current manufacturing process into a new digital manufacturing model. The digital transformation process can be conducted through the implementation of Cyber-Physical Systems (CPS) or Smart Factories complementary to the improvement initiatives inherent to the LM approach.

The LM was idealized by Taiichi Ohno in the 1950s with the implementation of the efficient Toyota Production System (TPS), whose objective was to reduce operating costs and increase industrial productivity based on two essential pillars: *just-in-time* and *jidoka*. While the *just-in-time* method allows the production of the right quantity and the right time (mainly through pulled systems and continuous flow), the *jidoka* concept proposes the integration between operator and machine to ensure the quality of the production (right quality) by specific techniques, such as mistake-proofing, visual controls and automated inspection (Ohno, 1988; Womack and Jones, 1996).

The basic principles of TPS were also presented by Womack and Jones, who suggests the following sequence of five principles for the LM implementation: (1) identify value; (2) map the value stream for each product family; (3) create continuous flow; (4) establish a pulled system; and (5) seek perfection (Womack and Jones, 1996). The implementation of these principles can follow different strategies, from hiring specialized consultants, to training internal specialists who can implement LM tools and techniques.

Recently, the integration between information technologies (IT) and industrial automation (IA) has changed the *modus operandi* of manufacturing processes. The IT tools transform products into complex systems that combine hardware, software, sensors, microprocessors, databases, and connectivity, forcing companies to rethink how they do everything internally to face new threats and opportunities (Porter and Heppelmann, 2014). In the scope of operational excellence practices, it is expected that the integration of I4.0 technologies will optimize the collection and analysis of data from manufacturing processes with high accuracy and speed, increasing the possibilities for improving business performance (Agarwal and Brem, 2015; Tamás *et al.*, 2016).

The fourth industrial revolution has created new opportunities and challenges for operational excellence initiatives, enabling the use of the I4.0 technologies, such as the Industrial Internet of Things (IIoT), CPS, Radio-Frequency Identification (RFID), and Big Data Analytics. (Tamás *et al.*, 2016; Schwab, 2017). Given the considerations presented, it is believed that the interaction between digital technologies and operational excellence practices may expand the scope of improvement actions conducted under the light of the LM approach. Hence, three research questions emerge in this context: *RQ1 - What are the Contact Points (CPs) between I4.0 technologies and LM practices? RQ2 -How is it possible to integrate these two subjects empirically*? *RQ3 - What are the results of this interaction?*

The purpose of this paper is to present a case study carried out in a Brazilian factory to describe the CPs between the newly I4.0 technologies and the LM practices investigated in the organization. Therefore, a single and in-depth case study was conducted based on a theoretical framework. The results show the adherence between the two subjects (LM and I4.0) and may represent a reference guide for conducting future research towards Digital Lean Manufacturing (DLM) practices.

The present paper is organized as follows. The next section presents a brief literature review on the I4.0 and CPs. The next one presents the methodological approach chosen for the research. Then, a discussion of the main results from the Brazilian case study is presented. The paper ends with a short discussion of conclusions, limitations, and future research.

THEORETICAL BACKGROUND

The Fourth Industrial Revolution emerged at the turn of the 21st Century, primarily based on advances in mobile internet, miniaturization, and the cheapening of sensors, along with artificial intelligence and the creation of machine learning (Schwab, 2017). However, the term "Industry 4.0" became globally recognized after an event held in 2011 in Germany (Hannover Fair) to stimulate business around Smart Factories and to promote digital solutions into the CPS concept (Kagermann *et al.,* 2013; Sanders *et al.,* 2016).

According to the report entitled *"Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries"*, published by Boston Consulting Group, a set of nine technologies associated with I4.0 will transform the manufacturing environment in the next years. They are: (1) Big Data Analytics; (2) Autonomous robotics; (3) Simulation; (4) Integration of horizontal and vertical systems; (5) Industrial Internet of Things or Internet of Things - IIoT; (6) Cybersecurity; (7) Cloud computing; (8) Additive manufacturing; and (9) Augmented reality (Rüßmann *et al.,* 2015).

The idea around CPS is consistent with the Smart Factory concept. However, it is necessary to understand “how” the connection between the physical and virtual worlds can be operationalized in an integrated system. Several authors refer to the classic pyramid automation model, which is structured from hierarchical levels and starts with the connection of sensors until reaching the level of business control (Brettel *et al.,* 2014; Rüßmann *et al.,* 2015; Bartodziej, 2016; Gilchrist, 2016; Marques *et al.,* 2017). The Reference Architecture Model for Industry 4.0 (RAMI 4.0) offers a guide for converting to the I4.0 model, according to IEC 62264 and 61512 standards (Adolphs *et al.,* 2015; Kolberg *et al.,* 2017; Ma *et al.,* 2017).

In terms of shop floor management, I4.0 technologies will be aligned to the Smart Factory concept, characterized by the use of CPS to enable the efficient connection between machines, robots, sensors, people, products, transport vehicles and computers (Kagermann *et al.,* 2013; Guo *et al.,* 2014; Marques *et al.,* 2017). Therefore, the Smart Factory must deal with the complexities of the production environment using decentralized communication and information structures, with the following specificities (Lucke *et al.,* 2008):

- Object recognition through tags, sensors, and readers.
- Positioning system and location recognition object to reduce idle times.
- Real-time machine and process monitoring.
- Embedded systems with low power consumption integrated into mobile devices.
- Wireless communication between manufacturing technologies and objects.
- Automatic identification of objects such as barcode and RFID devices.
- Systems for connecting different sensors and actuators on the shop floor.

Although the state-of-the-art of I4.0 emphasizes the CPS concept and the enabling technologies, it is essential to understand how these technologies can be implemented on the shop floor in a context of continuous improvement. In this sense, the literature highlights as technical requirements, the IT and automation architectures involved in the implementation of the CPS (Kagermann *et al.,* 2013; Brettel *et al.,* 2014; Guo *et al.,* 2014; Adolphs *et al.*, 2015; Bartodziej, 2016; Gilchrist, 2016; Pfeiffer *et al.*, 2016; Kolberg *et al.,* 2017; Ma *et al.*, 2017; Marques *et al.,* 2017; Wagner *et al.*, 2017), as well as the skills and competencies requirements (Rüßmann *et al.,* 2015; Susskind and Susskind, 2015; Schumacher *et al*., 2016; Romero *et al.,* 2018).

The literature on I4.0 is still developing. Recent studies from different areas of knowledge, including information sciences, operations management, industrial engineering, and computer sciences, have addressed in a theoretical and practical way, clear examples of CPs between I4.0 technologies and LM practices. Table 1 summarizes the primary studies on these CPs, which were identified through a literature review. In addition to lean principles, these studies show the connection between specific techniques of the LM approach, such as Value Stream Mapping (VSM), Overall Equipment

Effectiveness (OEE), among others. It is important to highlight that this reference gave rise to the research framework used in the case study.

Table 1 – Contact Points extracted from the literature.

Contact Points		LM Practices	I4.0 Technologies	Authors (Year)
CP.01	Value Stream Mapping (VSM) in real-time, aided by Big Data Analytics from the integration between RFID and ERP/MES systems.	VSM	CPS and Big Data Analytics	Tamás *et al.*, (2016); Lugert *et al.*, (2018); Ante *et al.*, (2018); Mayr *et al.*, (2018).
CP.02	Key Performance Indicators (KPIs) automatically generated through CPS and monitored in real-time.	*Hoshin Kanri* and OEE	CPS	Ante *et al.*, (2018).
CP.03	Data generated in the CPS can be stored on the cloud and used to prevent equipment failures using Big Data Analytics.	*Jidoka*	CPS, IoT, cloud computing and Big Data Analytics	Sanders *et al.*, (2016); Mrugalska and Wyrwicka (2017).
CP.04	Replacing paper cards with electronic controls (*e-kanbans*) to control inventory levels in real-time and promote the pull system.	Pull System	CPS, RFID and Vertical Integration	Kolberg and Zühlke (2015); Sanders *et al.*, (2016); Mrugalska and Wyrwicka (2017); Wagner *et al.*, (2017).
CP.05	Operators equipped with smartwatches will receive messages about failures in real-time, and a CPS will respond with corrective actions.	*Andon / Jidoka*	Smartwatches, IoT and CPS	Kolberg and Zühlke (2015).
CP.06	Industrial robots will be used in inspection and control activities to prevent errors in the manufacturing process.	*Jidoka*	Advanced Robotics	Hedelind and Jackson (2011); Ma *et al.*, (2017).
CP.07	Reduced setup time through plug-and-play, RFID, and machine learning solutions.	SMED	RFID, CPS and Big Data Analytics	Sanders *et al.*, (2016).
CP.08	Additive Manufacturing allows printing of parts on-demand, man-machine separation, and waste elimination.	7 Wastes and Pull System	Additive Manufacturing	Chen and Lin (2017).
CP.09	Preventive and predictive maintenance activities can be optimized through CPS, giving rise to the "*e-maintenance*" concept.	TPM	CPS and Big Data Analytics	Li *et al.*, (2015).
CP.10	Augmented reality can assist operational tasks and identifying problems in real-time.	Standardized work	Augmented Reality	Kolberg and Zühlke (2015); Pfeiffer *et al.*, (2016); Sanders *et al.*, (2017).
CP.11	Optimization of internal logistics through simulation, CPS, AGVs, and Big Data Analytics.	Continuous-flow	Simulation, CPS, AGVs and Big Data Analytics	Neradilova and Fedorko (2017); Powell *et al.*, (2018).

RESEARCH METHODOLOGY

This study can be classified as a descriptive approach since the research aims to describe a specific phenomenon (a real case about the implementation of the CPs) without the interference of the researchers. To respond to the research questions presented in the introduction section, a single and in-depth case study was carried out. The research was conducted in a company that manufactures metal structures and stringers for the heavy automotive industry, identified in this paper as "Alpha." The study was carried out between June 2019 and February 2020, based on interviews, *in loco* observations, and documents. The company has manufacturing plants located in six countries and employs approximately 15,000 people worldwide. The unit chosen for the study employs 300 people. Altogether, eight employees with different functions were interviewed, including directors, managers, developers, and analysts. All participants graduated in different engineering areas and have worked on internal projects related to CPs implementation. Experience in LM practices and participation in digital transformation projects were the selection criteria for the interviewees.

The following aspects were considered for the selection of the company: (1) size of the organization; (2) culture of operational excellence and experience of over five years in LM practices; and (3) evidence of conversion to the I4.0 model. Figure 1 illustrates the research planning based on a theoretical structure (Figure 1a), built from the literature synthesized in the previous section. This structure can be understood through a bottom-up perspective, where the investigation begins with the understanding of the manufacturing process (where), goes through the identification of the CPs between I4.0 technologies and LM practices (what), evolving to the understanding of IT, automation and people requirements (how), until finally reaching the results achieved (why). The steps for carrying out the case study (Figure 1b) were properly structured in a research protocol.

The data collection was focused on the process with more evidence of digitization to specify where the research would be carried out. A closed questions questionnaire using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was applied to respondents in order to verify the level of implementation of CPs in the company, according to the interviewees' perceptions. Otherwise, the open questions allowed the interviewees' free explanation regarding the requirements and results obtained.

Yin (2009) explains that the case study is recommended for research that seeks to find answers to questions such as “how” and “why” the phenomenon to be investigated occurs. All interviews were transcribed through software NVivo (version 11) and subsequently analyzed using content analysis techniques. The coding system and the frequency of occurrences of the codes allowed the construction of a conceptual map to synthesize the elements present in the research framework.

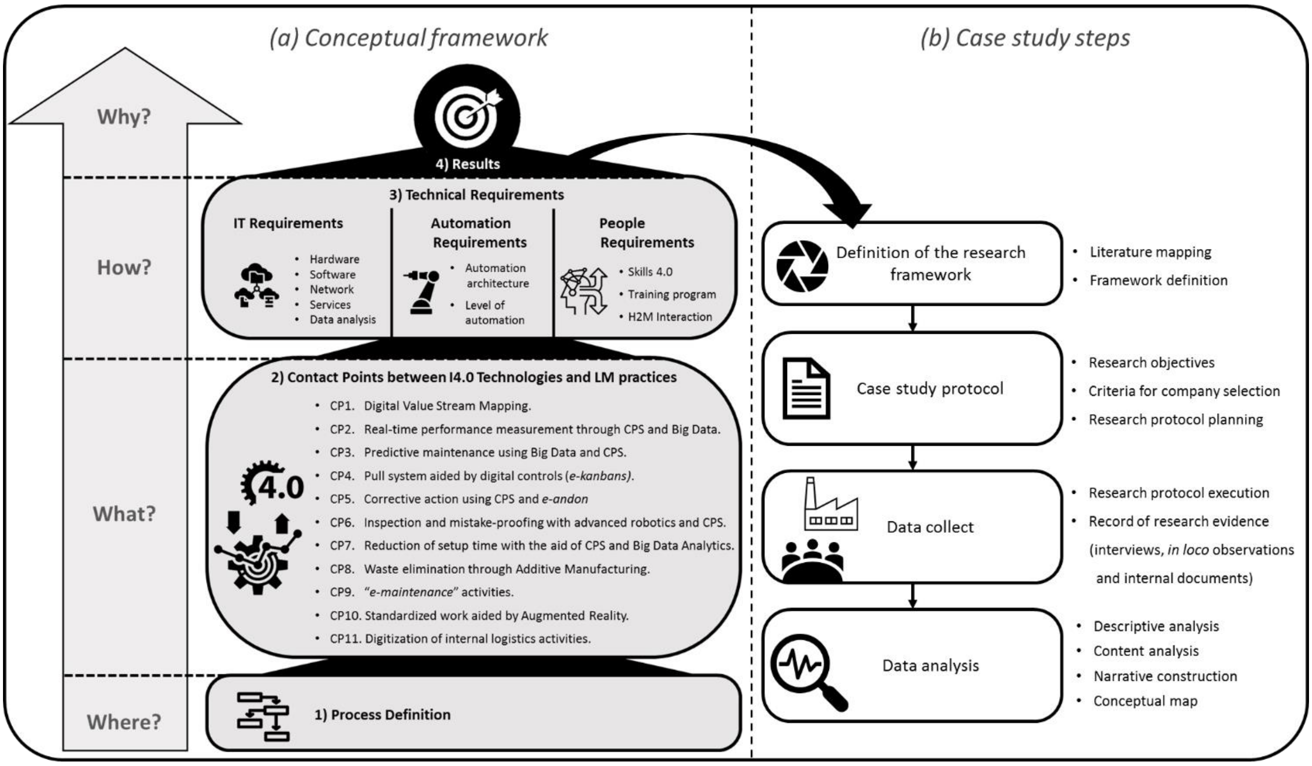

Figure 3 – Research planning.

RESULTS

The content of the qualitative interviews was used to find out answers to the research questions and empirical evidence. The research framework shown in Figure 1a synthesizes the main characteristics used to describe the implementation of the CPs at Alpha. Next, the considerations regarding the integration between these elements will be presented, as well as the analysis of the DLM practices observed in the organization.

The data collection was aimed at the manufacturing process of structural components for trucks representing the process with the highest adherence to I4.0 technologies. This process covers several activities, such as cutting, forming tooling charge, and assembly. Multifunctional teams have led the strategy of converting to the I4.0 model at Alpha by implementing proofs of concept. These projects cover receiving inspection activities using augmented reality, systems integration (MES, ERP, and BI), automated quality control, and computer vision inspection systems. The prioritization of LM practices at Alpha derives from the organizational strategy. Each year, the headquarters establishes a strategic plan and deploys it in the units using the *Hoshin Kanri* method. To foster and disseminate the LM culture, Alpha has implemented *kaizen* action called *Material Information Flow Chart* (MIFC), which replaces the traditional VSM. Currently, *kaizen* events are implemented in a workshop format with an average duration of five days and directed to specific topics, including MIFC, standardization, and Single Minute Exchange of Die (SMED).

The identification of the CPs implemented at Alpha took place through the verification of the questions with Favorable Response Indexes (FRI) greater than 50%, representing the sum of the percentages obtained in items 4 "agree" and 5 "strongly agree." Thus, of the eleven CPs present in the framework, six were fully implemented, as shown in Table 2. Cronbach's alpha coefficient for this group of questions was 0.6022, demonstrating the consistency of the answers obtained. After prioritizing the PCs with the highest company adherence, the research was directed to the implementation process of these PCs, seeking an understanding of the technical requirements, and the results provided by this strategy. Next, a narrative about the practices evidenced in Alpha will be presented, which was built from the content analysis of the interviews.

Table 2 – Perception of respondents regarding the implementation of PCs at Alpha.

Questions related to CPs	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree	Favorable Response Indexes (FRI)
	Frequency of responses (%)					
CP1. *Digital Value Stream Mapping.*	**0,00**	**0,00**	**37,50**	**25,00**	**37,50**	**62,50**
CP2. *Real Time performance management through CPS and Big Data.*	**0,00**	**0,00**	**0,00**	**37,50**	**62,50**	**100,00**
CP3. *Predictive maintenance using Big Data and CPS.*	12,50	12,50	37,50	0,00	37,50	37,50
CP4. *Pull system aided by digital controls (e-kanban).*	**12,50**	**0,00**	**12,50**	**50,00**	**25,00**	**75,00**
CP5. *Corrective action using CPS and e-andon.*	12,50	12,50	37,50	0,00	37,50	37,50
CP6. *Inspection and mistake-proofing with advanced robotics and CPS.*	**0,00**	**12,50**	**12,50**	**25,00**	**50,00**	**75,00**
CP7. *Reduction of setup time with the aid of CPS and Big Data Analytics.*	12,50	25,00	25,00	12,50	25,00	37,50
CP8. *Waste elimination through additive manufacturing.*	37,50	12,50	37,50	12,50	0,00	12,50
CP9. *"e-maintenance" activities.*	75,00	12,50	0,00	0,00	12,50	12,50
CP10. *Standardized work aided by Augmented Reality.*	**0,00**	**12,50**	**12,50**	**25,00**	**50,00**	**75,00**
CP11. *Digitization of internal logistics activities.*	62,50	12,50	12,50	0,00	12,50	12,50

Part of the manufacturing processes documentation, including operation sheets, work instructions, control plans, and process maps, is already in electronic format. However, according to Technology Director (TD1), the implementation of **CP1 - *Digital Value Stream Mapping*** could present real-time information not previously detected. The activities are mapped based on the requirements of the Advanced Product Quality Planning (APQP), which is widely used in the automotive industry. Although the development of flowcharts and process maps can identify important characteristics for the control of activities, the use of Big Data and simulation can help identify other less common characteristics (TD1).

According to the opinion of this interviewee, a map with updated information on the process in real-time would be useful to generate data that could be smoothed in a predictive way, as demonstrated in the statement below.

> TD01: *"To increase the process efficiency above 95%, it is necessary to have a system for predicting quality problems instead only identifying failures. It is essential to predict when these failures will happen. It is in this context that we need to expand monitoring and use other analytical tools*."

The implementation of **CP2 - *Real-time performance measurement through CPS and Big Data*** was conducted through a project that integrated the MES, IoT, PLC, BI systems, and cloud. According to the Quality Manager (QM1), before implementing this project, Alpha managed its measurement system through Microsoft Excel®. In 2014 the MES system was specifically implemented to control production. In 2017, this system started to be integrated with BI to monitor various indicators through smartphones, monitors, and screens. In terms of operational excellence, the indicators of setup time, productivity, quality, and OEE stand out.

All stages of the manufacturing process consume some material that must be available at the appropriate time and in quantity needed for production. As explained by the Quality Analyst (QA1), although the replacement of these materials is not yet performed automatically, the partial implementation of **CP4 - *Pull system aided by digital controls*** has allowed the real-time identification of the quantities consumed through MES system, which is fed with the aid of barcode. When the operator removes a certain quantity of specific material from the stock, this operation is registered through bar codes and notes in the MES system. The update of stock levels is performed automatically in the ERP system. From definitions of replacement point and minimum stock for each station, the operator can be informed about the withdrawal of materials.

This inventory control system can work as an alternative to the *kanban* system. The implementation of CP4 required the integration between the MES and ERP systems and the acquisition of printers, labels, and barcode collectors. According to the interviewee's opinion, "*The MES implementation has to be considered a watershed moment.*" (QA1).

The company has two applications of **CP6 - *Inspection and mistake-proofing with advanced robotics and CPS*** with an emphasis on RFID technology. The first application was in the plasma cutting area. Every 5 minutes, the operating system reads the tags installed on the operators' protective equipment and compares it with a register of operators qualified to work in the area. In this way, the machine is released only to the task-enabled operators. One of the significant problems in plasma cutting and welding processes is eventually allocating someone who is not qualified in the function (QM1).

The second application involved the calibration control and Measurement System Analysis. Each equipment has a tag that connects to the machine's PLC for automatic release or blocking of the operation, according to the observed situation (AQ2). It is important to highlight here that the MSA activity aided by CPS was not identified in the literature. According to the opinion of an Engineering Analyst (EA1):

> EA1: *"I think that this issue of blocking activities through an automated system is an excellent gain for quality. I believe that industry 4.0 and all the tools it provides have the potential further to improve production control in the sense of failure prevention."*

Finally, the implementation of **CP10 - *Standardized work aided by augmented reality***, is still undergoing experimentation. One of the challenges to be overcome is the weight of the equipment. However, this restriction can be offset by replacing the glasses with tablets. It is expected that the quality of inspection on receipt of materials can significantly improve, as the technology can optimize the task through 3D images, hologram, and instructional videos (QA2).

Among the most expressive **IT requirements**, systems integration (ERP-MES-CLP-BI), communication protocols, out-tasking, ethernet, and connectivity aspects (IoT) stand out, as well as the possibility of predictive analysis. As explained by the Senior Maintenance Analyst (MA1), information security management included a hierarchy with permission levels. The operator's access to the MES system is limited to monitoring production stages, with no possibility of changes in product variables. Besides, the organization developed the data receiving software (wireless) in partnership with a metrology solutions provider.

The investigation of **automation requirements** revealed that the most cited components regarding architecture for the implementation of CPS include RFID, wireless, Bluetooth technologies, PLCs, sensors, and actuators. Collection and transmission of shop floor data required PLC memory structures available on a server allocated for the CPS application. Thus, the software works as a gateway to capture the PLC memories and make the data possible in hardware resources. It should be noted that the communication by cabling is necessary since the manufacturing process has steps that consume too much electrical energy (plasma and solder), which interferes with wireless communication technologies (QA1).

The analysis of people requirements highlighted online training actions, hiring professionals from the IT area, and knowledge in the programming language, statistics and data analysis, network architecture, software engineering, and understanding of the business. Actions for the development of skills 4.0 involved not only training but also participation in workshops, congresses, and international fairs. Such events are fundamental for acquiring knowledge on cutting-edge technology and new suppliers representing an excellent opportunity to clarify doubts regarding the use of new technologies and equipment (DT1). The skills development strategy at Alpha covers the allocation of people with skills in software engineering, computer science, database, and M2M communication directly in the factory operations (AQ2). It was observed that IT staff acts as a support to the implementation of digitization projects and that this involvement is essential for the success of the projects.

> QM1: *"I needed a lot of training in IT, but when the IT staff joined our team in 2015, it became a revolution. If these people had not come to the process area and helped with the projects, we would not have progressed."*

Finally, the results from the implementation of the CPs declared by the interviewees are consistent with the literature on traditional LM, since they are aligned with the "House of Toyota" model, where the roof is represented by three targets: highest quality, lowest cost, and shortest lead time (Stewart, 2011). In addition to these results, respondents also cited the benefits of implementing CPs as eliminating waste in the process, increasing organizational competitiveness, and real-time information. Figure 2 shows a conceptual map synthesizing the entire narrative that was built from content analysis and codification. The comparison of this concept map with the research framework provides answers to the research questions presented concerning DLM practices in the investigated company.

CONCLUSIONS

The implementation of I4.0 technologies within the scope of operational excellence practices is still developing. The evolution of the LM to DLM approach requires the implementation of CPs between both areas. Although the specific literature on the topic presents some empirical studies combining specific enabling I4.0 technologies with LM practices, examples of the application of frameworks capable of integrating the two themes (LM and I4.0) still represent a research gap.

The present work mitigates this gap by presenting a real case study carried out in a Brazilian company undergoing a digital transformation process. The research framework tested in this study can bring together the managerial elements inherent to DLM in a single and simple structure, which can be used by practitioners and researchers. As answers to the RQ1, the PCs evidenced at Alpha included: CP1 - *Digital Value Stream Mapping*; CP2 - *Real-time performance measurement through CPS and Big*

Data; CP4 - *Pull system aided by digital controls*; CP6 - *Inspection and mistake-proofing with advanced robotics and CPS*; and CP10 - *Standardized work aided by augmented reality*.

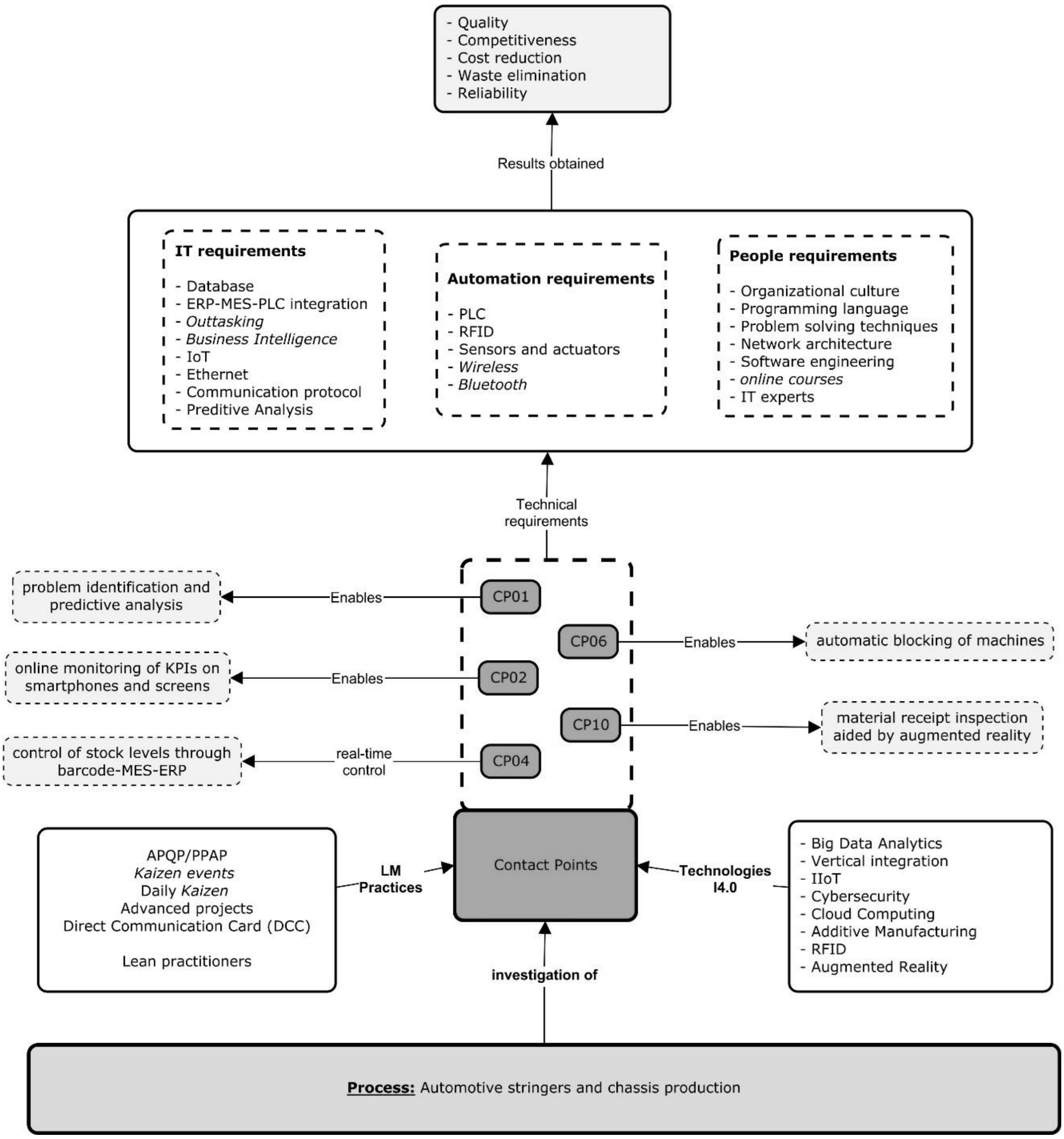

Figure 4 – Conceptual Map.

The results revealed that the implementation of these CPs had demanded specific requirements (RQ2), including IT requirements (integration of MES-ERP-PLC systems, outtasking, and communication architecture), automation requirements capable of connecting sensors, actuators, RFID, and PLC devices, as well as people requirements, with emphasis on digital culture and IT skills. Besides, interviews with Alpha professionals revealed that the results from the implementation of these CPs (RQ3) are in line with the LM theory, as they are aimed at reducing operating costs, eliminating waste, increasing quality, reducing lead time, and real-time information. However, it was also observed that the digitalization of LM practices increased the organizational competitiveness and the reliability of manufacturing processes. Such results evidence that the DLM implementation strategy can go beyond a simple "conversion" to digital manufacturing.

It is also worth noting that the implementation of DLM has managerial implications. The need for significant investments in technology and changes in shop floor routines is an example of these implications. In this context, the importance of multidisciplinary teams involved in I4.0 projects is highlighted. Regarding future research, this study will be extended to other companies, to allow a cross-case analysis and evidence the implementation of other CPs not discussed in this study. The analysis of a single case is the primary limitation research, as well as the impossibility of generalizing the results obtained. However, it is expected that the research framework presented in this paper will be able to be replicated in other studies related to DLM.

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Innovation, Technology and Quality

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ABSTRACT

Purpose: The purpose of this study is to understand the relationship between innovation and technology with quality through the review of previous studies and the real perception of individuals.
Project/Methodology/Approach: The research method used is qualitative. This study carried out based on a literature review and with the application of an online questionnaire, in order to understand the perception of individuals when these terms are addressed.

Findings: The findings are useful for business managers as these three areas are increasingly interconnected, being the path the organization's success. This study contributed to develop this concepts that be so important on nowadays. The focus on quality as a competitive tool is crucial but insufficient, and innovation and technology emerge as a new way of meeting customer requirements and expectations.

Research limitations/implications: The literature review was limited to a database. Future research despite the little bibliography available on this topic, where the innovation and the technology are related to the quality, it's a very pertinent topic to be deepened and suggested for future investigations.

Conclusions: This research concludes that the higher the level of investment in areas such as innovation, technology and quality, the best competitiveness and production performance will have the organizations. With the application of the questionnaire, it verifies that there isn't consensus among individuals on the definition of innovation and quality and even on technology only half of the participants had the same opinion.

Originality/Value: This study contributed to a better perception and systematization of the relationship between quality and innovation.

Keywords: Innovation; Technology; Quality.

Paper type: Literature review.

1. INTRODUTION

In the economic landscape that exists today mind, from the globalization of rapid technological and cultural change, the environmental pollution and the intense exploitation of scarce resources, organizations are forced to improve the day-to-day d their processes to achieve secure its competitiveness in the market and satisfy the needs of its customers.

In view of this situation, organizations are forced to innovate, offering their customers innovative and high quality products and/or services, in order to anticipate and satisfy market needs. Therefore must make rational use of resources, and the innovation of the current most important concepts in all aspects.

The dynamics of innovation and its technological aspects condition sharply our day-to-day at both professional as personnel. People and organizations will have to adapt to change and participate in it by overcoming the challenges they face.

Innovation, based on creativity, is embodied in inventions that in many cases involve new technologies that become new tools, products, services, processes and methods.

Currently, the quality word appears in all walks of life and point out that organizations not to adopt as a guiding principle, very soon cease to exist, since it is increasingly becoming a "must".

Faced with a market that is constantly evolving, with several changes in consumption and business patterns, research and development (R&D) disseminated and boosted innovation, in order to support organizations to acquire competitive advantages.

Innovation and technology are two of the most striking features of today. During human evolution, the pace of change has never been so fast as currently, observing that it tends to accelerate and not to soften. In this context, people and organizations will have to adapt before the new challenges that they will encounter, through something new and better, urging creativity and quality.

These changes can occur in our daily lives, such as airplanes, televisions, mobile phones, headsets that currently connect without any wire, among many others.

This work will give-emphasis on approaches to innovation, the technology and the quality. A qualitative analysis will be carried out through bibliographic research and through the analysis of a questionnaire in order to understand how individuals approach this increasingly important topic today.

2. PERCEPTION OF APPROACHED CONCEPTS: LITERATURE REVIEW

2.1. Innovation

Innovation makes a difference in all organizations, regardless of type or size. Products and services must be in constant innovation so that organizations don't run the risk of being overtaken by competition (Tidd, Bessant, & Pavitt, 2008).

Innovation can be understood as the development and implementation of new ideas by people over time and is based on four factors: new ideas, people, transactions and institutional context (Van de Ven, 1986).

Innovation is the process of translating ideas into useful and usable products, processes or services (Tidd, Bessant, & Pavitt, 2008). Innovation can take many forms and are known as the "4Ps of innovation" as shown in table 1.

Table 1 - Dimensions of change - the 4Ps of innovation.

Innovation	Definition
Product	Alterations in the products and/or services that an organization offers.
Process	Changes in the ways in which products and/or services are created and presented to the consumer.
Position	Changes in the context in which products and/or services are introduced.
Paradigm	Changes in basic mental models that guide what the organization does.

Source: (Tidd, Bessant, & Pavitt, 2008), adapted.

The success of innovation depends on resources such as people, equipment, knowledge and management capacity of the organization, the last being the most difficult to control, but it is what makes or breaks the process (Tidd, Bessant, & Pavitt, 2008).

The organizations that want to innovate must invest in communication values and on objectives related with innovation, in discussions that involve different areas and members of the business, working with agents outside the organization, and also in setting limits that specify an action camp for employees (Cruz, 2014).

As organizations intend to innovate in products or in production processes, the tasks become more uncertain, referring that "(...) the main way to reduce uncertainties is to do things repeatedly, avoiding innovation. Therefore, innovation becomes the main contingent factor underlying the contingency of the task with uncertainties" (Donaldson, 2008).

The administration of organizations begins to realize that innovation creates lasting advantages and produces changes in the competitive position (Dobni, 2008), being essential for organizational survival in an increasingly competitive market (Serrão, 2009).

The innovation doesn't exist without the invention. The invention is a new idea, a model, a prototype that arises for a new product or process and while innovation consists in putting this idea into practice , being an economic and social application of the invention (Fagerbeg, 2009). The innovation and the invention are clearly related, once innovation comes from the combination of several inventions or adaptation of something that has been invented in other circumstances. Resuming, the innovation assumes to be a multidimensional and systemic process, being an invention with economic significance.

On the table 2 are describes some of the definitions of innovation from the standpoint of some authors.

Table 2 - Some definitions of innovation.

Author	Definition
Schumpeter	The innovation underlies a rupture or discontinuity in relation to the past, associating itself with the expression "creative destruction", which underlies a radical cut with the past.
Drucker	The innovation is an instrument of entrepreneurs, through which they explore change as a new opportunity for a new product and/or service.
Lundvall	The innovation is a cumulative process, with the impossibility of separating invention, innovation and diffusion.
Utterback	Innovation is the conversion of an idea to a first use or sale.
Freeman and Soete	The innovation is the first commercial application or production of a new product or process, taking up the crucial contribution of the entrepreneur in connection process of new ideas with the market.
Deakins and Freel	Innovation is essentially related with the knowledge: creation new knowledge or recombination existing knowledge.

Source: (Carvalho, 2008), adapted.

After analyzing table 2, it can be seen that the authors reveal different perceptions about the concept of innovation.

The innovation is considered as a critical success factor, been necessary that it be established as one competitive advantage, allowing to the companies consubstantiate, in fact, its own differentiation ability in value.

The figure 1 illustrates briefly the concept of innovation.

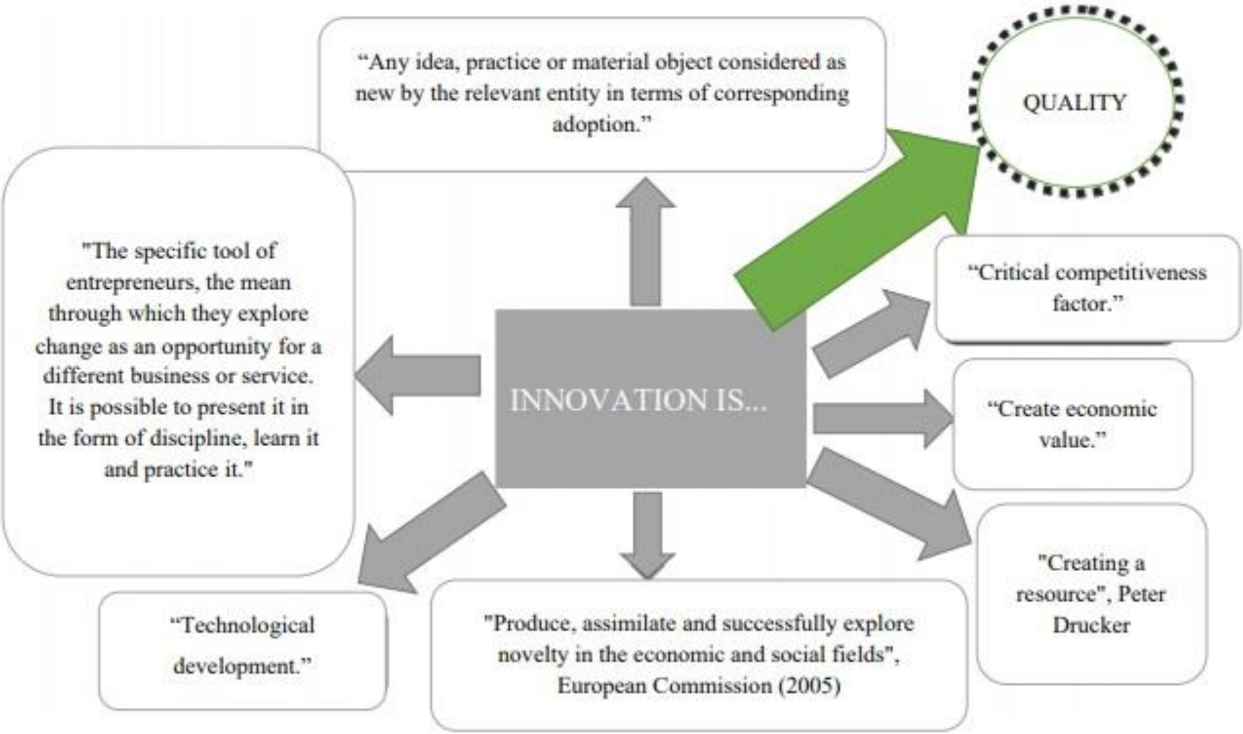


Figure 1 – Some definitions of innovation.

The innovation brings new challenges and advantages to the organization, such as: giving access to new markets, increasing profits, creating jobs, strengthening brands and quality. These advantages are crucial in a globalized world, in which organizations are obliged to compete as in the external market as in internal market, with competitors installed anywhere in the world.

2.2. Technology

The technology can be defined as a group of practical knowledge applications used for a purpose, including the skills and the competencies to apply that knowledge. One of the aspects to highlight about technology is its ability to produce and increase the usefulness of products and/or services (Negas, Carvalho, & Sousa, 2020).

The technology refers to form how an organization works, in other words, how this turns the raw material in products, including in this procedure the machines, the tools, the materials, the people and the knowledge (Chenhall, 2003).

The technology has occupied and occupies an important role throughout the evolution of humanity and can be seen as a lever of human intelligence while species.

Like almost everything, the technology has positive (advantages) and negative (disadvantages) consequences on humanity and it is sometimes difficult to differentiate one from the others. The table 3 shows some advantages and disadvantages related with the technology.

Table 3 - Advantages and disadvantages of the technology.

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Increase of food production.</td><td>Pollution.</td></tr>
<tr><td>Increase of production the goods and services.</td><td>Depletion of natural resources.</td></tr>
<tr><td>Improvements in comfort.</td><td rowspan="2">Disturbances in the use of time.</td></tr>
<tr><td>Better use of natural resources.</td></tr>
<tr><td>Ease of traveling.</td><td rowspan="2">Risk of extinction of the human species.</td></tr>
<tr><td>Improvement in communications.</td></tr>
<tr><td>Improvement in health care.</td><td>Great dependence of technology.</td></tr>
</table>

Currently, the evolution of technology is so fast that there are authors who classify it as a revolution, once we live in a time of relevant changes due to technology that doesn’t tend to slow down (Negas, Carvalho, & Sousa, 2020).

In the current technological revolution, this is replacing or at least changing the jobs that demand and rely on intelligence and not on physical work as it did at the beginning of the 19^{th} century in the industrial revolution.

The technological revolution that we are experiencing today has led to the extinction of many administrative functions performed by humans who performed more elaborate activities. This revolution did, does and will make many people lose their jobs and have to adapt to the new reality, including a reduction of the vast majority of salaries of those who can work. Only individuals who control in the professional skills currently required, a minority, will wage gains.

A little detail about this new reality is that the machines are being used to carry out increasingly elaborate functions, functions such that when performed by humans require many practice and intelligence. As a common example, medical diagnoses arise where increasingly the machines replace human intervention. This type of situation will tend to occur in many other areas and domains of intelligent human work, since the new machines will be able to perform the tasks better and/or at least in a cheaper way (Negas, Carvalho, & Sousa, 2020).

2.3. Quality

There is no concrete definition of quality, since it’s a subjective concept that is directly related to the perceptions of each individual. There are several factors that directly influence the definition of quality, such as the culture, the type of product or service, the needs and the expectations. As the term has several uses, its meaning isn’t always clear and objective.

The quality is a term difficult to define but easy to recognize, being associated with something good or exceptional. In this way, the quality of a product and/or service is related to its attributes and characteristics that may or may not satisfy the needs of an individual (Gaster & Squires, 2003).

The table 4 presents some definitions of the main quality gurus.

Table 4 - Some definitions of quality.

Author	Definition
Walter A. Shewhart	There are two common aspects in quality. One is the person who clings to the real and objective quality of something, regardless of the existence of men. The other is linked to what we think, feel or experience as a result of this objective reality.
W. Edwards Deming	The ability to satisfy desires.
Joseph M. Juran	Suitability for the use.
Kaoru Ishikawa	The ability to develop, design and produce (...) in the most economical, useful and pleasant way for the customer.
Armand V. Feigenbaum	The best for some customer requirements, being these requirements: utility and selling price of the product.
Geinichi Taguchi	The damage caused to society by the product, from the moment it is sold to the customer.
Philip B. Crosby	Compliance with requirements. Zero defects.
Paulo Sampaio	Give to the customers what they want and try to overcome their expectations.
Portuguese Quality Association (APQ)	The quality is the totality of the characteristics of a product or service that determine its ability to satisfy a given need.

Source: (Oakland, 1994), adapted.

According to the definitions presented, the quality has as main objective the satisfaction and well-being of customers. However, the definition of the concept of quality involves other perspectives, as can be seen in some of them outlined in figure 2.

Figure 2 - Quality definitions.

According to the definition in the standard NP EN ISO 9000: 2015 (9000, 2015), the quality is understood as the "degree of satisfaction of requirements given by a set of intrinsic characteristics of an object" and the success of any organization depends directly on the its ability to mobilize and organize the means and the resources necessary to carry out products and/or services that satisfy the requirements, needs and expectations of their customers. Therefore, the quality is the "engine" of the success of any the organization and its recognition, the distinction factor and choice of products and/or services. The development of a culture based on quality principles and their consequent values, will pave the way for the effectiveness and continuous improvement of methods and processes (Pinto & Soares, 2018).

The great competition between the organizations (between the various products and/or services), enhanced by the challenge of increasing globalization of the economy, relaunches and stresses the need to satisfy customers' requirements. Quality is thus a growing imposition whatever the market in which the organization is inserted, in many cases being an important criterion for selection or exclusion. However, the quality of products and/or services is not the result of inspiration or chance: the organization must demonstrably proven that it have the means and resources necessary for the development of quality products and/or services and their continuous improvement, for in order to accompany the growing and natural increase in the demand of its customers.

The organizations began to realize that quality is a non-negotiable factor, that is, the consequences of placing a “non-compliant” product or service on the market are catastrophic and can compromise the organization's future viability.

The highly competitive scenario makes that organizations remain in constant improvement of their products, processes and employees. Many Japanese organizations have adopted “Kaizen” which is a philosophy of personal, organizational and social improvement, and it has contributed considerably to the progress of quality concepts, promoting the concepts reported by Deming, such as, for example, the well-known PDCA Cycle. The Kaizen protected the various Japanese administrative production techniques, such as Total Quality Control, Zero Defect and Just in Time (Robles, 2003).

3. METHODOLOGY

This study is based on a bibliographic search, initially made through the reading of books related to the subject and then through a search and selection of articles in the Google Academic database, focused on the relationship between quality and innovation. The keywords used during the search of the articles were: innovation, quality, technology, relationship between quality and innovation, impact of quality and innovation, link between quality and innovation. The criterion used in the selection of articles was the choice of those articles that directly addressed the relationship between quality and innovation and where this was the central theme of the article.

An online questionnaire will be apply, in order to understand the perception of individuals when these terms are addressed and the research method used will be qualitative.

4. RELATIONSHIP BETWEEN INNOVATION AND TECHNOLOGY WITH QUALITY

After conducting the research, no study has been found that relates the innovation and the technology to quality. This relationship will be addressed between each one separately:

- Innovation and Technology;
- Innovation and Quality;
- Technology and Quality.

The relationship between the innovation and the technology with the quality will be addressed according to the proposals presented in the questionnaire, covered in point 4.

4.1. The relationship between innovation and technology

When society refers to innovation, it is natural to associate the term with an instrument, equipment, software, developed based on the most recent technological advances. Any innovation produces what the author described as "creative destruction" in which the "new stands next to the old" and later takes its place, leaving behind "dead and wounded" but driving progress. In this sense, the innovation may result from new combinations of productive means, designated per technological innovation, which brings with it innovation of the product (goods or services) and innovation of the process (Paiva, Cunha, Junior, & Constantino, 2017).

However, the concept of innovation can't and shouldn't exhaust in hillside of the technological development. Currently, the term is also linked to non-technological innovation. Non-technological innovation may include: the organizational or administrative innovation (namely new forms of work organization or changes in organizational structures); the access to new markets; the adoption of advanced management techniques (such as Total Quality Management or Just in Time on production, or the use of new raw materials less polluting and more environmentally protective). With this, the innovation has ceased to be exclusively focused on the technological aspect, to cover all internal areas within an organization.

The advances in information technology have spurred innovation and change in the collection, measurement, analysis and communication of the information within and between organizations (Burns & Vaivio, 2001).

Analyzing the work of Hyvönen, information technology refers to the highlight of the company in advanced applications of information systems and measurement only of variables that represent the use of information technology innovation in general. These variables include the e-commerce, the *enterprise resource planning* (ERP), the *customer relationship management* (CRM), the supply chain management (SCM) and the data storage (Hyvönen, 2007).

4.2. The relationship between innovation and quality

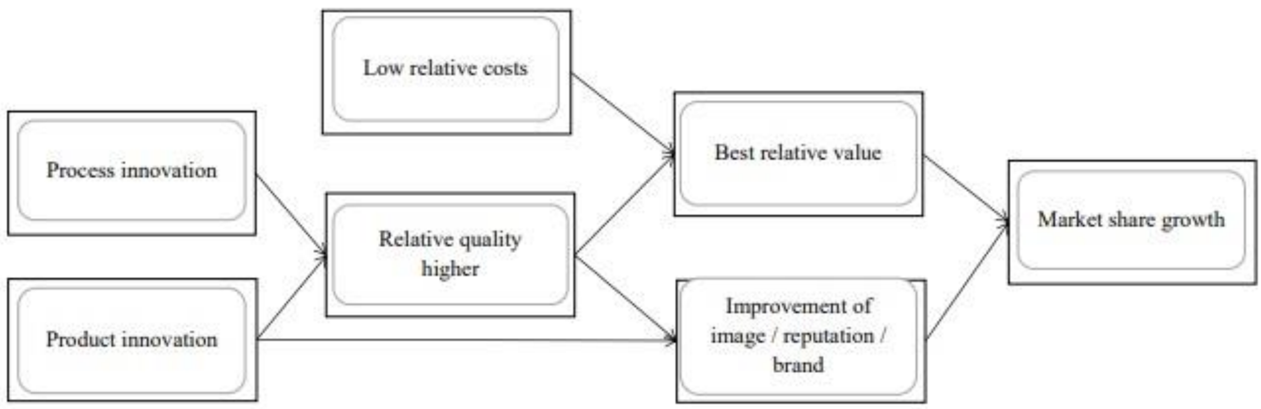
In the business community, the relationship between the quality and the innovation has sparked some controversy, given that there are studies that prove a positive relationship between the quality and the innovation, but there are others that argue the opposite. However, some studies about innovation consider total quality as a form of innovation (Cooper & Schindler, 2003). In this way, the discussion of the relationship between total quality and innovation is fundamental for the success of organizations.

The innovation has several advantages such as granting access to new markets, increase the profit, create new jobs, strengthen the brands and the quality. These advantages have become crucial in a globalized world, where companies are forced to compete as in the external market as in internal market, with competition in any part of the world.

On the other hand, the innovation can be seen at the level of strategy, resource management, design or monitoring of processes, forms of organization and structures, financial aspects, production, distribution, marketing and commercialization, brands, remuneration and reward policies, quality or environmental management, in short, in all activities related to the way of being an organization, which is also a characteristic shared with Total Quality Management.

A strong degree of innovation can be reflected in competition with other organization through the creation of new products, which is generally seen as the influence of the environment. Thus, the organizational structure is caused directly by the internal innovation factor and indirectly by the external environment factor. Thus, as the task of uncertainty increases, through innovation, structural simplicity is reduced and the costs are high, but is rewarded by the benefits of innovation (Donaldson, 2008).

The innovation of the process improves the relative quality, reduces the costs, and consequently, improves the relative value of the product. The innovation of the product also affects the quality, but the biggest effect is to rename and value, which together lead to the increase of the market space (Tidd, Bessant, & Pavitt, 2008), as illustrated in figure 4.



Source: (Tidd, Bessant, & Pavitt, 2008), adapted.

Figure 4 – The relationship between innovation and market performance.

The figure 4 shows a direct relationship between the innovation and the quality.

Next, two quality tools that are associated with innovation will be addressed: the Kaizen and the PDCA cycle.

4.2.1. KAIZEN

The Kaizen is a small innovation in continuous improvement and sits on a philosophy which holds that everything can be improved, involving all employees of an organization (Negas, Carvalho, & Sousa, 2020). The main objective of Kaizen is to eliminate waste, being used mainly in the quality area.

The Japanese companies were the pioneers in the use of this method after the Second World War and after the divulgation and achieving of great success, this method was released worldwide and adopted in many places.

The Kaizen involves all employees of an organization and it consists in the implementation of small improvements suggested by them (the s considered useful ideas are implemented on the same day in which are proposed). This method goes beyond the continuous improvement in productivity once it also contributes to humanize the workplace, such as example, reducing and if it's possible to eliminate hard work.

The good implementation of Kaizen requires the cooperation of the employees of the organizations, once without this cooperation, it isn't possible to obtain the benefits of using this method. The implementation of this method requires changes to made and they should be evaluated, and taking into account the evaluation, should be the adjustments made necessary.

For a good implementation of Kaizen individual suggestions from employees are used that focus on the work they perform and then can be implemented in the workstation of the person who suggested them. This is done with the involvement of a small number of people and if the proposed improvement is a success, it can (and in many cases should) be implemented in other sectors of the organization where appropriate (Negas, Carvalho, & Sousa, 2020).

4.2.2. PDCA CYCLE

PDCA is a circular change process that facilitates the introduction of innovations in organizations that adopt it (Rother, 2010). PDCA is an approach to solve problems, allowing to experiment possible solutions to a given problem in order to identify the improvement before executing it. The process, being circular, is endless and must be repeated indefinitely, having this repetition the purpose of improvement continuously the processes and the products.

This process has similarities to the scientific method which can be summarized as a process where hypotheses are placed, and then realized experiments in order to prove or disprove and finally, should proceed to the evaluation of the results of these experiments confirming or not the hypotheses initially proposals (Negas, Carvalho, & Sousa, 2020).

The implementation of the PDCA system can provide great benefits to organizations, such as: continuous improvements through a standardized method; reduction and barrier to resources spending in the implementation of inferior or ineffective solutions; promotion of group work and cost reduction.

As for continuous improvements through a standardized method, the PDCA cycle is a standardized method, which provides several advantages, such as the fact that it can be repeated numerous times on new or recurrent issues and it permit go that decisions are made based on objective data and information.

Regarding the reduction and barrier expenditure of resources in the implementation of solutions lower or ineffective, the PDCA cycle is an experimentalist method, that is, it tests possible solutions on a small scale in order to avoid big spending on ineffective solutions.

With regard to the promotion of group work, the PDCA method promotes group work by resorting to the solution of solving problems by calling on everyone involved.

Finally, regarding the reduction costs, the costs of implementation of this method, when compared with the advantages which provide organizations to remove obstacles and inefficiencies, result in an investment completely useful (Negas, Carvalho, & Sousa, 2020).

4.3. The relationship between technology and quality

According to (Baines & Langfield-Smith, 2003), the implementation of advanced industrial technology is a way that organizations present to respond to the high customers orders, ensuring quality, flexibility and confidence in the supply of products. The authors considered for the research some variables, such as: computer aided design (CAD), *Just in Time* (JIT), total quality management (TQM), resource planning, integrated production by computer (CIM) and flexible production systems (Baines & Langfield-Smith, 2003).

5. ANALYSIS AND DISCUSSION OF RESULTS

For this study, the method research realized was qualitative. This was done through bibliographic research and through a shared questionnaire, in order to understand the concepts and the importance of the terms under study for individuals. It was based on multiple choice and direct answers.

The size of the sample in study is irrelevant, once just want to know what it is that the people understand by innovation, technology and quality through a group of options by multiple choice.

Regarding the perception of the relationship of the three variables (innovation, technology and quality), it is intended to understand the opinion of individuals in relation to the topic under study.

5.1. Perception of the concepts under study

According to the study, most individuals define "innovation" as the process of translating ideas into useful and usable products, processes or services and as a multidimensional and systemic process, being an invention with economic significance, as shown in the figure 5.

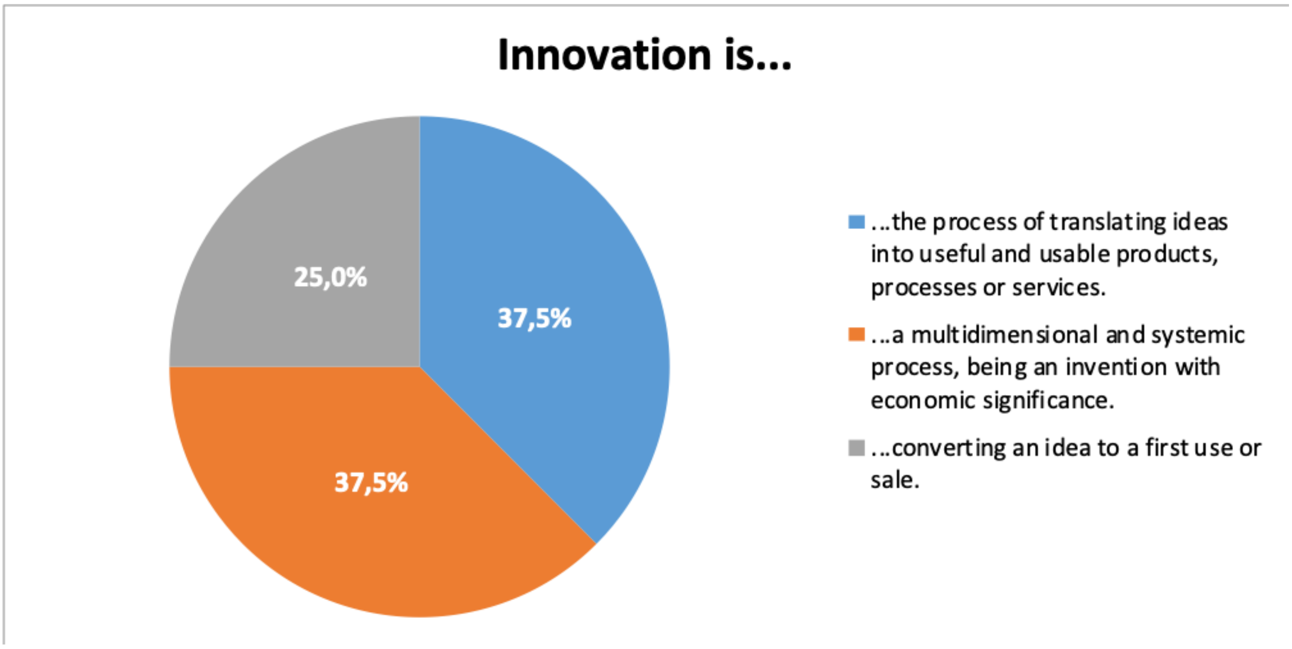


Figure 5 - Perception of the innovation by individuals.

According to the study, most individuals define "technology" as the reality where machines will be used to perform increasingly elaborate functions, functions that when performed by humans require a lot of practice and intelligence. In this concept, there is a consensus among the majority of individuals who participated in the study, as shown in figure 6.

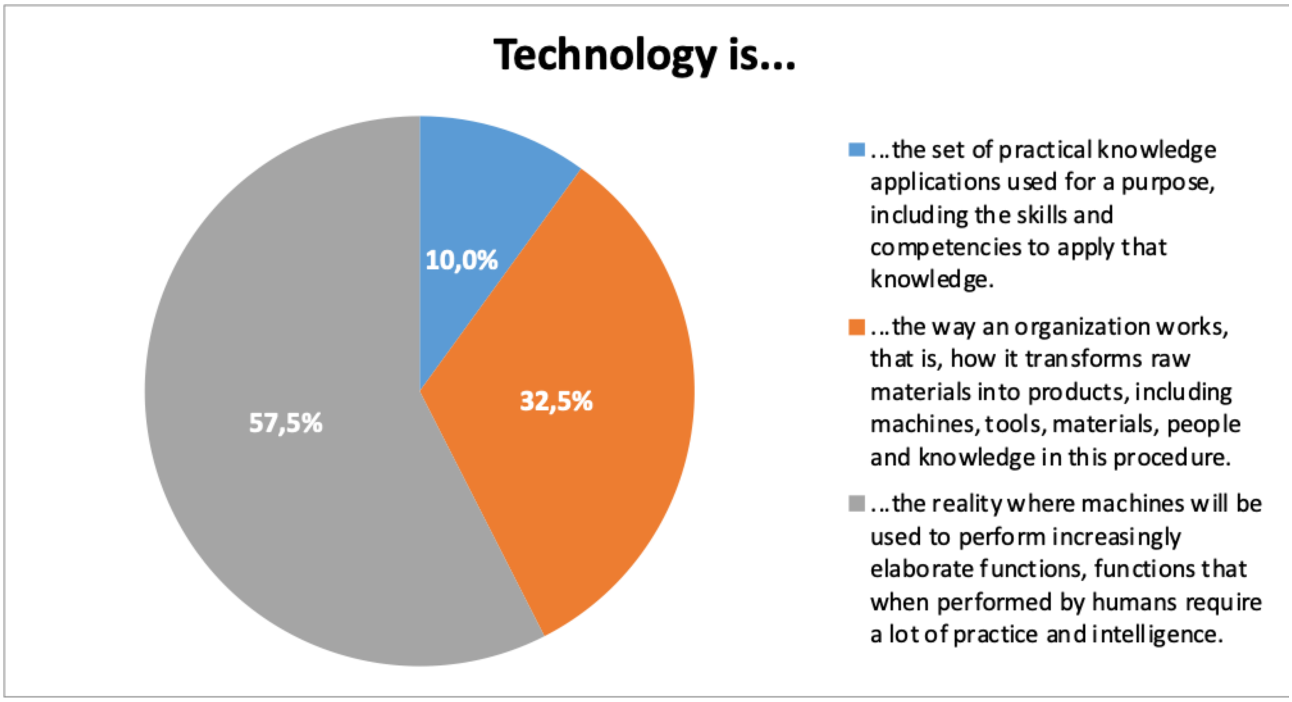


Figure 6 - Perception of the technology by individuals.

According to the study, most individuals define "quality" as being a standardization to give the customers what they want and trying to exceed their expectations, as shown in figure 7. This study itself proves what is mentioned in the literature review, that is, quality is difficult to define and there is no one concrete definition for it.

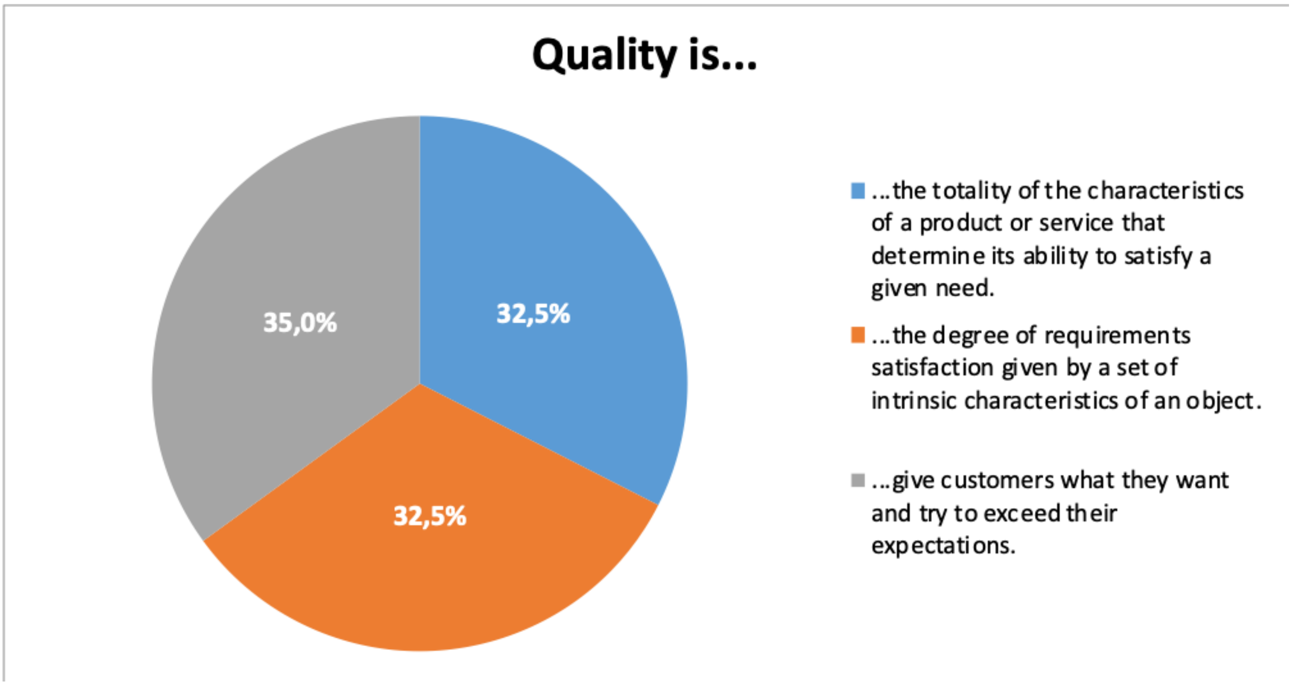


Figure 7 - Perception of the quality by individuals.

5.2. The relationship between innovation and technology

The relationship between innovation and technology is undoubtedly the most noticeable by the individuals who participated in the questionnaire, highlighting this relationship as:

- Essential, since part of the innovation exists due to technological development and vice versa;
- Modernization;
- Doing more and better, reducing waste and increasing the value of products and / or services.
- Direction of the organizations for Industry 4.0;
- The mutual accompaniment of both;
- Satisfaction of the needs to develop a product and / or service and transform it with the help of technology;
- Disruptive (technology helps to refine innovation as something new/different in society).

5.3. The relationship between innovation and quality

Although there is some grounded theory about this relationship, the relationship between innovation and quality is not very noticeable to individuals. This relationship was addressed as:

- Improvement;
- Increased productivity with fewer defects;
- Today's most important differentiating relationship;
- One variable raises the other;
- The quality brings benefits to innovation, when it helps to implement procedural controls, improving it;
- Improvement of internal processes.

5.4. The relationship between technology and quality

As for the relationship between technology and quality, there is almost no information, but it is the most noticeable for individuals, perhaps because it follows the evolution of technology. This relationship was addressed as:

- Industry 4.0;
- Decrease in human resources, therefore decrease in errors;

- Use a particular machine (technology) and achieve maximum quality from it;
- The technology helps to increase the quality, either through an improvement in management system or as an improvement procedural.

5.5. Relationship between innovation and technology with quality

The relationship between innovation and technology with quality is the focus of this study, but in order to understand this relationship, it was necessary to understand the isolated relationships of these variables.

With the questionnaire applied and after all the bibliographic review covered in this study, it can say that the relationship between innovation and technology with quality is seen as:

- Organizational effectiveness and efficiency;
- Facilitated production of a product with fewer defects (producing more and better);
- Evolution;
- The quality is an area that can be interconnected with all other areas. Innovation, sustained with an adequate technological base, goes beyond the requirements of customers through the implementation of quality management systems.

After analyzing the results obtained through the questionnaire applied, it should be noted that in open and direct answers, there is no consensus on the relationship that each variable has with the other, obtaining different opinions. This shows that this is an area that is rarely addressed when related to the three variables, with uncertainties still remaining.

Despite the little bibliography available on this topic, where innovation and technology are related to quality, it is a very pertinent topic to be deepened.

6. CONCLUSION

The quality is the engine of any organization's success. The development of a quality-based culture paves the way for organizational effectiveness and efficiency, enabling the achievement of more for less.

The Kaizen method is based on the idea of continuous improvement through the gradual adoption of small innovations. The PDCA cycle is a process of circular change that involves four phases and aims to identify the best solution to a problem before executing it, also based on the idea of continuous improvement.

Innovating without quality can lead the organization to an ephemeral result. However, the market may not recognize this innovation without quality. In this sense, it is possible to detect signs of convergence between the concepts of quality and innovation, which may result in reciprocal benefits within organizations.

The quality with a view to satisfying the end customer is the other side of innovation, whose purpose will be to create value. In short, the result of the implementation of quality and innovation strategies will lead to the creation of value and, consequently, to the increase in the competitiveness of organizations.

(Alves & Saraiva, 2011) report that the implementation of innovation and quality strategies tend to increase the competitiveness and create value, once your goal is focused on the satisfaction of the end customer.

The presence of the innovation in the quality universe becomes increasingly more visible, especially in the design and the planning of quality in respect to the development of new products and/or services, where innovation is focused on satisfying the needs of customers.

Due to the permanent and fast changing markets, organizations have to be creative and maintain the quality of their products and/or services in order to survive. Thus, innovation and quality are presented as aspects crucial in the functioning of organizations, able to tackle competitiveness, the instability and the requirement.

After conducting this research, it is concluded that the higher the level of investment in areas such as innovation, technology and quality, the best competitiveness and production performance will have the organizations.

As verified in the application of the questionnaire, there isn't consensus among individuals on the definition of innovation and quality and even on technology only half of the participants had the same opinion.

Despite the little bibliography available on this topic, where the innovation and the technology are related to the quality, it's a very pertinent topic to be deepened and suggested for future investigations.

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Analyzing the Implications of COVID-19 on Supply Chain Quality Management

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ABSTRACT

Purpose - Supply Chain Management (SCM) is one of the most important parts of business, which includes supply chain quality management (SCQM) and supply chain risk management (SCRM). One of the consequences of an epidemic outbreak can be a lack of reliable data and difficulty in accessing this information, which can simultaneously disrupt supply and demand. Because epidemics of infectious diseases such as Covid-19 cause many deaths worldwide. Therefore, in order to effectively control these epidemics and also to prevent the failure of health systems and laboratory services, having a quality management program and supply chain risk management seems to be essential. The main purpose of this article is to carefully review the studies that have analyzed the results of SCQM, SCRM techniques of different countries and industries in response to the COVID-19 crisis.

Design/methodology/approach - In this research, studies pursue and assess the problems and solutions based on a systematic literature review analysis.

Findings - By considering the researches which have been done related to disruptions of COVID-19, – important disruptions and risk management plans are mentioned to provide a better comprehension of this issue.

Research limitations/implications - Since this global pandemic is a completely new issue, analyzing and gathering reliable statics from companies was very a complicated task. In a different circumstance, exploring hidden disruptions costs and other related issues is continuing since thspread of this disease is not finished yet. Therefore, access to the related data for experts is limited that leads to publishing fewer case studies researches in this filed.

Originality/value – In this paper, the implication of the pandemic situation (COVID-19) is investigated for SCQM.

Keywords: Supply Chain Quality Management, COVID -19, Global Pandemic, Disruptions.

Paper type: Literature review

INTRODUCTION

In the competitive marketplace, supply chain management (SCM) is one of the significant parts of all business processes. Moreover, SCM involves challenges such as developing trust and collaboration among supply chain partners, identifying best practices that can facilitate supply chain process alignment and integration, and successfully implementing the latest collaborative information systems and Internet technologies that drive efficiencies, performance, and quality throughout the supply chain (Robinson and Malhotra, 2005).

Most companies expend specific plans to protect their strategic mission against unexpected problems during the supply chain process. By understanding the different dimensions of the interconnectedness of supply chain risks, decision-makers can create a coherence plan to reduce effective risks. Regarding the recent increasingly complex environment, Supply Chain Risk Management (SCRM) can adjust to improve financial performance and competitive advantage (Hauer, 2003). Risk management strategies are provided and important experiences to strategy selection that should be analyzed. Moreover, they argued that three moderators in the process of risk management are playing an important role which is team composition, supply chain complexity and inter-organizational learning (Manuj and Mentzer, 2008). The supply chain risks affect global supply chain decisions in different aspects; consumer-facing changes, converting the source of components that create the same functionality, and some changes that affect operational capabilities. Manuj and Mentzer (2008) identified that risk management in global supply chains leads to a reduction in loss, probability, speed, the frequency which harms the quality of the production process. In terms of supply chain perspective, the unreliable conditions or disruptions affect the flows of information, inbound materials, and products even by producer or supplier. In simple terms, supply chain risks refer to the possibility and effect of a lack of reality in the production plan which is dependent on demand and supply (Jüttner, Peck and Christopher, 2003). The term of risk sources could be organizational, environmental or supply chain-related variables that cannot be expected with certainty and that impact on the supply chain outcomes. SCRM is focused on supply chain outcome variables like quality or cost in different forms that the variance becomes visible that leads to managers to generate immediate plans and actions to overcome barriers. It should mention that one of the weakest faults in supply chain performance can happen in case when the facility recovery at different echelons in the supply chain is aligned in time. Meanwhile, the most negative effect on the performance is generated when long facility and demand disruptions downstream level regardless of the disruption period at the upstream level.

The consideration about the time of starting and the percentage of supply which is based on the origin region of factories is important, but the scale of the ripple effect should be analyzed precisely. Lücker et al. (2019), claimed that the observation of the simultaneous disruptions in demand and supply may have a positive effect on the Supply Chain performance as a reaction to an epidemic eruption. To some extent, these visions are partially in line and extending the existing body of knowledge on linked disruption in supply chain risk management.

One of the important reasons that decision-makers should handle is related to the lack of reliable data and the difficulty to achieve relevant data sets. Prasad et al. (2018) stated that the increasing capabilities for and consideration of data collection and retrieval provides the possibility to have usable big data for required operations. They added that in the humanitarian supply chain context different value stream plans require a wide range of data attributes which is based on their specific features. The simulation experiments can be one the practical tool to analyze the timing of the restarting firm´s activities at different stages become the main factor that determines the pandemic outbreak effects on the supply chain performance.

However, some factors such as lead-time, speed of epidemic propagation and downstream or upstream disruption in the supply chain process should be considered (Anparasan and Lejeune, 2018) Since Covid-19 is infectious diseases that cause a major of mortality, it is vital to have a plan of supply chain risk management to provide effective control with the quality management in the situation from the consequences of these disruptions. Accessible resources such as essential medical supplies and well-trained personnel need to be deployed quickly and to be managed in combination with available data and financial resources for containing the epidemic before it will expose more locations and people.

The main purpose of this article is to carefully review the studies that have analyzed the results of SCQM, SCRM techniques of different countries and industries in response to the crisis caused by COVID-19.

Supply Chain and Quality Management:

The emerging of quality management and SCM in manufacturing and services go back to the early 1970s (Shewhart and Deming, 1986). Robinson & Malhotra (2005) claimed that several research studies considered the different aspects of quality management within a supply chain perspective. Moreover, they examine that SCQM is one of the integrations of the business process in all organizations to evaluate and improve the products and services, as well as create value and satisfaction for end clients in the marketplace. Kuei et al. (2011) stated that empirical studies the reports from firms illustrates maintaining close relationships with suppliers tend to have the ability to produce high-quality products. They designed and validated a global SCQM model through an empirical case study, strongly suggesting future research to incorporate sustainability dimensions into future SCQM modeling studies.

If the manufacturer knows that his purchasing order is being outsourced to the mainland of producers, the supply risk management strategies would have a different vision. In fact, suppliers often provide clear information about product quality risk than the main firm, since the private knowledge of suppliers is linked to the state of operations, quality in production and input sources (Tse and Tan, 2012).

Quality infrastructure and standards are important in ensuring the availability of key medical devices, diagnostic tests and personal protective equipment. “It is now very obvious that laboratory services by ensuring the accuracy and quality of laboratory-developed tests will increasingly provide an essential contribution to the diagnostic reasoning, managed care, and therapeutic monitoring the vast majority of human diseases” (United Nations, 2020).

Management of Pandemic Situation:

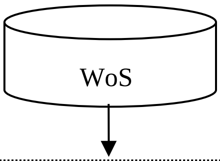
One of the outstanding risks for the supply chain process is pandemic diseases such as SARS and Covid-19. The coronavirus disrupts both demand and supply. Many companies believe that they have been suffering from a shortage of materials from suppliers especially those located in china and demand disruption in Europe which was seriously affected by Covid-19.

In these kinds of unstable situations, companies should make a specific plan to outbreak unexpected disorders. Ivanov (2020) argues that the plan of risk management should cover the following questions; how long SCQM can sustain a disruption, how long does it take. For a company to recover after an epidemic outbreak, which supply chain policy like the accepting the temporal shortages or reacting situational by changing the operation policies during the epidemic disease time, could be the most efficient solution to overcome with disruptions at a different stage of this complex situation. He stated that one of the case studies which were affected by SARS (Severe Acute Respiratory) and it caused negative subsequence into a wide range of industries sections in different counties. Singapore experienced it as the largest known outbreak of this virus in 2003, hit this country. The SARS virus infected around 8,500 people worldwide and caused around 800 deaths. The SARS epidemic brought about far-reaching public health economic consequences for the whole country.

As a positive aspect of an effective response to this issue, the outbreak was eventually limited via a series of risk-mitigating indexes illustrated by the Singapore government and practical participation of all Singaporeans. It should mention that this kind of risk-mitigating measures, depending on the public´s compliance, were swiftly adjusted to address the volatile conditions –such as when more epidemiological cases were unclear (Lai and Tan, 2015).

RESEARCH METHODOLOGY

This research study will pursue and assess based on a systematic literature review analysis. The question of this research is "What are the main implications and challenges of Covid-19 on SCQM?" The systematic literature review conducted in this research has as its main objective of the most recent relevant and significant research of Covid-19 and similar pandemic situation to provide a framework of implications and challenges to SCQM. A five-step process is considered in this research after defined aspects for this paper, the selection of the articles was specified. Figure. 1 presents a schematic overview of the research methodology. The first step examined the research questions based on the research gap found by literate review. These keywords were searched in all databases considering related literature. The third step is related to the screening process which after analyzing the titles of all resulting papers from the initial search, in a first iteration, only seventeen papers were identified. However, in the fourth step after critically reading the identified nine papers entirely in a second iteration. Finally, in the fifth step, six papers relevant to this research were determined the relevant literature for this critical review paper. The limited number of relevant papers and this new pandemic situation indicate the novelty of the topic. The analysis and synthesis of the results were undertaken breaking down each study in the year of publication and special notes. Finally, a discussion section regarding the main findings was undertaken and a novel comprehensive framework was proposed as a result of this review analysis.



STEP 1	**Object /Research Question**
	What are the main implications and challenges of COVID-19 supply chain quality management?
STEP 2	**Keywords Search**
	(a) Supply Chain (b) Quality Management (c) Covid-19 (d) Pandemic Situation (e) Supply Chain Risk Management (f) Supply Chain Quality Management (g) Challenges and implications (h) SARS (i) Frameworks (j) Critical review, (k) Corona Virus.
STEP 3	**Screening Process**
	Keywords, Title, Abstract (n=17) / Selecting the relevant Articles
STEP 4	**Analysis and Synthesis**
	Full articles Reading for assessment (n=6) / Framework Proposal
STEP 5	**Result and Conclusion**
	Final relevant article (n=5) / Discussion about Challenges and Opportunities

Figure 1- Schematic for Methodology adopted in this Paper.

RESULTS AND DISCUSSION

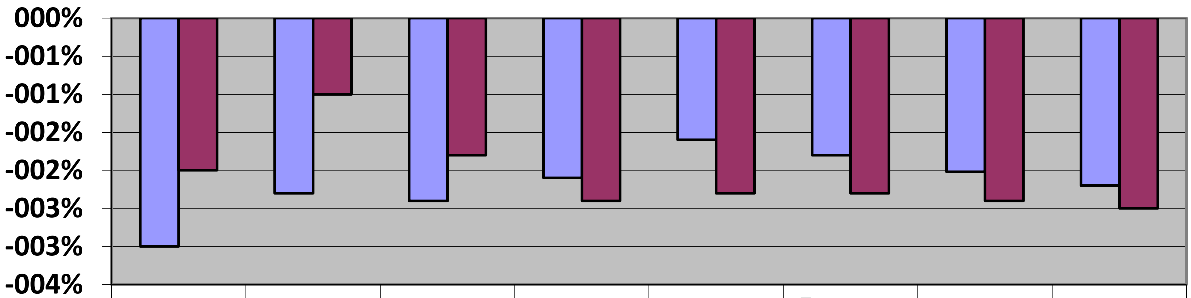
The studies illustrate that clear situation of supply chain disruption some statistics of Covid-19 pandemic problem which are presented in the following:

"Maersk" one of the biggest logistics companies in the world, has had to decline many of container ships, while that chines factories have been operating 50-60 % of their capacity. On the other hand, shipping goods to Europe from Asia through seas takes about five weeks, therefore goods belong to previous orders are still getting to ports that lead to over inventory costs. The international chamber of shipping states that Covid-19 is led to losing $350m a week. Companies have been forced to reduce 350 000 containers and it was 49% fewer sailing by container ships from China during mid-January and mid-February (Baldwin & Mauro, 2020; Chetty, Friedman, Hendren, & Stepner, 2020)

Simultaneously, ports and terminals are facing the same time an outstanding drop in income, mostly from extra costs in yard congestion due to buildup of empty containers and requests from companies to waive storage costs based on these special situations. In other sections like airlines industries, the worrying statistic is clear; IATA (International air transfer association) estimates that the aviation industry could face a loss of 29 million US dollars of passenger revenues (Iacus, Natale, Santamaria, Spyratos, & Vespe, 2020)

To reduce and reduce the impacts of COVID-19, lockdown is mostly linked to the number of countries striking restrictions since the losses are more sensitive to the duration of lockdown than its strictness. Meanwhile, a longer containment that can eliminate the disease imposes a smaller loss than shorter ones, on the other hand in the earlier stage, minor lockdown can minimize overall losses. (Guan *et al.*, 2020) state that a ´go-slow´´ approach to lifting restrictions may reduce overall damages if further lockdown won't be required. Base on this strategy, this difficult situation of the global supply chain will expand value losses through the direct effects of COVID-19. Therefore, risk management as a public requires that collective efforts and support to lower-capacity zones is a noticeable effort.

To provide more details of the effects of Covid-19 on industries of different countries figure.2 and figure.3 are illustrated.



	China	Japan	Korea	Best of developing asia	United States	European Union+Uk	Latin America	World Total
GDP	-003%	-002%	-002%	-002%	-002%	-002%	-002%	-002%
EXPORT	-002%	-001%	-002%	-002%	-002%	-002%	-002%	-003%

Figure 2 - Effects of Covid19 on GDP and Export adopted by (Maliszewska, Mattoo and Mensbrgghe, 2020).

Maliszewska, Mattoo and Mensbrgghe (2020) argue that exports at a worldwide level will be decreased around 2.5%. China, as a world´s factory, suffers a decline in the production process in different sectors because of the underutilization of labor and capital. Moreover, the increase in trade costs leads to the import budgets for all countries affected global exports. It is shown that China is dealing with a contraction in export by 3.7%. Vietnam faced a decline in its total exports by only 1% since it has a chance to an extent from the gap left by reducing Chinese esports. Other countries in East Asia and Pacific region have been affected by decreasing the export such as Hon Kong SAR, China suffering the noticeable percentage (5.2%), followed by the Lao People´s Democratic Republic (3.6 %), Cambodia (3.9 %) and Singapore (4.4 %).

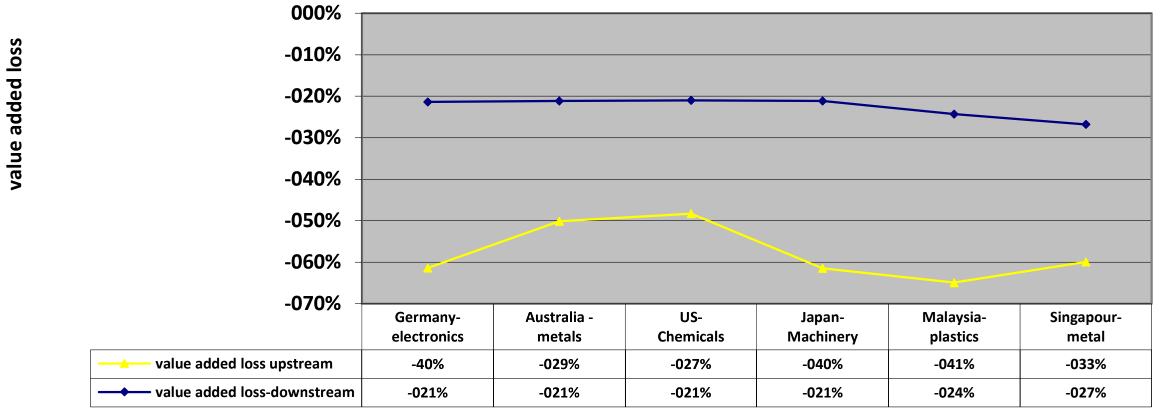


figure 3 - Impacts of Covid-19 adopted by (Guan et al., 2020).

The effect of disruption from different suppliers which are related to the German automobile industry is a suitable case to review the effects of disruption which is caused by Covid-19. Since this problem has massive impacts on different industries all around the world, therefore highly specialized suppliers that make a short-term substitution to recover deviation in different aspects of productions. As Fig.2 shows, some Value-add loses percentage that has affected from electronics suppliers on different European producers. According to theses statics among mentioned countries, Germany affected in major volume by -40% in the added value stream that results in a value-added loss in USA producers as upstream producers. In similar conditions, Malaysia lost 40 % of its value-added and has reciprocal around -24.3% on UK producers. According to ACAP (Automobile Association of Portugal) in March 2020 13,686 light passenger vehicles were produced which is 47.1 % is less than March 2019. It should mention that there is 18.3 % decrease in the total amount of all kinds of automobile productions in Portugal, regarding 77,204 units manufactured, with decreases to 20.5 %,4.5% and 36.4 % in the production of passenger cars, light commercial vehicles and heavy vehicles, respectively in comparison to the first quarter in 2019 (García-Olivares, Solé, Samsó, & Ballabrera-Poy, 2020)

In the recent decade, the nature of SCM dependencies has been changed sharply. Firms are encouraged to expand relationships with suppliers and customers to decrease disruptions during unexpected issues. Simultaneously, companies have also been adopted to follow Quality Management

(QM) tools and techniques if they wish to survive and remain validity and credibility of firms during the epidemic´s outbreak period (Dasaklis, Pappis and Rachaniotis, 2012).

To manage the disruption of this destructive phenomenon, certain control protocol should be stated for suppliers along with human resources and be available to be applied to reduce the containment effort. In terms of control of effects of Covid-19 on SC process, the establishment of an emergency supply chain as a plethora of logistics issues is increased regarding the management strategy adopted and the agent causing the unexpected effects. To have coherence supply chain quality strategies that be able to reduce effects of unexpected situations it should be noted that the ability to change production volumes rapidly, quality and long-term relationships with a different type of suppliers is an important issue. Besides, the quality flexibility and minimum order are two vital factors in terms of risk management for both producers and retailers. Due to demand uncertainty, a manufacturer would prefer contracts that would retailers to commit their orders, meanwhile, a retailer would prefer contracts that would allow them to adjust their orders when necessary (Tang, 2006). Regarding the lack of access to correct statics in results of Covid-19 on industries and economics, envisage model is proposed and configured based on the following assumption (Maliszewska, Mattoo and Mensbrgghe, 2020):

- Production elasticities have been reduced to around zero, therefore it is possible excess inputs in production.
- In order to get the strong relationship within global value chains, trade flexibility for products has been decreased from their standard values to illustrate the short-run inability to swap imported parts and final goods with products from other zones.
- Labor requirements are an important factor since the wages are deepened to demand and supply of labor.

In order to illustrate the importance of Quality Management role in responding to the impacts of Covid-19, figure 4 is illustrated .

Issues	Plans
The number of infected people increases exponentially, while adequate medical equipment is rare	Reliable results of medical laboratories by conducting tests to detect the virus.

Global trade contracts, while trade of medical equipment improves	Improving Trade Formalities as a vital role in remaining the availability of required medicines, medical products and protective tools
Businesses worldwide struggle to keep up the production of essential goods	Apply mandatory Standards to ensure that good produced in the response of Covid-19 such as masks, gloves to be fitted for people
Additional medical and perilous waste is generated	Standards help to manage increased dangerous waste by detect pollution levels
Millions of people around the world depend on global trade for their food requirements	Trade with global value chains to ensure the worldwide supply of required materials, while hygiene practices and food safety standards are an important factor to ensure global supply chain in food sectors.

figure 4 – Impacts of COVID -19 and responses

Since there is few of researches related to the COVID-19 and its effects on industries have been published and reliable statics from companies is not accessible which is based on companies' policies, it is suggested to mention solutions to the declined effects of this pandemic problem in a supply chain process. Hence, information from literature reviews and summaries of them in fig4 help to gather risk management techniques against to impacts of COVID-19.

CONCLUSIONS

The global pandemic like COVID-19 requires coherence urgent response from all departments of organizations and firms in all countries. The disruption impacts not just on public health but also on finance, trade, economic policies, and regulations. The goal of this paper is to carefully review the studies that have analyzed the results of SCQM, SCRM techniques of different countries and industries in response to the crisis caused by COVID-19. The reviewed literature that focuses on quality and risk management provides further insights on practices, performance measurement by relying on statistics. Since the effects of the pandemic problem on different aspects of industrial activities are not recognized completely so it is suggested that merging the TQM (total quality management) tools with formal process improvement methodologies can process-oriented could and lead to building the reliable path to for continual improvements in terms of quality of products and services. Since there is missing research on effects of Covid-19 on supply chain quality management in more details, this paper suggests effective responses by reviewing similar cases, but it is vital for further research by using quality tools in more details and updated data in a specific area such as reviewing cooperation between suppliers and producers and propose a coherence model.

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Quality Management in Higher Education.Using SERVPERF to assess services quality

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STRUCTURED ABSTRACT

Purpose: The implementation of comprehensive quality management systems in higher education institutions (HEIs) implies the need to consider not only its main mission processes but also support processes, including those providing internal services to students and teaching staff. This paper intends to illustrate how the SERVPERF instrument can contribute to HEIs quality management.

Design/methodology/approach: An empirical case was carried out to illustrate the potential of the SERVPERF instrument for the quality management of HEIs. A specific-designed questionnaire based on the SERVPERF instrument was used to collect data on students and teaching staff perceptions of post-service performance of three different support services of a selected HEI. An interview was later conducted to the institution's director to gain a richer understanding of the results obtained and pertinence of the study.

Findings: –Overall, students and teaching staff have a positive view of the services provided. Still, improvement actions were proposed to address the critical aspects identified. The SERVPERF instrument was an adequate tool to collect data on the services' performance and address the need for support processes quality management.

Practical implications: The research highlights the potentialities of the SERVPERF instrument in supporting managerial decisions addressing the quality of HEIs support processes.

Originality/value - The design and implementation of quality management systems in HEI has been mainly focused in the teaching and learning process, dismissing support processes. The paper sheds

some light on the potentiality of service quality instruments in improving these processes. It also contributes to the validation of the SERVPERF instrument in the higher education context.

Keywords: Quality Management Systems; Service Quality; SERVPERF; Higher Education Institutions.

Paper type: Research paper

INTRODUCTION

Different reforms have affected the public sector over the last decades. Of special relevance for higher education are the Bologna process (1999) and the Lisbon agenda (2000), which in line with the inspiration brought by new public management led national governments in Europe to explore new modes of governing higher education. These new modes include an increase in institutions autonomy, which has been counterbalanced by accountability demands, namely regarding their quality and the quality of their main processes, particularly teaching and learning. As such, external and internal quality assurance mechanisms have been developed in Europe since the mid-80s and are now a reality in all European countries (Amaral and Rosa, 2010; Rosa et al., 2019).

Regarding internal quality assurance, universities all over Europe have been developing and implementing their own systems, under the assumption that the responsibility for quality assurance lies ultimately with them (Cardoso et al., 2017). The Bologna Declaration has had a significant influence regarding internal QM systems design and implementation in European HEI in the last two decades. Following the declaration, many national evaluation and accreditation agencies prepared and adopted guidelines for institutions to set up their systems, especially in the cases where institutional audits of internal QM systems are in place. Furthermore, these guidelines have been inspired in most of the countries by another relevant European development, which was the draft of the European Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). In their Part 1, the ESG refer the need for HEIs to have QM systems in place, while providing guidelines for their implementation in line with the preconized standards for "quality assurance related to learning and teaching in higher education, including the learning environment and relevant links to research and innovation" (ESG, 2015: 7).

Similarly to what has been occurring in most European countries, in Portugal the European references on internal QM systems, namely the ESG Part 1, were translated into the QA legal framework and specific references defined by the national QA agency (A3ES). Institutions are expected to develop a quality policy closer to quality enhancement and the adequate procedures for its pursuit, a quality culture and a strategy for continuous improvement (Rosa and Sarrico, 2012), which should materialize in an internal QM system, in line with the ESG and the applicable legal requirements (Santos, 2011).

Both the ESG (2015) and the A3ES Reference Framework for Internal Quality Assurance Systems in Portuguese Higher Education (A3ES, 2016) assume HEIs as organizations built around the three nuclear processes of their institutional mission: teaching and learning, research, and relation with society. Guidelines are then established for the adequate management of the quality of these processes, with a special relevance being given to the teaching and learning one, especially in the ESG (Manatos et al., 2017). Besides the nuclear processes, the two frameworks also address support ones, mainly in relation to the processes which support teaching and learning. In particular, ESG 1.6 and Reference 10 of the A3ES Framework state, respectively:

> **ESG1.6 - Learning resources and student support**: Institutions should have appropriate funding for learning and teaching activities and ensure that adequate and readily accessible learning resources and student support are provided. (ESG, 2015)
>
> **Reference 10 – Material resources and services**: The institution adopts mechanisms which enable it to plan, manage and enhance services and material resources with a view to appropriate development of student learning and other scientific and pedagogic activities. (A3ES, 2016)

The guidelines provided in both standards call for the need of institutions not only providing a series of resources and services to support teaching and learning (e.g. libraries, study facilities, IT infrastructure, human support), but also having in place mechanisms for the collection and analysis of information on their maintenance, management and suitability. Furthermore, institutions should establish procedures to regulate and guarantee the corresponding decision-making around services and resources (A3ES, 2016). And their internal quality management systems should ensure that all resources are fit for purpose, accessible, and that students are informed about the services available to them (ESG, 2015).

Although the ESG and the A3ES Framework establish guidelines to help universities develop their internal quality management systems, each university should design and implement them according to its institutional mission and culture (ESG, 2015; Rosa and Amaral, 2014; Santos, 2011). Institutions are then free to decide on the best mechanisms and instruments to use to manage the quality of their processes, both nuclear and support ones.

Support processes include several services provided to students, teaching and non-teaching staff with the main goal of assisting the teaching and learning, research, and relation with the society processes (Manatos et al., 2017). Although these are not key organizational processes, they still need to be considered within the HEIs QM system, since they provide and maintain resources for all other processes (this is evidenced by their consideration under the ESG and A3ES Framework). Furthermore, the importance of considering administrative aspects in the assessment of quality in HEIs, as a complement of the core academic issues, has lately been emphasized (Mahmoud and Khalifa, 2015) . The question is then how to adequately manage the quality of support processes and what methodologies or tools can a HEI use to continuously monitor and improve their quality.

The fact that these support processes are mainly related with the provision of services to HEIs internal stakeholders calls for the possibility of using instruments specifically designed to measure services quality, such as SERVQUAL, SERVPERF or HEdPERF. The literature shows that these instruments have already been used in the educational context, namely in HEIs, helping to identify service areas that need improvement (Kawshalya, 2016; Galeeva, 2016). In particular, and as presented in the next section of this paper, the SERVPERF instrument has been mainly used to assess the quality of educational services based on students' perceptions.

However, and at least to the best of our knowledge, the use of these instruments has never been equated in the scope of the implementation of internal QM systems within HEIs, which is the purpose underlying the present study. In fact, our assumption is that the use of such instruments can indeed contribute to gather information on support services quality and as such assist managerial decisions addressing the quality of HEIs support processes. Under this context, this paper intends to illustrate how the SERVPERF instrument can contribute to HEIs quality management, by providing relevant information on users' perceptions of the quality of support services. This is of utmost interest not only for HEIs government bodies, namely those in charge of their quality management systems, but also for research on this area. So far, the literature on the design and implementation of quality management systems in HEI has been mainly focused on the teaching and learning process, dismissing support processes. This paper contributes to enlighten the need for research on quality management in higher education to also consider these processes, including the potentiality of using service quality instruments for their adequate improvement.

The paper proceeds as follows. In the next section the SERVQUAL, the SERVPERF and the HEdPERF instruments are briefly discussed, including their benefits and limitations, and their use in higher education analyzed. Then an empirical case is presented to illustrate the SERVPERF instrument relevance to measure the quality of three different services provided by an HEI (library; academic services; and reprography) according to students and teaching staff perceptions of their performance. The results of this case are then discussed to test the potential of the SERVPERF as an instrument to manage and improve the quality of HEIs support processes. The paper concludes with a summary of the most relevant lessons learned and with some final remarks.

SERVPERF IN THE HIGHER EDUCATION CONTEXT

Research on service quality has started with the so-called Nordic school. Within this school, Gronroos's (1984) distinction between technical and functional service quality dimensions – representing the “what” and “how” of service delivery – has attracted substantial attention.

Among the models typically used to evaluate services quality, the mostly widely used in Higher Education are the SERVQUAL, the SERVPERF and the HEdPERF instruments (Kawshalya, 2016). The first two are claimed to be generic and have been applied to different services, whereas the latter was specifically developed to the HEIs context.

The SERVQUAL instrument was proposed by Parasuraman, Berry and Zeithaml in the eighties (Parasuraman, Zeithaml and Berry, 1988) and is based on the assumption that consumers use their expectations to assess service quality by comparing them with the perceptions of the service received. If expectations are met (or exceeded), service quality is regarded as positive and that ultimately leads to satisfaction. Therefore, the disconfirmation paradigm provides the main foundation for SERVQUAL. According to this model, service quality comprises 22 items, grouped in five key dimensions:

- Tangibles: physical facilities, equipment, and appearance of personnel.
- Reliability: ability to perform the promised service dependability and accurately.
- Responsiveness: willingness to help and provide prompt service.
- Assurance: knowledge and courtesy of employees and their ability to convey trust and confidence.
- Empathy: caring, individualized attention that a firm provides to its customers.

Due to some of the criticism (e.g. Cronin and Taylor, 1992; Teas, 1993; Buttle, 1996) raised about the disconfirmation model and the SERVQUAL instrument properties of dimensionality, applicability and validity, Cronin and Taylor (1992) argued that service quality is better understood as a consequence of performance rather than as comparison between expectations and perceptions. Moreover, according to the authors, perceived service quality can predict customer satisfaction, and satisfaction plays a stronger role in future purchase intentions than service quality. Thus, the SERVPERF model is based on the perception paradigm. It uses the same 22 items and 5 dimensions of the SERVQUAL questionnaire for measuring the delivery of the service provided.

The HEdPERF model, proposed by Firdhaus Abdullah in 2005, is based on the previous, but was specifically developed to the Higher Education context, from a student's perspective. In the modified version of the scale, Abdullah(2006) suggests five evaluation criteria (dimensions): non-academic aspects, academic aspects, reputation, access and program issues.

As stressed by Galeeva (2016), using these kind of instruments to measure service quality in HEIs is quite appealing since they potentially help to identify service areas that need improvement, without requiring any prerequisites for implementation.

In line with the authors who suggest that performance-based measures explain more of the variance in an overall measure of service quality, are more reliable and allow for better discriminant validity (e.g. Cronin and Taylor, 1992), the SERVPERF instrument is used in the current paper. Despite the appeal of HEdPERF, this model was discarded because it is more complex (it implies collecting data on 41 items –13 items adapted from SERVPERF, and 28 items generated from literature review) and lacks wider acceptance, affecting its reliability and generalization (Law, 2013; Danjuma *et al.*, 2018). Furthermore, it involves dimensions that are not totally suitable to support services (e.g. program issues), which are the focus of this research.

In order to have a better understanding of the use of the SERVPERF instrument in the higher education context, a systematic analysis of the literature using it in the higher education context was conducted. Thirty papers were identified using the EBSCO Discovery Service, having [“SERVPERF” AND (“higher education” OR “universities”)] in the title, abstract or key words. Only papers published in English in peer-review journals were considered. Conference Proceedings, Working Papers and Dissertations were excluded from the sample. The results were cross-checked by searching the Emerald and Scopus databases. By screening the abstracts, three papers were excluded: one because it was not published in English and two because HE students were used in the samples, but measurement of service quality was not applied to university activities and services. Next, the abstracts and complementary information for the final 27 papers (see Table A in appendix) were once again read in order to collect information on the nature of the research (conceptual vs. empirical), instruments used (SERVPERF only or in combination with other questionnaires) and countries, institutions and services used in the empirical studies. When such information was not delivered in the abstract or was not totally clear the full text was used (in particular, the research design/methods section).

As depicted in Figure 1, selected papers cover the 2005-2019 timespan, with the number of papers published yearly varying from 1 to 4. Even if the absolute number of studies using the SERVPERF instrument remains relatively small, from 2015 onwards the number of publications on the matter has clearly increased.

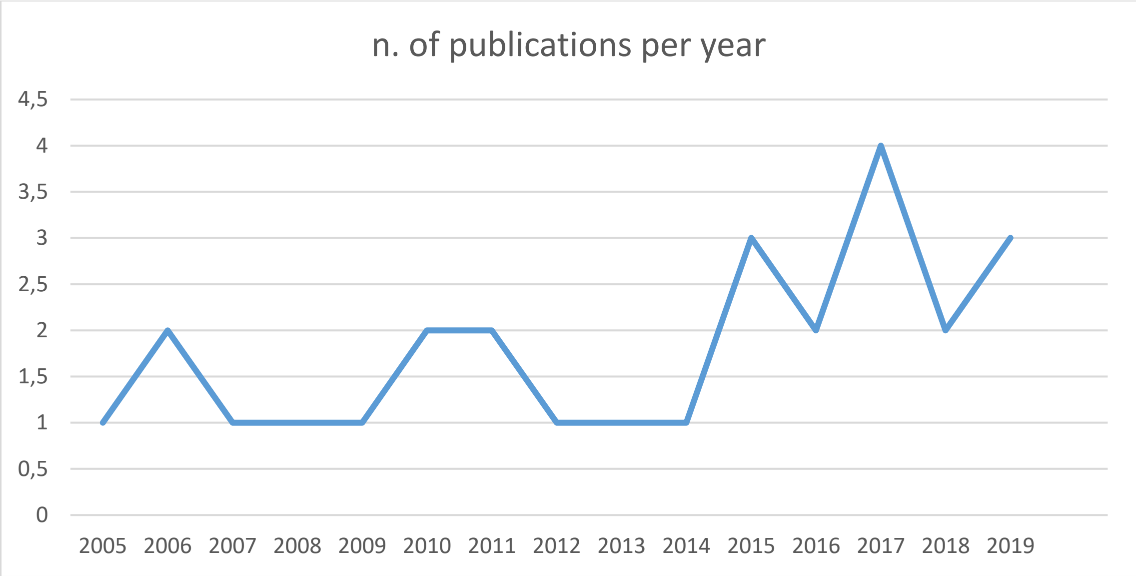

Figure 1. SERVPERF studies in HE over time

Except for two literature reviews, the remaining papers are empirical. The geographical coverage is quite broad (see Table 1), with an emphasis on Asian countries.

Table 1. SERVPERF studies in HE: countries

Country	N. of studies
Bangladesh	1
China	1
Croatia	1
India	2
Iran	1
Iraq	1
Malaysia	5
Nigeria	1
Pakistan	2
Portugal	1
Romania	1
Russia	1
South Africa	2
Syria	1
Taiwan	1
Turkey	2
Zambia	1

Table 2 shows the journals where the identified studies have been published. Research is scattered among 21 journals, although the "Quality Assurance in Education" journal emerges as a main source of SERVPERF studies in higher education.

Table 2. SERVPERF studies in HE - Journals

Journal	**Education Journal**	**Nº of papers**
Quality Assurance in Education	Yes	5
Procedia - Social and Behavioral Sciences	No	3
Annals of Library & Information Studies	No	1
Asian Journal of University Education	Yes	1
Congent – Business and Management	No	1
Dirasat, Educational Sciences	Yes	1
Education and Training	Yes	1
Expert Journal of Business and Management	No	1
Global Management Journal for Academic and Corporate Studies	No	1
Indian Journal of Pharmaceutical Education & Research	Yes	1
Interdisciplinary Management Research	No	1
International Journal of Research & Method in Education	Yes	1
International Journal of Social Sciences & Educational Studies	Yes	1
Journal of Education and Training Studies	Yes	1
Journal of Management and Business Administration	No	1
Library Management	No	1
Malaysian Journal of Library & Information Science	No	1
Marketing Intelligence & Planning	No	1
Quality Management Journal	No	1
TQM Journal	No	1
Turkish Online Journal of Distance Education	Yes	1

As shown in Table 3, studies have been covering both public and private institutions. A considerable number of papers (9) have focused on a single case study. Interestingly, 11 out of the 27 papers have simultaneously applied more than one service quality instrument (SERVPERF and SERVQUAL – 5 papers; SERVPERF and HEdPERF – 5 papers; SERVPERF, SERVQUAL and HEdPERF - 1). For the most cases, the instruments have been applied at the institutional level with the main purpose of assessing service quality of educational services based on students' perceptions. Three papers have used the SERVPERF scale to measure the quality of the service provided by libraries, but only one (Demir, 2017) has considered other kinds of support services, namely student affairs, accounting, academic departments, dean of students, and cafeteria. Moreover, all the papers have administered questionnaires to students, without considering other stakeholders.

Table 3. Summary of the empirical papers using the SERVPERF instrument

Paper	Context	Instrument	Methods used	Participants
Abdullah, F. (2005)	Public and Private HEIs	HEdPERF + SERVPERF	questionnaire	Students
Abdullah, F. (2006a)	Public and Private HEIs	HEdPERF + SERVPERF	questionnaire	Students
Abdullah, F. (2006b)	Public and Private HEIs	HEdPERF + SERVPERF	questionnaire	Students
Azar (2012)	1 private HEI	SERVQUAL + SERVPERF	questionnaires + focus group	Students
Bayraktaroglu, G. and Atrek, B. (2010)	1 HEI	SERVQUAL + SERVPERF	questionnaire	Students
Brochado, A. (2009)	1 public HEI	HEdPERF + SERVQUAL + SERVPERF	questionnaires + focus group (experts)	Students
Demir, A. (2017)	1 HEI	SERVPERF	questionnaires + workshops	Students
Galeeva, R. B. (2016)	n.s.	SERVQUAL	questionnaires	Students
Hamid, F. S. and Yip, N. (2019)	Public and Private HEIs	SERVPERF	questionnaires	Students
Hassan, N. and Jafri, M. H. (2017)	10 private HEIs	SERVQUAL + SERVPERF	questionnaires	Students
Hossain, M. J., Islam, A. and Saadi, M. S. (2014)	Libraries of 4 private HEIs	SERVPERF	questionnaires	Users
Johari, R. and Zainab, A. N. (2007)	Libraries of private HEIs	SERVPERF	questionnaires	Students
Law, D. C. (2013)	n.s.	HEdPERF + SERVPERF	questionnaires	Students
Legčević, J. (2010)	8 HEIs	HEdPERF + SERVPERF	questionnaires	Students
Mahmoud, A. B. and Khalifa, B. (2015)	Public and Private HEIs	SERVPERF	questionnaires	Students
Mandal, K. and Gupta, H. (2019)	6 private HEIs	SERVQUAL + SERVPERF	questionnaires	Students
Manea, N. P. and Iatagan, M. (2015)	1 Public HEI	SERVPERF	questionnaires	Students
Mwiya, B. et al. (2019)	1 Public HEI	SERVPERF	questionnaires	Students

Nejati, Mehran and Nejati, Mostafa (2008	A library of 1 public HEI	SERVPERF	questionnaires	Users
Oluwunmi, A., Durodola, O. and Ajayi, C. (2016)	Libraries of 4 private HEIs	SERVPERF	questionnaires	Students
Rajab, A. et al. (2011)	1 HEI	SERVPERF	questionnaires	Students
Rodrigues, L. L. R. et al. (2011)	1 HEI	SERVQUAL + SERVPERF	questionnaires	Students
Soni, S. and Govender, K. (2017)	1 HEI	SERVPERF	questionnaires	Students
Soni, S. and Govender, K. (2018)	2 HEIs	SERVPERF	questionnaires	Students
Wu, Y.-C., Hsieh, L.-F. and Lu, J.-J. (2015)	3 HEIs (distance learning)	None	questionnaires	Students

EMPIRICAL CASE

In this section the empirical case used to test the potential of the SERVPERF as an instrument to manage and improve the quality of HEIs support processes is described. The section starts with an account of the methodology followed for the application of the SERVPERF to measure the quality of three support services in one Portuguese HEI. Then the main findings obtained from this instrument application are presented.

Empirical Case Methodology

To test the potential of the SERVPERF instrument to assess the quality of support services of HEIs, a Technological and Management School of a Portuguese polytechnic was used. The School offers 15 bachelor's degrees and 13 technical courses, having more than 2000 students enrolled. Among the various support services provided, three were selected – academic services, reprography, and library – as they are the most used by both students and teaching staff. It follows a brief description of the three services selected for this study.

<u>Academic Services</u>

Placed in the first floor of the Administrative Building, these services occupy 4 rooms. Six people work in the academic services, each one with its own computer. Opening hours are from 9.00 to 12.00 and from 14.00 to 16.30, except on Tuesdays when the service is open from 9.00 to 20.00 without interruption. Students and teaching staff can also use the telephone or the email to send their requests to the academic services. These services are in charge of students records and communicate with students and applicants with the support of the academic portal.

Reprography

It is located in the ground floor and has two rooms: the main room (which includes a waiting area and the attendance area) and a storage room. At the counter, there are two computers: one for the students/teachers to make their requests and one other to the reprography staff member who is attending. Printing requests can equally be made using the net and collected later. The service has only one staff member at full time. Among other services, the reprography prints examination papers and for the distribution of supplies for the rooms and laboratories. Opening hours are from 9.00 to 12.30 and from 14.00 to 17.30, every weekday.

Library

It occupies rooms in the 4 floors of the Administrative Building. It assists the academic community in teaching and research tasks, by providing books, papers, and other resources, both physically and online. It also promotes training courses and organizes cultural events. It includes rooms for reading, working in groups and offices for the staff. Four people work in the documentation center, each one with his/her own computer. There are 5 computers for students use. Library is open Monday to Thursday from 9.00 to 20.00 and on Fridays from 9.00 to 18.00.

The research design is summarized in Figure 2.

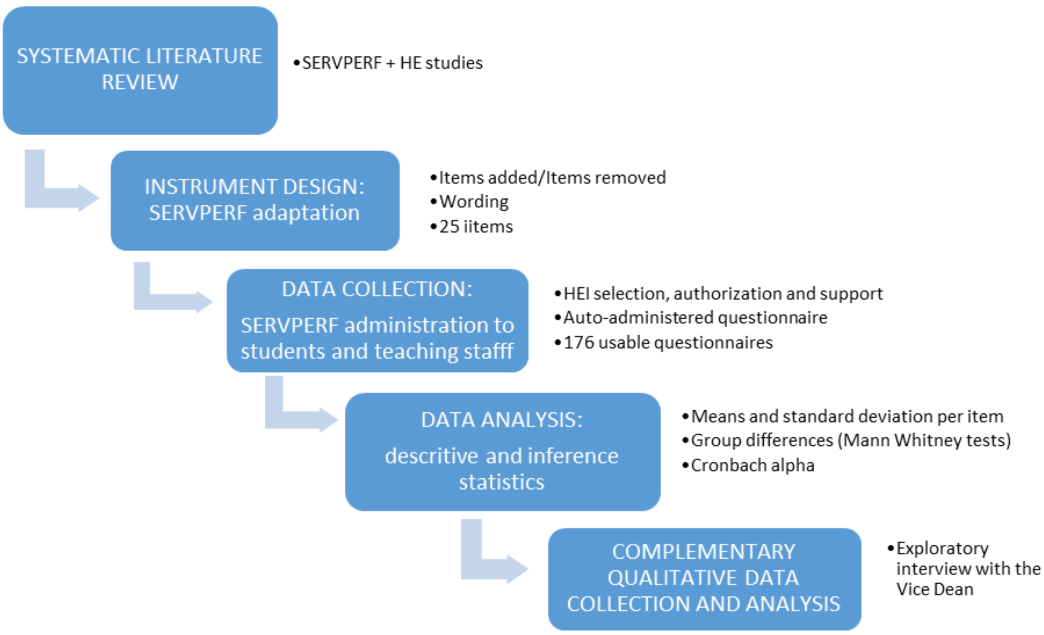

Figure 2. Research design outlook

Data was collected by means of a questionnaire survey applied online to all the students and teaching staff being part of the School in the academic year 2018/19 (the questionnaire was available for data collection between June and August 2019). 176 usable successfully completed questionnaires were received (139 from students and 37 from teaching staff), corresponding to an overall response rate of 7% (the population comprised 2306 students and 191 teachers and the questionnaire was sent to all of them).

The source for the questionnaire was the SERVPERF instrument with the items wording adapted to the specific context of the support services of a HEI. Twenty-five items were used to cover the five proposed dimensions (see Tables B to F in the appendix – the tables contain all the items included in the questionnaire grouped according to the SERVPERF five dimensions). Table 3 illustrates the main changes introduced. Items were measured on 7-points Likert scale. The use of a 7-points Likert scale was thought to be the most adequate to potentially generate some variability between user groups and among items. At the end of the questionnaire, there was also an open question to give room for comments and suggestions.

Table 3. SERVPERF adaptation

Dimension	**Items changed**
Tangibles	Accessibility to disabled people (Added) Internal signs (Added)
Reliability	Services delivered with error-free records (Deleted)
Responsiveness	Functioning of the IT system (Added) Procedures explained to the user (Added)

Collected data were analyzed using the Excel and SPSS software. Descriptive statistics and non-parametric Mann Whitney tests were used to statistically treat the data. The tests were meant to uncover differences in the perceptions of students and teaching staff regarding all the items in analysis.

Internal consistency was analyzed using the Alpha-Cronbach. As recommended in the literature, the indexes for all dimensions were well above 0.8 (see Table 4).

Table 4. Internal consistency assessment

Dimension	N. of items	Service	Cronbach alpha
Tangibles	6	Academic Service Reprography Library	0.893 0.854 0.897
Reliability	4	Academic Service Reprography Library	0.930 0.915 0.913
Responsiveness	6	Academic Service Reprography Library	0.925 0.923 0.925
Assurance	4	Academic Service Reprography Library	0.956 0.956 0.955
Empathy	5	Academic Service Reprography Library	0.933 0.934 0.951

Following the questionnaire administration and data analysis, an exploratory semi-structured interview was conducted with one of the school vice-deans on the 5th of November 2019. The aim was to improve the knowledge regarding the results obtained from the questionnaires, analyzing the possibilities of defining improvement actions for the assessed services and discussing the potential use of the SERVPERF instrument to support the quality management of the support processes characterizing these services. More specifically, an interview guideline was developed with the following questions:

i. How far do you think the assessment of the degree of satisfaction of students and teaching staff with the three support services will improve these services provision?

ii. Can you anticipate the main results obtained from the analysis of the data collected (answers of students and teaching staff to the questionnaire)?

iii. Would you like to comment on the results obtained? Was it expectable to have differences in perceptions among students and teaching staff?

iv. Considering the results obtained, which improvement actions can the school activate to improve the worst perceived aspects identified by the respondents?

Empirical Case Main Findings

This subsection presents the main findings obtained from the analysis of the questionnaires, looking at the perceptions of students and teaching staff on the three different services and according to the five dimensions of the SERVPERF instrument. Such perceptions were later discussed with the director of the school and his views on the matter are also reported. Table 5 summarizes the key results (in the appendix detailed information is given for each questionnaire item composing the SERVPERF questionnaire: means, standard deviations and results of the non-parametric tests, considering the answers of students and teaching staff for the three services under analysis).

Globally, all the dimensions got average scores between 4 and 5, which means that overall students and teaching staff are satisfied with the services being provided to them (even if not very satisfied). The dimensions of *Reliability* and *Assurance* were the ones showing a better performance according to the respondents' perceptions about the three services. On the contrary, the *Tangibles* was the dimension considered to have a lower performance. These results are consistent across the two groups under analysis, considering the three services as whole. Interestingly though there is a significant statistical difference between students and teaching staff perceptions for each one of the SERVPERF dimensions in analysis, considering again the services as a whole. The mean scores obtained are higher for teaching staff than for students, which allows concluding that globally the teaching staff is more satisfied with the services provided by the HEI than the students.

Table 5 – Mean, standard deviation and results of the Mann-Whitney test for students and teaching staff perceptions of each service according to the SERVPERF dimensions.

Dimension	Service	Students		Teaching staff		MW test
		Mean	SD	Mean	SD	(p)
Tangibles	Academic Services	4,48	1,37	5,04	1,46	**0,004**
	Reprography	4,28	1,40	4,58	1,46	0,056
	Library	4,48	1,40	5,26	1,27	**0,000**
	Global	4,41	1,39	4,96	1,51	**0,012**
Reliability	Academic Services	4,75	1,33	5,72	1,16	**0,000**
	Reprography	4,90	1,27	5,82	1,09	**0,000**
	Library	4,82	1,29	5,80	1,10	**0,000**
	Global	4,82	1,30	5,78	1,11	**0,000**
Responsiveness	Academic Services	4,56	1,34	5,47	1,38	**0,000**
	Reprography	4,67	1,31	5,54	1,34	**0,000**
	Library	4,66	1,31	5,59	1,31	**0,000**
	Global	4,63	1,32	5,53	1,34	**0,000**
Assurance	Academic Services	4,69	1,30	5,72	1,19	**0,000**
	Reprography	4,76	1,28	5,78	1,08	**0,000**
	Library	4,77	1,25	5,85	0,96	**0,000**
	Global	4,74	1,28	5,79	1,08	**0,000**
Empathy	Academic Services	4,53	1,34	5,49	1,24	**0,000**
	Reprography	4,54	1,34	5,56	1,15	**0,000**
	Library	4,59	1,32	5,72	1,01	**0,000**
	Global	4,55	1,33	5,59	1,14	**0,000**

Considering each service separately, the results highlight that for the students the highest performance occurs in the *Reliability* dimension for all services. As for the teaching staff the highest performant dimensions are *Reliability* and *Assurance* for the academic services, *Assurance* for the library and *Reliability* for the Reprography.

Tangibles is the dimension getting the lowest perceptions of satisfaction regarding the services performance, both for teaching staff and students. The reprography is the service regarded as the one having the lowest performance in this dimension (it was the only service/dimension for which the mean score of the teaching staff answers was bellow 5). The Mann-Whitney tests confirm that for all services teaching staff is more satisfied than students for all dimensions in analysis, except for the *Tangibles* of the reprography where no statistical significant difference has been identified between the answers of the two groups.

Tables 6 and 7 highlight the items that got the highest and lowest scores for each of the groups analyzed. For both groups, the worst perceived items mainly relate to different aspects of the *Tangibles* dimension, while the strongest points are scattered among the various dimensions, even if *Reliability* gets most of the positive highlights. Interestingly, students tend to concentrate their best and worst perceived items in the reprography, while the teaching staff points strengths and weaknesses in other areas: the academic services in terms of the worst perceived items and the library in the top perceived ones.

Students are especially critical of the attractiveness of furniture and technological equipment in the three services; they also perceive different aspects of the reprography (facilities' pleasantness; opening hours; facilities internal signals) as not being so good. As for the teaching staff the worst perceived items also correspond to the physical characteristics and equipment of the different services, mainly the reprography, but also the academic services. Furthermore, the teaching staff perceives the informatic system of both the reprography and the academic services as not being sufficiently operational.

As for the best perceived items, other quality dimensions emerge, namely the reliability and the responsiveness in the views of both students and the teaching staff. Students mainly appreciate the verbal and oral language used by reprography and library employees and tend to emphasize different aspects of the reprography service, related mainly with their employees and with the service being delivered on-time and errors-free. Teaching staff also highlights the reprography employee's behavior, but in this case specific aspects of the library also emerge, again related with the way the employees interact with them.

Table 6 – Top best and worst perceived items (students' perceptions)

Bottom 5			Top 5		
Item	**Service**	**Mean**	**Item**	**Service**	**Mean**
The school support services' materials (technological equipment and furniture) are visually appealing. (Tangibles)	Reprography	3,92	The school support services' employees use simple and clear oral and written language in their interaction with users. (Responsiveness)	Library	4,97
The school support services' physical facilities are visually appealing. (Tangibles)	Reprography	4,01	The school support services are provided at the time they were promised, which are reasonable. (Reliability)	Reprography	4,94
The school support services' materials (technological equipment and furniture) are visually appealing. (Tangibles)	Academic Services	4,06	The school support services are provided correctly and error-free. (Reliability)	Reprography	4,92
The school support services' facilities have adequate internal signs. (Tangibles)	Reprography	4,09	The school support services' employees are sympathetic and reassuring to users. (Reliability)	Reprography	4,91
The school support services opening hours are convenient to users. (Empathy)	Reprography	4,26	The school support services' employees use simple and clear oral and written language in their interaction with users. (Responsiveness)	Reprography	4,91
The school support services' materials (technological equipment and furniture) are visually appealing. (Tangibles)	Library	4,26	The school support services' employees give individual attention to users. (Empathy)	Reprography	4,91

Table 7 – Top 5 best and worst perceived items (teaching staff perceptions)

Bottom 5			**Top 5**		
Item	**Service**	**Mean**	**Item**	**Service**	**Mean**
The school support services' materials (technological equipment and furniture) are visually appealing. (Tangibles)	Reprography	3,81	The school support services' employees are sympathetic and reassuring to users. (Reliability)	Reprography	5,95
The school support services' physical facilities are visually appealing. (Tangibles)	Reprography	4,05	The school support services' employees are sympathetic and reassuring to users. (Reliability)	Academic Services	5,92
The school support services have up-to-date equipment. (Tangibles)	Academic Services	4,38	The school support services are provided at the time they were promised, which are reasonable. (Reliability)	Reprography	5,92
The school support services' materials (technological equipment and furniture) are visually appealing. (Tangibles)	Academic Services	4,43	The school support services' employees use simple and clear oral and written language in their interaction with users. (Responsiveness)	Library	5,92
The school support services' IT system is operational. (Responsiveness)	Academic Services	4,46	The school support services' employees' behavior is polite. (Assurance)	Library	5,92
The school support services' IT system is operational. (Responsiveness)	Reprography	4,59	The school support services' employees give personal attention to users. (Empathy)	Library	5,92
The school support services' facilities have adequate internal signs. (Tangibles)	Reprography	4,59			

The interview with the school vice-dean occurred after the SERVPERF data has been collected and analyzed. As previously mentioned, the purpose was to better understand the results obtained from the questionnaires and to discuss the relevance of the use of this particular instrument to assess students and teaching staff satisfaction with the services and, based on that assessment, better manage their quality.

The results obtained from the answers to the questionnaire matched to a great extent the school's vice-dean perspective. He anticipated positive results from the study in terms of overall satisfaction level, as well as the existence of differences between the perceptions of students and teaching staff regarding the three services. Differences would arise mainly because teaching staff has been working in the school for several years and, as such, knows better the services staff with whom has an empathic relationship. The differences detected between services, mainly regarding the *tangibles* dimension, were also foreseen due to their physical location which differs considerably in terms of spaces occupied.

Regarding the worst perceived items, the vice-dean assumed his will to address them and improve the situation. Some aspects were already being addressed, such as the informatic system, while others, such as the opening hours of the reprography services, depend on the possibility of hiring more staff which is a decision that cannot be solely taken by the school leadership. He also regrets not being able to allocate the reprography to a more pleasant space, but unfortunately the school does not have any other physical spaces available to install this service. In the future, and if there are additional funding available, the vice-dean intends to overcome the deficiencies pointed out in the services both by students and teaching staff, as well as address other aspects of these services, in order to improve the satisfaction level of its users.

The vice-dean found the use of the SERVPERF instrument pertinent and relevant, and raised his willing to use the same questionnaire in the future to monitor the users' satisfaction with these services and to validate improvement actions implemented to solve the causes behind the worst perceived items. He also argued that the study could be useful for other higher education institutions, as they could have "a more concrete idea of how certain services are perceived by those using them, namely students and teaching staff".

The findings obtained with the SERVPERF application and the interview with the school vice-dean led to a set of recommendations meant to improve the support services quality and the degree of satisfaction of their users:

- a review of accessibility and signaling aspects;
- identification of the needs for new equipment for the reprography and reformulation of its allocation within the available facility;
- if additional funding is available, hiring of new staff; if not, exploring other alternatives to have more staff allocated to some services (e.g. internships; students association support; new ways of welcoming new students);
- extension of opening hours;
- improvement of the service's response capacity during peak service periods;

- development of a specific survey to find out what are the main weaknesses of the informatic system;
- check, in a systematic way, the collection of information from the users' suggestion boxes, ensuring a careful analysis of their complaints/suggestions and assess whether there are concrete measures aimed at improving users' satisfaction;
- periodically apply short questionnaires to assess users' satisfaction in order to verify if improvement actions implemented in the services are being effective.

LESSONS LEARNED AND CONCLUDING REMARKS

The purpose of this paper was to illustrate how the SERVPERF instrument can contribute to HEIs quality management, by providing relevant information on users' perceptions of the quality of support services. The results of the empirical case clearly corroborate this contribution.

Firstly, it was possible to adapt the instrument for the school context and to make it clear and simple enough to be able to collect a significant number of answers from both students and teaching staff. In fact, the adhesion of both groups to the survey denotes to a certain extent their willingness to give their perceptions on the analyzed services and to contribute to their quality improvement. In a time where students' voice should be given a significant attention in the scope of HEIs quality management systems, this instrument may indeed be a good option to take this group's views into account when managing the quality of support processes, ensuring that all resources are fit for purpose and accessible, as foreseen in the ESG (2015).

Secondly, the results obtained through the application of the SERVPERF instrument allowed to identify some of the weakest aspects of the services assessed and to propose a set of recommendations to improve them. Furthermore, these aspects matched the perspectives of the school vice-dean, which to a certain extent confirms the validity of the instrument as a mechanism capable of collecting relevant and pertinent data for decision-making about the quality of support services. As such, this instrument provides the opportunity for HEIs to respond to both ESG (2015) and A3ES References since it is a mechanism for the collection and analysis of information on the maintenance, management, and suitability of services. Besides, the data collected with the application of SERVPERF contributes to guarantee the corresponding decision-making around services and resources (A3ES, 2016).

Overall, and in the same line of previous studies (e.g. Brochado, 2009; Azar and Khan, 2012; Law, 2013; Hamid and Yip, 2019), it was possible to conclude that the SERVPERF is adequate to measure the perceived quality of an HEI support services, which is one more contribution to further validate the SERVPERF instrument in the higher education context. Moreover, and even more pertinent, is the fact that the data collected through such an instrument can indeed boost decision making around support services and, as such, contribute to the implementation of more effective quality management systems in HEIs.

Additionally, the current study has also highlighted the importance of comparing students and teaching staff perceptions in order to have a sounder identification of strengths and improvement areas. As shown in the literature review, the simultaneous consideration of more than one stakeholder when measuring service quality in HE is an originality of our research.

The study has however some limitations the authors acknowledge, namely the fact that it is based on a sole HEI. Also, the results obtained from the assessment of the three support services' quality have only been discussed with one of the school's vice-deans. In the future, it would be good to extend the study to other HEIs in Portugal, to be able to further validate the potential of the SERVPERF instrument as a useful tool for the quality management of these organizations' support processes. This validation would imply the discussion of the results of each HEIs to its several decision-making bodies, particularly with those in charge of the institutions' quality management systems.

Furthermore, it is fair to say that despite the proved usefulness of the used SERVPERF instrument in the higher education context, in the future it would be interesting to think about the possibilities of improving the instrument itself, by including a scale of importance for the items/dimensions in analysis. This improvement could further help decision makers in their tasks, by allowing them to put their improvement efforts in the service aspects more important for students and teaching staff.

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APPENDIX

Table A – SERVPERF studies in HE

List of papers selected for analysis
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Table B – Perception analysis by service quality item

(SERVPERF Instrument) – Tangibles

Item	**Tangibles**	**Service**	**Students**		**Teaching staff**		**Test**
			Mean	**SD**	**Mean**	**SD**	**MW (p)**
1.1.	The school support services have up-to-date equipment.	Academic Services	4,31	1,23	4,38	1,48	0,730
		Reprography	4,37	1,19	4,70	1,41	0,175
		Library	4,33	1,21	4,70	1,13	0,067
1.2.	The school support services' physical facilities are visually appealing.	Academic Services	4,53	1,22	4,86	1,44	0,068
		Reprography	4,01	1,34	4,05	1,65	0,864
		Library	4,63	1,35	5,32	1,20	**0,004**
1.3.	The school support services' facilities have adequate internal signs.	Academic Services	4,51	1,35	5,43	1,24	**0,000**
		Reprography	4,09	1,41	4,59	1,54	0,076
		Library	4,29	1,47	5,41	1,19	**0,000**
1.4.	The school support services are accessible to disabled people.	Academic Services	4,65	1,46	5,51	1,45	**0,001**
		Reprography	4,58	1,50	5,08	1,80	**0,042**
		Library	4,55	1,50	5,41	1,59	**0,001**
1.5.	The school support services' materials (technological equipment and furniture) are visually appealing.	Academic Services	4,06	1,46	4,43	1,42	0,317
		Reprography	3,92	1,41	3,81	1,66	0,639
		Library	4,26	1,49	5,03	1,24	**0,008**
1.6.	The school support services' employees are well dressed and appear neat.	Academic Services	4,78	1,35	5,62	1,26	**0,000**
		Reprography	4,72	1,36	5,22	1,70	**0,013**
		Library	4,82	1,30	5,68	1,08	**0,000**

Table C – Perception analysis by service quality item

(SERVPERF Instrument) – Reliability

Item	Reliability	Service	Students		Teaching staff		MW test (p)
			Mean	SD	Mean	SD	
2.1.	The school support services are provided as planned.	Academic Services	4,83	1,35	5,54	1,19	**0,003**
		Reprography	4,83	1,27	5,57	1,24	**0,002**
		Library	4,81	1,27	5,62	1,14	**0,001**
2.2.	The school support services' employees are sympathetic and reassuring to users.	Academic Services	4,70	1,41	5,92	1,16	**0,000**
		Reprography	4,91	1,27	5,95	1,08	**0,000**
		Library	4,80	1,41	5,89	1,17	**0,000**
2.3.	The school support services are provided correctly and error-free.	Academic Services	4,79	1,25	5,62	1,21	**0,000**
		Reprography	4,92	1,17	5,84	1,07	**0,000**
		Library	4,85	1,22	5,84	1,07	**0,000**
2.4.	The school support services are provided at the time they were promised, which are reasonable.	Academic Services	4,68	1,33	5,78	1,08	**0,000**
		Reprography	4,94	1,37	5,92	0,95	**0,000**
		Library	4,81	1,29	5,86	1,03	**0,000**

Table D – Perception analysis by service quality item

(SERVPERF Instrument) – Responsiveness

Item	Responsiveness	Service	Students		Teaching Staff		MW test (p)
			Mean	**SD**	**Mean**	**SD**	
3.1.	The school support services' employees use simple and clear oral and written language in their interaction with users.	Academic Services	4,86	1,17	5,86	1,13	**0,000**
		Reprography	4,91	1,22	5,86	1,18	**0,000**
		Library	4,97	1,22	5,92	1,09	**0,000**
3.2.	The school support services' employees explain the procedures to the users.	Academic Services	4,59	1,34	5,76	1,26	**0,000**
		Reprography	4,69	1,36	5,76	1,12	**0,000**
		Library	4,70	1,27	5,78	1,11	**0,000**
3.3.	The school support services' employees provide prompt services to the users.	Academic Services	4,60	1,26	5,70	1,13	**0,000**
		Reprography	4,73	1,27	5,81	1,10	**0,000**
		Library	4,71	1,23	5,81	1,13	**0,000**
3.4.	The school support services' employees are always willing to help students.	Academic Services	4,60	1,39	5,84	1,09	**0,000**
		Reprography	4,78	1,30	5,89	0,99	**0,000**
		Library	4,65	1,41	5,89	0,99	**0,000**
3.5.	The school support services' employees are never too busy to respond to users requests promptly.	Academic Services	4,34	1,39	5,22	1,29	**0,001**
		Reprography	4,46	1,30	5,30	1,27	**0,000**
		Library	4,53	1,35	5,43	1,19	**0,000**
3.6.	The school support services' IT system is operational.	Academic Services	4,37	1,42	4,46	1,76	**0,622**
		Reprography	4,43	1,35	4,59	1,80	**0,313**
		Library	4,37	1,33	4,68	1,81	**0,109**

Table E – Perception analysis by service quality item

(SERVPERF Instrument) – Assurance

Item	Assurance	Service	Students Mean	Students SD	Teaching Staff Mean	Teaching Staff SD	MW Test (p)
4.1.	The school support services' employees' behavior is adequate.	Academic Services	4,75	1,29	5,84	1,19	**0,000**
		Reprography	4,80	1,24	5,89	1,05	**0,000**
		Library	4,82	1,22	5,89	0,97	**0,000**
4.2.	The school support services' employees transmit a feeling of safeness in their transactions with users.	Academic Services	4,61	1,34	5,73	1,15	**0,000**
		Reprography	4,72	1,28	5,76	1,04	**0,000**
		Library	4,69	1,27	5,84	0,96	**0,000**
4.3.	The school support services' employees' behavior is polite.	Academic Services	4,65	1,28	5,78	1,16	**0,000**
		Reprography	4,75	1,30	5,86	1,03	**0,000**
		Library	4,72	1,25	5,92	0,89	**0,000**
4.4.	The school support services' employees' have the knowledge to give adequate answers to users' requests.	Academic Services	4,73	1,31	5,54	1,30	**0,000**
		Reprography	4,78	1,31	5,62	1,21	**0,000**
		Library	4,85	1,26	5,76	1,06	**0,000**

Table F – Perception analysis by service quality item

(SERVPERF Instrument) – Empathy

Item	Empathy	Serviço	Students Mean	Students SD	Teaching Staff Mean	Teaching Staff SD	MW Test (p)
5.1.	The school support services' employees give individual attention to users.	Academic Services	4,73	1,35	5,76	1,16	**0,000**
		Reprography	4,91	1,34	5,76	1,12	**0,000**
		Library	4,69	1,31	5,86	0,92	**0,000**
5.2.	The school support services opening hours are convenient to users.	Academic Services	4,30	1,42	4,97	1,28	**0,006**
		Reprography	4,26	1,43	5,05	1,18	**0,001**
		Library	4,45	1,41	5,59	0,90	**0,000**
5.3.	The school support services' employees give personal attention to users.	Academic Services	4,61	1,32	5,78	1,15	**0,000**
		Reprography	4,63	1,30	5,86	1,00	**0,000**
		Library	4,64	1,28	5,92	0,98	**0,000**
5.4.	The school support services' employees have users' best interests at heart	Academic Services	4,42	1,25	5,43	1,21	**0,000**
		Reprography	4,49	1,28	5,54	1,12	**0,000**
		Library	4,50	1,28	5,57	1,09	**0,000**
5.5.	The school support services' employees understand users' specific needs.	Academic Services	4,58	1,33	5,51	1,28	**0,000**
		Reprography	4,61	1,29	5,59	1,19	**0,000**
		Library	4,65	1,33	5,65	1,14	**0,000**

The Relationship between Quality Management and Innovation

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ABSTRACT

Purpose: The purpose of this study is to understand the relationship between quality management and innovation, since although quality and innovation issues are dealt with extensively, there is still little information on this relationship.

Project/Methodology/Approach: For this study, an exploratory bibliographic research was conducted in order to extract the most important ideas from the literature.

Findings: Most studies suggest a positive link between quality management practices and innovation performance in firms, although there are also studies suggesting a neutral or negative relationship. The focus on quality as a competitive tool is crucial but insufficient, and innovation emerges as a new way of meeting customer requirements and expectations. The coexistence of quality management practices and innovation management practices seems to be important although difficult to achieve.

Research limitations/implications: The literature review was limited to a database.

Practical Implications: The implementation of quality management systems in parallel with innovation poses enormous challenges, as the philosophy governing the two areas can be contradictory. This requires that companies have well-structured and knowledgeable teams.

Originality/Value: This study contributed to a better perception and systematization of the relationship between quality and innovation.

Keywords: Innovation, Quality, Relationship of Innovation with Quality, Review.

Paper type: Literature review

INTRODUCTION

The introduction of total quality management has played an important role in the development of contemporary management practices. Quality is considered an essential strategic factor to achieve success in companies' businesses. To improve the competitive position in the market and improve business performance, most companies around the world, whether large or small, have applied the principles of total quality (Hoang, Igel, & Laosirihongthong, 2006). However, in a knowledge-based society, high quality alone is not enough. Quality is not a basis for sustainable competitive advantage and needs to be complemented by innovation practices.

Innovation has been a major concern for researchers and professionals, as the literature provides conflicting theoretical arguments on the relationship between total quality management and innovation. It is not certain whether total quality management practices support or hinder the development of innovation (Prajogo & Sohal, 2001). The contribution of total quality management to innovation, although it attracts considerable attention, has not been sufficiently exploited in previous research, so that there is still not enough information about the relationship between the two (Perdomo-Ortiz, González-Benito, & Galende, 2006).

This study aims to investigate, in an exploratory way, the relationship between quality management and the innovation performance of a company, as well as the contribution of specific practices that quality management may have. There are two distinct thoughts on the relationship between quality management and innovation. Some believe that quality management supports innovation, implying that organizations that have implemented a quality management system will succeed in innovation. Others argue that a quality management system hinders innovation (Kim D. Y., 2010). The intention is to explore the nature of this relationship.

METHODOLOGY

This study is based on a bibliographic search, initially made through the reading of books related to the subject and then through a search and selection of articles in the Google Academic database, focused on the relationship between quality and innovation. The keywords used during the search of the articles were: innovation, quality, technology, relationship between quality and innovation, impact of quality and innovation, link between quality and innovation. The criterion used in the selection of articles was the choice of those articles that directly addressed the relationship between quality and innovation and where this was the central theme of the article.

BASIC CONCEPTS

This section will address the basic concepts related to quality and innovation, as well as the respective standards on which they are based.

Quality

There is no single definition of quality, since it is a subjective concept that is directly related to the perceptions of each individual. Its meaning is not always clear and objective, being a term difficult to define but easy to recognize, being associated with something good or exceptional. Thus, the quality of a product and/or service is related to its attributes and characteristics that may or may not satisfy the needs of an individual.

As defined in NP EN ISO 9000:2015 (IPQ, 2015a) Quality is understood as the "degree of satisfaction of requirements given by a set of intrinsic characteristics of an object" and the success of any organization depends directly on its ability to mobilize and organize the means and resources necessary for the realization of products and/or services that meet the requirements, needs and expectations of its customers. Therefore, quality is the "engine" of any organization's success, and its recognition is the distinguishing factor for the choice of products and/or services. The development of a culture based on quality principles and its consequent values will pave the way for the effectiveness and continuous improvement of methods and processes (Pinto & Soares, 2018).

In 1980, total quality management spread globally as a management philosophy (Goldman, 2005). Total Quality Management is defined as "an integrated approach to achieve and sustain high quality results, with a focus on maintenance and continuous process improvement and defect prevention at all levels and in all functions of the organization, in order to meet or exceed customer expectations" (Flynn, Schroeder, & Sakakibara, 1994).

Quality standards are published by national or international agencies and serve two main purposes. They constitute a systematic repository of knowledge about quality management and are a multi-purpose management tool. A standard is a document of voluntary application, unless there is a legal document that makes it mandatory. Standards are considered a suitable reference for the market for which they are intended and are therefore used in processes of legislation, accreditation, certification, metrology, technical information and commercial relations (IPQ, 2020a).

In the area of quality, three standards stand out:

1. ISO 9000 describes the concepts and fundamental principles of quality management that are applied globally, i.e. this standard specifies the terms and definitions that are applicable to all

quality management and quality management systems standards that are developed by ISO/TC 176, the largest technical committee of ISO (IPQ, 2015a).

2. ISO 9001 is the most widely used management system standard worldwide and is the international reference for the certification of quality management systems. This standard was created in international terms in order to define the best quality practices to be adopted, with a central focus on customer and other stakeholders' expectations of the organization. ISO 9001 adopts a process approach, which incorporates the PDCA cycle of continuous improvement (a methodology that promotes continuous improvement, developed in four phases, planning, executing, verifying, acting, and can be applied to each process and to the whole system) and integrates risk-based thinking, allowing not only customer loyalty but also the competitiveness of the organization based on the pillars of sustainability (IPQ, 2015b).
3. ISO 9004 provides guidelines that enable any organization to achieve sustained performance in a complex, demanding and continually changing environment through a quality management approach. It can be used to assess the maturity of a quality management system and is aimed at organizations wishing to achieve excellence (defined as a high degree of execution of requirements and satisfaction of expectations), in addition to meeting the requirements of ISO 9001 (IPQ, 2011).

Quality management is a holistic management philosophy that promotes all the functions of an organization through continuous improvements and organizational changes (Kaynak & Hartley, 2005).

Innovation

Innovation can be understood as the development and implementation of new ideas over time and is based on four factors: new ideas, people, transactions and institutional context (Van de Ven, 1986).

Innovation does not exist without invention. The invention is a new idea, a model, a prototype that appears for a new product or process, while innovation consists in putting that idea into practice, either an economic or a social application of the invention (Fagerbeg, 2009). Innovation and invention are clearly related, since innovation arises from invention, from the combination of several inventions or the adaptation of something that has already been invented in other circumstances. In short, innovation is a multidimensional and systemic process.

The definition of innovation is somewhat ambiguous. There is an approach that views the concept in dual terms, according to the level of novelty, considering as radical innovation the discovery of a new idea and incremental innovation as the exploitation of an existing idea (Negas, Carvalho, & Sousa, 2020).

Another duality of the definition has to do with the technological and non-technological dimension. Technological innovation is often associated with technology-based product and process innovation. This technological vision of innovation has been the target of some criticism, namely not being able to capture innovation in services, and innovation in companies does not relate only to the development of technological applications, but also to organizational restructuring and the adoption of relations with the market through new marketing practices. The importance of product, process and organizational system integration for the implementation of new ideas and new business opportunities in the market is highlighted. For these reasons, the concept of innovation should encompass the non-technological dimension (Negas, Carvalho, & Sousa, 2020).

In the study conducted by (Crossan & Apaydin, 2010) the authors confront the types of innovation by mentioning another duality: a process to create ideas and implement them properly; and the results, that is, the final results of implementation, which can be a product or a process. According to (Bon & Mustafa, 2013) the process is the way and techniques by which an idea is created and implemented, while the results are the products, services or business processes. There are two main inputs that are essential to the results performed. First, an organization's team must be able to create and sustain the configurations that support innovative ideas, and second, decide which ideas have potential. Understanding and knowing the types of innovation is essential for organizations. Each type of innovation needs specific treatment and responses from the organization.

The Oslo Manual (OECD/Eurostat, 2018) tries to clarify and standardise these concepts. The term innovation can be used in different contexts to refer to a process or an outcome. To avoid this confusion, this manual uses the term “innovation activities” to refer to the process and the term “innovation” limited to outcomes (OECD/Eurostat, 2018). Innovation activities include all research, development, production, financial and commercial activities carried out by a company that result in innovation in the companies. The document proposes two main categories of innovation:

- Product Innovation: is a new or improved good or service that differs significantly from previous goods or services of the company and has been introduced to the market;
- Business Process Innovation: is a new or improved business process for one or more business functions that differs significantly from previous business processes of the company and that have been used in the company.

Product innovation is divided into two types (goods and services) and business process innovation is divided into six broad types (production of goods or services, distribution and logistics, marketing and sales, information and communication systems, administration and management, product and business process development).

In the area of innovation there have been efforts to produce innovation management standards which are inspired by quality standards. Spain was the first country to implement an innovation management standard, followed closely by Portugal (IPQ, 2006a; IPQ, 2006b; IPQ, 2006c; IPQ, 2006d). The European Union is currently studying the possibility of implementing a European standard.

RELATIONSHIP BETWEEN QUALITY AND INNOVATION

Positive relationship between quality management and innovation

Most of the articles obtained in this study suggest a positive relationship between quality management and innovative performance. Several articles present empirical results that positively relate a set of quality management practices to innovation (Prajogo & Hong, 2008; Kim, Kumar, & Kumar, 2012; Martinez-Costa & Martinez-Lorente, 2008; Bourke & Roper, 2017; Perdomo-Ortiz, González-Benito, & Galende, 2006; Hoang, Igel, & Laosirihongthong, 2006; Baldwin & Johnson, 1996; Flynn, Schroeder, & Sakakibara, 1994; Samson & Terziovski, 1999). The studies highlight that quality management practices can provide opportunities to apply quality management principles and techniques in innovative activities, allowing for the efficient detection of customer needs, originate knowledge sharing and foster systems and processes improvement. The adoption of a quality management system helps companies to innovate according to customer needs, minimizing activities without value and reducing the time and costs of developing new products. Quality management conceives customer satisfaction, innovation and the improvement of the performance of most businesses. These articles are briefly described below.

A study (Kim, Kumar, & Kumar, 2012) analysed eight different quality management practices to see which of these practices related directly or indirectly to five types of innovation. Using a sample of ISO 9001-certified product and/or service companies, the authors verified that process management is directly and positively related to incremental, radical and administrative innovation. The organizational capacity to manage processes plays a vital role in identifying routines, establishing a learning basis and supporting innovative activities.

In an empirical study of 451 companies, the authors found that the use of quality management tools leads to product and process innovation (Martinez-Costa & Martinez-Lorente, 2008). Implementing quality management tools can help identify potential areas for innovation, develop innovation plans and produce innovative products and processes (Martinez-Costa & Martinez-Lorente, 2008).

Another study (Perdomo-Ortiz, González-Benito, & Galende, 2006) analyses the links between the broader concepts of total quality management and entrepreneurial innovation capacity. The study involved 102 companies from the machinery and instruments sectors for measurement, analysis and control. The study suggests that both concepts are compatible and allow identifying which dimensions of total quality management explain the creation of entrepreneurial innovation capacity.

(Bourke & Roper, 2017) use data from a group of Irish companies to verify the influence of adopting quality improvement methods on the performance of innovation in the short and long term. The temporal effects are complex but there appears to be destabilising effects in the short term but beneficial in the long term. The results suggest that maximising the return on innovation and quality improvement requires an adaptive implementation of quality improvement methods, time and sequence of their adoption.

Studies have identified a positive relationship between total quality management and innovation in terms of market speed (Flynn, Schroeder, & Sakakibara, 1994) and the level of innovation in organizations (Baldwin & Johnson, 1996).

Most studies agree that quality will always be critical for competitiveness, but innovation is likely to continue to grow as a key element of competitive strategy (Leavengood, Anderson, & Daim, 2014). One of the challenges of today's companies is to determine how to integrate the two.

The study of (Schniederjans & Schniederjans, 2015) seeks to address the relationship between social and technical quality management and innovation. The authors argue that social and non-technical quality management practices are positively associated with innovation. The positive relationship between quality management and innovation is moderated by the effects of the organisational dimension, task and ethics of the manager. However, there is no significant relationship between technical quality management and innovation.

The strength of the relationship between total quality management practice (independent variables) and organizational performance (dependent variables) was tested by (Samson & Terziovski, 1999). The authors consider innovation as a dependent variable that represents the organizational performance measured by the number of new products produced. Total quality management has a significant positive relationship with product quality and product innovation performance, although the magnitude of the relationship seems to be greater in relation to product quality. The study does not confirm a significant positive effect on innovation. However, the correlation between the two variables seems to depend on the specific sector under study.

(Zhao, 2011) addresses key issues of innovation and quality, helping to develop strategies to improve the integration between innovation and quality, suggesting that the critical factors of successful innovation management incorporate and are interrelated to the main concepts associated with quality management. The challenge for organizations to gain competitive advantage in the marketplace is to exploit innovative opportunities and deliver what the customer wants in the fastest, most effective and economically viable way.

In general, and to conclude this section, there are two general arguments put forward by studies suggesting a positive relationship between quality and innovation. One argument is that innovation is the result of combining different activities such as research and development, process development, design, marketing, organizational restructuring, resource management and employee development and is therefore likely to be supported by total quality management practices that enhance the combination of multifunctional activities. The other argument is that total quality management practices help create an environment and culture that supports innovation. One of the main requirements of total quality management is customer satisfaction. Companies implementing a total quality management system need to explore and find ways to best meet customer needs and expectations and this makes companies innovative in developing and launching new products and/or services to meet customer needs (Hoang, Igel, & Laosirihongthong, 2006).

Negative relationship between quality management and innovation

Although a minority, there are studies which argue that total quality management can hinder innovation (Kim & Marbougne, 1999; Prajogo & Sohal, 2001). The main argument is that the customer focus is on product conformity (product quality) but not on product novelty (product innovation), and that these perspectives are in practice conflicting or do not feed off each other (Atuahene-Gima, 1996).

The study of (Singh & Smith, 2004) does not find sufficient statistical evidence to suggest that total quality management is related to innovation performance in enterprises. They suggest that the relationship between these concepts may be more complex than suggested by the mentioned studies. However, they do not completely reject the arguments that total quality management can support innovation and admit that total quality management can facilitate innovation, but only to a very limited extent.

While admitting evidence of a positive influence on innovation, advocates of the opposite view believe that the implementation of total quality management is likely to create more disadvantages for innovation over time than advantages (Prajogo & Sohal, 2001).

A negative relationship between quality management and green innovation

The study of (Li, Zhao, Zhang, Chen, & Cao, 2017) identified a negative relationship between quality and green innovation, which seems to give additional substance to the arguments presented in the previous section. The study analysed the impact of quality management on green innovation, considering the moderating role of environmental regulation. With a sample of 407 observations obtained from the top 100 listed companies in China from 2008 to 2014, the results indicate that quality management was significantly correlated negatively with green technological innovation and green innovation management. In addition, environmental regulation significantly mitigates the negative impact of quality management on green innovation management and green technology innovation. The results seem to indicate that quality management limits corporate focus on developing existing production and management systems rather than exploiting green innovation geared towards sustainable development. Thus, quality management tools and practices may not necessarily be in line with sustainability considerations (Maxwell & Vorst, 2003; Luttropp & Lagerstedt, 2006) and may not be properly integrated with more environmentally sustainable business models (Asif, Searcy, Zuthi, & Fisscher, 2013). The significant mitigating effect of environmental regulation illustrates the importance of better institutional design and implementation (Ford, Steen, & Verreynne, 2014). Appropriate environmental standards and strict environmental monitoring can trigger green innovations within companies and can thus reduce compliance costs (Li, Zhao, Zhang, Chen, & Cao, 2017).

SUMMARY OF RESULTS

Table 1 summarizes the essential points (objectives and conclusions) of the studies analyzed for this work.

Table 2 - Summary of objectives and conclusions of the various studies analyzed.

Authors	Objective	Conclusions
(Prajogo & Hong, 2008)	Demonstrate the effect of total quality management practices on research and development performance in terms of product quality and innovation.	Total quality management, as a set of generic principles, can be adapted in environments of different manufacturing or production areas.
(Kim, Kumar, & Kumar, 2012)	Analyse the different quality management practices and investigate which of these practices related directly or indirectly to five types of innovation.	A set of quality management practices, through process management, have a positive relationship with five types of innovation under study. Process management is directly and positively related to incremental, radical and administrative innovation.
(Martinez-Costa & Martinez-Lorente, 2008)	Clarify the relationship between total quality management and organisational innovation.	Evidence that total quality management promotes innovation in companies. Evidence that companies that apply total quality management and therefore develop organizational innovation get more benefits. Firms where innovation is continuous can see total quality management not only as a good way to improve quality, but as a way to facilitate the innovation process.

Authors	Objective	Conclusions
(Perdomo-Ortiz, González-Benito, & Galende, 2006)	To study the relationship between quality and innovation through the analysis of the existing links between the broader concepts of total quality management and the capacity for business innovation.	Total quality management favours the development of entrepreneurial innovation capacity. The study revealed that both concepts are compatible and make it possible to identify which dimensions of total quality management explain the creation of entrepreneurial innovation capacity.
(Bourke & Roper, 2017)	Highlight the short and long term beneficial effects of adopting quality improvement methods on product innovation performance.	Maximizing the return on innovation and quality improvement requires an adaptive consideration of the nature of quality improvement methods, the time and the sequence of their adoption.
(Leavengood, Anderson, & Daim, 2014)	Research quality and performance management practices in relation to quality and innovation of forest product manufacturers.	Companies that focus only on quality saw innovation as an end and not as a means to achieve a certain business goal. The main result was based on the way companies interact with customers, i.e. companies focused on innovation proactively seek to identify and meet the needs demanded by customers, while companies focused on quality mainly emphasize responding to customer complaints.

Authors	Objective	Conclusions
(Zhao, 2011)	To contribute to the theory and practice of research and development management in order to develop strategies for integrating innovation and quality	Effective innovation management, combined with the principles of total quality management, improves the quality of research and development by promoting cutting-edge applications of the results researched.
(Schniederjans & Schniederjans, 2015)	Address the relationship between social and technical quality management and innovation.	Social quality management practices and non-technical practices are positively associated with innovation. The positive relationship between quality management and innovation is moderated by the effects of organisation dimension, task and ethics of the manager. However, there is no significant relationship between technical quality management and innovation.
(Hoang, Igel, & Laosirihongthong, 2006)	To investigate the relationship between total quality management practices and innovation performance.	It confirms that total quality management has a positive impact on the company's ability to innovate, but not all total quality management practices increase the company's ability to innovate. Only leadership and people management, strategic and process management and open organization have shown a positive impact on innovation performance.
(Li, Zhao, Zhang, Chen, & Cao, 2017)	Highlighting the preliminary impact of corporate quality management on green innovation and the moderating role of environmental regulation in this relationship.	Quality management is significantly correlated negatively with green technological innovation and green innovation management. In addition, environmental regulations significantly mitigate the negative impact of both.

CONCLUSION

This article contributes to enrich the literature on the relationship between quality management and innovation, a topic which, although pertinent, is still under researched.

Two main arguments are put forward by studies suggesting a positive relationship between quality and innovation. One argument is that innovation, as a process, is made up of various business activities and, as such, total quality management practices have a positive impact on those activities that lead to innovation. The other argument is that total quality management practices help to create an environment and culture that supports innovation.

The main argument of studies suggesting a negative relationship is the finding that the two practices (quality and management) are based on different assumptions and objectives, which are by nature antagonistic or conflicting, and which will lead to problems sooner or later.

Most of the articles selected in this literature review and cited in this study point to a positive relationship between quality and innovation, but there are articles that point to a marginal, negative or non-existent positive relationship between both terms. All sides present empirical evidence.

It seems pertinent to point out from this review that the integration of the two dimensions, more or less explicitly or in a more or less intense way, seem to be a necessity dictated by the competitive contingencies of the current market. Quality without innovation does not give the company a sustainable competitive advantage, and innovation without quality does not allow the maintenance of the competitive advantage that innovation gives. On the one hand, quality is an essential requirement for market acceptance and reputation, and on the other hand, innovation confers sustainability and long-term vision. Thus, the interconnection between the two concepts seems irrefutable. However, it is still not well understood, and the limited available literature that directly addresses the relationship between quality and innovation seems to indicate an area that needs further study.

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Reducing the percentage of broken drops using the lean six sigma methodology

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ABSTRACT

Purpose – This paper aims to demonstrate the empirical study regarding the implementation of a Lean Six Sigma project through the DMAIC method to reduce the percentage of broken drops in the manufacturing process of a food factory.

Design/methodology/approach – The research was carried out through a single and longitudinal case study, where the interviews followed the sequence of steps and practices observed in the theoretical framework.

Findings - The analysis performed in this project indicated that the presence of bubbles in the dough had influenced the percentage of broken drops. The main root causes of the problem were identified as conveyor belt, nozzles, and cold chamber. The project allowed an increase of 4.79% in the final process yield index and the sigma level evolved from 2.87σ to 3.25σ.

Research limitations/implications - The research results are limited to a single case study, and it is not intended to generalize the results to other types of industry.

Practical implications – This paper can be used as a reference guide for researchers and practitioners to implement operational excellence projects in their organizations, following the steps presented in this study.

Originality/value – This paper is a real case study on Lean Six Sigma practices in a food factory. This sector still lacks empirical studies regarding the implementation of operational excellence strategies.

Keywords: Lean Six Sigma, DMAIC, Operational Excellence, Food Industry.

Paper type: Case study.

INTRODUCTION

The implementation of operational excellence strategies in industrial organizations has generated significant results in terms of cost, quality, and speed. The adoption of principles, techniques, and tools inherent to Lean Six Sigma (LSS) methodology is directly associated with this type of strategy. It requires the implementation of improvement projects with financial impact implemented by *ad hoc* teams and led by professionals with proficiency in the various techniques inherent in this approach. Currently, the adoption of this strategy has enabled companies to meet and exceed customer expectations in a changing and competitive global environment (Byrne et al., 2007).

While the Lean Manufacturing (LM) approach discusses the importance of waste across all process and focusses on speed and time, the Six Sigma (SS) methodology focusses on reducing defects and process variability as well as reducing costs, which makes it evident that the joint-use LSS strategy offers a solution that creates more robust, flexible and cost-efficient process (Andersson et al., 2014). The integration of these two approaches (LSS) increases the possibility of efficiency and effectiveness gains. It helps to achieve superior performance faster than the implementation of each strategy in isolation (Salah et al., 2010).

The food industry can be characterized by technological product disruptions and incremental improvements associated with the acquisition of new process technologies (Raimundo et al., 2017). Moreover, the perishability of food products and the distances traveled in the supply chain, demand innovations in the areas of logistics, organization, production, and marketing (De Mori, 2011). Factors such as food safety, quality, and level of services are fundamental in this sector, where industrial costs must be carefully controlled to maintain organizational competitiveness (Dudbridge, 2011).

LSS projects have been widely applied to a variety of industries including automotive assembly processes (Lee-Mortimer, 2006; Pugna et al., 2016), telecommunications (Psychogios et al., 2012; Andersson et al., 2014), pharmaceutical industry (Goodman, 2012), health products (Jirasukprasert et al., 2014), and so on. However, the literature on the implementation of LSS projects in the food industry highlights some specific applications, for example, initiatives to reduce the variation in the weight of processed food (Desai et al., 2015; Dora and Gellynck, 2015), lead time and customer complaints reduction (Nabhani and Shokri, 2009), as well as the reduction in the dimensional variation of the product (Seow et al., 2004). Given these considerations, studies with applications aimed at reducing breakages in food products are scarce in the literature on LSS.

The purpose of this article is to present an empirical study regarding the implementation of an LSS project through the DMAIC method, whose objective is to reduce the percentage of broken drops in the manufacturing process of candies and drops factory. Based on the investigation performed, the paper reveals the activities carried out in each stage of the DMAIC method, as well as the tools and techniques implemented in these stages. Therefore, this paper can be used as a reference guide for researchers and practitioners to implement operational excellence projects in food industries.

This article is structured as follows. In the next section, a previous literature review on LSS is presented. Section 3 describes the methodological procedures defined to achieve the objective of this study. Section 4 presents the results of the empirical research following the sequence of steps performed in the implementation of the LSS project. Finally, the last section presents the main insights and conclusions, as well as suggestions for future work.

LITERATURE REVIEW

The LM approach gained worldwide popularity after the publication of the book *The Machine that Changed the World*, written based on research on trends in the automobile industry, with emphasis on the efficient Toyota Production System (TPS) developed at Toyota by Taiichi Ohno after the Second World War in the 1940s (Womack et al., 1990). LM principles focus on the value stream analysis to identify and eliminate seven forms of waste (*muda*) on the shop floor: over-production, defects, unnecessary inventory, inappropriate processing, waiting, motion and excessive transportation (Womack and Jones, 1996).

The Six Sigma methodology was conceived at Motorola in 1987 to improve the quality of its products dramatically. Two years after this initiative, the company received the Malcolm Baldrige National Quality Award in recognition of the results obtained with the program (Pande et al., 2001). However, the success of this approach was reinforced in the following decade, based on the results obtained at General Electric, under the leadership of Jack Welch, who at that time held the position of CEO (Chief Executive Officer) at the company (Black and Revere, 2006). Since then, this approach has been adopted by several organizations to improve products, services, and processes (Evans and Lindsay, 2014).

LSS approach can be defined as “a business strategy and methodology that increases process performance resulting in enhanced customer satisfaction and improved bottom-line results” (Snee, 2010). The proposal for integration between the two approaches was presented in the book *Lean Six Sigma: Combining Six Sigma with Lean Speed* (George, 2002). Although these approaches have different origins and can be differentiated by their specificities, the effectiveness of complementarity between them has become common sense among practitioners and researchers.

The isolated application of the SS techniques cannot remove all types of waste from the process and applying only LM principles cannot control the process statistically and remove variation from the process (Corbett, 2011). Regarding the organizational structure, it is observed that SS techniques are implemented by few trained individuals in the company, while LM principles cover all levels and require that all employees should receive training and empowerment to identify and eliminate activities that do not add value (Higgins, 2005).

The programmes SS prescribe that improvement actions are performed in a project-by-project fashion (De Koning and De Mast, 2006). However, projects that involve LM tools implemented for existing products and processes through the DMAIC (*Define*, *Measure*, *Analyze*, *Improve*, and *Control*) methodology are recognized as Lean Six Sigma Projects (Snee, 2010). Still, for product and process development activities (Design for Six Sigma), the DMADV methodology (*Define*, *Measure*, *Analyze*, *Design*, and *Verify*) is recommended (Mehrjerdi, 2011). Thus, the logical sequence of actions for implementing an LSS project in existing processes includes five phases (De Koning and De Mast, 2006; Montgomery and Woodall, 2008; Ismyrlis and Moschidis, 2013):

(1) *Define*: Establish the characteristics-specifications of product that satisfy the customer. Defines the problem to be solved, including customer impact and potential benefits. Develop project charter and build a team.

(2) *Measure*: Translate the problem into a measurable form. Identify potential root causes. Develop and validate measurement systems. Estimate the short-and long-term process capability and determine the sigma performance level.

(3) *Analyze*: Identify key process variables that cause defects. Benchmarking key product performance metrics (gap analysis). Formulate, investigate, and verify root cause hypotheses. Find areas that need to be addressed.

(4) *Improve*: Design an effective and efficient solution to the process to improve the performance of the CTQs. Verify and gain approval the final solution.

(5) *Control*: Implement a mistake-proof process. Monitor and control critical process. Develop out of control action plans. Transfer responsibility, share learning, and best practice.

Critical Success Factors (CSF) are very important for the effectiveness of operational excellence strategies in companies. In this context, Jeyaraman and Teo (2010), highlight the following CSF: established LSS dashboards; effective training program; projects stories, best practices sharing and benchmarking; project prioritization selection; frequent communication and assessment on the result;

company financial capability; competency of MBB/BB; reward and recognition system; management engagement and commitment; and organization belief and culture.

RESEARCH METHODOLOGY

In order to achieve the objectives of this research, a single and longitudinal case study was carried out. Because it is characterized as a qualitative approach, the case study can be essentially interpretive, where the researcher describes the scenario through a constructivist perspective, using data analysis to identify themes or categories through a personal lens (Creswell, 2007). This type of research is recommended for studies that have as characteristics the need to find answers to the “how” and “why” questions, little or no control over the event by the researcher, and focus on contemporary problems within a real context (Yin, 2009).

The research was carried out in the second half of 2019 at a company that produces candies and cookies, which will be called “Alpha”. The company is located in the State of São Paulo, Brazil and has more than 500 direct employees. The selection criteria considered the current context of the company, which in recent years has implemented several LSS projects and provided green belt, black belt, and lean practitioners training. A case study protocol was developed to structure the data collection. Semi-structured questionnaires were used to capture the interviewees' perspectives. Thus, only people who had active participation in the execution of the project were interviewed.

Data were collected and recorded through interviews involving employees who participated in the project and document analysis. The interviews were conducted in a semi-structured manner. The application of a case study must cover the development of a conceptual framework based on the literature on the research topic and explain narratively the main elements of the research, including the variables involved, the main constructs and possible causal relationships (Voss et al., 2002). An analysis regarding “how” the company has implemented the LSS project was carried out as well as the sequence of activities and the techniques and tools used. The analysis was guided by the DMAIC model and contrasted with the recommended practices in the relevant literature.

RESULTS

In the last five years, Alpha has implemented several actions related to the LSS approach as part of its operational excellence strategy to reduce quality costs, due to failures in the manufacturing process, and increase customer satisfaction. This strategy includes the internal training of green belts, black belts, and lean practitioners. The green belt program certification at Alpha includes an 80-hour training program, the application of a theoretical test, as well as the implementation of a project with a financial impact on the organization. These projects follow the steps of the DMAIC method where project teams can use various techniques and tools present in the LSS toolbox. The project to reduce the percentage of broken drops emerged from this context and its breakdown will be presented below.

Define phase

LSS projects must include the definition of metrics and key indicators to guide the selection of the project and identify its objectives, as well as the definition of a specific problem of the process to be improved (Snee, 2010). These actions were recorded in a project charter that presents a clear definition of the problem observed, the Project Team (PT), the scope of the project, the Critical to Quality (CTQs) factors, the expected benefits and the schedule of the steps provided for in the DMAIC method. Table 1 summarizes the information contained in the project charter.

Table 1 – Project Charter.

Project title	**Reduction the percentage of broken drops**
Problem Statement	Broken drops represent a significant quality defect generated during the manufacturing process, which causes imperfections in the packaged product and contributes to the increasing waste in the manufacturing line. This problem has generated some complaints from Alpha' customers for not receiving the product as expected.
Project team	1 trainee (project leader), 3 machine operators, 1 maintenance supervisor, 1 process analyst, and 1 quality assistant.
CTQs	*Broken / Chipped Drops*. Non-conformity noticeable to the naked eye and which can be caused due to the fragility of the product or incorrect processing.
Expected Benefits	Reduction of quality costs related to product disposal, reprocessing, and returns. Increased customer satisfaction.

The project started in April 2018 and was completed in February 2019. Seven people from different areas participated in the project, which was led by a trainee, who during the project's execution period, was a candidate for green belt certification at the company. After the production director has approved the project charter, the first step was to visualize the data on the historical percentage of broken drops (%BD) in a time series plot shown in Figure 1.

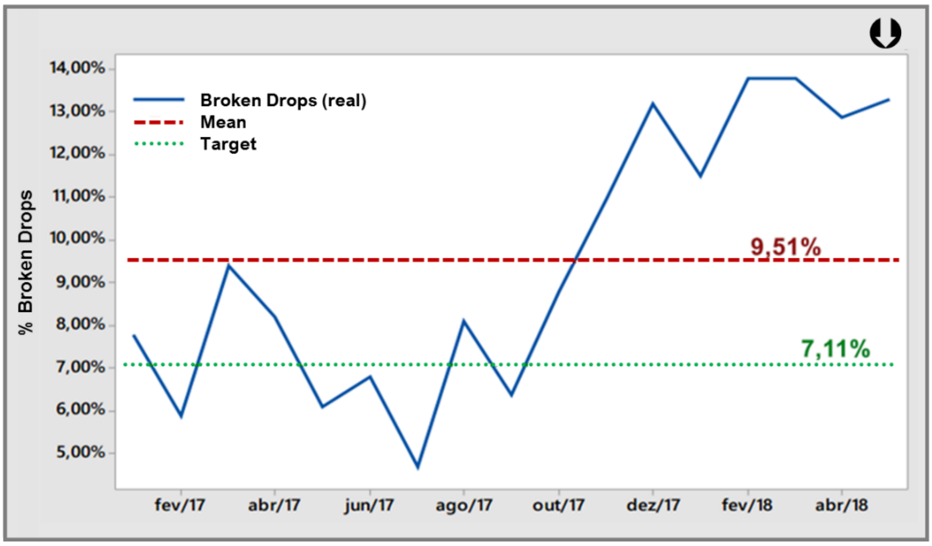


Figure 1 – Percentage of broken drops.

The time series plot was elaborated by PT to understand the historical nature of the average of the percentage of breakage in the drops. Figure 1 shows data from February 2017 to April 2018. Thus, there is a significant increase in the percentage of BD from July 2017. The investigation then focused on verifying this hypothesis, finding ways to understanding the causes, and finally mitigating the causes to improve the process so that the BD percentage is reduced to a level where the company can be more successful in marketing its products.

To define the goal of the project, PT carried out a gap analysis between the current performance of the process and a benchmark value. The target was then defined considering a subtraction of 50 percent of that reference value from the average observed in the period. Therefore, the final goal established for the project was "*reduce the percentage of broken drops from 9,51% to 7.11% by the end of February, 2019*". Define phase was concluded after PT has prepared a SIPOC matrix (Suppliers, Input, Process, Output, and Customers) to identify the main activities related to the manufacturing process as well as their inputs (x's) and outputs (Y's), as shown in Table 2.

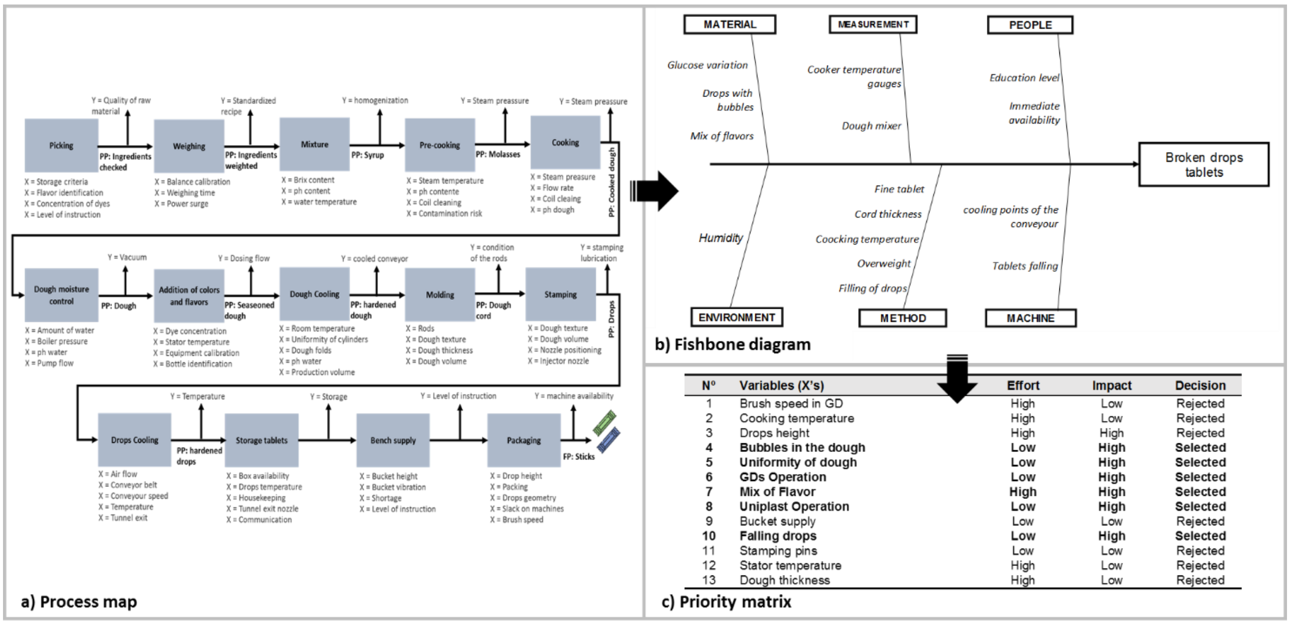
Table 2 – SIPOC matrix.

Suppliers	***Input***	***Process***	***Output***	***Customers***
Warehouse	Approved recipe / raw material	Weigh	Ingredients weighted	Cooker 3,000
Scale / pot	Ingredients weighted and picked up	Cooking the dough	Dough cooked	Uniplast
Cooker 3,000 / Uniplast	Dough cooked and folded	Stamp drops	Drops stamped	Cooling Tunnel
Stamping / Chiller	Drops stamped	Cool drops	Crystallized drops	Packing machines GD's
Cooling Tunnel / Warehouse	Crystallized drops and packaging	Pack drops	Finished drops	Storage

Measure phase

Measure phase includes the translation of the problem addressed into a measurable and quantitative way as well as the measure and estimation of the current performance of the process through the sigma level. An essential activity in this phase is the formulation of the transfer function, which can be explained in mathematical terms such as $Y = f(x_1, x_2, \dots x_n)$, where the root causes "x's" represent the inputs of the process that are converted into outputs "y's" (Pyzdek and Keller, 2003).

The activity of identifying and selecting the root causes for the formulation of the transfer function was carried out systematically by PT. Figure 2 illustrates the sequence of steps performed for this purpose. The first step was performed during a brainstorming section where the participants developed a high-level map (Figure 2a) identifying the process parameters (PP) for each stage of the process as well as their inputs (x's) and CTQs (Y's). Then the section was directed to the construction of a fishbone diagram (Figure 2b) to complement the identification of the variables inherent to the project problem. Among the 41 variables identified, 13 were submitted to a prioritization matrix (Figure 2c), where six key variables were finally selected: x_1 – *bubbles in the dough*; x_2 – *uniformity of dough*; x_3 – *GDs operation* (packing machine); x_4 – *mix of flavor*; x_5 – *uniplast operation* (product molding machine); and x_6 – *falling drops*.



Nº	Variables (X's)	Effort	Impact	Decision
1	Brush speed in GD	High	Low	Rejected
2	Cooking temperature	High	Low	Rejected
3	Drops height	High	High	Rejected
4	**Bubbles in the dough**	**Low**	**High**	**Selected**
5	**Uniformity of dough**	**Low**	**High**	**Selected**
6	**GDs Operation**	**Low**	**High**	**Selected**
7	**Mix of Flavor**	**High**	**High**	**Selected**
8	**Uniplast Operation**	**Low**	**High**	**Selected**
9	Bucket supply	Low	Low	Rejected
10	**Falling drops**	**Low**	**High**	**Selected**
11	Stamping pins	Low	Low	Rejected
12	Stator temperature	High	Low	Rejected
13	Dough thickness	High	Low	Rejected

c) Priority matrix

Figure 2 – Steps to identify and select root causes.

The next activity was to estimate the current capacity of the process through the sigma level. However, to validate the quality of the data collected, the PT performed an "Attribute Agreement Analysis" with three inspectors in each work shift. Inspection by attribute implies a binary classification of the type "approved" or "failed". Analysis Between Appraisers can be performed using Minitab software by examining the frequency with which each inspector agrees with the classification made by the other inspectors or by the Fleiss Kappa coefficient of correlation. According to Bass and Lawton (2009), this coefficient is within the range of -1 to +1. If it is equal to +1, there is a perfect agreement and if it is -1, there is complete disagreement. Besides, the Kappa value of 0.7 indicates an acceptable measurement system.

A total of 30 samples randomly chosen were examined by three inspectors, revealing a low agreement between the appraisers (Kappa coefficient equal to 0,3162). To solve this problem, the PT developed an operational definition and instructed all inspectors in this standard. After performing this training, a new study revealed that the new Kappa coefficient was equal to 1, thus evidencing agreement between appraisers and measurement system reliability.

The calculation of the sigma level must be performed according to the type of data referring to the characteristic of the measured quality. For continuous data, the sigma level can be obtained from process capacity indices (Cp and Cpk). For discrete data, which refer to the percentage of samples that contain one or more defects, measures of defect proportion and Final Process Yield are used, according to expressions (1) and (2).

$$Proportion\ Defective = \frac{Number\ \ of\ defective}{Number\ \ of\ units} \tag{1}$$

$$Final\ Yield = 1 - Proportion\ Defective \tag{2}$$

The sigma level correspondent to the final yield was obtained from a query on a conversion table between final yield and sigma levels that consider the “discount” of 1.5σ, considering the hypothesis that in the long term the process it can deviate by more or less 1.5σ (Pande et al., 2001). A sample of 3,000 units was randomly taken from the process, and 253 defectives (broken drops) were identified. Thus, the current sigma level for the drops manufacturing process was reported as 2.87σ since the final yield is equal to 0.916.

Analyze phase

The main objective of the Analyze phase is the identification of the root causes of broken drops through data analysis techniques. The data analysis approach used at Alpha encompasses the application of LM tools, Failure Modes and Effects Analysis (FMEA), as well as statistical analysis through basic graphics and hypothesis testing. After selecting the probable causes that affect the *“Y”* of the project, the PT conducted a sequence of analyzes involving statistical techniques appropriate to the characteristics of the project.

Considering that two of the potential causes are categorical variables (x_1 – *bubbles in the dough*; and x_4 – *flavor mix*), the PT has considered that the most suitable hypothesis test for the project would be the chi-square test (χ^2). To perform the tests, random samples were taken in different work shifts, according to an operational definition. According to Berenson et al., (2002) the χ^2 test statistic is equal to the square difference between the observed and expected frequencies, divided by the expected frequency in each cell, added over all cells, as shown in expression 3:

$$\chi^2 = \sum \frac{(f_0 - f_e)^2}{f_e} \tag{3}$$

Where f_0 is the frequency observed in the real count in a given cell of a contingency table, and f_e is the expected or theoretical frequency, that is expected to be found in a given cell if the null hypothesis is true. A first test was performed to verify the hypothesis that the various types of flavors (x_4) influence the percentage of broken drops. The null (H_0) and alternative (H_1) hypotheses for conducting this test are shown below:

H_0: *The occurrence of broken drops is independent of the flavor mix.*

H_1: *The occurrence of broken drops is dependent of the flavor mix.*

Once formulated, the hypotheses were tested through the Chi-Square test for association running on Minitab software. According to Montgomery and Runger (2010), the independence hypothesis must be rejected if the value of the χ^2 statistic test is too large. Moore et al., (2009) point out that the *p-value* represents the rejection when this value is less than a significance value. As seen in Table 3, Pearson's Chi-square statistic is 4.278 (*p-value* = 0,370) and the Likelihood Ratio Chi-Square statistic is 4,111 (*p-value* = 0,391). Thus, with a 5% significance level, the EP did not reject the null hypothesis and so there was not enough evidence to conclude that the percentage of broken drops depends on the flavor mix. Furthermore, Table 3 also presents the contribution values for the Chi-square statistic (contribution χ^2), which represents the squared standardized residues for each cell. These show that the largest difference between the frequencies observed occurs in the case of strawberry flavor but the overall difference, considering all flavors, is not statistically significant.

Table 3 – Chi-Square test for association between broken drops and the flavor mix.

		Strawberry	Eucalyptus	Cherry	Melon	Grape	All
Broken	*Count*	12	6	12	8	7	45
	Expected count	7,61	9,51	11,73	7,61	8,56	
	Contribution χ^2	2,538	1,293	0,006	0,020	0,283	
Not broken	*Count*	228	294	358	232	263	1375
	Expected count	232,39	290,49	358,27	232,39	261,44	
	Contribution χ^2	0,083	0,042	0,000	0,000	0,009	
All		240	300	370	240	270	1420

Pearson Chi-Square = 4,278; DF = 4; P-Value = 0,370
Likelihood Ratio Chi-Square = 4,111; DF = 4; P-Value = 0,391

A second statistical analysis involved other hypothesis test considering the possibility of an association between the breakage of drops and the presence of bubbles in the dough. This hypothesis was formulated by PT, who considered that the formation of bubbles (x_1), which can occur at different stages of the manufacturing process, could make drops more fragile and susceptible to breakage. The hypothesis pair was formulated as follows:

H_0: *The occurrence of broken drops is independent of the presence of bubbles in the dough*.

H_1: *The occurrence of broken drops is dependent of the presence of bubbles in the dough*.

The data were submitted to the chi-square test for the statistical confirmation of the formulated hypotheses. Table 4 shows that Pearson's Chi-square statistic is 146,597 (*p-value* = 0,000) and the Likelihood Ratio Chi-Square statistic is 108,831 (*p-value* = 0,000). Both *p-values* are smaller than the 0.05 significance level. This time the EP rejected the null hypothesis concluding that there is statistical evidence to conclude that the percentage of broken drops depends on the presence of bubbles in the product. It is seen that the frequency of products with bubbles observed in the broken drops is 3.66 times the expected frequency and in fact the cell Chi-squares are all significantly large, which indicates a strong relationship between the type of the drop (broken or not) and the whether or not there were any bubbles.

Table 4 – Chi-Square test for association between broken drops and bubbles.

		With bubble	Without bubble	All
Broken	*Count*	57	32	89
	Expected count	15,57	73,42	
	Contribution χ^2	110,18	23,37	
Not broken	*Count*	118	793	911
	Expected count	159,43	751,58	
	Contribution χ^2	10,76	2,28	
All		175	825	1000

Pearson Chi-Square = 146,597; DF = 1; P-Value = 0,000
Likelihood Ratio Chi-Square = 108,831; DF = 1; P-Value = 0,000

Then, PT decided to investigate the percentage of breaks in the different control points of the process of cooling and packaging, which presented a higher incidence of bubbles and broken drops. Random samples of 100 drops were taken for each control point in the different work shifts. The results of this measurement were presented in the form of a Pareto chart illustrated in Figure 3. It is possible to observe that three specific points of the process (conveyor belt, cold chamber, and spout) are responsible for 85.3% of the broken drops. Therefore, these variables were selected as the main root causes of the problem addressed in the project. In addition to these variables, causes not treated statistically (x_3 – *GDs operation*; x_5 – *uniplast operation*; and x_6 – *falling drops*) were also considered as opportunities for improvement in the next phase of the project.

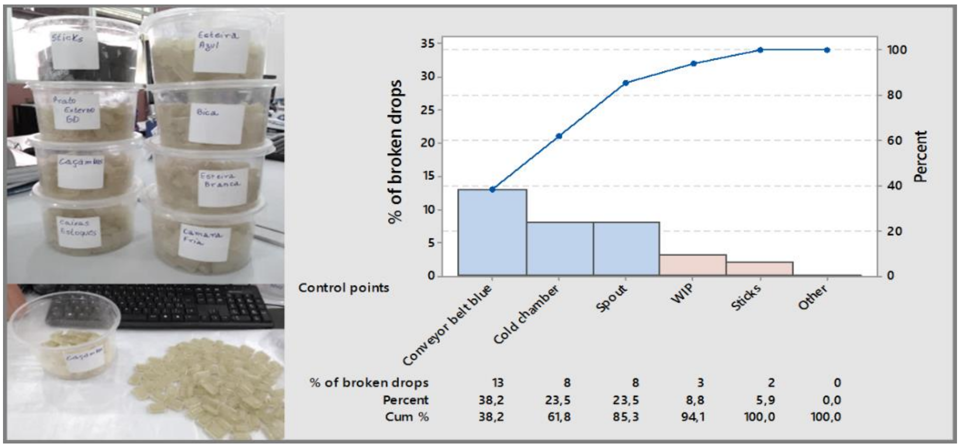


Figure 3 – Pareto Chart for percentage of broken drops.

Improve phase

After verifying and selecting the root causes of the project in the Analyze phase, the next step was the generations of ideas and solutions to act on these root causes to improve the performance of the process. The functionality of the actions characterizes this phase through the design and implementation of adjustments to the process to improve the performance of the CTQs (De Koning and De Mast, 2006). In this context, PT conducted a brainstorming meeting to discuss and select the best solutions. An action plan was developed to guide the implementation of the following actions:

- Replacement of the squeegee used to fold the dough.
- Implementation of conveyor temperature control.
- Adjustment of the spout.
- Review of the GD's operational standard.
- Implementation of one-point lessons at Uniplast 03.
- Implementation of a control plan for the adjustment of the nozzles and operation of the cold chamber.

It should be noted that part of these actions did not require any financial approval and was implemented through a *kaizen* event with the mobilization of operators. After carrying out all these actions, PT conducted a new study following the same procedure adopted in the Measure phase to estimate the new sigma level for the improved process, which evolved from 2.87σ to 3.25σ, resulting in a new final yield index of 95.99%. Although the percentage change for this index seems small (only 4,79%), it corresponds to a 52,57% reduction in the occurrence of defects per million opportunities, according to the six sigma conversion table previously cited.

Before starting the Control phase, PT prepared a time series graph to verify the sustainability of the improvements obtained with the project. Figure 4 shows the significant decrease in the percentage of broken drops from the implementation of the Measure, Analyze, and Improve phases started in June 2018. The target established for the project (7.11%) was reached in October 2018, and the percentage of broken drops remained below that value in the following months. This performance shows the effectiveness of the actions implemented.

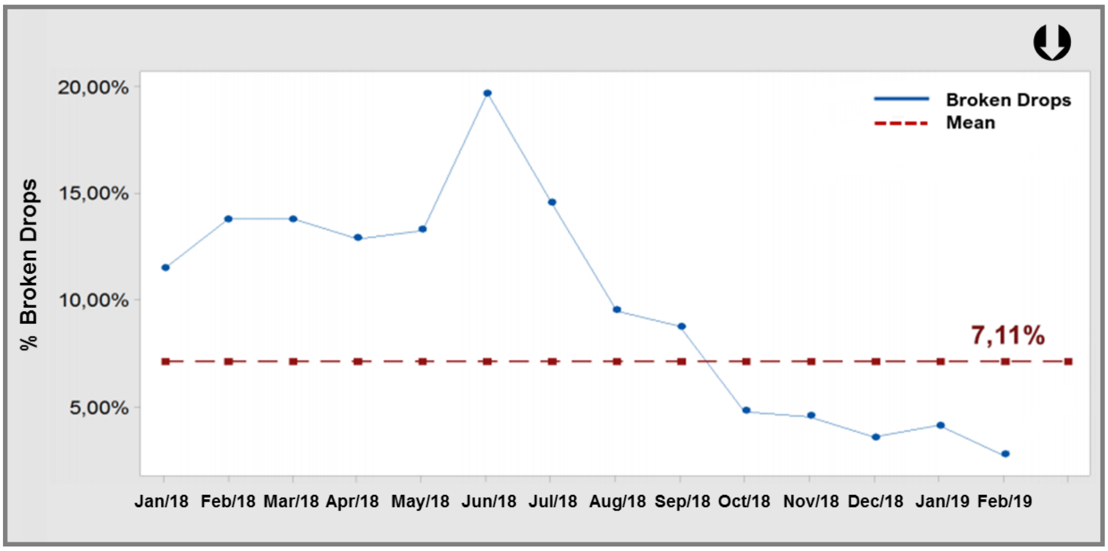


Figure 4 – Percentage of broken drops (after improvement actions).

Control phase

In the Control phase, the responsibilities assigned to the project team are transferred to the people who operate the process benefited by the LSS initiative. During this phase, it is necessary to implement actions that ensure the control of activities to avoid deterioration of the process in the long term. Therefore, the activities carried out in the Control phase are directed towards the establishment of standards measures to maintain the performance, and correct any possible problem, as needed (Ismyrlis and Moschidis, 2013).

The first action implemented in this phase refers to the implementation of a control plan for the operation of the nozzles and the cold chamber in the cooling stage. This plan included a visual inspection method in the cooling stage, clarifying the inspection points (spout and GD's), those responsible for this activity, the new measurement method, and its frequency, as well as the corrective action procedure when deviations are observed. Besides, a review of the inspection plan was carried out where those responsible for this activity receive training in the new standard.

To monitor the proportion of defects and identify any special causes of variation a P Chart was elaborated according to the expressions (4), (5), and (6), where: D is the number of defective units (broken drops) in a random sample of size n, and P is the proportion estimated from preliminary samples. The control limits (Upper Control Limit and Lower Control Limit) are estimated based on ± 3 standard deviations for a binomial distribution.

$$\overline{\boldsymbol{P}} = \frac{\boldsymbol{D}}{\boldsymbol{n}} \tag{4}$$

$$\boldsymbol{UCL} = \overline{\boldsymbol{p}} + \mathbf{3}\sqrt{\frac{\overline{\boldsymbol{p}}\,(\mathbf{1}-\overline{\boldsymbol{p}})}{\boldsymbol{n}}} \tag{5}$$

$$\boldsymbol{LCL} = \overline{\boldsymbol{p}} - \mathbf{3}\sqrt{\frac{\overline{\boldsymbol{p}}\,(\mathbf{1}-\overline{\boldsymbol{p}})}{\boldsymbol{n}}} \tag{6}$$

The implementation of Statistical Process Control (SPC) involves two distinct phases, known as Phase I and Phase II (Chakraborti et al., 2009). While Phase I is retrospective in nature and the primary interest is to understand the process better and assess process stability, Phase II (monitoring phase), consists of trying to bring a process in control by analyzing historical or preliminary data to eliminate any assignable causes of variation. However, in the context of implementing LSS projects, control charts are used to ensure that the improved performance of the process is sustained after the PT has completed its work and moved onto another project (Snee, 2010).

Regarding these considerations, the P Chart was initially developed to verify the stability of the process after the implementation of the improvement actions (Phase I). Figure 5 shows a P chart running on Minitab software, referring to 25 samples of 30 drops randomly taken from the packaging process. When the calculation of the lower control limit (LCL) results in a negative number, LCL is assumed to be equal to 0. Therefore, it is possible to verify that the percentage of defects varies around the average proportion (4.13%) without the presence of special causes or points outside the control limits. Also, there is no trend line formed by consecutive points close to any control limit, which shows a process under statistical control.

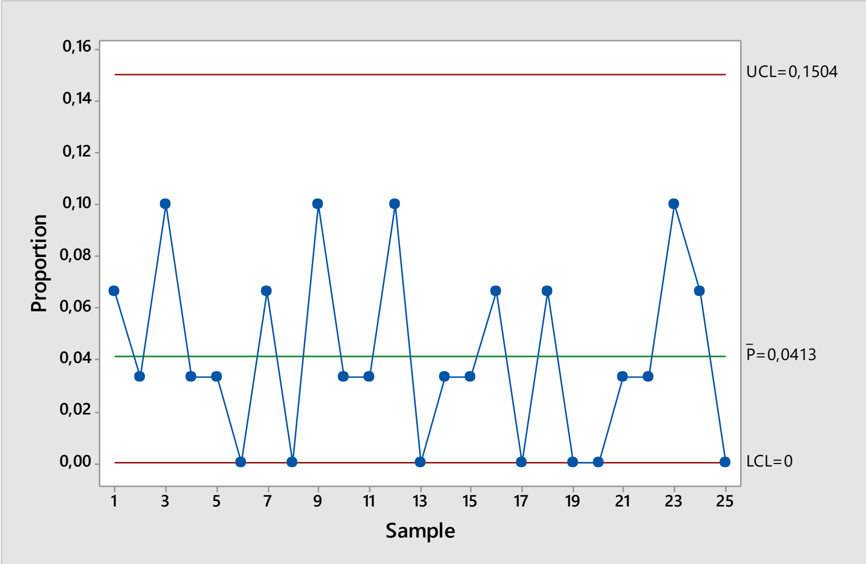


Figure 5 – *P* Chart for monitoring the percentage of broken drops.

After the end of the project, the statistical monitoring of the proportion of broken drops started to be conducted daily in the packaging process in a standardized way to verify the occurrence of assignable causes of variation (introduction to Phase II).

CONCLUSIONS

LSS approach is understood as a useful strategy of operational excellence suitable for the food industry and able to improve the organizational performance in terms of quality, cost, and speed. The current study started with the aim of reducing the percentage of broken drops in a Brazilian food factory. To achieve this objective, the company implemented an LSS project according to the DMAIC method. The project was defined from a bottom-up perspective, as part of a green belt certification program at the company.

The actions carried out in the Measure and Analyze phases revealed that some variables inherent to the manufacturing process contribute to the increase in the percentage of broken drops. These variables represent the following factors: (i) presence of bubbles in the dough; (ii) conveyor belt temperature; (iii) GD's operation; (iv) nozzle adjustment at Uniplast; and (v) operation of the cold chamber. The investigation also highlights the use of statistical tools to solve problems. The implementation of improvement actions resulted in a 66% decrease in the defective drops. As a result, the sigma level evolved from 2.88σ to 3.35σ.

This research is limited to the implementation of a single case, where some statistical techniques were used at a basic level. It can be assumed that operational excellence strategies differ in other companies and industries. However, although this study does not intend to generalize the results, this paper can be used as a reference guide for researchers and practitioners to implement operational excellence projects in food industries.

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Contributions to the development of an evaluation model of the organizational culture of food safety

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STRUCTURED ABSTRACT

Objective: This article has as the main purpose to make known the results collected during a research study focused on the development of a model aiming at the evaluation of organizational culture of food safety, taking into account the relative importance of potential indicators/metrics that may be suitable to assess it.

Project/methodology/approach: Metrics and indicators potentially suitable to assess the culture towards food safety were identified through bibliographic review. In addition, audit reports were consulted and contacts within the area of the food sector were gathered. The identified metrics/indicators were clustered considering the model proposed by the paper published by GFSI "Food Safety Culture". The indicators/metrics identified were evaluated through two online surveys, where the respondents were first asked to assess their importance (classification according to an importance 5-point Likert scale (1- not important,…, 5-extremely important)), and later the respondents were asked to identify in which sub-dimensions the metrics indicated should be included, taking into account each proposed dimension (survey still in progress). Later, statistical tests were performed to assess the normality of the variables (Kolmogorov-Smirnov test) and their statistical relevance according to several grouping variables (Kruskal-Wallis test). These statistical tests were developed in the IBM SPSS v.26 software program. Afterwards, a preliminary structural equations model was developed using the AMOS Software program.

Conclusions: The results show different perceptions of experts in the food field, it was possible to conclude several aspects regarding the importance of each dimension and its impact on the evaluation of the food safety culture in an organization. Comparing the results obtained from the respondents and the SEM model the main conclusions were that the dimension with the highest importance score was the DIM2 "People", for respondents and DIM1 "Mission and Vison" by the analysis with Structural equation model. It was also possible to determine the most important or relevant metrics for each dimension. In this way for some dimensions the metrics coincided between respondents and the model, but for others the results where different. It was also possible to conclude the different impacts of the dimensions in the level of food safety culture, through direct and indirect paths (mediating analysis).

Research limitations/implications: The data used in this research was gathered in 2019 so, a more recent data collection should be carried out in order to ascertain at which extent these conclusions are valid. Also, it will be necessary explain the remain 69% of variables not considered in this study that affects the level of food safety culture.

Practical implications: These results will be adopted to develop an improved, more reliable and rigorous model in the future. This work will have an impact on academia (the proposal to evaluate the culture of food safety) and on companies (the evaluation of the commitment to the culture of food safety).

Originality/value: Currently, there are scarce instruments/tools that allow the evaluation of the Food Safety culture, both in terms of effectiveness and efficiency. The reported results will support the development of a new proposal to evaluate the commitment of the Food Safety Culture that, in the final analysis, will indicate to companies an optimized path to reach a higher level of maturity (within this area).

Keywords: Food Safety Culture; Food Safety; Metrics; Evaluation Model; SEM model.

Type of work: Research work

INTRODUCTION

The culture of food safety is a specific form of organizational culture that represents the way an organization deals with food safety and has been defined (Griffith et al., 2010a) as “the aggregation of predominant, constant, learned attitudes, values, and beliefs, shared and that contribute to the hygiene and food safety behavior used in a specific food handling environment ”. The research theme “Contributions to the development of an Organizational Culture Assessment Model for Food Safety” is a scarce explored topic, but with a growing interest in the present. However, the theme “Food Safety Culture” has been addressed by many authors over the past few years. After an extensive and comprehensive bibliographic review on the subject, it was possible to conclude that few authors have developed evaluation models aiming at the assessment of the commitment towards the culture of food safety and that those that exist are not very specific and usually very rudimentary. This study is based on the model proposed by the Global Food Safety Initiative (GFSI) on the commitment towards culture of food safety, which is characterized by five dimensions, 1) Mission and Vision; 2) People; 3) Consistency; 4) Adaptability; 5) Dangers and Risk Awareness. It should be stated that each dimension is associated with several critical success factors. The main goal of this project is to develop a model for evaluating the culture of food safety in order to highlight the importance of safety in food handling throughout the life cycle of the foodstuff, and also to incorporate a positive mindset and efficient and fluid communication throughout the organization so that it can be achieved excellence in the quality of its products and workers. For this, it is necessary to define indicators, which will be the variables to be measured and which will subsequently populate each of the dimensions and sub-dimensions. After the identification of these metrics, the importance of each sub-dimension and consequently each dimension will be assessed. Once the metrics are gathered and organized, the scale supported by the proposed model will be effectively developed and validated. Initially, data collection was carried out through the contacts available in platforms such as LinkedIn and LimeSurvey. In addition, to support the information gathered, audit reports were analyzed, and a thorough bibliographic review was carried out on the metrics/indicators usually adopted to monitor the performance of organizations in the agrifood sector.

LITERATURE REVIEW

Food safety

Currently, food safety is a topic of great impact on the public opinion. Consumers are increasingly demanding improved food safety of the products they eat and, therefore, it is necessary to keep this topic in mind. Food safety can be defined as the assurance that the food consumed does not cause any harm to the consumer, as long as it is prepared or ingested following the rules of intended use, being intrinsically linked to the hygiene of foodstuffs. Thus, according to Regulation (EC) No. 852/2004, it is defined as the set of measures and essential conditions to control the hazards and risks of contamination, ensuring that foodstuffs are fit for human consumption (WHO / FAO; 2003).

Organizational Food Safety Culture

Organizational culture is the foundation of an organization and encompasses common beliefs that are manifested in habits and traditions (Mintzberg, 2000). On the other hand, it is the dynamic result existing in organizations (Schein, 2004) and also, the result of the cultural dynamics of the society in which the organizations/companies are inserted. The concept of organizational culture can then be referred as the system and norms that determine the behavior of the members of an organization, which is directly influenced by the cultural context in which an organization is included, *i.e.*, being the result of the reality and the cultural dynamics of the society in which the organization is included (Hofstede, Hofstede, & Minkov, 2010; Vaitsman, 2000). The food safety culture is a specific form of organizational culture that represents the way an organization deals with food safety and was conceptualized as "the aggregation of predominant, relatively constant, learned, shared attitudes, values, and beliefs, contributing to the behavior of hygiene used in a specific food handling environment " (Griffith et al., 2010a). Taking into account some of the cultural elements found in occupational safety and health, several authors have proposed components of the food safety culture applicable to the agrifood sector (Griffith et al., 2010b; Yiannas, 2009). In a simple way, the culture of food safety encompasses the set of beliefs that employees of food companies have about food safety, what they think is correct and incorrect, important or irrelevant to do to protect food against possible hazards and risks and, consequently, to protect the consumer being the most visible expression of this culture its behavior.

Evaluation and different types of Food Safety Culture models

Assessing culture is an approach to discovering transparencies to cultural strengths and weaknesses, which can help prevent disease and mortality for consumers, caused by contaminated food during its life cycle. Some manufacturers adopt cultural assessment systems to prevent their consumers from being exposed to food-borne risks and for brand protection and job security (Cameron & Quinn, 2006; Jespersen e Huffman, 2014; Seward,2012; referenced by (Jespersen, 2017). In this way, if culture evaluation systems exist and are adopted, it is necessary to determine the reliability of the results in relation to the accepted methods to evaluate their viability and rigor. However, over the years, different models for assessing food safety culture have emerged, which are presented below: Ball System (Ball, Wilcock, & Aung, 2009; Wilcock, Ball, & Fajumo, 2011); *De Boeck System* (Boeck, Jacxsens, Bollaerts, Uyttendaele, & Vlerick, 2016; Boeck, Jacxsens, Bollaerts, & Vlerick, 2015); *Denison System* (Denison & Mishra, 1995; Denison, 1997; Denison, Hooijberg, Lane & Lief, 2012, referred by (Jespersen, 2017)); *Jespersen system (*Jespersen e Huffman, 2014; Jespersen et al., 2016 referenced by Jespersen, 2017); *TSI system* (Taylor; Garat; Simreen; & Sarieddine, 2015, referenced by Jespersen, 2017); *Wright system* (referenced by (Jespersen, 2017); *CEB model* (CEB, 2016 referenced por (Jespersen, 2017); *NFS model* (NFS, 2016 referenced by (Jespersen, 2017).

Indicators and metrics

Management indicators are understood as the basic tools for the management of the organizational system, that is, they are measures adopted to aid describe the current situation of a given phenomenon, making comparisons, verifying changes or trends and evaluating the execution of the planned actions during a period, in this case, regarding food quality and safety. The quality of the indicators is defined as the measures of customer satisfaction and the characteristics of the product/service, that is, they are attributes that demonstrate the performance of certain activities and that are adopted by the food safety management system, regardless of whether their impact is positive or negative on customer service (Saraiva & Camilo, 2011). A set of associated, consistent and complementary indicators can give rise to a “dashboard”. The "dashboard" aims to provide global and synthetic information, allowing the development and implementation of a strategy, by monitoring the evolution of the defined goals. A system of indicators allows the organization to:

• Measure the state of the organization;

• Assess performance;

• Compare performances;

• Identify strengths and weaknesses;

• Track progress and changes over time.

In turn, the analysis of the indicators allows the organization to:

• Define objectives;

• Plan strategies and actions;

• Share results in order to inform and motivate people.

The selected key performance indicators must be measurable, allowing the organization to outline and define measurable goals, capable of predicting trends and identifying potential corrective and preventive actions, as well as promoting continuous improvement. The choice of the proper key performance indicators must be made by the top management, based on the needs for strategic and tactical decision making.

“Food Safety Culture - a position paper from the global food safety initiative, GFSI”

The document “A culture of food safety - a position paper from the global food safety initiative (GFSI)” was prepared by a GFSI technician from the working group (TWG) as a model for incorporating and maintaining a positive food safety culture in any company, regardless of size or focus. The purposes defined for a food safety culture is to investigate how shared values, beliefs and norms affect the mindset and behavior regarding food safety throughout the organization. The document was designed to aid the promotion of food industry professionals to improve and maintain a positive culture of food safety in their respective organizations. It offers the vision of experts from different industry segments who collectively bring international perspectives to this important issue of food safety culture. The emphasis is placed on:

• The essential role of leaders and managers throughout the organization, from the CEO to the workers; field and factory supervisors; from grocery stores to large franchises of restaurant organizations;

• Why communication, education, regular metrics, teamwork, and personal responsibility are vital to promote a positive food safety culture;

• How skills learned, including adaptability and awareness of hazards and risks in food safety, promote important practices in addition to a theoretical conversation about food safety.

The GFSI believes that practices dedicated to maintaining a safe food supply, globally, should be habitual and systemic. In addition, it is believed that these qualities can be developed naturally within a positive culture environment - although it requires conscious investment, strategic supervision and ongoing involvement on the part of the organization. The purpose of this document is to provide global information to GFSI stakeholders, to position on which organizational dimensions drive the maturity of food safety and how the organization's culture can be sustained over time. As such, the document is addressed to a wide range of stakeholders, including entrepreneurs, manufacturers, retailers, restaurant managers and food safety experts. The content presented is divided into five chapters each, addressing each of the five dimensions of the food safety culture (Fig. 1). These dimensions are based on the analysis of existing models adopted to assess food safety and organizational culture. Each chapter defines a specific dimension and explains why it is important to promote a culture of food safety. The chapters provide the reader with critical information on the areas an organization should examine if it wants to better understand its current food safety culture and make improvements to strengthen it.

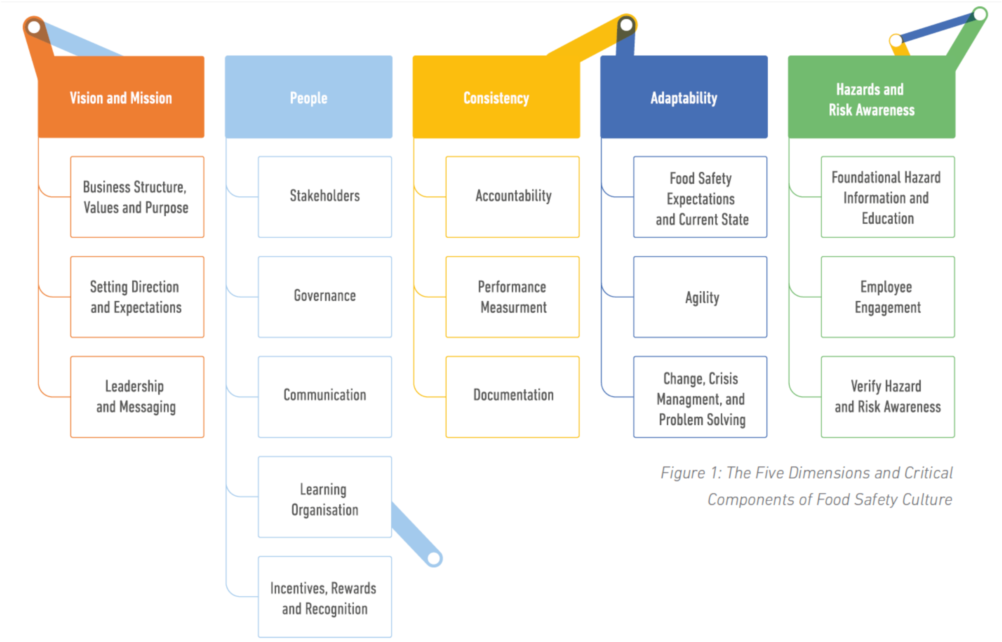

Figure 1: The five dimensions and critical compoents of food safety culture, by GFSI

DIMENSIONS PROPOSED BY GFSI

Mission and Vision

Organizational leadership sets the tone and the different contributions to food safety culture. The objectives of the vision and mission need not mention food safety specifically, although their importance must be reflected in company communications. Defining the direction, the organization should take helps to establish a good culture of food safety because it requires a clear, shared and embedded vision across the organization. The investment alignment ensures that the organization has adequate resources for food safety initiatives. The effective use of positive food safety messages across the organization is essential. The messages must be clear, consistent and adapted to different stakeholders. A good message structure and its respective tools must distribute vital food safety messages throughout the organization. The credibility of the organization's food safety messages depends on the value the organization attaches to food safety.

People

People are one of the critical components of a food safety culture. Employee behavior and activities contribute to food safety and potentially reduce or increase the risk of foodborne illness. It is important to establish a food security framework, with clearly defined individual roles and responsibilities. Key elements of this dimension include educating employees and reinforcing good behavior to create a safe environment and metrics to be met. To the extent that people have the power to promote food safety that will impact the organization's ability to adapt, improve and sustain its food safety culture. Good communication ensures that food safety messages are understood by everyone within the organization. All leaders must "walk the talk" and remain consistent in their messages to ensure that there is a clear understanding that food safety is a period of continuous improvement.

Consistency

Consistency refers to ensuring the alignment of food safety priorities, with people, technology, sources, and processes, to effectively implement a food security program and support its culture. Consistency occurs across a variety of related decisions, actions, and behaviors, including accountability, compliance, performance measurement, and documentation. Other essential processes where consistency is crucial, including risk definition, investment and consistent communications on food safety. Consistency needs to flow through all decisions, actions, and behaviors related to the organization, from top management to actions.

Adaptability

Adaptability refers to an organization's ability to adjust to changing influences and conditions. The change can be anticipated, or it can take the form of an event, such as a product or customer recall in question. In any company with a strong culture of food safety, its adaptability is reflected in its ability to participate, prepare, respond and adapt to change. Strong and ingrained leadership plays a significantly important role in how well a commercial company adapts to change and responds to crisis

Hazard and risk awareness

Understanding the dangers of all organizational levels and the functions performed, it is essential to establish an effective food safety culture. This can be done through continuing education, the use of metrics, rewards, disciplinary actions and recognition, and reinforcing the importance of recognizing and controlling food security risks

RESEARCH METHODOLOGY

An extensive, comprehensive, and thorough literature review was carried out aiming at the identification of the soundest published studies on this topic. It was possible to conclude that many published studies made it possible to collect information on the different subjects that this project covers. The collected data were later analyzed using statistical techniques. According to the literature, a specific, totally reliable technique is absent, *i.e.*, all existing research on techniques and methods is attributed to pros and cons, depending on the context in which they are adopted, being the most important characteristic the adaptation of the method to each specific goal. For this study, a survey was designed, developed, implemented, and held online in order to validate the information collected during a previous and complete review of the literature. Therefore, for the elaboration of the proposed methodology, the following topics were considered: 1) Existence of a set of indicators/metrics related to the organizational culture of food safety; 2) presentation of the indicators/metrics to a group of experts with knowledge in the food field, using an online survey and application of questionnaires to obtain concordant results among the specialists; 3) statistical analysis of the collected data and, finally, 4) development of the structural equation model.

As mentioned previously the work started with a high bibliographic search, for that, different methodologies were used, such as gray literature (use of doctoral and master's theses; scientific and technical reports; working papers or unpublished conference papers) and also, through databases of multidisciplinary scientific articles such as Scopus; Web of Science or Academic Search Complete; or even using digital document repositories, such as the repository of the University of Porto and the University of Minho, among others. In the last elements cited as research methodology, the process only consisted of inserting keywords on the topic of interest and then making a selection of the documents that most interested us, in the case and this work, issues related to food security; organizational culture; development of indicators and metrics; development of measurement models, etc.

Simultaneously with the bibliographic research, with the support of a large certification company, case studies were carried out in two companies in the agri-food sector that allowed the identification of metrics and indicators. In total, 57 metrics/indicators were identified, as can be seen in the table.

Subsequently, having the metrics identified, a questionnaire was developed to assess the importance of each metric in the respective dimension inserted having been disseminated through social networks, via LinkedIn, together with dissemination by e-mail. to some companies in the agri-food sector. At the end of the active period of the survey, 563 responses were collected, of which 383 were partial (which were excluded from analysis) and 180 complete, which were validated for the work in this study.

Then, the statistical treatments of the 180 validated responses were proceeded, with a descriptive statistical analysis and some statistical tests such as normality (Kolmogorov-Smirnov) and Kruskal-Wallis, with the help of the IBM SPSS Statistics 26 software.

Having successfully performed the statistical analysis, the structural equations model was developed and validated using the IBM SPSS AMOS 26 Graphics Software. Then, having the results of interest selected, the "Safety Culture Ladder" was used, which recognizes five stages that indicate the level of development at which the company operates in the field of food safety awareness. After the development of the model, its interpretation was made through a numerical scale, with intervals that delimit different levels to be reached or overcome. Between each level there are different objectives to be taken into account, which allow the company to raise or maintain at that level

1. Identification of metrics/indicators

After the literature review on the topic several metrics/indicators were identified on the domain of the culture of food safety and, with the help of experts in the food field, it was possible to determine a series of indicators (Table 1) for each dimension proposed for the GFSI. 57 indicators were identified, as can be seen in the table 1 below:

Table 3: Metrics and indicators found for each dimension

Dimension	Variable name	Metrics/Indicators
Mision and Vision	DIM1	
	V15_D1M1	Existence of objectives and a defined policy, both at the level of purpose and intention, either at food safety management system planning level or at Risk Assessment level, or company strategic level
	V16_D1M2	% of top managers with knowledge of Risk Assessment results.
	V17_D1M3	% of middle managers involved in Non-Conformity management
	V18_D1M4	% of production supervisors with knowledge of HACCP methodology (besides legal obligation)
	V19_D1M5	Number of annual food safety objectives and how relevant it is for those objectives to be accomplished.
	V20_D1M6	No. of Food Safety certificates
	V21_D1M7	Internal communication effectiveness
	V22_D1M8	Verify if there is a commitment to the culture in food security policy.
	V23_D1M9	Top management commitment to continuous improvement
	V24_D1M10	% of top management replies to Quality or Food Safety department communications
	V25_D1M11	Influence of Food Safety on corporate decision making (eg. whether actions are based on risk,

		profit, reputation, or as a standard business procedure).
	V26_D1M12	% of organization's investment associated with Food Safety
	V27_D1M13	Update of Food Safety communication
	V28_D1M14	Recognition for good conducts and accountability for bad behaviors
	V29_D1M15	Existence of a specific Food safety budget
People	DIM2	
	V30_D2M1	Communication with stakeholders about Food Safety responsibilities
	V31_D2M2	% of employees with knowledge of Food Safety objectives
	V32_D2M3	Communication of NC's by employees from the "ground floor".
	V33_D2M4	% of employees involved in the production / handling of foods with high understanding of your commitment to Food Safety.
	V34_D2M5	% of employees involved in the production / handling of foods with high understanding of the implications of NCs
	V35_D2M6	% of incentives due to good results obtained in Food Safety
	V36_D2M7	Importance given to Food Safety in the recruitment of workers
	V37_D2M8	% Investment in training dedicated to Food Safety area
	V38_D2M9	Investment / existence of a continuous training program in Food Safety
	V39_D2M10	Performance evaluation in Food Safety-related activities
Consistency	DIM3	
	V40_D3M1	% of NC's related to breach of responsibilities
	V41_D3M2	% of NC'srepeats by same suppliers
	V42_D3M3	% of analysis plan compliance
	V43_D3M4	% of analysis results not meeting established criteria
	V44_D3M5	% of NC's related to lack of documentation in Food Safety
	V45_D3M6	Consistency between proposed strategies and actual actions
	V46_D3M7	Compliance of workers Food Safety responsibilities
	V47_D3M8	Failure in following Food Safety instructions
	V48_D3M9	Work performance assessment planning for top management and workers
	V49_D3M10	% of consumer complaints
	V50_D3M11	Verification of food safety manuals based on the plans proposed by the organization

	V51_D3M12	Existence of documents with clear description of tasks/responsibilities
	V52_D3M13	% of standard operating procedures implemented and understood
Adaptability	DIM4	
	V53_D4M1	% compliance with actions in: improvement opportunities, smaller NC's, larger NC's and NC's critical within the deadline
	V54_D4M2	% of Corrective Actions implemented timely and effectively
	V55_D4M3	% of compliance with deadlines resulting from Food Safety Review Output
	V56_D4M4	Effectiveness of customer complaint handling procedure
	V57_D4M5	Occurrences of Market Withdrawals/Recalls
	V58_D4M6	NC's average correction time and improvement opportunities
	V59_D4M7	Response to verification plan failures
	V60_D4M8	Customer Satisfaction (Response Rate and Customer Satisfaction Index)
Hazard and Risk Awareness	DIM5	
	V61_D5M1	% of employees complying with Food Safety Training Plan
	V62_D5M2	% of employees with in-depth knowledge of CCP's and the importance of their control
	V63_D5M3	% of NCs resulting from behaviors that put Food Safety at risk
	V64_D5M4	Compliance with procedures related to CCP deviations
	V65_D5M5	General knowledge of microbiological/chemical/physical criteria
	V66_D5M6	Performance evaluation of employees in emergency situations/simulations
	V67_D5M7	Number of instructions and training on how to minimize Food Safety risks across the enterprise and throughout the production chain
	V68_D5M8	Internal communication about new technical/scientific information
	V69_D5M9	Information and understanding about hazards and risks identified in the organization.
	V70_D5M10	Developed materials that provide consumer insight into food safety risks
	V71_D5M11	Procedures for updating Food Safety training

2) Presentation and application of metrics online, via survey.

Once the metrics and indicators were identified, contact was made with qualified agents or food workers, in various ways, such as via email or LinkedIn, in addition to the contacts created during the performance of the various audits, to conducting surveys.

Therefore, two surveys were created as mentioned above, in which the first focused on the evaluation of the importance of each metric within each dimension (following a 5-point Likert scale). The second survey asked to insert the metric/indicator in the sub-dimension where the respondent found it most appropriate. It should be noted that the two surveys had two versions, one in Portuguese and one in English. These surveys were carried out in the *LimeSurvey* program, which was provided by the University of Minho's system and production department. The survey structure consisted of an introductory part where the theme of the work was presented, followed by the sociodemographic characterization part, and finally 5 parts corresponding to questions about each dimension proposed by GFSI. Some excerpts of the survey are in the following figures (Figures 2A; 2B; 2C).

Figure 2A: Excerpt of the inicial part of the survey developed

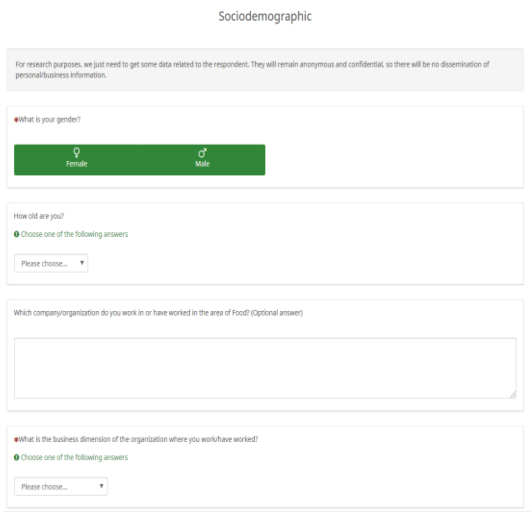

Figure 2B: Excerpt of the sociodemographic characterization of the survey developed

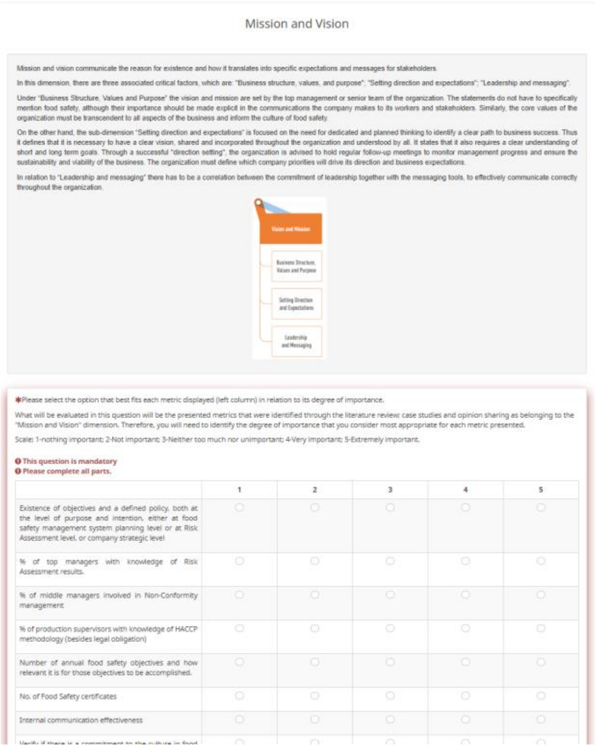

Figure 2C: Excerpt of one dimension questions of the survey developed

3) Statistical analysis of the data collected

The data collected from the questionnaires carried out, in English and Portuguese, were analyzed using the statistical program IBM SPSS 26, and different tests were carried out, namely those of descriptive analysis that allows to summarize the set of data collected in an investigation according to the interest groups, which in this study were: gender; age; business dimension; market activity; number of establishments; organization's certification and, consequently, the total number of certifications. This descriptive study shows that our sample of responses is not biased, pointing out that there are statistically equal responses between the different groups studied. Then, normality tests were performed, as they allow to determine whether the data set of a random variable is well moderated by a normal distribution or not.

Thus, the Kolmogorov-Smirnov (K-S) test, in which H0: the sample has a normal distribution and H1: the sample does not have a normal distribution, was developed to determine the normality of the variables. However, the Kruskal-Wallis test was also performed, which tells us whether or not the distribution of means is the same among the groups under study, taking into account H0: the sample has a normal distribution within the study group and H1: the sample does not have a normal distribution within the study group**.**

4) Construction of the structural equation model.

The analysis of structural equation models is a generalized modeling technique, which allows testing the validity of theoretical models to define causal or hypothetical relationships between variables. These relationships are represented by parameters that indicate the magnitude of the effect of the variables, called independent, present on other variables, called dependent, in a set of hypotheses regarding patterns of associations between the variables in the model.

Therefore, once the statistical analysis of the data was performed, the SOFTWARE IBM AMOS 26 Graphics was used to perform the construction of a measurement model and, subsequently, the final model of structural equations, together with its validation.

Firstly, it was necessary to insert all variables understudy in the program, from the sociodemographic characterization groups, to the independent variables - the metrics/indicators identified - and, finally, the dependent variable of the study, the level of food security culture. Then, it will be necessary to insert the independent variables taking into account the dimension to which they are associated, being necessary to covariate the dimensions. Subsequently, it will be necessary to adjust the data to determine whether all variables are correctly suited to the model, to obtain the final measurement model.

Once the measurement model is defined, it will be necessary to insert the dependent variable in this case, it will be the level of food safety culture, and to carry out a series of hypothetical models that will allow us to determine which is the best structure to obtain the highest R^2 in the dependent variable, after numerous attempts, it was found that the best structure would be in the form 3: 2 as can be seen in figure 11. As can be seen, the covariance was removed, assuming that the dimensions would not be related to each other. Then, the fit of the model was verified to make sure that the model was well built.

Finally, the model of structural equations was moderated to determine if the model is robust among the different groups in studies identified in the sociodemographic characterization, through multigroup analysis.

RESULTS AND DISCUSSION

Research sample

A total of 180 respondents, from 46 countries, with food safety training or workers, contributed by answering the survey. As previously mentioned, the first part of the survey encompassed the sociodemographic characterization considering the following variables: gender (Figure 3A) – 47.8%

of respondents were female; age of the participants (Fig. 3B) – mainly respondents between 31 to 50 years; business dimension (Fig.4A) – mainly companies above 51 employees; market activity (Fig. 4B) – mainly national and international; number of compounds (Fig.5) – mainly companies with four or more establishments; company certification (Fig. 6A) – mainly with certification; and number of certification (Fig.6B) – mainly with 1 to 3 certifications.

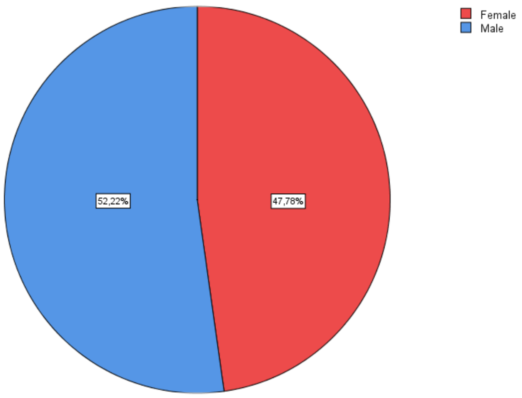

Figure 3A: Gender characterization

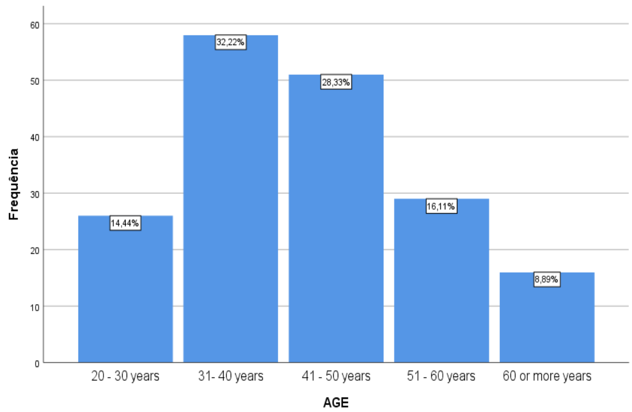

Figure 3B: Age characterization

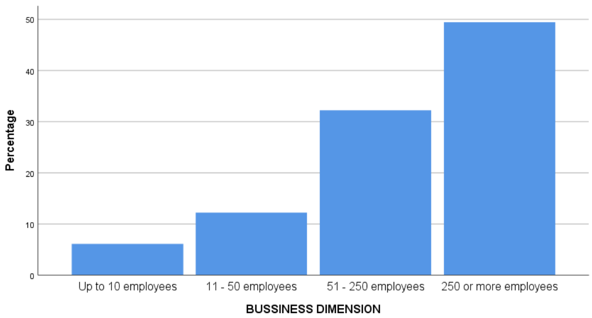

Figure 4A: Bussiness dimension

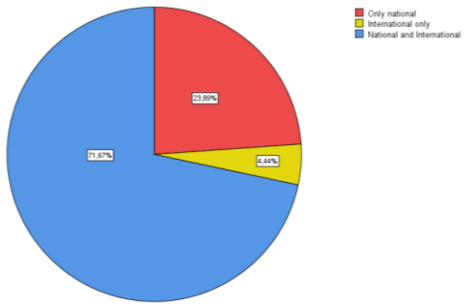

Figure 4B: Market activity

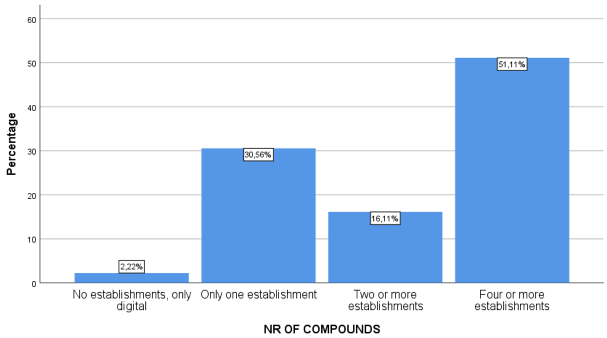

Figure 5: Characterization of the number of compounds

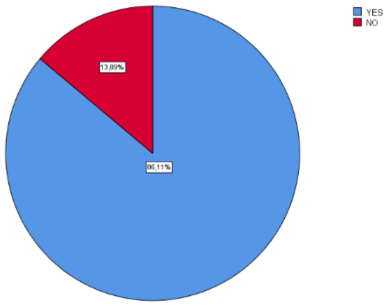

Figure 6A: Certification of the organizations

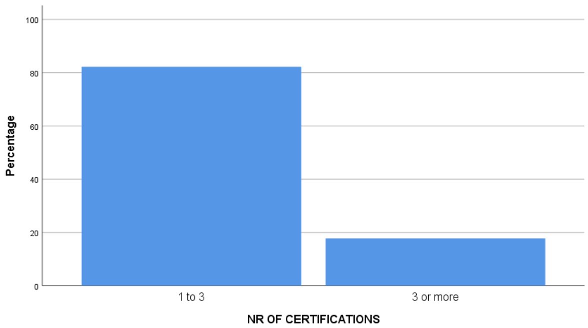

Figure 6B: Number of certifications

In addition to the descriptive analysis presented, normality tests were performed, and it was observed that according to the non-parametric K-S test and considering a significance of 1% (0.01), our sample did not present a normal distribution, given that all values were lower at 0.01.

For the Kruskal-Wallis test, we can see the results in table 2, for significance values of 5% (0.050), as the results show that each dimension does not have a normal distribution. On the other hand, as most of the results were shown to have a normal distribution (H0 was accepted) it was possible to identify the software program to be used for the construction of the structural equation model. Thus, the approach used to create the structural equation model was the use of the IBM SPSS Amos 26 Graphics program, for the reason presented above. If our sample presented mostly H1 acceptance results, the program to be used should be SmartPLS 3 as it would best adapt to the normality of the sample.

Table 4: Study of the significance by Kruskal-Wallis test in the diferent dimensions

GROUPING VARIABLES	MEASURED VARIABLES														
	DIMENSION 1 - MISSION AND VISION														
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15
Gender	H1	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Age	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Bussiness dimension	H0	H0	H0	H1	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Market activity	H0	H1	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H1	H0	H0
Nr compounds	H1	H1	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Company certification	H0	H0	H0	H0	H0	H1	H0	H0	H0	H0	H0	H0	H0	H0	H0
Nr of certifcations	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0

GROUPING VARIABLES	MEASURED VARIABLES									
	DIMENSION 2- PEOPLE									
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Gender	H0	H0	H0	H0	H0	H0	H0	H0	H0	H1
Years/Age	H0	H0	H0	H0	H0	H1	H0	H0	H0	H0
Bussiness dimension	H0	H0	H0	H0	H0	H1	H0	H0	H0	H0
Market activity	H0	H0	H0	H0	H0	H0	H0	H0	H1	H1
Nr compounds	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Company certification	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Nr of certifcations	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0

GROUPING VARIABLES	MEASURED VARIABLES												
	DIMENSION 3 - CONSISTENCY												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
Gender	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Years/Age	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Bussiness dimension	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Market activity	H0	H0	H1	H0	H1	H0	H0	H1	H0	H0	H0	H0	H0
Nr compounds	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Company certification	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Nr of certifcations	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0

GROUPING VARIABLES	MEASURED VARIABLES							
	DIMENSION 4 - ADAPTABILITY							
	M1	M2	M3	M4	M5	M6	M7	M8
Gender	H0	H0	H0	H0	H0	H0	H0	H0
Years/Age	H0	H0	H0	H0	H0	H0	H0	H0
Bussiness dimension	H0	H0	H0	H0	H0	H0	H0	H0
Market activity	H0	H0	H0	H0	H0	H0	H0	H0
Nr compounds	H0	H0	H0	H0	H0	H0	H0	H0
Company certification	H0	H0	H1	H0	H0	H0	H0	H0
Nr of certifcations	H0	H0	H0	H0	H0	H0	H0	H0

GROUPING VARIABLES	MEASURED VARIABLES										
	DIMENSION 5 - HAZARD AND RISK AWARENESS										
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Gender	H0	H0	H0	H0	H0	H0	H0	H0	H1	H0	H0
Years/Age	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Bussiness dimension	H0	H0	H0	H0	H1	H0	H0	H0	H0	H0	H0
Market activity	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Nr compounds	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0
Company certification	H0	H0	H0	H0	H0	H0	H0	H1	H0	H0	H0
Nr of certifcations	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0	H0

Later on the average, standard deviation and median, broken down by variable, and by dimension were calculated: of the five dimensions presented, the one that was referred to as the most important (according to the average) was the dimension 2 “Personal”, with an average of 4.214 (figure 7). It was possible to verify which metric, indicated by the respondents, is most important in each dimension, as can be seen in the following graphics (Fig. 8A; 8B; 8C; 8D; 8E). By analyzing the data and the respective graphs of the averages of the various metrics/variables in each dimension, it is possible to state that for Dimension 1 “Mission and Vision” the metric that had the greatest importance was V23_D1M9 “Top management commitment to continuous improvement ", for Dimension 2" People "was the metric V33_D2M4"% of employees involved in the production/handling of foods with high understanding of your commitment to Food Safety. "; for

Dimension 3 “Consistency” was V42_D3M3 “% of analysis plan compliance”; for Dimension 4 “Adaptability” was V54_D4M2 “% of Corrective Actions implemented timely and effectively”; and finally, for Dimension 5 it was V64_D5M4 “Compliance with procedures related to CCP deviations”.

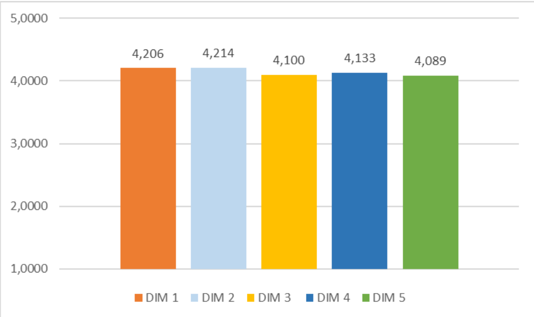

Figure 7: Mean of variables of each dimension

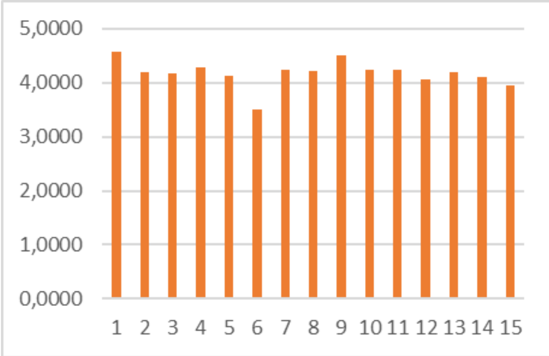

Figure 8A: Mean of variables of Dimension 1 "Mission and Vision"

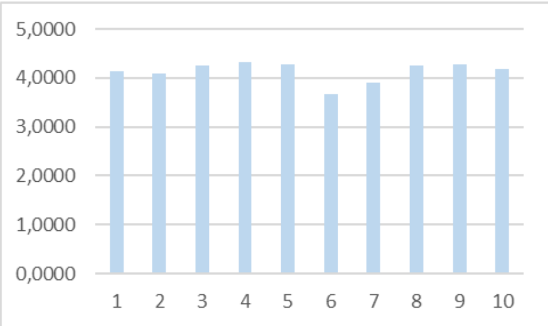

Figure 8B: Mean of variables of Dimension 2 "People"

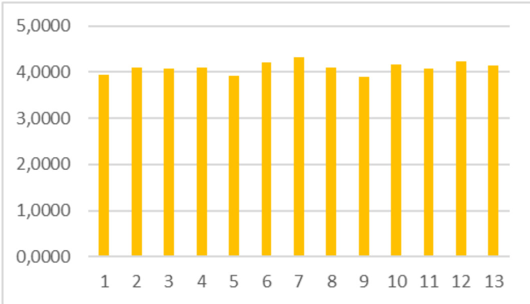

Figure 8C: Mean of variables of Dimension 3 "Consistency"

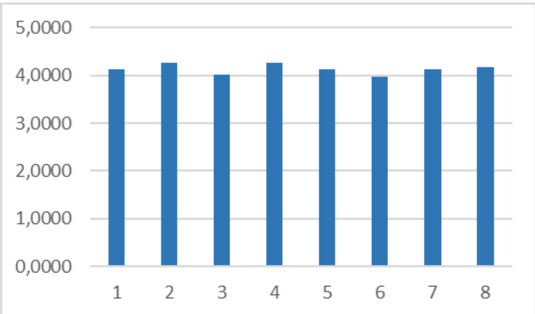

Figure 8D: Mean of variables of Dimension 4 "Adaptability"

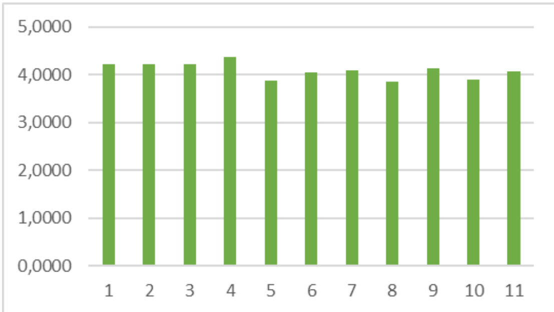

Figure 8E: Mean of variables of Dimension 5 "Hazard and Risk

Scale reliability

A reliability analysis was carried out on the perceived importance (rated through a 5-point Likert type scale) comprising the 57 items that were assessed by the respondents. Cronbach’s alpha (Table 3) showed the questionnaire to reach acceptable reliability (α = 0,979) suggesting a high internal consistency and a reliable questionnaire. Additionally, none of the items results in an increase in the alpha if deleted (not shown) (all the items can be retained).

Table 3: Reability analysis by dimension and totally

Reliability analysis		
Dimension	**Cronbach's alpha**	**Nº of items**
Total	0,979	57
D1 – Mission and vision	0,931	15
D2 - People	0,931	10
D3 – Consistency	0,933	13
D4 – Adaptability	0,916	8
D5 – Hazard and Risk Awareness	0,934	11

Analyzing each dimension individually, we can observe that the dimensions D1, D2, D3, and D5 obtained very close values and were considered of high reliability. Only dimension 4 resulted from a lower coefficient compared to the other dimensions, without, however, losing its high value.

Dimension 2 of the questionnaire deals with aspects of adaptability in an organization. Thus, it is possible that due to the technical nature of the questions together with the reduced number of items, a lower value of Conbrach's alpha was appreciated in relation to the other dimensions.

It should be noted that in dimension 1 “Mission and Vision” it was possible to detect an item that presented a higher Conbrach’s alpha when removed (0.937 in relation to 0.931), this being the item D1M6. Likewise, for dimension 2, the item D2M1, which when removed the value of Conbrach's alpha exceeded the standard value, 0.932 in relation to 0.931.

STRUCTURAL EQUATION MODELING

Measurement Model

The primary purpose of modeling structural equations is to obtain a model that adequately describes the data in a sample. If any signs of lack of adjustment are found, the next step will be to detect the source of the error, for this, the Model Fit of our model of structural equations must be observed. Figure 9 represents the measurement model based on covariance before adjusting the variables.

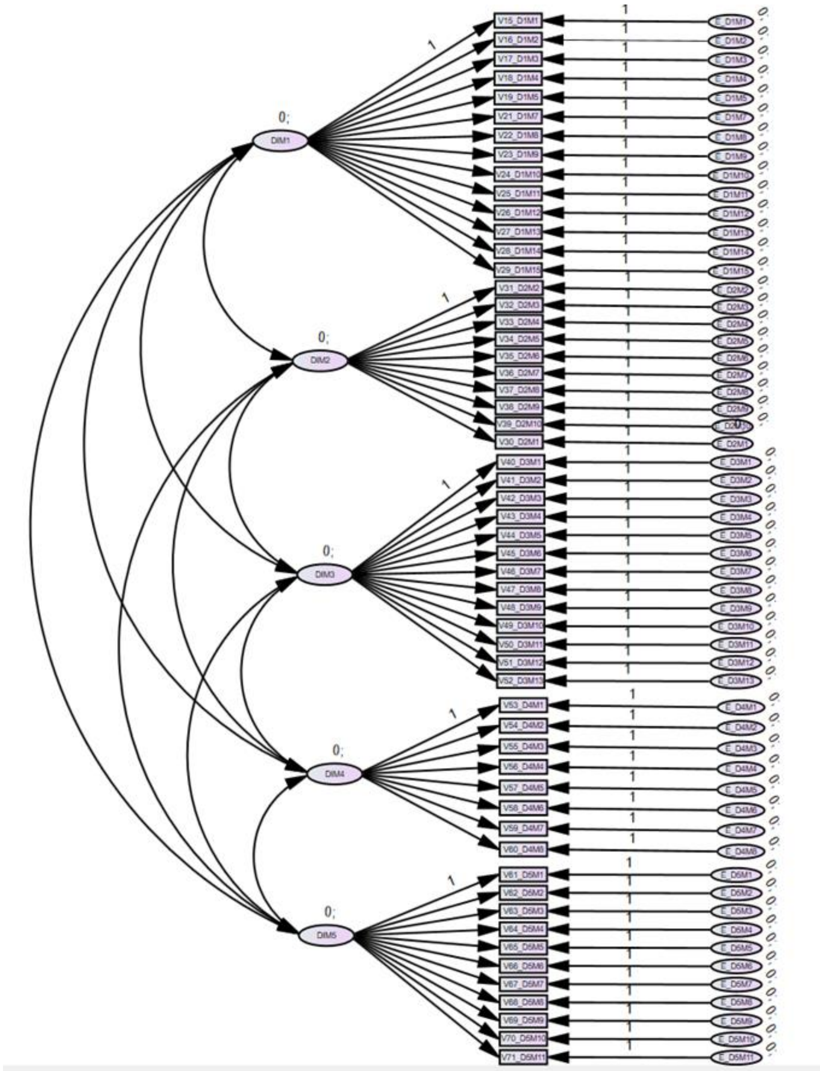

Figure 9: Representation of the model based on covariance before adjusting the variables

Not all variables affect the corresponding dimension in the same way, which implied that some of the variables were removed from the measurement model. In order to adjust our model, and as previously mentioned, after the reliability analysis study, two values were detected (D1M6 and D2M1) which, when removed, increased the reliability of the dimensions, so they were eliminated, this being the first step for the construction of the measurement model (Fig. 10). Next, it is necessary to use the observation of the covariance table obtained through the output of the software used for the development of the model, and in this we must take into account the errors of each variable presented, in the case of this study, the errors of each dimension. If the errors between the variables of the respective dimension are very high, it means that we can "covariate" between them. Subsequently, we must remove the metrics that have the lowest loading after this covariance between errors, as they are those that receive less influence from the corresponding dimension and thus disturb the results. Comrey and Lee (1992) referenced by (Laros, 2014), suggest that loads greater than 0.71 are excellent, greater than 0.63 are very good, greater than 0.55 good, greater than 0.45 reasonable and greater that 0.32 poor. Therefore, in this measurement model, the criterion of removing variables with loads below 0.63 was used, in order to obtain a more reliable model. Thus, the variables were removed for each dimension and are identified in table 4.

Table 4: Removed items for the construction of mediation model

Dimension	Removed items
D1 – Mission and vision	D1M6; D1M13
D2 – People	D2M1; D2M10
D3 – Consistency	D3M6; D3M7; D3M9
D4 – Adaptability	D4M4; D4M8
D5 – Hazard and Risk Awareness	---

In this way, we obtained the model represented in figure 10. Then, a confirmatory factor analysis (CFA) was performed to verify if there is a good model fit. The indices presented in Table 5 suggest an adequate adjustment of the model to the data, after the removal of unnecessary variables. Many publications adopt the following criteria: CFI (comparative adjustment index) ≥ 0.90; RMSEA (root mean square error) <0.08; that is, the scores achieved by the measurement model are aligned with the criteria established in the current literature (Byrne, 2010; Hair Jr., Gabriel, & Patel, 2014), and the model was accepted.

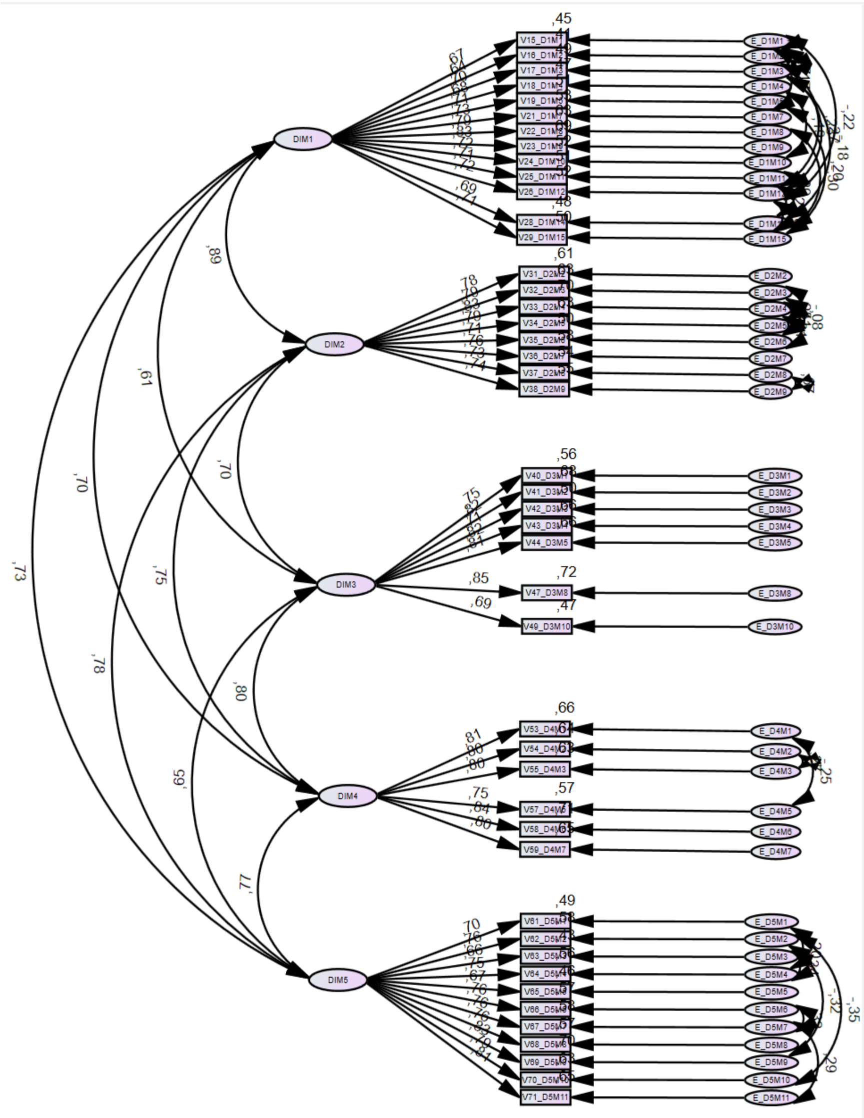

Figure 10: Final mediation model

The next step was to examine the reliability of our model. Table 5 also shows the extracted average variances (AVE). The stroke is a measure of the convergent validity of the model and must be 0.50 or higher (Hair, Sarstedt, & Ringle, 2012). For this model, the strokes ranged from 0.5100 - 0.6433 and thus, all constructs showed convergent validity.

Table 5: Model fit of mediation model

Index	**Score**
CFI	0,892
RMSEA	0,065
90% I.C.	[0,060; 0,070]
CMin	1594,254; p<=0,001
CMin/df	1594,254/909= 1,7539 < 5
AVE Dim1	0,5100 > 0,5
AVE Dim2	0,5925 > 0,5
AVE Dim3	0,6071 > 0,5
AVE Dim4	0,6433 > 0,5
AVE Dim5	0,5655 > 0,5

After the adjustments and the reliability check, the results obtained from the measurement model are considered globally robust, thus allowing them to proceed to the elaboration of the structural equations model.

Covariance Based-Structural Equations Modelling

Figure 11, present the model of structural equations, showing the relationships between the five dimensions and the impact they have on the evaluation of the food safety culture, that is, the impact on the dependent variable of the study in question, this being the "Level of Food Safety Culture - LEVELFSC " having been measured by a section of the questionnaire, as previously described.

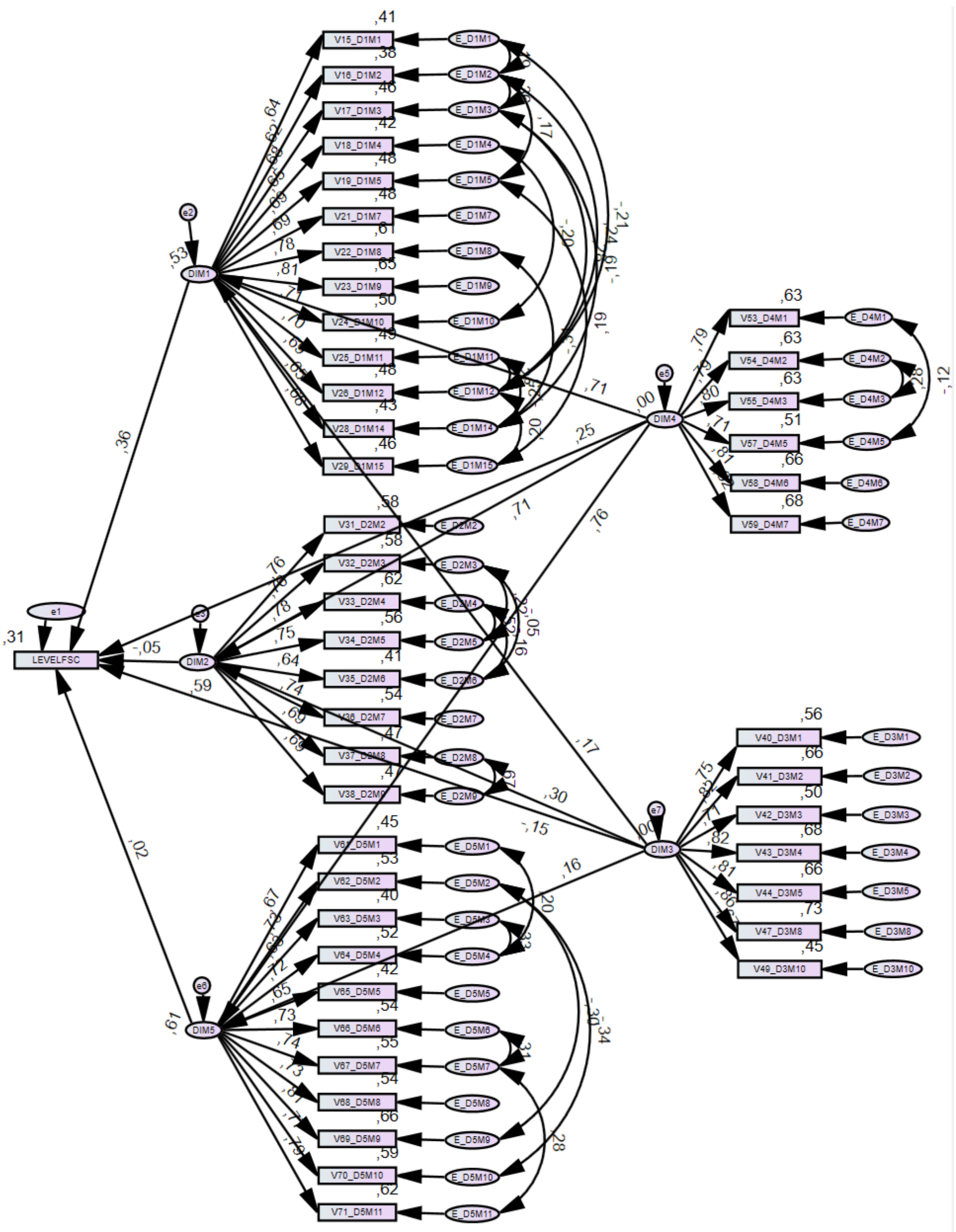

Figure 11: Final model of structural equations to evaluate Food Safety

Through the analysis of figure 11 we can conclude that the model of structural equations obtained explains 31% of the objective of the work, that is, of the measurement of the level of culture of food security. Despite being a relatively low value, it should be noted that initially there was no model to explain this topic, we must also show that the dispersion of the model may be associated with the lack or ambiguity of the indicators, so the 69% in the absence of explanation may be related to the lack of data.

In addition, by interpreting figure 11 and, specifically, the influence of metrics on the dimension - observing the loadings - we can conclude the following: in dimension 1 (Mission and Vision) the metrics with the greatest impact (highest loadings) are D1M9 (0 , 81); D1M8 (0.78) and D1M10 (0.71); in dimension 2 (Personnel) they are D2M4 (0.78); D2M2 (0.76) and D2M3 (0.76); in dimension 3 (Consistency) they are D3M8 (0.86); D3M2 (0.82) and D3M4 (0.82); in dimension 4 (Adaptability) they are D4M7 (0.82); D4M6 (0.81) and D4M3 (0.80) finally, in dimension 5 (danger and awareness of risk) are D9 (0.81); D5M11 (0.79) and D5M10 (0.77).

It is also possible to observe the different impacts of the dimensions on the “Food Safety Culture Level” (LEVELFSC), so it is possible to state that the dimension with the greatest direct effect is dimension 1 (Mission and Vision) with 0.36 load and also dimension 4 (Adaptability) with a load of 0.25. However, observing alternative paths (mediation analysis), that is, those that have a path with two dimensions as opposed to the direct method (only one dimension), it is possible to observe that the most efficient paths (always taking into account the highest average value loadings) will then be: Dimension 4 + Dimension 1 with loading of 1.07; Dimension 4 + Dimension 5 with loading of 0.78 and Dimension 3 + Dimension 1 with loading of 0.53. These loads indicate the importance, effectiveness, or value of the impact of dimensions on the Culture and Food Security Level; and therefore, the higher the value, the more important and effective.

The indices presented in Table 6 suggest an adequate adjustment of the structural model to the data, according to the criteria previously adopted.

Table 6: Model fit of the structural equation model

Index	**Score**
CFI	0,853
RMSEA	0,074
90% I.C.	[0,069; 0,079]
CMin	1894,810
CMin/df	1894,810/953= 1,988

CONCLUSIONS

This paper presented a research study aimed at evaluating the assessment of food safety culture. An online survey was answered by 180 respondents (Food safety experts) and contributes with a different perspective than previous studies on this domain (previously mentioned). This research sheds a new light on the assessment of food safety culture. The results show different perceptions of experts in the food field, based on the document of the GFSI of the food safety culture, thus it was possible to conclude several aspects regarding the importance of each dimension and its impact on the evaluation of the food safety culture in an organization. A SEM model was developed based on the answers provided by the respondents. The main conclusions were that the dimension with the highest importance score -in terms of the respondents' assessment- was the DIM2 "People". However, contrasting the information with the model of structural equations, the dimension with the highest importance/weight was DIM1 "Mission and Vison". On the other hand, to evaluate the metrics of each dimension, through the results it was possible to observe that for dimensions 1 and 2, both respondents and the structural equation model concluded that the most relevant metric were D1M9 and D2M4, respectively. However, for the remaining dimensions, the metrics did not match, so respondents determined that for DIM 3, 4 and 5 the most important metrics were D3M3, D4M2 and D5M4, respectively, instead of the one concluded by the structural model by AMOS model that determined the metrics D3M8, D4M7 and D5M9, respectively to the dimensions mentioned, as being the most important/with the greatest impact. It was also possible to conclude the impact of the dimensions on the observable variable (level of food safety culture) through the different paths that can be taken, direct or indirect (mediation analysis). Therefore, through direct paths, dimensions 1 and 4 are those that positively affect the culture of food safety culture. However, the indirect routes determine that the most favorable path will be the union of DIM4+DIM1, having recorded a loading of 1.07 of effectiveness on the food safety culture, *i.e*, there are mediating effects that should be considered. The results suggest that the relationships between the dimensions should be considered and should be considered when aiming at improved perception of food safety by the employees, *i.e*, there emerge several mediating issues that were not previously identified.

LIMITATIONS

Since this study is supported by data gathered in 2019 a more recent data collection should be carried out in order to ascertain at which extent these conclusions are valid. The total variance explained by the model (0,31) clearly points that other variables (not considered in this study) impact on the perception of the food safety culture by the employees. So, further studies should be carried out in order to identify those missing variables or dimensions.

ACKNOWLEDGEMENTS

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Impacts from the Implementation of the ISO 22000

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STRUCTURED ABSTRACT

Purpose- The main purpose of this article is to assort different impacts of the ISO 22000 implementation considering internal or external impacts, positive or negative impacts. It also intends to provide a worldwide overview on the topic, to distinguish companies from different sectors and to gather different methodologies that are used in previously published articles related with this implementation.

Design/methodology/approach- Different articles of the ISO 22000 implementation from different countries were gathered and singled out according to the information that was provided. The information of interest was analyzed and rewritten according to the initially established categories.

Findings- The results from several studies, researches and points of view from different authors show that the ISO 22000 implementation carries positive impacts. Negative impacts are hard to find. Most of the impacts are directly related to the organizations themselves, hence being internal impacts. Studies are mainly carried out with the help of questionnaires that are presented to the companies.

Research limitations/implications- The main goal was to come across different impacts and classify them either as positive and negative or internal and external. However, it’s unusual to find authors that consider negative impacts from the ISO 22000 implementation. Also, external impacts are not so common.

Originality/value- This article mainly highlights the ISO 22000 implementation positive impacts in worldwide organizations. It summarizes the different countries views towards Food Safety Management Systems (FSMS) and how they affect the performance of their companies.

Keywords: ISO 22000, Food industry, Impacts, Worldwide organizations

Paper type: Literature review

INTRODUCTION

As food safety represents a matter of public health, there is a higher demand of better and more purposive food safety systems. Therefore, this aspect has risen over the past three decades (Voca, 2014). Due to the affection of the safety of food products, caused by the recurrent crisis in food chains, there emerged a need to create precautionary measures for this type of problems (Teixeira and Sampaio, 2011). Moreover, consumers also became more concerned with this aspect which made food standards and regulations to be more developed in order to increase food safety standards, being set in developed countries first, and established in developing countries later (Kök, 2009; Teixeira and Sampaio, 2011). It was then perceived large improvements in food management systems through the combination of both national and international standards with consumer's demands and other aspects (Voca, 2014).

HACCP (the acronym to Hazard Analysis and Critical Control Points) is a system of safety management, in which the monitoring and the control of biological, chemical and physical risks are insured in every single step of the production (Varzakas et Arvanitoyannis., 2008). Since its development in the 1960's, it has been effectively implemented in several food industries in order to reduce and control risks that can cause food unsafe to consume (Voca, 2014).

HACCP system includes seven principles:

1. To conduct a hazards analysis;
2. To determine Critical Control Points;
3. To establish critical limits for each CCP;
4. To establish a monitoring system for each CCP;
5. To establish corrective actions;
6. To establish verification procedures;
7. To establish documentation and record keeping.

The ISO 22000, developed in 2005, appeared to strengthen the HACCP system. This standard comprises the preliminary HACCP steps/principles, defines management responsibility and it also uses an approach to the systems that aims to avoid new hazards in the food production process again (Warren, 2015). The main goal of this standard is to attune the food safety management globally among food chains organizations (Zimon and Domingues., 2019).

ISO 22000:2005 was published by the International Organization for Standardization (ISO) in 1st September and it was reviewed for the last time in 2018. It is both an international ISO standard and

European EN standard (Teixeira and Sampaio, 2011). This type of standards establishes the requirements that can be objectively audited for certification purposes (APCER, 2011). Additionally, the "Plan-Do-Check-Act" (PDCA) methodology is applied to the ISO 22000: 2005.

This methodology focuses on an ongoing improvement and can be described in the following steps:

- Plan: to set both goals and procedures to propound the results according to client's requirements and the politics of the organization;
- Do: to put in practice the previously planned procedures;
- Check: to verify and monitor, not only the procedures, but also the product itself, comparing politics, goals and requirements for the product and to report the results obtained;
- Act: to take actions in order to improve the performance of the procedures in a continuous way (APCER, 2011).

Regarding the standards' implementation, the gathered information and the assessment and analysis of the magnitude of cost of planning before the actual implementation, play a major role (Maldonado, 2005). Also, implementing this type of standards carries along several impacts: internal, which brings benefits to the organization throughout the process of implementation, or external, which privileges other parts, external to the organization; and on the other hand, positive, when the procedure of implementation results on the improvement of quality of something, or negative, when there is a clear damage to the quality of something, or even neutral, when the impact doesn't have neither a positive or a negative effect. Different countries and cultures are expected to experience different impacts when implementing this system.

RESEARCH METHODOLOGY

Articles and documents on the ISO 22000 implementation and its impacts were mainly researched in platforms such as *Google Scholar* and *Research Gate*, using keywords such as "ISO 22000", "ISO 22000 implementation", "impacts of ISO 2200 implementation" and "ISO 22000 worldwide". The APCER website and several documents were also an excellent source of information. After analyzing approximately 25 articles and documents, adhering to 12 of them, this review about the impacts of the implementation of the ISO 22000 in seven countries was developed. The selection was done choosing those about positive and negative aspects of the standard implementation, the effects of the standard in the organization and in external entities and also about the implementation in several countries and different sectors of activities.

RESULTS

There are several studies concerning the ISO 22000 implementation and impacts of the standard. After the analysis of existing literature related to the theme, different positive impacts were observed in various countries and sectors, as described below.

Most studies include questionnaire testing to organizations to understand the impact of the standard implementation in different departments.

ISO 22000 brings positive impacts to the organizations that adopt the implementation procedure.

According to Zimon and Domingues (2019), this standard, in a wider way, contributes to:

- The production and the relinquish of safe products;
- The organizations having a good agreement with the legal requirements and with food safety regulations;
- Better communication between individual links and external stakeholders;
- Diminishing of the non-conformities in the procedures;
- Increase confidence in organizations working throughout the supply chain;
- Ensure to the institutional clients the quality and the safety of the products;
- Increase the staff awareness of its impact in food quality and safety.

Despite these broad considerations, the perception of the ISO 22000 implementation impact is different according to the geographical region. The dimension of the company and Food Safety Management System don't seem to affect that perception (Zimon and Domingues, 2019).

Figure 1: Word cloud- impacts from the implementation of the ISO 22000

Different methodology to study the impact of the ISO 22000

1. Portugal

Teixeira and Sampaio (2010) developed a questionnaire composed of 6 groups of questions. With this questionnaire, authors intended to collect information about the company, to identify motivations that led to the standard implementation, to understand which had been the benefits of Food Safety Management Systems implementation and also the main difficulties and drawbacks from the implementation, to know about the implementation and certification costs and impact on the final consumer and, finally, to evaluate the evolution perspectives concerning the ISO 22000 certification. The scale adopted in the questionnaire was a 5-point Likert scale. Data were analyzed using SSPS.

2. Poland, Slovakia and Portugal

To assess the impact of standardized Food Safety Management Systems on food safety in the supply chain in Poland, Slovakia and Portugal, Zimon and Domingues (2019) presented a questionnaire to several organizations.

The authors' main focus was if the company was certified by the ISO 22000, how many employees are part of it, how many years the company have the ISO 22000 MS implemented, if the implementation impacted (successfully) in the food safety of products, the level of impact of the standard on production, purchase, distribution and design and development processes and process control, the improvement on the detection of potential errors and mistakes, the improvement of the integration of individual partners and if the implementation of FSMS in companies operating in the food supply chain is needed. All the questions were formulated with "I don't know", "Yes" and "No" answers, except the question about the level of impact of the standard, presented as a 5-point Likert scale. At last, companies were asked to express in words an opinion on the legitimacy of implementing the ISO 22000 standard in supply chains.

3. Sudan

The authors used a descriptive method in their research. To conclude about the impact of the ISO 22000:2005 implementation on a food organization, a questionnaire test about the effects of the standard on marketing, sales, quality control and supply chain departments was used. The questionnaire was developed with a 5-point Likert scale, from strongly disagree to strongly agree. Data were analyzed using SSPS (Khames, 2017).

4. Romania

The study developed by Păunescu et al. (2017) included a quantitative research which builds upon a questionnaire-based survey. It was presented to Romanian companies distributed at all levels of the food supply chain, but mainly at the production level.

The questionnaire was organized with six sections: a general question about the achievements of the ISO 22000 certification, a question about the certification motivations, a question about the effectiveness of certification, a question about the difficulties of the ISO 22000 adoption, a question about food safety methods in use, and a question regarding the company's and respondent's general profile. Most of the answers were indicated with a 5-point Likert scale. The answers to the questionnaire were analyzed using SSPS.

5. Turkey

This research aims to holistically examine the implement ability of the ISO 22000 in food and beverage Turkish companies. The data were collected through face-to-face interviews with the help of an interview form, sound recordings of the interview as well as notes taken by the researchers - "semi-structured interview" technique. Researchers presented questions mainly related with companies' characteristics, performance of the standard used before the ISO 22000, facilities and difficulties involved in the transition process to the ISO 22000, safe product planning and realization, contribution of the ISO 22000 to revenues and expenses and reliability and image and evaluation of redundancy/insufficiency status of the items in the ISO 22000.

The data collected were organized in tables and posteriorly interpreted using 8 of the companies interviewed (Mercan and Bucak, 2013).

6. China

In China, to investigate the status of FSMS implemented at pork slaughter plants, Xiong et al. (2016), prepared a questionnaire and checklist with scoring system. The questionnaire was developed with the aim to collect companies' information. Checklist was used to analyses the Food Safety Management System - for example, specifications including product release, management responsibility, procedures, purchasing - Good Manufacturing Practices - personal hygiene, facility layout and process flow, staff facilities - and Control of Food Hazards - control of allergens, HACCP, food defense.

Data analysis and statistic were developed using Kruskal-Wallice nonparametric tests (Xiong et al., 2016).

To summarize all the methodologies used in the different studies, for different countries, information was graphically organized (Figures 2 and 3), considering the questioning method and scale used, data analysis method and the main topics addressed with the questionnaires. The information used to construct the graphics is organized in tables in Annex 1.

It's possible to conclude that the preferred methodology used to data collection were questionnaires using 5-point Likert scale (Figure 2). The data collected were analyzed mainly with SSPS. Also, table analysis and Kruskal-Wallice nonparametric tests were used (Figure 3).

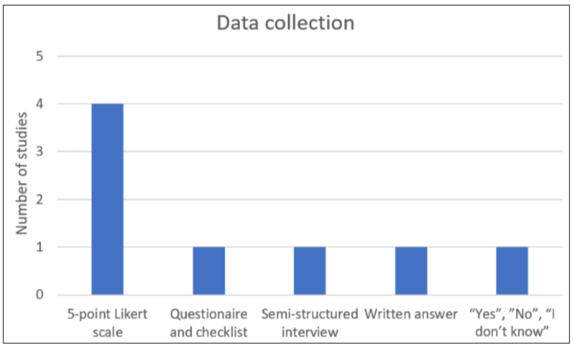

Figure 2: Methodology used for data collection

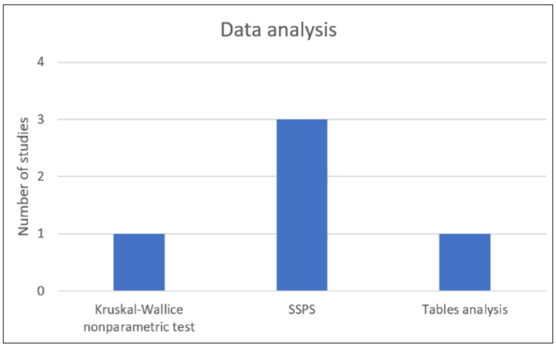

Figure 3: Methodology used for data analysis

Finally, the main topics addressed with the questionnaires, common to most of the studies, were information about the companies and benefits of FSMS. The distribution of those and other topics are presented on Figure 3.

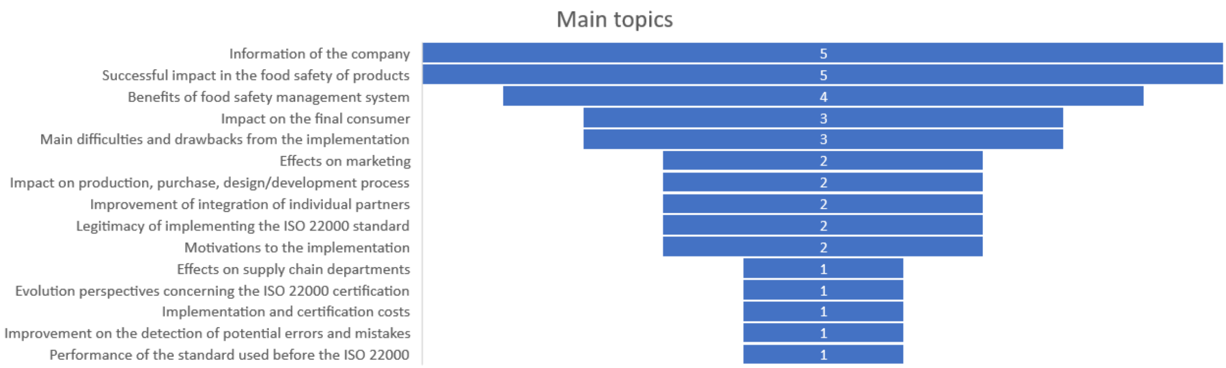

Figure 4: Main topics addressed in the questionnaires used in different studies by different authors

Impacts from the implementation of the ISO 22000 in different countries

1. <u>Portugal</u>

Zimon and Domingues (2019) analyzed in their paper a total of 38 Portuguese enterprises throughout a survey. They claimed that all the companies (100%) answered "yes" when they were asked if there was a successful impact when the ISO 22000 standard and its requirements were implemented. After that, it was introduced a question to rate from 1 (negative) to 5 (positive) the impacts of the ISO 22000 implementation in some key procedures.

The highest rate of positive impacts of the standard implementation was given to the control procedure. The ISO 22000 standard requires records of deliveries and processing and tracking system in order to relate individual batches of products to a specific batch of raw material. Such requirements aimed only at the improvement of the level of safety in the food chain that turns on an increased confidence between its individual cells and between the companies and the customer(s) (Zimon and Domingues, 2019). In addition to the control process, the production, purchase and distribution process rated high values of positive impacts.

The strengths of cooperation within the supply chain was other positive impact observed by Zimon and Domingues (2019) in Portugal. Furthermore, when asked, companies answered that the ISO 22000 helped improving the integration of individual partners and additionally it eased the identification of eventual errors and mistakes.

Teixeira and Sampaio (2010) also analyzed food safety management systems in Portugal. The majority of the surveyed companies were large companies (51,6%), and part of the sector of the "Manufacture of other food products" (25,8%).

Analyzing companies' answers about the benefits of ISO 22000 certification, authors noted that most of the companies determined the "improvement of food safety methodologies and practices, and management system related documentation" as the main benefit (50% of the answers) followed by "improvement of customers and other interested parts satisfaction" (32,2%). Other positive impacts were likewise registered: "consumers' confidence improvement", "food safety improvement", among others (Teixeira and Sampaio, 2010), which sustains the information of the above article. These impacts can be simultaneously considered as positive and internal impacts due to their internal influence nature (Teixeira and Sampaio, 2010).

2. Poland and Slovakia

To understand the ISO 22000 implementation impact on the running of the supply chain in Poland and Slovakia, Zimon and Domingues (2019) included 43 organizations in their research. Similar to what had been done with Portuguese organizations, several questions were made to Polish and Slovak organizations.

About the standard implementation, having a positive effect on improving the food safety throughout the food chain, 67% of the companies involved in the research confirmed a positive impact, whereas 15% didn't consider any effect and the remaining 18% were not familiar with the topic. Those who didn’t find positive impacts on the implementation of this standard on food safety, defend that the ISO 22000 in order to fulfill the main goals should be backed by other systems, since it doesn't seem to affect the growth of food safety in itself in a very significant way. According to the authors, these derogatory opinions about ISO 22000 may result from anomalies in the standardized systems implementing. (Zimon and Domingues, 2019)

In the same research, companies were questioned on the ISO 22000 impact in some key processes in the food supply chain improvement. Polish and Slovak organizations considered that the standard implementation had a greater impact in the production process, control process, and design and development process. The less affected procedures were the ones of purchase and distribution, which might be connected by the fact that Eastern European companies don’t have a very important role in the food supply chain so the norm impact in the distribution phase it wasn’t substantial.

Both in Poland and Slovakia, 65% and 16% of the enquired companies agreed and strongly agreed, respectively, that the ISO 22000 favored to the integration of several partners as being part of the supply chain. However, 5% and 2% of the organizations disagreed or strongly disagreed, and the remaining 12% neither agreed nor disagreed. Polish and Slovak organizations also agreed on the importance of the implementation of this standard in what the identification of potential errors and mistakes are concerned. 21% and 67% of these organizations strongly agreed and agreed, respectively, that ISO 22000 eased the identification of errors and mistakes. Only 2% strongly disagreed, 5% disagreed and the remaining 5% neither agreed nor disagreed. To conclude, several organizations were asked if the Food Safety Management Systems in companies operating in the food supply chain was needed. Only 4% of them answered negatively. The majority of the Polish and Slovak organizations (86%) considered that the implementation is needed. The remaining 10% answered that they didn’t know (Zimon and Domingues, 2019).

3. Sudan

In Sudan, a study was developed by Khames (2017) about the impact of the ISO 22000:2005 application on a food organization, with results obtained through a questionnaire testing which included the departments of marketing, sales, quality control and supply chain. Based on the obtained results, the author concluded that the ISO 22000 implementation set several positive impacts.

Considering the profit of the company, this implementation increased the sales, and the marketing department was impacted by an increase in the market share. The ISO 22000:2005 also had a positive impact in what the resource management is concerned when based on the optimum distribution of the resources and the customer satisfaction/retention was also impacted positively by enhancing customer confidence. Moreover, it had a positive impact on internal procedures, and this is due to the reduction of waste and enhanced performance.

Finally, the ISO 22000 had a positive impact on the quality of the product by upgrading the safety and the quality on the final product (Khames, 2017).

4. Romania

In Romania, a study based on the motivations, difficulties and key benefits of the ISO 22000 implementation was developed and it was carried out through a questionnaire. The Romanian food companies were the subject of study, being companies that act in different levels of the food supply chain.

According to the review literature, Păunescu et al. (2018) registered 16 benefits pointed by the certified companies with the standard. The classification of the extent to which each company achieved the benefits mentioned above, due to the application (implementation and certification) of the ISO 22000 was achieved through a 5-point Likert scale (1- not important to 5- very important).

Based on the obtained results, it was viable to acknowledge which were the main obtained benefits in the studied companies:

- Improvement in food safety;
- A reduction in foodborne illnesses and other dangers;
- Consumer confidence had been increased;
- Customer and stakeholder satisfaction were improved- increasing the volume of sales (Păunescu et al., 2018)

5. Turkey

Other similar survey made in Turkey aimed to study the application and the ISO 22000 standard impacts in food and beverages certified companies from İzmir/Turkey (Mercan and Bucak, 2013). In this survey, it was reported material benefits with the standards implementation, such as material benefits as in waste and loss reduction in the system due to the standardization of operations. Moreover, the catering sector highlighted that companies that adhered to the standard provided trust to customers. The same certification allows companies to gain a higher status and reputation in the market too (Mercan and Bucak, 2013). These impacts can be considered as positive and internal.

6. China

In China, the Food Safety Management Systems status was assessed in the Chinese pork slaughter plants, by Xiong et al. (2016).

60 different companies were included in this study, 78,3% of them had the ISO 22000 certification. In this research, the organizations answered to a scoring checklist so that researchers could assess the impact of the implemented system by checking the compliance of the requirements. After analyzing all the data, the higher scores were related to a complete compliance of the requirement, which corresponds to a good consequence of management systems implementation, a positive impact.

Implementation performance was better in FSMS that got a score of 82,9%, including specifications related with product release, traceability, corrective actions, procedures, product analysis, etc. After, with a score of 73,8%, Control of Food Hazards, and, at last, Good Manufacturing Practices, such as personal hygiene, cleaning and disinfection, pest control and water quality, with a 62,7% score. Considering these results, authors considered that there was a need to help food business operators improve their actions so the organizations could take full advantage of this type of systems, particularly in this case, of the ISO 22000 (Xiong et al., 2016).

The ISO 22000, implemented in worldwide organizations, carried a wide range of positive impacts (Figure 5).

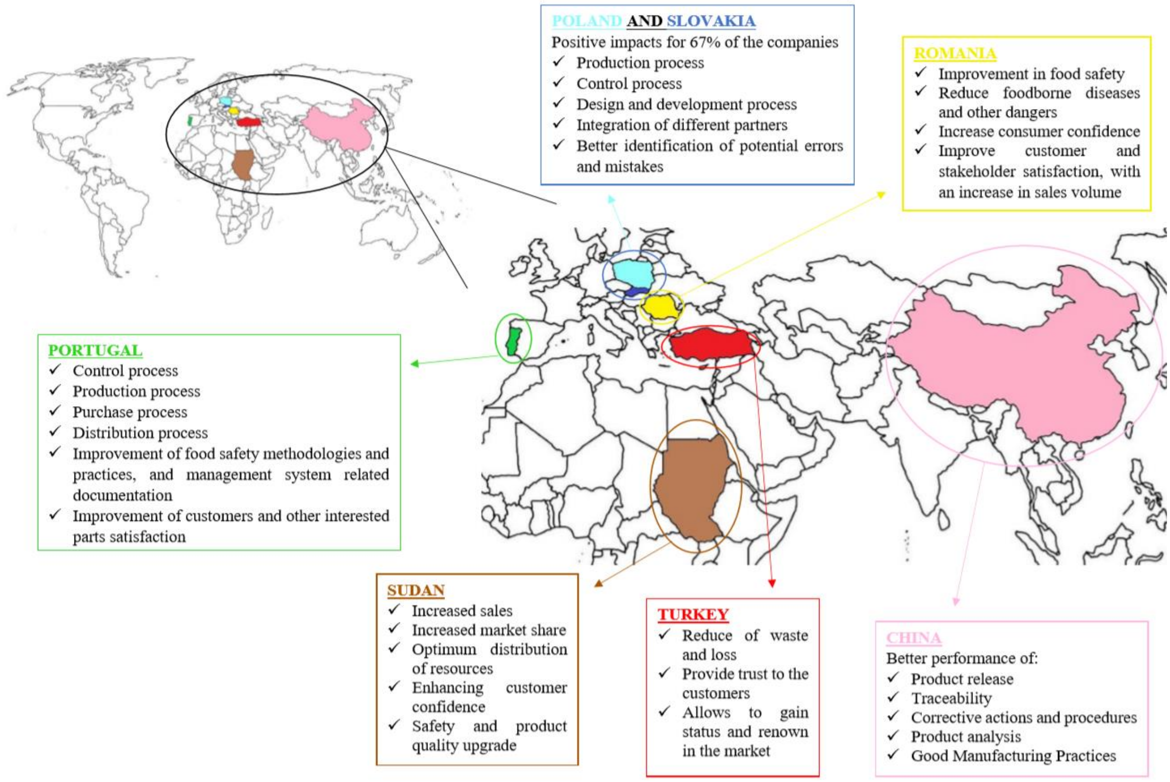

Figure 5: Worldwide view in the countries involved in the mentioned studies and impacts of the ISO 22000 implementation in the organizations

CONCLUSIONS

The analysis of the several studies previously mentioned associate different impacts from the ISO 22000 implementation to diverse food industries and systems. The results obtained were mainly qualitative, acquired through surveys and questionnaires presented to the different enterprises. In general, the implementation of the ISO 22000 standard leads to positive impacts regardless of the country and food sector. The outcome benefits from the standard implementation in the companies seemed to develop increased confidence in consumers and clients, and consequently the enterprise’s status. The benefits observed were also mainly internal impacts, since they directly influenced the company and their products. The improvement of the identification of potential errors and mistakes is one example of these internal benefits, which translates in less waste and loss, and better food security.

It can thus be concluded that getting a company certified by the ISO 22000, is an investment to the company that, in a long term, will bring several benefits to the industry in question and therefore to the consumer and client that will buy the product of that company in the future.

ACKNOWLEDGEMENTS

We would like to thank the Professor Pedro Domingues for all the help and attention given to this review paper and the knowledge given during classes. Also, Professora Mónica Cabecinhas that, during classes, helped to increase our comprehension about some concepts and ways of thinking. To all our teachers of ours from the Department of Biological Engineering, University of Minho and Department of Chemistry and Biochemistry, University of Porto, for the knowledge given throughout this year, that also helped us to improve this work. Finally, thanks to our family, friends and colleagues that are also an important part of our growth.

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ANNEX 1 - INFORMATION REGARDING QUESTIONNAIRES AND SCALES; DATA ANALYSIS; AND MAIN TOPICS ADDRESSED

Table 1: Type of questionnaire and scale used to collect data by different authors in different articles

Type	Countries	Authors	Total studies
5-point likert scale	Portugal; Poland, Slovakia and Portugal; Sudan; Romania	Teixeira and Sampaio (2010); Zimon and Domingues (2019); Khames (2017); Păunescu et al. (2017)	4
Questionaire and checklist	China	Xiong et al. (2016)	1
Semi-structured interview	Turkey	Mercan and Bucak (2013)	1
Written answer	Poland, Slovakia and Portugal	Zimon and Domingues (2019)	1
“Yes”, ”No”, “I don’t know”	Poland, Slovakia and Portugal	Zimon and Domingues (2019)	1

Table 2: Data analysis by different authors in different articles

Program	Countries	Authors	Total studies
Kruskal-Wallice non-parametric test	China	Xiong et al. (2016)	1
SSPS	Portugal; Sudan; Romania	Teixeira and Sampaio (2010); Khames (2017); Păunescu et al. (2017)	3
Tables analysis	Turkey	Mercan and Bucak (2013)	1

Table 3: Main topics addressed in the questionnaires by different authors in different articles

Topics	Countries	Authors	Total studies
Benefits of food safety management system	Portugal; Romania; Turkey; China	Teixeira and Sampaio (2010); Păunescu et al. (2017); Mercan and Bucak (2013); Xiong et al. (2016)	4

Effects on marketing	Sudan; Turkey	Khames (2017); Mercan and Bucak (2013)	2
Effects on supply chain departments	Sudan	Khames (2017)	1
Evolution perspectives concerning ISO 22000 certification	Portugal	Teixeira and Sampaio (2010)	1
Impact on production, purchase, design/development process	Poland, Slovakia and Portugal; China	Zimon and Domingues (2019); Xiong et al. (2016)	2
Impact on the final consumer	Portugal; Sudan; Turkey	Teixeira and Sampaio (2010); Khames (2017); Mercan and Bucak (2013)	3
Implementation and certification costs	Portugal	Teixeira and Sampaio (2010)	1
Improvement of integration of individual partners	Poland, Slovakia and Portugal; China	Zimon and Domingues (2019); Xiong et al. (2016)	2
Improvement on the detection of potential errors and mistakes	Poland, Slovakia and Portugal	Zimon and Domingues (2019)	1
Information of the company	Portugal; Poland, Slovakia and Portugal; Romania; Turkey; China	Teixeira and Sampaio (2010); Zimon and Domingues (2019); Păunescu et al. (2017); Mercan and Bucak (2013); Xiong et al. (2016)	5
Legitimacy of implementing the ISO 22000 standard	Poland, Slovakia and Portugal; Turkey	Zimon and Domingues (2019); Mercan and Bucak (2013)	2
Main difficulties and drawbacks from the implementation	Portugal; Romania; Turkey	Teixeira and Sampaio (2010); Păunescu et al. (2017); Mercan and Bucak (2013)	3
Motivations to the implementation	Portugal; Romania	Teixeira and Sampaio (2010); Păunescu et al. (2017)	2
Performance of the standard used before ISO 22000	Turkey	Mercan and Bucak (2013)	1
Successful impact in the food safety of products	Poland, Slovakia and Portugal; Sudan; Romania; Turkey; China	Zimon and Domingues (2019); Khames (2017); Păunescu et al. (2017); Mercan and Bucak (2013); Xiong et al. (2016)	5

Impacts from the Implementation of ISO 14001

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ABSTRACT

Certification of an ISO 14001 Environmental Management System is a widely accepted standard in the international market and a good sense of a company's environmental conscience for the public. In recent years, an increasing amount of companies seek certification and the present paper serves to summarize the studied impacts of said certification in different kinds of companies, from the construction to the chemical sector. We found that the impacts do not necessarily come from certification, and many of the desired impacts come from implementation alone, like reduced costs and lower waste emissions. We also used available ISO survey data to better illustrate ISO certification over the years in different regions of the world and which industry sector has the most certificated companies.

Keywords: Environmental Management Systems, Industry, ISO 14001, Impacts, Benefit, Process

INTRODUCTION

Environmental management is a subject that has become of great importance, worldwide, with more and more companies concerned with its sustainability. Then came the need for a comprehensive set of standards that would satisfy both companies and the environment. In 1996, a set of standards for environmental management was published by the International Organization for Standardization. This set of standards was named ISO 14001 (https://www.iso.org/2015/11/Ref2013.html). In 2015 the standard was revised and now presents a new structure that is common to all management systems of the International Organization for Standardization. The ISO 14001 standard is currently the most widely used environmental certification worldwide. During the past few years, the number of companies seeking and obtaining this certification has grown significantly (annual average growth of 23%), leading to a total of more than 300,000 certified companies in 2017 (Sartor et al. 2019). Most companies certified with this standard do so voluntarily, as the benefits outweigh the costs. The potential costs of this implementation vary from sector to sector, however some that are common to all can be identified, such as costs with specialized training, reorganization of the production process, alteration of decision-making processes, large technological investment and rates of consulting and obtaining certificates. The future benefits that this implementation can bring are the increase of profits and the reduction of costs, that is, the implementation of ISO 14001 can identify opportunities that mean a lower cost of production, thus increasing sales and, at the same time, pleasing a public increasingly concerned with environmental sustainability (Welch and Mori and Aoyagi - Usui 2002). This increase in the number of certifications has attracted the interest of many researchers looking to study a very wide range of topics related to the standard, for example, what are the motivations for companies to seek this certification (Treacy et al 2019) and effects on the company's performance (Manurung and Rachmat 2019).

According to figure 1, one can observe the evolution that the number of certifications, in each industry, only those that were considered most relevant are represented, recorded from 2012 to 2017. As can be seen, the construction industry has always been the one which held the greatest number of certifications, with great advantage. Next up are the metal industry and the electronic and optical material industry. All the industries presented show a greater increase in the number of certifications from 2012 to 2013, having, in the sense bet, decreased from 2016 to 2017, with the exception of the construction industry which has never seen a decrease in their numbers. The food, chemical and textile industry have their numbers quite constant without major fluctuations, except for the year 2012 to 2013 as previously mentioned. In the period considered, all industries showed an increase in certifications, with the construction industry standing out in the first place with an increase of 130%.

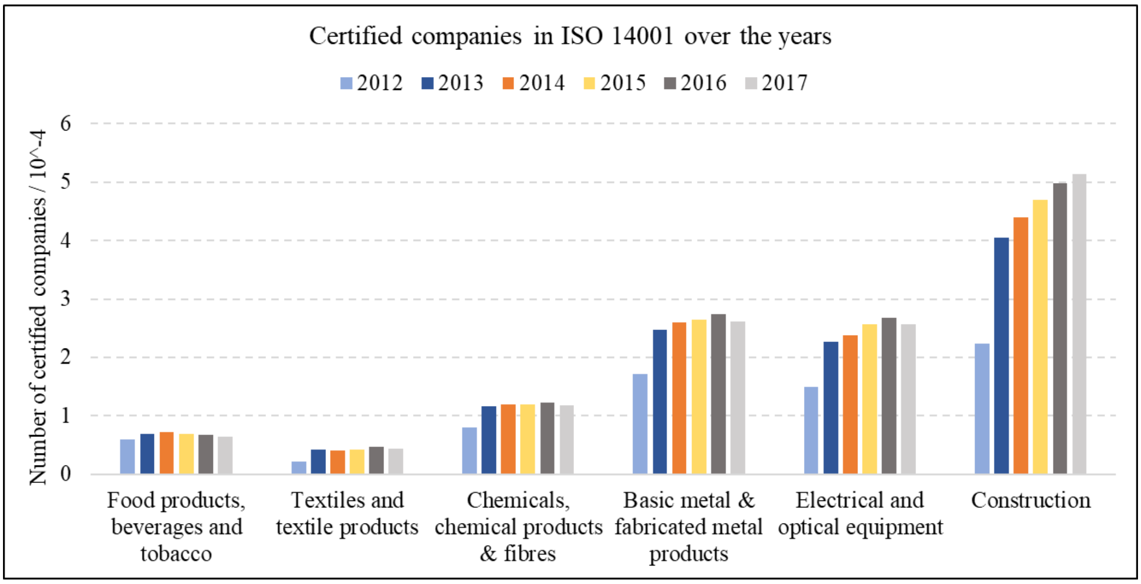

Figure 23 - Number of ISO 14001 certified companies in different sectors

Analyzing now the number of certifications by region, figure 2, it can be seen that Europe and East Asia and Pacific stand out on a large scale from the remaining regions due to the large number of certifications that their companies have, with Africa being the region with the smallest number. In the same way as in the industries, and as a consequence, the regions with the highest number of certifications saw these numbers decrease from the year 2016 to the year 2017, while in other regions this number remained constant.

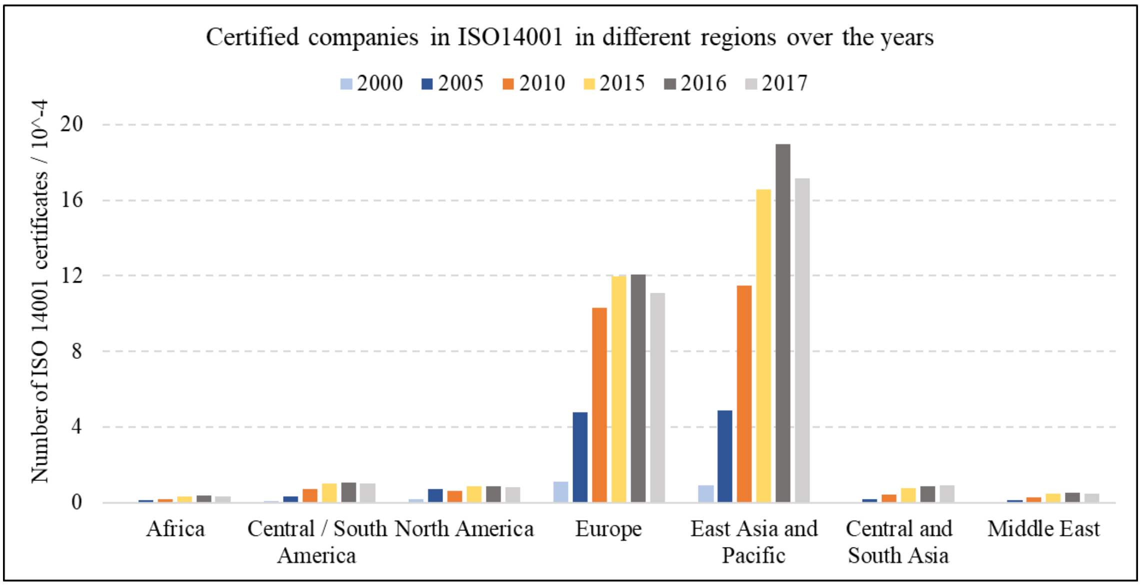

Figure 24- Number of ISO 14001 in different world regions over the years

Therefore, the main goal of this work is to try to understand what are the implications of ISO 14001 in some of the most important industries in the world.

METHODS

This paper reviews the published literature to identify studies of ISO 14001 that refer to impacts, positive or negative, of its application in five major industries of extreme importance in the world economy, chemistry, food, textile, construction, and metal industry. For this purpose, searches were carried out in some databases that were considered the most appropriate, with ScienceDirect, Scopus, and Google Scholar being chosen. The keywords used in the research were "ISO 14001", "Construction ISO 14001", "Impacts ISO 14001", "Metal Industry ISO 14001", "Textile Industry ISO 14001" and "Implementation ISO 14001", “Food Industry ISO 14001”, “Chemical Industry ISO 14001”, “Pharmaceutical Industry ISO 14001”, “Petrochemical Industry ISO 14001” and “Plastic Industry ISO 14001” Initially, 66 articles were considered relevant to the topic under study. After this first selection, the abstracts of each of the articles were analyzed and 37 were selected, which thus became the base articles of this paper.

FINDINGS

What drives a company to seek ISO 14001 certification?

The adoption of an environmental management system can bring several benefits to a company, whichever it’s work sector, from the textile industry, all the way to the food industry. In the following text, we will describe the many impacts on the implementation of an environmental management system or EMS, like the one portrayed by the ISO 14001 in industries belonging to the food and chemical sectors.

Before we discuss the impacts though, it is important to know what motivates a company to adopt and seek certification of an EMS. Some authors state that there are three main reasons for which firms seek certification: social, legal, and economical (Chin et al., 1999).

Related to the social reasons, (Pan, 2003), investigating primarily oriental companies found that a major deciding factor in seeking implementation of an environmental management system is the company’s image to the public given that ISO 14001 certification usually leads to a clean, environmentally friendly reputation. Furthermore, this kind of infrastructure can ameliorate the company’s image from the stakeholder’s perspective, improving overall market status. In general, the social component to the adoption of this kind of system is important, due to the gains related to the society and community acceptance and new market opportunities.

Related to the legal motivations, given that one of the goals of the environmental management system described by the ISO 14001 is the improvement and continuous application of present environmental regulations (Yiridoe and Marett, 2004), the implementation of a framework like this one would help to manage the firm's emission and consumptions. Besides helping the company comply with established regulations, it could also enable the acquisition of funds and supports many governments to give out to environmentally friendly companies (Liyin et al., 2006).

Finally, related to the economical motivations, a certain company can seek certification if its goal is to improve the production process by cutting or improving certain inefficient processes (da Silva and De Medeiros, 2004), however, after ISO 14001 implementation, firms don't always aim for certification given that the low hanging fruit from the implementation of an EMS and doesn't require certification (Halkos and Evangelinos, 2002)

Construction Industry

The number of studies that exist with a focus on the implementation of ISO 14001 and its impact on the construction industry is limited, however, it is possible to identify several positive and negative aspects that this implementation has in the various companies in this sector. According to Tepaskoualos and Chountalas (2017), the implementation of this environmental management system brings with it several advantages such as the reduction of management costs and the company's operations, a faster and more effective resolution of the health and safety problems of its workers, a marked reduction in bureaucracy and helps to fulfill more effectively and efficiently the requirements that some shareholders of companies may impose. The factors identified as most important in obtaining all the potential of this standard were the commitment and presence of top management in the process, effective management of employee uncertainties and conflicts, as well as their involvement throughout the process and the creation of a system that is above all simple without many complications. Valdez and Chini (2002) present another advantage associated with reducing costs with the transport of resources and waste. Also according to Tepaskoualos and Chountalas (2019) but in a more recent study, the implementation of ISO 14001 also brings with it several economic benefits in several areas, such as internal and external audits, and compliance with current legislation. The operational advantages that these companies acquire are mainly due to the simplification of systems and processes. There is also an increase in the promotion of innovation. Thus, these companies can satisfy the requirements of interested parties, customers, and can attract more business partners. On the other hand, and still, according to the aforementioned study, the implementation can bring some problems such as the lack of availability of resources and, due to the lack of knowledge of the procedures, there is a lack of technical guidance which leads to a negative impact. in employees and consequently in the company.

Campos et al. (2016) report that companies in this sector that have implemented this system present a greater number of advanced technological investments because they present a more demanding environmental regulation, thus positively affecting the performance of companies. These companies also have a reduction in environmental pollution, a goal so desired worldwide. However, some constraints are pointed out, the biggest one being the difficulty of articulation between the various sections of the company. The fact that there is a possibility of a loss of competitiveness due to extensive regulations on energy and environmental policies and the fact that it is a resource that takes time to improve environmental performance is also indicated. Owolana and Booth, (2016) reveal that the implementation of the standard reduces the fines associated with infractions and complaints, thus improving the corporate image for customers of companies that have implemented ISO 14001, which contributes to an improvement in public environmental standards and environmental protection. Despite this, some flaws are also revealed, the difficult coordination of environmental performance among subcontractors and, again, the delay in obtaining practical results. In the construction sector in the USA, Christini and Fetsko and Hendrickson (2004) states that the benefits of ISO 14001 are linked to the improvement of public image, improving relations with regulators and, at the same time, obtaining a competitive advantage. The benefits for these companies also included minimizing waste and greater energy efficiency. However, the implementation costs are very expensive, and the subcontracting systems create difficulties in the management of the environmental management system. Another limitation is due to the fact that some companies are large, which may mean that the employees responsible for maintaining ISO 14001 do not have the necessary resources. A study in Singapore exposed other benefits such as the reduction of material waste, reducing the costs associated with it, and the fact that it alleviates the company's environmental system, regulating some aspects of it (Turk 2009). The same study, on the other hand, also revealed some negative impacts, such as difficulties in covering costs and, sometimes, lack of support from customers. He also noticed that there is a great lack of qualified personnel and specialists in this area as well as an increase in the company's management costs.

Metal industry

At the level of this industry, present in all countries, the number of studies related to the impacts of the implementation of ISO 14001 is very scarce, and there are not many studies on the subject in question. Thus, the benefits identified with the implementation of ISO 14001 in this industry are increased awareness of material waste. Although the target levels differ from company to company, they have in common the fact that their workers are more aware of the level of waste, also providing an improvement in the treatment of waste, that is, less waste is sent to landfills and a greater number waste is recovered and recycled. However, top management seems to show only interest in maintaining the certificate and nothing more, which makes it impossible to do more in this area, and may even be an obstacle to reaching other goals (Kvist and Pongrácz and Keiski 2005).

Wu et al. (2019), refer that the certification of this standard makes companies in this branch have a cleaner production, with a reduction in environmental pollution. However, due to the existence of some contradictory information, external investors need additional risk compensation, which can increase companies' financing costs. But on the other hand, the implementation may mean that companies will have fewer environmental risks in the future, making investors feel more confident and more willing to invest in these companies. Also in this article, it is discovered that the effect of cleaner production that ISO 14001 brings is more prominent in non-state companies, as companies that are owned by the state tend to have better resources in accessing credits. Unlike private companies that need to transmit their sustainability to the market through certification and other means. Givano and Sholichah (2019), show that the implementation of this standard has other positive impacts in this industry. The increase in environmental awareness and the mitigation of the risk of environmental pollution, which is verified by upgrading to superior production technology and the use of more efficient and ecological equipment and fuel alternatives, is pointed out as the great benefits in this sector. Also, the incentive to install some WWTP or a similar project that cleans and recycles the water, guaranteeing its sustainable use, during the production cycles, is seen as an added value, from the environmental point of view.

Textile Industry

Also in this industry, studies on the impacts of the implementation of ISO 14001 are, again, quite scarce, contrary to what one might think because this is an industry with several implications for the environment and due to the fact that the number of companies certified in this industry sector is still considerable. However, it was possible to identify some impacts, positive and negative, of the application of ISO 14001 in this industry. According to Hayat et al. (2019), in a study carried out in Pakistan, this sector appears to be less willing to protect the environment and, consequently, to invest in an environmental management system. Thus, only a limited number of textile companies are certified with an environmental management system (ISO 14001). In addition, companies that are focused on exports do not show much knowledge in the area while local companies are not even aware of the existence of these systems. Companies that are certified with ISO 14001, according to the same authors, have their environmental performance improved, while increasing their competitiveness, thus increasing their profits. It can also be seen that these companies establish more efficient production processes, thus being able to reduce costs without reducing the quality of their products. Another advantage of this certification is the more reliable image vis-à-vis partners and potential customers, a factor that can often become decisive in choosing one or the other company. These companies have only encountered some difficulty in exporting their products and are still unable, sometimes, to compete with other companies.

Zimon and Madzik (2019) refer that the application and development of the standard procedures, as well as the implementation in supply chains, affect this sector in a very positive way. Advantages are mentioned, such as an improvement in the forms of communication, both internal and external, the control of significant environmental aspects, the rapid detection of potential threats and failures, a positive impact on the environment, through the monitoring of relevant parameters and being aware, as well as evaluate the conformity of the processes carried out with the current normal ones. To achieve these objectives, the importance of top management and leadership is mentioned. It must be fully committed to all policies and implementations to be carried out. Compliance with the guidelines of the standard, in addition to affecting the company itself, can also have an impact on relationships and the establishment of new contacts outside the company, both environmental and political. Thus, and with the support of top management, in addition to what was previously mentioned, ISO 14001 not only leads to the minimization of material and energy consumption through recycling and maximum rationalization of activities but also to take into account issues environmental issues such as the product cycle, an increasingly important concept in industry and society today. The reduction of waste resulting from the implementation of the standard has recently become one of the areas of interest in which science in industrialized countries is concerned.

Ahmed et al. (2018) mention that what makes the norm attractive in this sector is mainly due to the advantages that it entails, highlighting the ability to reduce contamination, cost reduction, and, as a result, an increase in competitive advantage. According to the authors, other positive aspects of the implementation of the standard included the reduction of energy consumption in carrying out activities, the optimization of transport operations, thus reducing the carbon footprint, the correct disposal, reduction, or designation of another waste destination. and the increased use of renewable energy sources to the detriment of non-renewable ones.

Food Industry

In a study conducted by (Psomas et al., 2011) in which several surveys were sent out to multiple food sector companies, the researchers discovered that the greatest impact to the implementation of an EMS was the enhancement of the efficiency of certain processes, leading to higher profits and lower expenses and waste, however, and as mentioned previously, this benefit is obtained immediately after implementation, hence, certification is not needed. Additionally, the surveyed companies answered that another great benefit of ISO 14001 implementation was the improvement of company image as perceived by society, which in turn, would allow for market expansion, acquisition of new potential clients, especially foreign ones, looking for a business partner that meets environmental legislation. The same study also reports that the least impacting change brought upon by the implementation of the EMS was the replacement of conventional processes by more sustainable ones.

A different study by (Massoud et al., 2010) in which several food sector companies from Lebanon were reviewed, the greatest impacts sought after by firms that seek ISO 14001 certification are connected to environmental performance improvement, following the trend set by international companies of the same sector. However, the authors report that the results described contradicted a previous article by (Mezher and Zreik, 2000), reporting that companies in the same geographical location would implement and get certification in the EMS to be granted access to international markets.

Although the objective of ISO norms is mainly to help companies in different sectors, sometimes the implementation and certification can represent some challenges to the firms. In a study conducted by (Turk, 2009) the greatest challenges represented by the implementation of the EMS are the lack of trained employees, lack of knowledge, and mainly the necessary investments required upfront. Another downside of ISO 14001 implementation is the worker's disapproval of added responsibilities, added bureaucracy and paperwork needed for certification (Ann et al., 2006) and the belief that once implemented, the EMS wouldn’t need to be constantly revised and improved (Chavan, 2005).

Chemistry Sector

The chemistry sector, like the name implies, encompasses all industrial processes based on chemistry or chemical synthesis. Industries like petrochemistry/ oi refining, pharmaceuticals, sodium hydroxide, pesticides, plastics, paints, pigments, polymers, and all other intermediaries belong to the chemistry sector. In fact, by looking at the statistics from European countries belonging to the EEA – European Environment Agency, that from all hazardous waste produced between 2007 and 2017, 11.5% was produced by the chemistry sector (EEA-33 - Industrial Pollution Profile, 2019). Unfortunately, this sector and chemists themselves are often seen as a problem by society (Clark, 1999) but professionals have tried for a long time to apply green chemistry principles to industries, replacing former reactions with stoichiometrically efficient ones and reducing inherent risk from reagents, instead of minimizing exposure (John, 2004).

A certain oil company located in Belgrade implemented an EMS based on ISO 14001 to evaluate environmental aspects and monitor possible improvements regarding its environmental performance (Takić et al., 2013). The result was a decrease in wastewaters has shown by the company’s flocculants consumption test between 2008 and 2010.

ISO 14001 impact can also be indirectly applied to a certified company supplier if the company in question is environmentally conscious and strives to improve. In an article by (Ochsner, 2000), a rubber company convinced it's metal parts supplier to use a water-based lubricant because the previously used grease coating required a very toxic and expensive solvent to remove. However, the article shows that the company applies ISO 14001 principles mainly to reduce costs and environmental consciousness being a secondary issue.

Finally, in an article by (Radonjič and Tominc, 2007), by studying several industrial sectors from Slovenia, chemistry industries would implement ISO 14001 with the main goal of improving environmental impact, by reducing solid and gas waste, improving energetic efficiency and to improve social image, enhancing worker security through the reduction of toxic solvent use. However, the article also explains that small companies or companies with reduced capital have difficulties in implementing an EMS even without seeking certification, given that the initial investment in energetically efficient equipment, qualified staff, and alternative solvents is too big, even if the positive impacts are significant.

Finally, to better understand how the different sectors are connected through the impacts that come from ISO 14001 certification, the results of this paper's focus are summarized in table 1.

Table 18- Impacts from ISO 14001 certification in different industry sectors

Industry Sector	Impacts
Construction	• lower costs with the transport of resources and waste • increase in the promotion of innovation • greater number of advanced technological investments • reduction in environmental pollution • reduction of fines associated with infractions and complaints • difficult coordination of environmental performance among subcontractors • delay in obtaining practical results • improving the corporate image
Metallurgy	• increased awareness of material waste • cleaner production • less waste is sent to landfills and a greater number is recovered and recycled • mitigation of the risk of environmental pollution
Textile	• more efficient production processes • improvement of the image vis-à-vis with partners and potential customers • increasing competitiveness • rapid detection of potential threats and failures • positive impact on the environment • reduction of contamination
Food	• Higher process efficiency

	• Improved social image • Market expansion • Increased workload • Increased staff frustration
Chemical	• Waste management solutions • Cost reduction • Transition to Green Chemistry principles • Improved social image;

CONCLUSION

The present literature review contributes to the findings and evidence that companies are increasingly concerned with their sustainability, whether due to the demands of their customers or their own conscience. It appears that the existence of an environmental management system can increase the turnover of companies, thus presenting these companies with a competitive advantage in the global market that is constantly changing.

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Critical success factors during the implementation of ISO 22000:2018

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STRUCTURED ABSTRACT

Purpose - The purpose of the paper is to evaluate why companies still struggle with ISO 22000 implementation and maintenance, identifying which aspects are key for its success.

Design/methodology/approach - A literature review was carried out based on Scientific articles and implementation guides collected from Google Scholar, ScienceDirect and ResearchGate.

Findings - Nine aspects seem to have a broader impact on organizations’ maintenance of ISO 22000 and other FSMS. Furthermore, the empirical research reveals that having an efficient food safety management system is a prerequisite for company’s competitiveness.

Practical implications - The findings show that many of the critical success factors for a FSMS implementation are based on regular and adequate management of people inside the company.

Originality/value - A novel model of segmenting critical success factors is presented, which has practical implications for ISO 22000 achievement.

Keywords: ISO 22000, implementation, critical success factors, FSMS.

Paper type: Research paper.

INTRODUCTION

Over the last few decades, the food supply chain has become a complex and highly controlled structure within the food companies, mainly as a result of globalization and science advances, since it's well known that small-scale mistakes can lead to global food poisoning catastrophes (Griffith, 2006). This way, mismanaging the food production chain may harm consumers' health and risk food manufactures' reputation. Today, the biggest responsibility of food manufactures, way beyond mere aspects of taste, innovation, or nutrition, is to ensure high quality food products, which should be clean and safe to consumers (Chung et al., 2020). Food quality embraces a wide range of subjects, among them, food safety (FS). A FS hazard is defined in ISO 22000:2018 as a "biological, chemical or physical agent in food with the potential to cause an adverse health effect".

Implementing a food safety management system (FSMS), such as BRC, IFS, HACCP, or ISO 22000, is key to achieve FS (Qijun and Batt, 2016). Hence, firms may implement a FSMS for a variety of reasons, which can be internal, such as the voluntary perception that the benefits should outweigh the costs, or external, in the case of a forced-up situation by customers or public authorities (Taylor, 2001; Karipidis et al., 2009). Some of the benefits of having a FSMS are the improvement of product quality and safety; increased competitiveness in the global market, granting the access to new markets; fewer customer complaints, superior productivity, improved company reputation or image and greater consumer confidence (Qijun and Batt, 2016). On the other hand, there are plenty of constraints that may impact upon the adoption of a FSMS, such as a lack of financial resources, a lack of formal management; a lack of awareness; a lack of motivation; a lack of top management commitment or other external factors (Yapp and Fairman, 2006).

Industries can get certified by the ISO 22000 Standard, which is getting increasingly popular as a solution to improve food safety. This Standard combines aspects of the ISO 9001 Quality Management System and the HACCP Food Safety System, covering organizations through the whole food chain. Since September 2005, when ISO 22000 was first published, it has been widely adopted by many companies around the world. However, it has being recently updated into ISO 22000:2018, making it necessary for the companies to adapt to this new version until maximum 3 years after this publication, as established by the International Accreditation Forum (IAF).

One of the differences between ISO 22000:2005 and ISO 22000:2018 is that the latter version has introduced a High Level Structure alignment (HLS), which is based on a text and structure that is common to all ISO management system standards, making it easier for organizations to combine ISO 22000:2018 with other management systems. Other major differences between these two versions include new changes in some definitions and vocabulary; the inclusion of animal food (which is the food for animals that are not intended to be eaten and therefore are not part of the human food chain); and more detailing of the objectives (ISO, 2018).

Adequate ISO 22000 implementation provides organized and effective communication with stakeholders, such as health authorities, customers, suppliers, and business partners (Escanciano, et al., 2014). According to Faergemand (2008), an ISO 22000 certified company increases its credibility with food safety authorities, allowing them to reduce the frequency of audits and inspections by demonstrating the company's commitment to food safety. Today, there are approximately 32,139 companies worldwide certified with ISO 22000, China being the country with the largest number of certifications (DQS, 2017). This way, identifying which factors may influence a company to achieve a successful ISO 22000 implementation is fundamental. Hence, the objective of this study is to determine the critical success factors during the implementation of ISO 22000:2018, dividing them between internal and external aspects that deserve to be highlighted.

RESEARCH METHODOLOGY

For the development of the research paper, the investigation process was done mainly by using Google Scholar, ScienceDirect and ResearchGate and required the use of the keywords “ISO 22000”, “implementation”, “critical success factors” and “FSMS”. Due to the novelty of the topic, the available information is limited, specially related to the study cases and the implementation of the Standard in the organizations. Therefore, the literature review was based on the reading of the abstracts of approximately 100 articles and further selection of the pertinent ones, comprising data between the years of 2001 and 2020. Also, a careful examination of the versions 2005 and 2018 of the ISO 22000 Standards was performed, as well as a critical review of the available ISO 22000 implementation guides.

The selection and analysis of the critical success factors was performed against the requirements of the Standard ISO 22000:2018, as well as the cases of success in the implementation of the Standard found in the literature. Since the topic is very recent, the most important internal and external factors were explored, because they will have a relevant impact in the implementation. The factors with lesser impact were not considered because the scarce available evidence.

RESULTS

Today, many enterprises, mainly medium and small ones, still struggle with the implementation of FSMS (Taylor, 2001). The understanding and analysis of critical success factors amid ISO 22000 implementation is paramount. In this context, there were identified nine factors that are key to the successful implementation of ISO 22000, which can be divided between internal and external elements (Table 1).

Table 1. Main critical success factors for the implementation of ISO 22000

INTERNAL FACTORS	EXTERNAL FACTORS
Leadership	Context of the organization
Staff training	Risk and opportunities
Performance evaluation	Stakeholders
Planning	Support
Financial resources	

Internal success factors

Leadership

The ISO 22000:2018 itself highlights the importance of leadership and commitment by the top managers when it comes to being successful. The senior manager must be able to command and guide employees through the process, as well as show responsibility to establish, implement and maintain food safety policy (Purwanto, Asbari and Santoso, 2019). Also, the establishment of the food safety policy can include aspects that are specific to each company's context, making it necessary to engage in particularities apart from those directly required. The top management must be able to communicate properly with all parties, ensuring the management system is well understood and continuously available, assigning pertinent responsibilities to each member of the team and making sure all team members have the experience or appropriate training to accomplish their tasks successfully.

Besides, leadership style can be divided in transformational or transactional, generating different results (Purwanto, Hutagalung and Yanthy, 2020). Transformational leadership is about leading a team by identifying collectively the aspects that need change, creating a vision to guide the transformation through inspiration and connecting workers to a sense of collective identity (Odumeru and Ogbonna, 2013). On the other hand, transactional leadership focuses mainly on supervision and performance, implementing both rewards and punishments. Studies show that transformational leadership has the biggest impact on employee performance and promotes higher job satisfaction, while transactional leadership is more effective during crisis or emergency situations (Odumeru and Ogbonna, 2013; Isnawati et al., 2016; Rahim et al., 2018). Hence, it is decisive that top managers lead with a transformational approach, inspiring the team to give their best performance and guaranteeing a sustainable food safety culture.

Staff training

Many problems with food safety come out of a lack of competent staff, which ultimately results in flaws in the good manufacture practices (GMPs). In macro enterprises (more than 1000 employees) with a more complex production chain, many of the difficulties detected were related to constant staff training (Xiong et al., 2017).

Staff training can be conducted internally or in partnership with accredited companies and universities. In an investigative study made over Turkish poultry industry, the majority of companies limited their staff training to annual courses (Kök, 2009), which is a potential vulnerability for ISO 22000. Both managers and employees must comprehend the meaning and function of the management system as a way of controlling foodborne hazards and quality assurance, implementing its principles in a continuous and proper way (Sofos, 2008).

Performance evaluation

In terms of performance evaluation, there are tools to diagnose the performance of an implemented FSMS (diagnostic tools), tools to help a selection process (selection tools), and tools to improve the FSMS performance (improvement tools) (Jacxsens et al., 2011). Also, the establishment of an internal audit department is key to improve the effectiveness of the food safety control measures and to help the company to achieve its objectives. An internal audit aims to evaluate the company's internal controls, ensuring compliance with laws and regulations. It also helps to identify problems and make corrections before they are discovered in an external audit.

The SMEs tended to have a poor understanding of food safety management system and insufficient finance support resulting in limited adoption of FSMS (Fielding, Ellis, DrBeveridge, & Peters, 2005). The smaller enterprises needed more incentives and faced more difficulties in allocating resources to food safety systems.

Ultimately, it is of utmost importance that all evidence is kept in the form of documented information, so that results can be periodically evaluated. (Duman et al., 2017).

Planning

Far beyond being responsible for producing safe food for consumers, it is expected that food companies demonstrate transparency on how food hazard control is made, planning actions to guarantee products are harmless (Pozo, Barcelos and Kazue, 2018) At the same time, change is an inherent part of the process, so organizations must be able to address transformation making precise adjustments, planning necessary improvements for short, mid and long term.

Financial resources

It is indispensable to remark that the difficulties involving performance evaluation are far most evident in small and medium enterprises (SMEs) (KÖK, 2009). According to Xiong et al. (2017), smaller enterprises tend to have a poor understanding of FSMS and more limited financial resources. This, consequently, may result in an imperfect ISO 22000 implementation or in a complete withdrawal of the system. According to Taylor and Kane (2005), most of the small enterprises (67%) operate with deficient staff training frequency, which is suggestive of their inability to provide more frequent training courses, probably as a result of the great financial burden that FSMS implies on them (Taylor and Kane, 2005). Thus, more monetary incentives are needed to face those difficulties and make ISO 22000 attainable for all organizations.

External success factors

Context of the organization

The national and international commerce is a competitive scenario in constant evolution (Mensah and Julien, 2011). The higher competitivity in national and international commerce and the access to international markets is one of the greatest motivations for organizations to implement FSMS, and the certification with ISO 22000 can provide high revenue compared to the effort.

The implementation of safety and quality standards can help food companies to be more competitive in the market (Kafetzopoulos and Gotzamani, 2014; Weyandt et al., 2011). In this sense, ISO 22000 implementation proves to be a very important tool to manage food safety. One of the objectives of this Standard is promoting trust in the company capability to offer a high-quality product, and therefore, obtaining a competitive advantage for future sales (Karipidis et al., 2009).

Risk and opportunities

The evaluation of the external risks and opportunities allows the incorporation of stakeholders' status in the implementation of the Standard. The organization can see this factor as a tool to enhance their objectives involving all the external components. In the "Planning" section, the ISO 22000:2018 establishes some key points to manage the risks and opportunities, stating the risk as an opportunity to improve the organization from both sides: inside and outside (ISO, 2018).

Basically, the first step to perform is the determination of the risk and opportunities, in order to obtain a clear view of all related factors (Chen *et al.*, 2020). Determination of risks and opportunities can be achieved by different analytical ways, which must be chosen by the organization, considering their necessities and goals. This analysis is the first step to detect the undesired effects, thereby preventing, reducing and improving them until the accomplishment of the required standard (Pedraza, 2019).

Once the organization employed the analytical risk tool, it is mandatory to create a plan with the associated actions to manage those factors. All actions should be fitted in into the FSMS implementation plan and must be corroborated to check the desired success. As a result, these actions will be equivalent to the needs and requests made by the customers and all the participants in the food chain (ISO, 2018.; Pérez, 2019; Chen *et al.*, 2020).

There are many methods to evaluate and analyze internal and external factors into the organization. These analytical methods are an efficient tool to uncover the features related to the external and internal factors and regularize them to fulfil the requirements. Several tools are well known, but two of them are the most important and widely used (Gürel, 2017; Pedraza, 2019): PESTLE (Political, Economic, Social, Technological, Legal and Environmental) and SWOT (Strengths, Weaknesses, Opportunities and Threats).

When PESTLE analysis is used, there is an overall view about how national and international elements influence on the organization, making easier to notice the possible impact that those elements may have in it. As an example, the analysis of legal factor involves all the legislation that is around of the organization's interest, in this case, food legislation (Rastogi and Trivedi, 2016; Stoyanova, 2019).

SWOT is a very common methodology, because it shows the actual situation around the organization, specifically about the organization environment from the internal (Strengths and Weaknesses) to the external perspective (Opportunities and Threats), providing an useful tool to find risks and convert them into opportunities (Peña, 2017; Nielsen, 2018; Zaman, 2019).

Stakeholders

To achieve success in the FSMS implementation, the whole organization must be motivated. One of the greatest motivations for implementing management systems, like ISO 14001, ISO 22000, or IFS 5, is the confidence boost in their clients (Weyandt et al., 2011), once the organization is certified by third parties. None of the FSMS produces safe food by itself, but after the proper implementation and application of the Standard it can be assured to the customer a minimum level of food safety, increasing their trust towards the products done by the certified organization.

Given the fact that the modern customer is every day more conscious regarding food safety, and also more interested in obtaining a product that is not just safe, but with a high quality, the implementation of FSMS can work as a key factor in the acquisition of certain product. Both ISO 22000 Standard as other internationally recognized food safety standards can guarantee that the certified organization has the capability of manufacturing safe products, avoiding sickness and losses related to accidents caused by unsafe food (Pozo, Barcelos and Kazue, 2015), increasing trust in their customers regarding their products and the organization itself.

Support

There are 6 critical points involved in the successful implementation of ISO 22000:2018 related to external factors: people (specifically subcontractors), infrastructure (mainly transportation), externally developed elements of the food safety management system, control of externally provided processes, products or services, competence and external communication (ISO, 2018; Chen *et al.*, 2020).

As noted in the "People" factor stated in the Standard, the organization's human resources should provide guarantees of their skills to fulfil a task, therefore the Standard demands that in case of absence of duly trained and prepared workforce, it will be required to hire external services, like subcontractors. These external services must comply with all requisites defined by the organization, but also, they must adapt to the requirements demanded by the Standard (ISO, 2018; Pedraza, 2019).

Transportation is an element of the infrastructure clause 7.1.3, and it needs to be controlled during the implementation of the ISO 22000:2018. Certainly, transportation involves the import of raw materials and the distribution of the product; both can be done by external support. However, this external support must comply the Standard specifications, and therefore the organization must ensure the conformity towards their goals (Purwanto *et al.*, 2020; Purwanto, Santoso and Asbari, 2020).

In the FSMS implementation, it is necessary that the organization uses external elements to achieve their improvement and actualization, and these elements cannot be exempt from the Standard requirements but must comply them. The external FSMS elements must be adequate to the type of organization and to the product or service provided. Therefore, they not only should fulfil the organization objectives, but also, they must be fully implemented and adjusted by the food safety team. It will always be needed to document every detail done to implement these elements, being extremely careful about keeping these documents updated to maintain control on the development and management of all external elements (Pozo, Barcelos and Kazue, 2018; Pedraza, 2019; Purwanto *et al.*, 2020).

The previous critical point should be evaluated by the organization, assuring that is consistent with the objectives and requirements of the company, to avoid that the organization is affected by situations that can be evaded. It is necessary to establish strategies, protocols and criteria that will be used in the external element evaluation, as well as the methodology to prove and document that the control step is done and kept updated (ISO, 2018; Kafetzopoulos and Gotzamani, 2014).

Inside its working group, the organization must be able to have trained people with adequate and actualized skills for each function they are hired for. However, not all companies achieve this step (Ochoa and Pernett, 2019). Therefore, the organization can also implement two solutions to ease this problem: train their staff to keep them as their own working force inside the organization (Grijalba and Paz, 2019) or hire external services that are required to comply with the requirements. The external services hiring is justified when the company does not have the skills in their own organization, and, they are needed in some punctual occasions, such as plague control, internal audits, staff training, among others (ISO, 2018; Peñafiel and Lucero, 2019; Chen *et al.*, 2020). However, if the organization hires external services as staff, they must have adequate mechanisms to evaluate them and test that the hired services comply with the necessary skills to fulfil its objectives, keeping updated records of the process (Peñafiel and Lucero, 2019).

External communication is more than just reaching clients and suppliers, since there are legal authorities that regulate the organization’s activity, as well as others external components that influence in the organization environment. This communication must be clear, effective (Escanciano and Santos-Vijande, 2014; Pedraza, 2019), and use the right language to each receptor, and extremely careful measurements should be taken when reporting information regarding food safety where there is not space for mistakes. Therefore, the food safety team has the responsibility to keep all their information fully updated (Chivandi and Maziriri, 2017; Chen *et al.*, 2020).

CONCLUSIONS

The main conclusion to be drawn from this study is that there are many aspects that can determine the success of ISO 22000 implementation. However, some internal factors (Leadership, Staff training, Performance evaluation, Planning, and Financial resources) and external factors (Context of the organization, Risk and opportunities, Stakeholders, and Support) seem to have a broader impact on organizations’ maintenance of FSMS, with many of those critical aspects depending upon the correct and consistent management of people inside the company.

It has been noticed that the internal factors can show how the organization is operating, revealing its capacity and limitations, consequently providing a good tool to approach the organization goals to implement the Standard, increasing the chance of success in the process. These internal factors give an entire view of the organization performance because they analyze every related area and promote their improvement, providing more control over the internal environment and making it capable to work according to the requirements of the Standard.

Also, the external factors can be useful to the same purpose but related to control the surroundings of the organization. If the organization is as strict with the external environment as with his own internal issues, the success rate in the implementation of the Standard is higher. These factors can be determinant to obtain the best Standard implementation, so the organization has to work harder with these factors because they are not easily controllable as the internal factors. However, this task is not impossible and if every detail is established in conformity of the organization goals, the result can be very satisfying. Additionally, it is a good way to encourage other organizations to improve their owns standards and making their work better, creating an entire system of certified organizations to be competitive in the economic sector.

Furthermore, the empirical research conducted in this paper reveals that having an efficient food safety management system, such as ISO 22000, is a prerequisite for the company to remain competitive. The segmentation of critical success factors into internal and external factors can be a useful tool to analyze how elements can be controlled, which ultimately can lead to better planning and achievement of a company’s goals.

Due to the novelty of this Standard and the current implementation worldwide, the evidence for successful strategies is still under development. Therefore, this is a topic with continuous growth and should be explored after new successful strategies are available.

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ISO 14001 standard: Benefits, Motivations and Difficulties throughout the Implementation Process

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ABSTRACT

Purpose– The purpose of this paper is to present a summary of the benefits, motivations and difficulties in implementing the ISO 14001 standard, which is the key reference in the field of corporate environmental management.

Design/methodology/approach- A literature research was carried out in order to get understanding about the key concepts of ISO 14001, to investigate the reason why companies feel motivated to adopt this EMS and to identify the associated benefits and difficulties in the implementation.

Findings – This paper shows the benefits found by certified companies can be classified in internal, external and relations benefits. The impact of the certification on financial and organizational performances showed to be positive. Enhancement of internal processes, strengthening of results, prevention of potential problems and a larger number of stakeholders are pointed as important performance improvements.

Originality/value - This paper focuses on the ISO 14001 certification motivation and importance. Thus, this paper contribution lies on providing information regarding possible benefits and difficulties that may occur due to EMS implementation.

Keywords: ISO 14001, Standard, Environmental management systems.

Paper type: Literature review.

INTRODUCTION

The concern with the environment is nowadays an important issue for the general population and, consequently people become more demanding in their choices and tend to pick environmentally friendly products and services. According to this, organizations require adjustments regarding environmental policies and need to acquire practices that may lead to environmental conscious products and services. Therefore, several companies choose to adopt an Environmental Management System (EMS), namely the ISO 14001 standard which is the main reference in this field (Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017).

Released in 1996 through the ISO 14000 series and with a structure based on the ISO 9001 standard, the ISO 14001 was developed by the International Organization for Standardization to encourage the implementation and external recognition of a certifiable EMS. This is presented as an effective tool to improve environmental practices and organizational effectiveness. Furthermore, this standard became the leading EMS worldwide and has suffered updates in 2004 and 2015.

ISO 14001 is based on the Plan, Do, Check, Act (PDCA) cycle and this methodology promotes a process of continuous improvement of the organization's effectiveness, enables organizations to evolve their environmental performance and demonstrate compliance with the existing laws and increase their relationship with stakeholders (Sorooshian, Cai Qi, & Li Fei, 2018; Sousa Lira, Gomes Salgado, & Beijo, 2018).

While the Eco-Management and Audit Scheme (EMAS) is only applicable at the site level, ISO 14001 can be applied at the facility, company, or organizational levels (Sousa Lira, Gomes Salgado, & Beijo, 2018). Companies implement this EMS since it allows them not only to improve their environmental aspects but also provides an increase in staff morale, profit growth and a better relationship with clients and investors. This due to the fact that ISO 14001 is associated with an improvement of the company's reputation and image.

LITERATURE REVIEW BY BIBLIOMETRIC ANALYSIS

In Bibliometric Analysis the size of each item is proportional to the co-occurrence frequency of that keyword. In terms of frequency, the "ISO 14001" is the keyword with the largest one (64). Other high frequency keywords include: "certification" (29), "performance" (27) and "adoption" (26). In addition, "benefits" appears further in the list, with a frequency of 11, although with strong linkage with recurrent keywords, such as "ISO 14001", "performance" and "impact" (Fig 1).

As far as clusters of keywords is concerned, we identified three clusters in Fig.1 with the help of VosViewer: blue, red and green. The red cluster's keywords include "ISO 14001", "certification" and "adoption" that define the research in general regarding the adoption of the EMS and the certification process. The blue cluster reunites keywords such as "performance", "benefits", "motivations" and "environmental-management" focusing on the reasons to adopt the EMS and the benefits that may come from that implementation. The green cluster focuses on keywords such as "impact", "environmental management system "and "environmental performance" highlighting the papers that approach the environmental impacts and outcome of the ISO 14001 implementation.

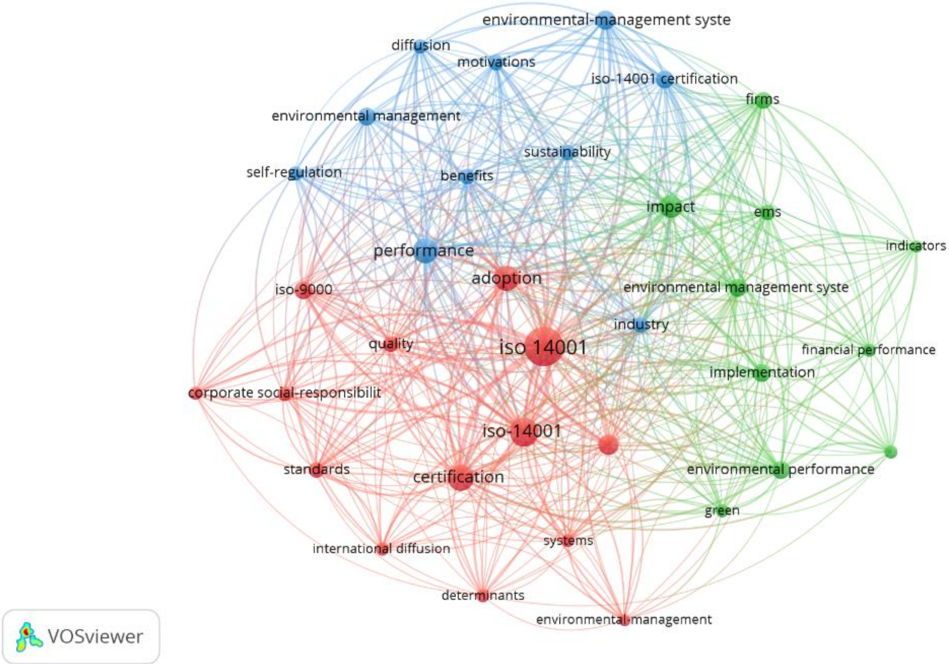

Figure 1. The keywords co-occurrence network. Source: Visualization in VOSviewer from Web of Science. 416 keywords, minimum number of occurrences of a keyword = 6, 75 items & 3 cluster & 443 links.

Besides an analysis of the frequencies of some keywords, we have created a world map where the number of articles we analyzed for this review are distributed by country. Of the thirty-two articles, six originated in Canada, four in the United States of America (USA) and three in Malasya, and these were the countries with the most articles published in the ones we analyzed (Fig.2).

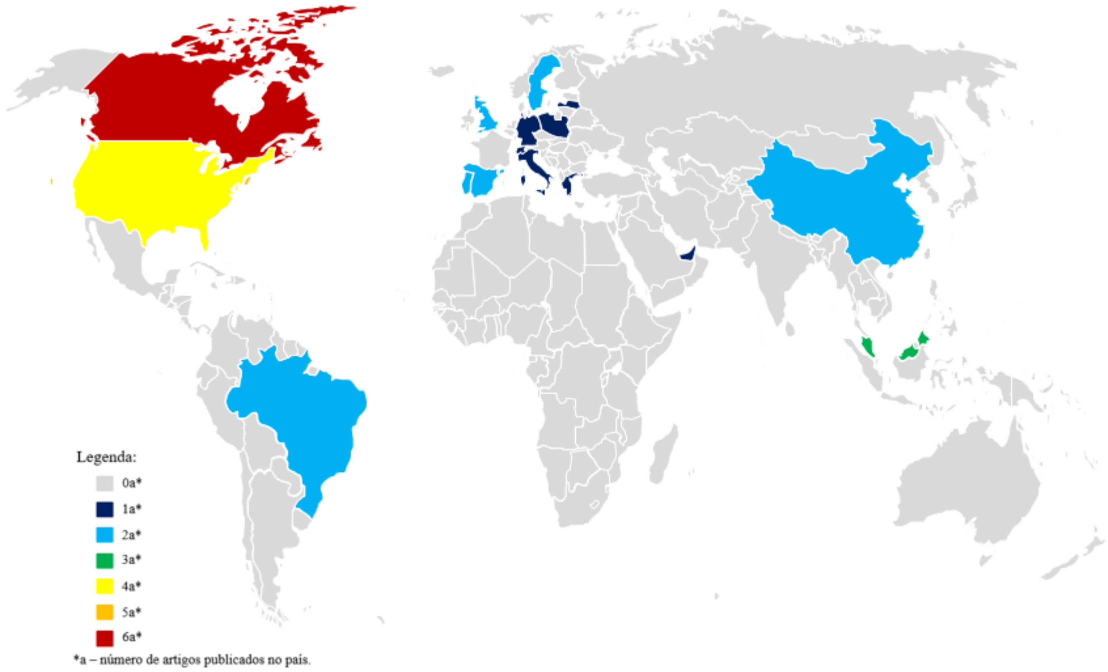

Figure 2. World map with distribution of the articles analyzed in this review.

Looking at the map (Fig. 2) with attention we notice that the European continent has the largest number of published articles (14) followed by the American (12) and lastly Asia (6). Although at first look there seem to be more publications in the American continent, the European has more countries to publish, even if each one publishes less than Canada or USA.

RESEARCH METODOLOGHY

This article consists on the research and bibliographic review of published articles regarding ISO 14001. The databases to acquire those articles were Web of Science, Researchgate and Scopus. In order to find these articles keywords such as “Implementation of ISO 14001”, “ISO 14001 benefits”, “ISO 14001 motivations” and “ISO 14001 difficulties” were used.

Due to the extended number of publications, some relevant articles were chosen to be further analyzed. Selection of publication that may possess relevant information was made according to the title and abstract presented. After analysis, we gathered a set of articles that had important information about the benefits, motivations and difficulties related to ISO 14001 implementation and some studies that presented results based on companies’ surveys.

The distinction between benefits, motivations and difficulties was not difficult since in all the articles analyzed information was very clear. Since benefits are all the advantages that the company gets with the implementation of this standard, the motivations are what leads the company to seek certification and, at last the difficulties are characterized as being the barriers that the company faces when implementing or the reasons for some to not want to implement ISO 14001.

Benefits

The benefits of EMS can be divided into two categories:

- Internal
- External:

Internal benefits state the advantages obtained within the company, while the latter refers to the benefits of the implementation of the EMS obtained from outside the organization and these two categories are interconnected and do affect each other. For example, the improvement of processes that save raw materials lead to increased profit and, consequently, to increased competitiveness and investors interest as shown in Table 1.

Internal benefits

The processes improvement will lead to saving of raw materials, reductions in the use of energy and water as well as waste minimization, which, consequently, causes the reduction of costs and provides an increase in the company's profit. Furthermore, usage of improved processes and technologies increases employee's safety thus improving their moral and motivation and becoming an incentive to improve the work efficiency (Sorooshian, Cai Qi, & Li Fei, 2018).

ISO 14001 provides steps and goals that allow an improved communication between employees and top management and contribute to the organization's effectiveness. Besides that, companies display improved employee training and knowledge, increasing their awareness of environment issues, criteria, and processes (Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017).

The implementation of the ISO 14001 certification requires the application of measures and the obedience of laws that thus allow the organization to become compliant of such laws and anticipate legal risks, reduce fines and penalties (Morrow & Rondinelli, 2002).

External benefits

As a result of the ISO 14001 certification there is an improvement of the company's reputation and image, due to the fact that the measures applied for environmental protection changes consumer's perception of the organization that is seen as environmentally friendly and is releasing less waste to the environment.

This will lead to an improvement in the relationship with shareholders, investors and clients, consequently increasing customer satisfaction (Reis, Neves, Hikichia, Salgado, & Beijo, 2018).

The fact that the EMS increases employee's safety and promotes law compliance attracts the interest of investors since it minimizes problems that may occur in comparison with companies that do not possess this certification (Sorooshian, Cai Qi, & Li Fei, 2018).

Due to the exponential growth of the population's environmental consciousness, costumers tend to prefer environmentally friendly products compared to non environmentally friendly products or the products of competitors that do not have EMS, becoming an opportunity for market expansion (Sorooshian, Cai Qi, & Li Fei, 2018).

Therefore, a company can achieve competitive advantage by increasing operational efficiency, improving its image and introducing new products and market opportunities (Roy, Boiral, & Lagace, 2001).

Table 1- Internal and external benefits.

Benefits	Internal	Increased employee's safety	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Enhanced staff morale	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Waste minimization	(Hillary, 2004),Tan (2005), (Psomas, Fotopoulos, & Kafetzopoulos, 2011) (Sorooshian, Cai Qi, & Li Fei, 2018)
		Environmental awareness	(Hillary, 2004, (Sorooshian, Cai Qi, & Li Fei, 2018)
		Reduction in energy use	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Reduction in costs	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Saving of raw materials	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Profit growth	(Hillary, 2004), (Tan, 2005),Sambasivan and Fei (2008)
		Compliance with existing laws	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Improved internal communication	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
	External	Market expansion	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Improvement of the company's reputation and image	(Psomas, Fotopoulos, & Kafetzopoulos, 2011), (Hillary, 2004), (Tan, 2005), (Sambasivan & Fei, 2008)
		Enhancement of the relationship with clients, shareholders and investors	(Hillary, 2004), Tan (2005), (Sambasivan & Fei, 2008)
		Increased competitiveness	(Tan, 2005), (Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)
		Improved customer satisfaction	(Hillary, 2004), (Sorooshian, Cai Qi, & Li Fei, 2018)

MOTIVATIONS

Due to globalization and consequent strong competition within the industry, it becomes imperative that companies stand out and differentiate from one another. In order to do so new technologies, management plans, missions and values are adopted, namely with environmental character.

The pressure applied upon organizations to become environmentally friendly grows more and more every day and the implementation of ISO 14001 becomes an asset and one of the main reasons for the EMS certification, with external motivations (Boiral & Heras-Saizarbitoria, ISO 9001 and ISO 14001: Towards a Research Agenda on Management System Standards, 2013; Heras-Saizarbitoria, Boiral, & Allur, 2018). Internally, the motivations include legal requirements that the certification entails and environmental performance, once it reduces uncertainties of the company's environmental impact. Externally, many organizations advocate good environmental practices. Despite all, the major motivation for the EMS certification is in fact economical (Liu, Yuan, Hafeez, & Li, ISO 14001 certification in developing countries: motivations from trade and environment, 2019).

According to some authors the motivations may be divided in not two, but in four categories: market drivers, social drivers, financial drivers and regulatory drivers (Sorooshian, Cai Qi, & Li Fei, 2018). In analysis, motivations can be grouped in two main groups, internal like a reduce the costs of energy (Sorooshian, Cai Qi, & Li Fei, 2018) and external, and then divided in two subgroups, regulatory and financial drives, and market and social drivers, respectively. (Table 2)

Table 2 - Motivations distributed by categories.

External	Regulatory Drivers	Public environmental disclosure requirements.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Liu, Yuan, Hafeez, & Li, 2019)
		Regulatory agency inspections.	(Sousa Lira, Gomes Salgado, & Beijo, 2018)
		Green Certification.	(Sorooshian, Cai Qi, & Li Fei, 2018)
		Regulatory simplification.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Psomas, Fotopoulos, & Kafetzopoulos, 2011)
	Financial Drivers	Special tax exemption for expenditure and insurance coverage.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Psomas, Fotopoulos, & Kafetzopoulos, 2011) (Sousa Lira, Gomes Salgado, & Beijo, 2018)
		Social – ethical investing.	(Sousa Lira, Gomes Salgado, & Beijo, 2018)
		Environmental capital	(Sorooshian, Cai Qi, & Li Fei, 2018) (Psomas, Fotopoulos, & Kafetzopoulos, 2011)
		Increase investor confidence.	(Sousa Lira, Gomes Salgado, & Beijo, 2018) (Sorooshian, Cai Qi, & Li Fei, 2018)

		Prevent or minimize financial damages.	(Sousa Lira, Gomes Salgado, & Beijo, 2018) (Psomas, Fotopoulos, & Kafetzopoulos, 2011) (Sorooshian, Cai Qi, & Li Fei, 2018)
Internal	Market Drivers	Technological advantage.	(Psomas, Fotopoulos, & Kafetzopoulos, 2011) (Sorooshian, Cai Qi, & Li Fei, 2018)
		Overcoming export barriers.	(Sorooshian, Cai Qi, & Li Fei, 2018)
		Experience and differentiation advantage.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Sousa Lira, Gomes Salgado, & Beijo, 2018)
		First-mover advantage in leading the market.	(Psomas, Fotopoulos, & Kafetzopoulos, 2011) (Sorooshian, Cai Qi, & Li Fei, 2018)
		Improves the organization's image.	(Psomas, Fotopoulos, & Kafetzopoulos, 2011) (Sousa Lira, Gomes Salgado, & Beijo, 2018)
		Greening of trade.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Social Drivers	Community and trading partners pressure.	(Liu, Yuan, Hafeez , & Li, 2019) (Sorooshian, Cai Qi, & Li Fei, 2018)
		Activist Campaigns.	(Liu, Yuan, Hafeez , & Li, 2019) (Sorooshian, Cai Qi, & Li Fei, 2018) (Psomas, Fotopoulos, & Kafetzopoulos, 2011)
		Media attention.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Liu, Yuan, Hafeez , & Li, 2019)
		Green policians.	(Liu, Yuan, Hafeez , & Li, 2019)

The implementation of the EMS is motivated by another major category, the environmental, which consist in the improvement of environmental effectiveness. In result can be observed the reduction of negative environmental impacts, growth of the international green consumerism and enhanced relationships with clients, investors and overall community that will lead to improvement of the corporation’s image.

In conclusion, most of these motivations are linked and together lead to two major ones: improved environmental practices and economic growth.

DIFFICULTIES

For a company is crucial to detect and comprehend its difficulties, in order to overcome them. The same principle is applied to the ISO 14001 implementation since difficulties in the detection of problems regarding environmental performance can interfere with certification. However, this may not happen if the organization is able to use its strengths and transform their weaknesses in opportunities, overcoming any difficulties that may arise. (Sorooshian, Cai Qi, & Li Fei, 2018).

Table 3- Difficulties distributed by categories.

Internal	High implementation cost.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017)
	High maintenance cost.	(Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017) (Sorooshian, Cai Qi, & Li Fei, 2018)
	Lack of in-house professionals, knowledge, and skills.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017)
	Organization's vision and mission not align with EMS	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Lack of resources.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017) (Psomas, Fotopoulos, & Kafetzopoulos, 2011)
	Difficulties in motivating the sense of environmental responsibility among some employees.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Lack of commitment from organization's employees.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Process of making strategic environmental decisions encompassing all organizational departments is time consuming.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Uncertainty over the benefits of certificate outcome.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Number of preparation phases for implementing environmental management system.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	High volume of documentation and paperwork activities.	(Sorooshian, Cai Qi, & Li Fei, 2018) (Santos, Rebelo, Lopes, Silva, & Alves, 2015)
External	Lack of government support and incentives.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Lack of environmental laws and regulations.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Long registration process.	(Sorooshian, Cai Qi, & Li Fei, 2018)
	Outdated legislation.	(Sorooshian, Cai Qi, & Li Fei, 2018)

According to Sorooshian, Cai Qi, & Li Fei (2018) and like in other topics previously discussed, the difficulties and barriers that an organization may encounter due to ISO 14001 certification can be divided into two groups, internal and external (Table 3). Several authors address high costs and highly time consuming as the main barriers, as well as the most transversal.

Since two of the motivations to acquire this certification are to improve the company's image and to present a competitive advantage over other organizations, the difficulties of small companies to support the involved costs may lead bigger ones to take advantage of the opportunity. They may adopt the EMS in a superficial way and not alter significantly their environmental practices, as suggested by numerous studies (Boiral, Guillaumie, Heras-Saizarbitoria, & Valery Tayo Tene, 2017).

According to Santos, Rebelo, Lopes, Silva, & Alves (2015), in Portugal the lack of investment support is the main reason mentioned by companies to non-certification, followed by companies viewing the EMS only as a marketing tool. The high implementation costs of the EMS are seen by many companies as not worth it since many consider that low environmental risks don't justify the expense. This leads to believe that many small and medium-sized enterprises (SMEs) are not aware of the current environmental problems. Nevertheless, some of this companies adopt certain behaviors taking into account a rudimentary EMS.

These difficulties are perceived in different ways by different companies, and the same struggle may be easier or not to overcome depending on the means, capability and approach of each company (Tambovceva & Geipele, 2011). Thus, the difficulties faced due to the EMS adoption and ISO 14001 certification are also imperative factors for the company's decision to adopt the EMS standard. It is important to keep in mind that internal difficulties can be controlled by the company, while the external ones cannot.

CONCLUSIONS

ISO 14001 is a certification that ensures that a company has an environmental management system with a developed structure, allowing control of the significant environmental impacts and continuous improvement of procedures and business strategies.

Due to the current trends and populations' awareness of the environmental problems that humanity faces, there is an exponential growth of adoption of environmental measures taken by organizations in order to gain customer satisfaction and investors trust. Benefits of EMS implementation also include increased employee's safety, profitability and competitiveness.

Nevertheless, high implementation costs financial, staff training and time-consuming paperwork that may deviate employees from essential tasks. Small and medium-sized firms face internal and external barriers when seeking to address their environmental issues and adopt EMSs. Initially, internal barriers have the more significant role in impeding progress giving the fact that many SME are skeptical of the benefits obtained through environmental improvements (Hillary, 2004).

Taken into consideration all the information regarding the EMS, ISO 14001 may be seen as a step towards a more environmentally friendly organization and as a tool to promote and implement consciousness, not only in employees but also in the general public.

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Examining the Predictors of Unit Price of a Readymade Garment in Bangladesh

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ABSTRACT

Purpose- The prime objective of the present research study was to determine the antecedents of unit price for a readymade garment 'XYZ' and to investigate the influence of three variable- raw material, quality labor cost, quality cost on per unit price.

Design/methodology/approach- In this study a simple random sample has been drawn constituting production manager as the sample unit. The present study used a sample of 50 RMG companies. Further, the influences of predictor variables on the per unit price has been assessed using multiple linear regression analysis.

Findings-The findings in this paper supports the two variables; raw material and quality because result revealed that both are significant whereas, labor cost is insignificant. It implies that labour cost is not influencing the unit price.

Research limitations/implications- The paper leads to a research question for future researchers- why labor cost is non-significant predictor of unit price? despite being very much important theoretically. Limitations of the paper include the data that is specific to Bangladesh RMG industry, therefore it cannot be generalised, further the economic meltdown due to COVID-19 pandemic might have influenced the results.

Originality/value – The paper's prime contribution is based on the assessment of predictor variables and their influence on unit price of readymade garment XYZ. It is based on the estimates provided by the production manager.

Keywords- Raw material cost, Labour cost, Quality cost, Unit Price, Ready Made Garments, Bangladesh.

Paper type- Research paper.

INTRODUCTION

In today's era, textile industry make a significant contribution in the economic development of a country. In Bangladesh, RMG sector is booming and its growth is remarkable. It helps to gain a competitive edge (Dicken, 1998; Jones, 2002). The RMG industry is one of the major contributors in the growth of Bangladesh's economy. RMG industry of Bangladesh also plays a pivot role in shaping the economic structure. It contributes enormously to the economic development by creating more employment opportunities particularly for women and men, which contribute a good share in (GDP) Gross Domestic Product and Foreign Exchange Earnings (Yunus and Yamagata, 2012). Bangladesh also has high competitive manufacturing base in the world. In today's scenario, competition among firms is increasing with an ever changing business environment (Banerjee & Mishra, 2017).Textile industry can increase the sales level and get name and fame among consumer and competitors through maintaining the level of quality. In today's era, market is more competitive, and the driving factor to sustain in market is nothing but quality. Quality helps to increase the productivity level as well as the economic development. For instance- no one like to waste the money on that clothes, if their quality is poor. That is generally true, what if a button comes out on the first try of your baby's dungaree dress? In such a case, there is a risk of choking to death if the little Princess puts the shiny button in her mouth to taste it. Such is the fodder from which lawsuits are made. So, the quality of garments is a serious business, too. Not meeting the customer's standards, even if they are unique, is not the way to build customer loyalty and sustainable competitive advantage.

Review of literature has provided the insights that researchers have mainly focused on the challenges that are faced by the RMG industry for example- Kurpad (2014) evaluated the challenges of the (RMG) industry in Bangladesh such as problem of low wages and unsafe working conditions that act as a hurdle in the expansion and growth of the industry. Islam (2018) also found the similar challenges like lack of initiatives to improve working conditions, lack of compliance with social standards, poor government policy, nature of relationships among factories etc. Moreover, other authors highlighted the term Total quality management. TQM has been more focused in literature (Kaddar 2019; Rashid 2016; Syduzzaman et. al. 2016 & Syduzzaman and Dalal, 2016). The studies supported that RMG companies are not fully aware of the value of TQM and its impacts. They regarded the various challenges faced by industry while implementing TQM such as limited human resources, shortage of finance, lack of knowledge, lack of leadership, inadequate resources etc. Other researchers focused on CSR (corporate social responsibility) in RMG industry like Perry (2013) provided a conceptual framework on CSR implementation in the garments sector. Study supported that CSR helps to improve the industry performance and helps to get a competitive edge and it attracts the quality workers, buyers, and suppliers.

It is apparent from the literature that cost involved in order to produce quality product in RMG sector especially in Bangladesh has not been addressed by the researchers. Further, the antecedents to the per unit price of readymade garments has not been discussed before. Therefore, the present study aims to check the influence of raw material cost, labour cost, quality cost on per unit price through multiple linear regression analysis. Therefore, present study aims to utilise these three variables as the predictors of the unit price.

LITERATURE REVIEW

Quality In Ready-Made Garment Industry

In today's world, the supply chain network becomes more complex and in Bangladesh ready-made garment (RMG) industry there is increased disruptions and risks. Chowdhury et al. (2019) found that disruption risk seems the most influential risk in RMG industry and it hinders the implementation of supply chain management (SCM) practices. Researchers suggested that industrial managers should take steps to mitigate supply chain risk as firms are facing competition in an ever-changing environment (Banerjee & Mishra, 2017).

In the textile industry of Turkey, Edril (2019) opined that QFD (Quality Function Deployment) easily demonstrates customer requirements, needs, expectations, and quality level of the industry. It helps to reduce the failure modes, because QFD provides the preliminary requirements of the business and customer satisfaction. This means QFD is a systematic method of improving a new product or sustainability, through which association provides guarantee that customer's requirements translated into its specifications. It also supports to categorise the requirements for the sustainability of the lifecycle of textiles products. In textile industry, quality factor also plays a vital role. Nowadays buyers are more conscious about the quality. One of the researcher considered quality as a multidimensional aspect (Babu, 2012). The author identified various aspect of quality for garments exporters such as maintenance of quality in production, design, purchasing, financial inspection and mainly the sales. Quality of marketing activity was equivalently considered as important as the garment quality itself. The author cited various measures for quality control such as quality inspection in cutting areas and quality control in sewing line. Further, quality drill and quality specification sheets were emphasised by the authors. The study provided the specification to maintain quality in garments.

In the Bangladesh context, Rahman (2009) found that different garments factories use different quality control and different tools for quality check. But not in a systematic way. When they need, they use tools haphazardly. Whereas, some of the garment manufacturers are inspecting during the manufacturing process. And each garment manufacturer gives priority to its customer's requirements. Gersak (2013) identified various key requirements desired by consumers. It includes physical characteristics of the fabric, the color of fabric, design, finished width, etc. from these quality characteristics is a major factor that affects the decision. Apart from this poor quality materials lead to customer dissatisfaction.

Hossain et al. (2018) conducted a study on the quality assurance system of garments in the context of Bangladesh. It was found that quality assurance system is in far better position and it helps for further development. Study shows that improvement in quality assurance system helps to increase the productivity level as well as economic development. This system also contributes to providing a competitive edge with high quality in the textile market. Whereas low quality means loss of competitive position. Further, researchers suggested that factories need to take an initiative to use the quality insurance system for better conditions. Quality assurance and quality control are a unique, important, and complex area of textile industry (Keist 2015). Both the term quality assurance and quality control are not similar. Quality assurance is the "process of designing, producing, evaluating, and assessing products to determine that they meet the desired quality level for a company's target market" (Kadolph, 2007). Whereas, Quality control is one of the parts of Quality assurance. In the textile industry quality is assessed during pre-production, post-production, and production phase (Ibid). Further the author revealed that in preproduction phase sewing threads, fabric, closures and accessories etc. are tested. Whereas in the production phase pressing, cutting, assembling are tested. At last in post-production phase garments are assessed for quality. Study concluded that in textile sector both, quality assurance and quality control are evolving with advanced technology. With the help of technology, defects can be find with more accuracy in less time. Thus, it saves money and efforts in the long run. In Indian context, Bheda et al. (2003) identified critical success factors to improve apparel productivity and suggested some measures to achieve that. First CSF is 'technology deployment & exploitation', which can be done by developing technology index, upgrading the needs and identification of the difference between actual and estimated productivity. Second, CSF is 'Quality System' which can be maintained via establishing repair and rejection level and identifying cost of quality. Further skill matrix and supervisory skill index were identified as the measures for the third CSF 'technical capability of the workforce'. Further, to improve productivity they recommended strengthening of work measurement and improvement in methods, initiation of managers and supervisors training, setting up of operator training cell, strengthening of quality system, technological upgradation, introducing productivity measurement systems in the organisation, production planning and scheduling, and introducing incentive schemes for workers and staff.

Challenges Faced In Textile Industry In The Context Of Bangladesh

Kurpad (2014) identified the challenges faced by RMG industry such as the problem of low wages and unsafe working conditions which acts as a hurdle in the expansion and growth of the industry. Apart from this, other challenges include improvement of quality, high labor standards, lead time, etc. Now Manufacturers and retailers are becoming conscious about the high-quality products. Because plenty of apparels are flattering which leads to an increase in the cost of production. Considering this matter, Hanif (2020) conducted the study on implementation of traffic light system to minimized the defect rate. Traffic light system is a system that enhances the quality of the output. Study found that it also maximizes the production capacity of an industry. Researchers suggested that garment manufacturing companies should implement this system to obtain profit without increasing the resources. This system also helps to save lead time and improve supply chain performance. Islam (2018) carried out the study to understand the challenges of achieving social upgrading in the apparel industry. Apparel is a typical starter industry that engaged in export-oriented industrialization (Memedovic and Gereffi, 2003). The study revealed that lack of initiatives to improve working conditions, lack of compliance with social standards, poor government policy, nature of relationships among factories are the challenges which are faced by industry. It is essential to build a good relationship between buyers, workers, suppliers, and unions (Ibid).

Reshoring is the phenomenon that gained momentum because of numerous challenges related to long-distance trade and transactions (Kinkel and Maloca, 2009; Gray et al., 2013; Kinkel, 2014; Tate et al., 2014). Wiesmann et al. (2017) stated that managers are influenced by the current challenges while making reshoring decisions. In reshoring textile, Pal et al. (2018) identified those challenges, which includes lack of resources, high cost of production, low skill set presence etc.

Kumar (2014) explained the condition of women employment system in Indian textile and clothing industry. T&C industry is labor-intensive which offers low wages to unskilled and semi-skilled workforce. Prior 1990, the ratio of females in the T&C industry was low as compared to male workers. Because mills employed male workers permanently with full benefits. During 1990’s economy started to grow and created numerous job opportunities with different job profiles such as- knitting, creeling, doffling, stiching, and sewing. At that time mills found difficult to retain and attract male workers. Therefore, the demand for female workers arise. Similarly, in Bangladesh, RMG industry plays a vital role. It contributed enormously to economic development by creating more job opportunities particularly for women (Ahmed and Sattar 2004). “Nearly 80% of the 3.5 million workers in the industry comprise of women" (Muhammed, 2011) and contributing more towards women empowerment. Ahmed et al. (2019) focused on different types of garments defects such as defect in fabric, cutting and spreading defect, sewing and finishing defects. They considered that garments defects holds prime importance for manufacturing industry because such kind of defect projects negative image of the real productivity. Defect occurrence leads to reductions in prices which hampers company growth, therefore the authors suggested automation for defect identification.

TQM in RMG Industry

Kaddar (2019) highlighted the concept of TQM (Total Quality Management). TQM is a system that focuses on customer satisfaction with a concept of "continuous improvement". This concept emerged after 1980s, Feigenbaum (1991) defined total quality management as- "system of integrating the quality development which allows to fulfill the customer satisfaction". Kaddar (2019) also considered the concept of Kaizen which is derived from the Japanese word. Kaizen focuses on continuous improvement within organization and maintaining the workplace so that objective can be easily achieved and fulfill adequately. Study revealed that it seems difficult to limit all the processes related to the quality control in clothing industry. Rashid (2016) give the viewpoint on the adoption of TQM in Bangladesh. The study supports that RMG companies are not fully aware of the value of TQM and its impacts. Research also shows that companies give more importance to ISO 9000. As a result, the growth rate and performance of the RMG sector is decreasing. Although it was revealed that there is a positive relationship between TQM and organizational sustainability. Thus, for RMG sector TQM is an essential step to gain a sustainable advantage. It was suggested that the RMG sector should focus more on TQM as compare to others.

(Syduzzaman et al. 2016 & Syduzzaman and Dulal,2016) conducted the study on the implementation of TQM and its effect. Similar results were obtained from both of the study and it was found that due to diverse customer requirements and characteristics regarding the quality etc.it becomes more difficult to fulfill for an industry. To cope with this, RMG trying to implement the TQM. Nowadays to ensure the quality factor there are so many techniques and tools that have been emerged. Among them, TQM is one of the most significant and smartest tool. With the implementation of the TQM production environment can be created which delivers the quality product. But the study found that there are various challenges faced by industry while the implementation of TQM. They are:

- Limited human resources
- Shortage of finance
- Lack of knowledge
- Lack of leadership

- Inadequate resources etc. According to Quazi and Padibjo (1998), unlike large firms, SMEs have limited resources and management capacities, lack of business knowledge and experience. Thu,s these are the problems that are faced during the implementation of TQM. Researchers concludes that RMG is booming in Bangladesh; therefore, to sustain the development as well as maintain the high growth rate, industry should use TQM.

CSR (Corporate Social Responsibility) In RMG Industry

Perry (2013) provided a conceptual framework on CSR implementation in the garments sector. Study found that SCM principles supports CSR implementation in global fashion garment. Supply chain overcome the negative effect of buying practices. It also encourages the suppliers to become innovative and take ownership of the CSR agenda. Thus, SCM (Supply Chain Management) seems more critical in the progression of CSR implementation. Further, Study explored that CSR improves the industry's performance and it helps to address difficulties in recruiting good quality workers. CSR helps to get a competitive edge and it attracts the quality workers, buyers, and suppliers. Elkington (1997) opined that company performance should be measured by ethical, social, and environmental parameters with traditional financial indicators.

According to 'The true cost movie' which launched in 2015 sustainable fashion is more than a simple fad, but rather considers the natural, social and economic 'price' paid in fashion production (Henninger et al. 2016). Past research on sustainable fashion focused on consumers purchasing behavior (Shen et al. 2013) and consumers perceptions and attitudes (Mc Neil and Moore 2015; Goworek et al. 2013).

Raw Material in RMG Industry

Rehman et al. (2019) conducted the study to identify the role of Raw Material Inventory Control Model in RMG sector. Result supports that raw material helps to enhance the production level. Whereas, Shahriar et al. (2014) explored the role of supply chain management (SCM) model in RMG industry and it found that SCM appraise the performance towards the fulfillment of ultimate goals, that's is producing high-quality garments product, reducing the wastage of human labor and time and money. Another researcher(Akhtar and Uddin, 2017) highlighted the importance of supply chain operation model in the context of raw materials in Bangladesh. gradually study revealed that work load of industries will be reduced through the implementation of this model , which help to create efficient team and also helpful to remove obstacles and hurdles. It will also help to enhance the production process flow.

Research Gaps from the Literature Review

Earlier production manager's opinion has not been taken therefore, the present study is taking the data from production manger and their estimates about the RMG industry for readymade garment XYZ. Earlier studies did not focus on the quality factor to determine the unit price. Therefore, the present study aims to assess the influence of quality, cost raw material, labor cost on unit price and try to fill this gap. Conceptual model was developed after identification of gap.

Conceptual Model

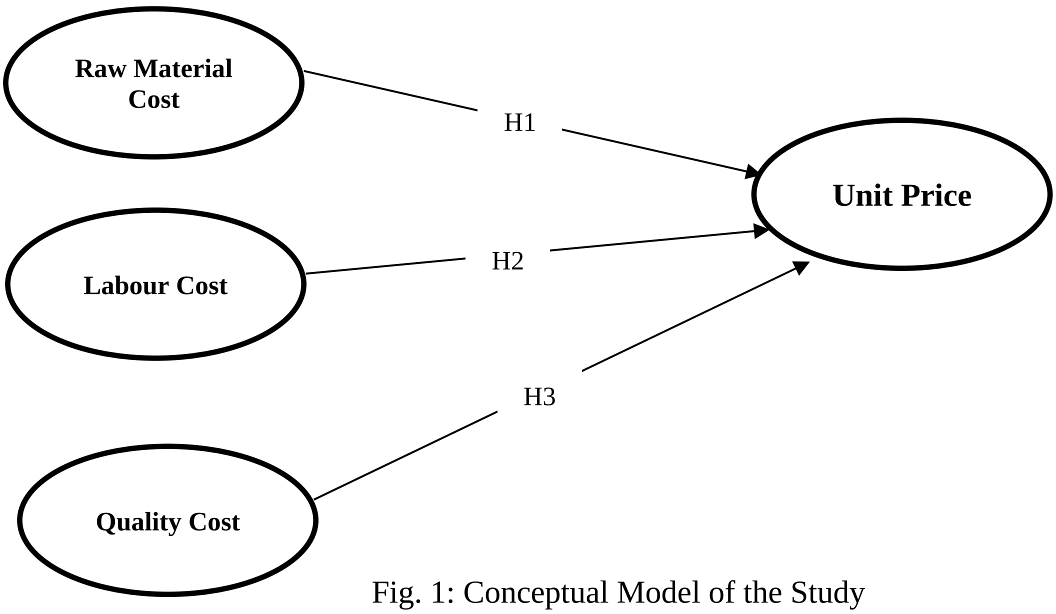

Fig. 1: Conceptual Model of the Study

Hypothesis Development and Testing

From the above conceptual Model three null hypothesis have been formulated as under.

H1: Raw Material cost does not have a significant influence on unit price of XYZ garment.

H2: Labour cost does not have a significant influence on unit price of XYZ garment.

H3: Quality cost does not have a significant influence on unit price of XYZ garment.

Hypothesis testing has been done through multiple linear regression analysis with 5% level of significance.

RESEARCH METHODOLOGY

The prime objective of the present research study was to determine the antecedents of unit price for a readymade garment XYZ. To achieve this objective 50 RMG companies were selected through a simple random technique and their production manager was contacted. They provided their estimate on raw material cost, labour cost and quality cost and unit price for the preparation of a readymade garment 'XYZ'. For costing and unit price Bangladesh's Taka has been used as a currency measure. All the data were noted and a SPSS data file was prepared from it for the analysis purpose. Sample size is small because of the nature of the target respondents as it's a daunting task to reach hundreds of companies. Companies within the geographical boundaries of Dhaka city were selected for the study purpose.

Conceptual model was developed based on review of literature and three hypothesis were formulated as discussed earlier. Hypothesis testing has been done through MLR. Multiple linear regression (MLR) technique has been applied to check the influence of three predictor variables (raw material cost, labour cost and quality cost) on the dependent variable (Unit price). All the assumption of multiple linear regression has been duly met in order to apply the technique. The results reported are based on the output obtained from SPSS. Tables and figures have been used to interpret the results.

DATA ANALYSIS

Multiple Linear Regression

Meeting the Assumptions

1. Dependent variable must be measured on continuous scale either interval scale or ratio scale: Unit price value has been utilized as dependent variable and it has been assumed on continuous scale as a numeral value.

2. To perform multiple regression analysis there must be two or more independent variable and the variables should be measured on continuous scale either interval scale or ratio scale: In this research there are three independent variables; raw material cost, labor cost and quality cost. Like dependent variable, all the independent variables are measured on continuous scale as a numeric expression. Therefore, the research qualifies this assumption also.

3. There should be no auto correlation among the independent variables. To test this, Durbin-Watson statistics is adopted worldwide. The value of the DW test should lie between 1.5-2.5 (Marshall & Boggis, 2016). 1.50 is the value obtained for Durbin-Watson statistics in this research. Thus, this assumption has been duly met.

4. Multicollinearity: The tolerance level in table 3, for all the three independent variables is above 0.10 indicating no issues of multicollinearity. Thus, this assumption is satisfied.

5. Linearity: There should be linear relationship between the dependent variable and the independent variable. This was checked through visual inspection of the scatter plot graph. The scatter graph for each independent variable with the dependent variable depicted the linear relationship between the variables.

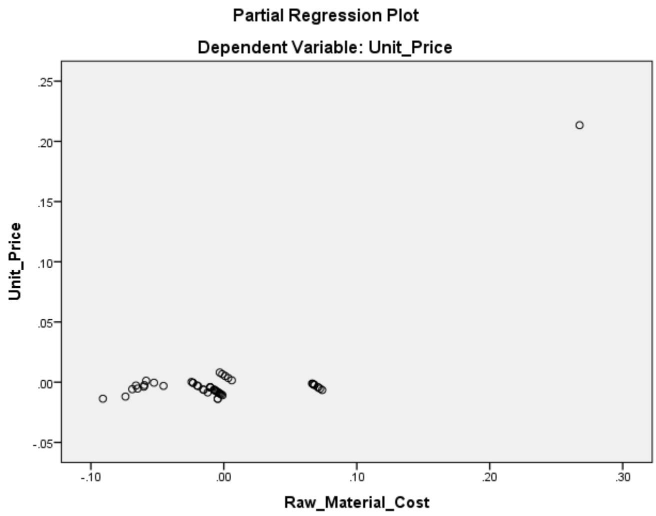

Fig. 2: Partial Regression Plot between Raw Material Cost and Unit Price

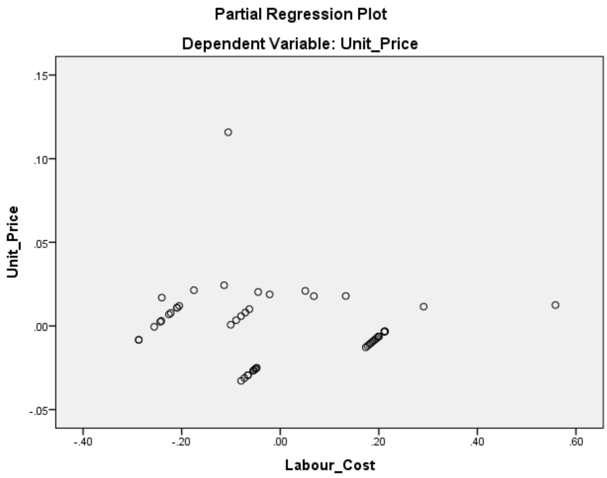

Fig. 3: Partial Regression Plot between Labour Cost and Unit Price

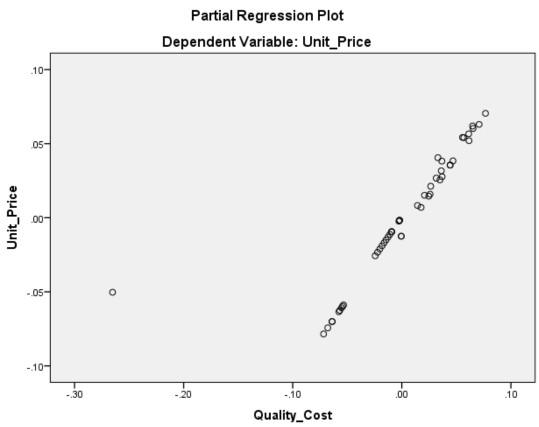

Fig. 4: Partial Regression Plot between Quality Cost and Unit Price

6. Normal distribution between the residuals and the predictors:

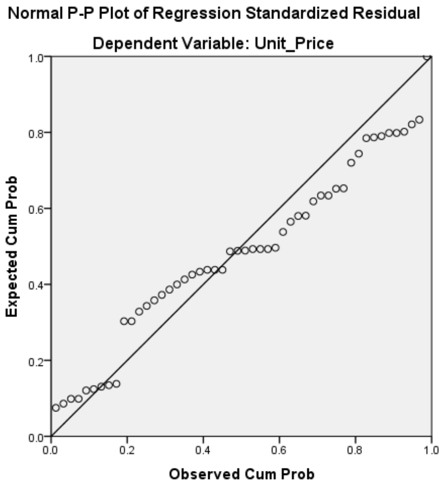

Figure 5: Normal P-P plot Curve for the assumption of Normality

The values of predictors and residuals around the regression line is clearly depicting the normality of the data.

7. Homoscedasticity: It refers to equality of variance among the residuals and predictors being plotted by the scatter diagram. The points on the plots needs to be appear in a rectangular form to show the equality in variance. The scatter plot shows the rectangular pattern, it is sufficient enough to prove the homoscedasticity of the data.

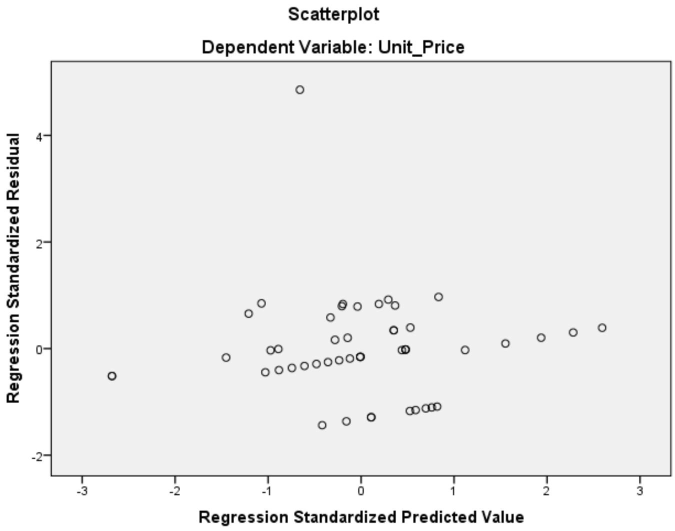

Figure 6: Scatterplot to check homoscedasticity

Regression Model Summary

Table 1: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.997[a]	.994	.994	.02356	1.505

a. Predictors: (Constant), Quality_Cost, Labour_Cost, Raw_Material_Cost
b. Dependent Variable: Unit_Price

Table 2: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.205	3	1.402	2525.431	.000[b]
	Residual	.026	46	.001		
	Total	4.230	49			

a. Dependent Variable: Unit_Price
b. Predictors: (Constant), Quality_Cost, Labour_Cost, Raw_Material_Cost

Table 3: Coefficients Table

Coefficientsa							
Model 1		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics
		B	Std. Error	Beta			Tolerance
	(Constant)	2.088	0.156		13.343	.000	
	Raw_Material_Cost	0.37	0.059	0.387	6.31	.000	0.035
	Labour_Cost	-0.013	0.018	-0.015	-0.754	0.454	0.318
	Quality_Cost	0.621	0.06	0.627	10.419	.000	0.036
a Dependent Variable: Unit_Price							

Explanation to the Model

Table 1 shows the Adjusted R square value as 0.994. It represents that 99% variation in unit price is caused by the three independent variables together. Adjusted R square value obtained is very high, determining the great amount of influence of raw material cost, labour cost and quality cost to fix up per unit price of a readymade garment XYZ. Other determinants of per unit price needs further investigation in future as the results are surprising. Sig. value obtained from table 2 is 0.000 which shows the significance of this regression model with the set of independent and dependent variable.

Table 3 provide constant value as 2.088. Raw material cost is a significant predictor of unit price as it has sig. value of 0.000, H1 is rejected. It has beta coefficient as 0.387. It implies that one unit change in raw material cost will bring a change of 38% in unit price. Labour cost was found to have a negative impact on unit price as it has negative beta coefficient of -0.015. Its predictability is also low and non-significant as it has sig. value of 0.454 which is greater than 0.05, therefore H2 cannot be rejected. The third predictor of the equation is quality cost which is a significant predictor variable of a unit price as it has sig. value of 0.000, which implies rejection of H3. Further, it has beta coefficient as 0.627, which indicated one unit change in quality cost will bring 62% change in unit price. Thus, two predictor variables have been found significant to predict the dependent variable unit price.

Table 4: Results of Hypothesis Testing

Hypothesis	Variable	Result
H1	Raw Material Cost	Rejected
H2	Labour Cost	Can't be Rejected
H3	Quality Cost	Rejected

Table 4 represents that out of three predictor variable only two of the variables, which are raw material cost and quality cost are significant indicator of per unit price of readymade garment XYZ. Labour cost needs further assessment in future research.

To conclude, the regression equation can be written as:

Unit price= 2.08+Raw Material Cost (0.387) +Labour Cost (-0.015) +Quality Cost (0.627)

DISCUSSION AND CONCLUSION

Extending the existing literature, this study aimed to measure the impact of three predictor variables (raw material, labor cost, quality) on unit price. Result revealed that raw material cost is significant. Raw material is an important contributor of production process, without raw material, price cannot be determined. So this study validate this assumption that raw material significantly contribute to the price of a ready garment, without raw material it cannot be prepared. Bangladesh is a labor intensive country mainly RMG industry. It is an important component of cost; however, contrasting results were obtained and labor cost was found to be a non-significant predictor variable to determine the unit price of a readymade garment XYZ. This needs future research consideration. Though, cost of quality is the second important predictor to determine unit price. In the present study quality cost is taken on the basis of production manager's estimates. Researchers in near future need to focus on defining quality cost and to develop a scale to measure quality cost. Different dimension of quality cost can also be explored in future. In a nutshell, two significant predictors of unit price are raw material cost and quality cost.

Technology is dominating this century, and it is overtaking every sphere of life, hence the case is same for RMG industry of Bangladesh. Another interesting areas of research emerging from this study include the analysis of the role of automation on labor cost and employment opportunities and how it will impact unit price and other related variables.

The present study suffers from various limitations. First, this study has been carried out in the context of Bangladesh. So it cannot be generalised for another country. Second, the data has been collected during the COVID-19 pandemic, when all the businesses are facing downturn. Therefore, the results obtained in the present study might be different in favorable environment.

Quality is an important, unique, and complex area of the textile industries. Quality needs to be incorporated into every aspect of a product line. The outcome of the study add a degree to confidence level of the factory about their quality, which can contribute to increase their competitiveness in the global RMG trade. It can be concluded that quality is very important factor for competitive advantage in the readymade garments industry of the world; but in Bangladesh do not yet have a clear plan to be implemented to achieve the required quality standard. Though, maintenance of quality and quality assurance is important for RMG industry of the country.

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ISO 22000 standard implementation: Benefits, Motivations and Obstacles

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ABSTRACT

Purpose - The aim of this paper is to evaluate benefits, motivations, and obstacles of the implementation of ISO 22000 in the food industry and do a comparative relation in multiple countries. The study identifies the main difficulties faced by companies during the adoption process and the benefits found on their overall satisfaction with ISO 22000.

Design/methodology/approach - A research was performed to identify the existence of studies about difficulties and benefits of ISO 22000 implementation. The literature review resulted in the selection of studies about the Food Safety Management System (FSMS) in different countries, with special focus on ISO 2200 implications.

Findings - There are several benefits that companies can obtain from having an implemented and certified FSMS. It is possible to observe similar benefits when ISO 22000 is implemented. The difficulties to the implementation of ISO 2200 were identified by all companies, however they demonstrated to be pleased with the benefits (internal and external) of the certification.

Research limitations – A small percentage of papers were found about the ISO 22000 implementation. Most case studies focus on Food Safety without a specific focus on ISO 22000.

Originality/value - The studied papers comprised certified companies and analyzed benefits and obstacles of the implementation of ISO 22000, including representatives of all links in the Food Chain.

Keywords: Benefits, Food security, Obstacles, FSMS, ISO 22000

Paper type Literature review

INTRODUTION

The aim of this study is to compare the benefits, motivations and obstacles of the ISO 22000 implementation in different countries. The general context of Food Safety Management System (FSMS) is approached on the next chapter, Literature Review, where the stakeholders' concern about food safety during all the stages of food chain is described. The methodology section presents the research method, the analyzed countries and the characteristics of the questionnaire used by them. The results and discussion describe the several motivations, benefits and obstacles for the different analyzed countries during Food Safety (FS) certification. The final section, conclusion, presents the common aspects between the analyzed countries. On this section the difficulties to find studies that focus on ISO 22000 were mentioned.

LITERATURE REVIEW

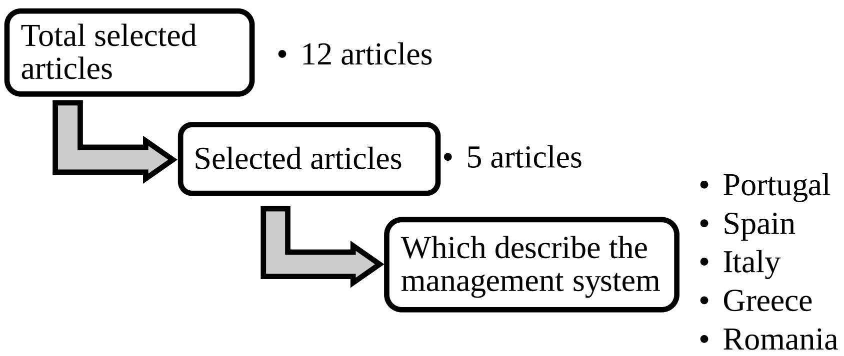
Food safety (FS) is related to the presence of hazards in food at the time of its consumption. It is essential the existence of a proper control during the food chain production because hazards can occur at any stage of production. Therefore, FS is ensured by the efforts of the several parts that integrate the food chain (ISO 22000:2018). The food safety and the food security are a global concern, not only because of the public health, but also because of the impact on the international commercial trade (Escanciano & Santos-Vijande, 2014). Due to the necessity to be competitive with other countries for international trade in food, most of developed and developing countries are removing the trade barriers, such as quotes, and applying more rigorous measures to ensure the FS (Mensah & Julien, 2011). The FSMS has been used as a tool by the producers to traceability and track of the products to ensure the FS (Chaoniruthisai, Punnakitikashem, & Rajchamaha, 2018). When it comes to FS regulation, consumer safety is the essential key. Controllers must be aware of FS risks on consumers and the cost implications of the implementation without compromising consumer safety (Mensah & Julien, 2011).

The implementation, the achievement and the application of a certified system is a time-consuming process that presents benefits but also involves several obstacles. Numerous studies identified the obstacles that companies had to go through to implement a certified system. This difficulty involves both internal and external factors, and it depends on the country or the size of the company (Chaoniruthisai *et al.*, 2018). Some of the pointed complications were the "inefficient validation and verification of the HACCP plan" (Teixeira & Sampaio, 2011), "high cost of development and implementation" (Escanciano & Santos-Vijande, 2014) and "internal resistance to change" (Păunescu, Argatu, & Lungu, 2018).

There are several benefits to implement a certified system and there has been an increasing number of standards that promote FS, these included the British Retail Consortium's global food safety standard (BRC), the International Food Standard (IFS), the Dutch Hazard Analysis and Critical Control Point (HACCP), the Safe Quality Food (SQF) 2000 Level 2 (Mensah & Julien, 2011) and the ISO 22000:2018. According to Escanciano and Santos-Vijande (2014) the implementation of ISO 22000 can reduce the misinformation among producers and consumers, and still provide a competitive advantage to certified companies promoting their access to new customers and markets. The image improvement, the increase of consumers' confidence and the prevention of food poisoning with the achievement of market differentiation were the most common reasons for the adoption of ISO 22000 (Păunescu *et al.*, 2018).

RESEARCH METODOLOGHY

For the accomplishment of this literature review article several publications were consulted. The aim of this review is to understand the benefits, motivations and difficulties of ISO 22000:2005 implementation by different countries:



To understand which obstacles are faced by companies looking for ISO 22000:2005 certification and the benefits that were appreciated after the standard adoption each company was contacted via phone and/or email. It was asked to the company employees to answer a questionnaire using a Likert scale in order to assess the agreement regarding the benefits and difficulties of implementing ISO. The Likert scale used reveals a distinct range of scores.

RESULTS

Benefits

Companies may have many reasons to implement and certify their food safety management systems since this process results in several potential benefits. The implementation and certification of an ISO 22000 FSMS is a source of benefits to the company (Table 1). Some are external, linked to commercial advantages, communication, and competitiveness in the market and others internal – organizational.

The benefits of ISO 22000 implementation in Portuguese inquired companies reveal "Improvement of food safety methodologies, and management system related documentation" and "Improvement of customers and other interested parts satisfaction". The respondents of Portugal food companies verified that the most relevant benefits were about internal factors (Teixeira & Sampaio, 2011).

The study of ISO 22000 implementation by Spanish companies listed a total of 29 benefits. The results represent the valuations that respondents made of the extent and how their companies have obtained these benefits. For these companies the main benefits were those facilitating compliance with legislation and those representing various improvements. The latter were both internal ("Better management/control of food hazards", "Better emergency response", "Improved product quality and safety", and "Improving workers' level of training") and external ("Improved image in the market" and "Increased customer confidence"). However, the commercial benefits recorded the lowest score, even though they are usually associated with the possession of FS certification (Escanciano & Santos-Vijande, 2014).

The study developed in Greek food companies reveals that the most important reason for ISO 22000 certification was the control and increase of safety and hygiene on food products. Company managers wanted to offer secure products to achieve customer satisfaction and expectations. In general, it was agreed that company protection was a reason for the ISO implementation. All participants considered certification as a promotional and marketing tool (Mamalis, Kafetzopoulos, & Aggelopoulos, 2009).

For the Romanian companies the study reports that key benefits were obtained by FS improvement, such as reduction of illness and other risks arising from food, improvement of consumers' confidence, improvement of customers and stakeholders' satisfaction, followed by improvement of sales volumes (Păunescu *et al.*, 2018).

The study based on Italian companies classified the benefits from ISO 22000 certification into three main categories: benefits related to market, technical management aspects and those related to regulatory aspects. The major benefits were the improvement of product safety and traceability of products. The increase of communication in the food chain also revealed to be an important benefit. On the other hand, improving productivity seems not to be a significant benefit of ISO 22000 application. The results also revealed a positive correlation between company size and a higher rate of satisfaction derived from ISO 22000 application, consistent with the other studies (Casolani, Liberatore, & Psomas, 2018).

Table 1 Benefits from ISO 22000 implementation in Portugal, Spain, Greece, Romania and Italy.

Portugal	Spain	Greece	Romania	Italy	Factor	Group
Improvement of food safety methodologies	Better management/control of food hazards	Improvement of management system	Improvement of food safety and hazard control	Improvement of quality management system	**Improved food safety**	**Internal**
Food safety improvement	Continuous improvement of food safety		Reaching continuous improvement			
Increase of the products shelf time	Improvement of product quality and safety	Improvement and control the level of safety and hygiene on food products.	Product quality enhancement and of the production processes	Improvement the product safety		
	Greater worker participation in FS management					
Improvement of the employee's skills	Improvement of workers' training level	Employee training and experience improvement				
	Better emergency response					
	Facilitates compliance with food safety legislation		Adapt to the legal framework established to ensure food safety	Respect the Food Safety legislation		
	Increase of exportation				**Commercial benefits**	**External**
	Access to foreign retail chains					
	Private (distributor) label manufacturing					
Access to new markets	Access to new geographical markets			Improve the capacity to access the European and International markets		
	Increase market share			Possibility to increase market share		
Sales volume improvement	Increase sales					
	Better use of time and/or resources			Documentation improvement	**Internal efficiency**	**Internal**
Production costs reduction	Improvement of productivity	Reduce the operational cost		Internal processes and procedures improvement		
	Better coordination with suppliers			Improve the traceability of products		
	Fewer incidences					
	Fewer customer claims and complaints					
	Internal communication improvement					

Portugal	Spain	Greece	Romania	Italy	Factor	Group
Consumers' confidence improvement	Increase customer confidence	To enhance the firm's reputation		Improve the consumers' image of the firm	**Improved competitive position**	**External**
	Competitive advantage					
Corporate image improvement	Improve image in the market	Market requirements	Advance of the company's market position	Improve the firm's image in the commercial market		
Improvement of customers satisfaction	Increase customer satisfaction	To achieve customer satisfaction and meet customer expectations	Minimizes the probability of customer dissatisfaction and product flaws.	Improvement of customer satisfaction		
	Attract new customers			Facilitate the access to new customers and markets		
	Improve the relationship with health authorities			Provide guarantee regarding Food Safety with official Authorities	**Improved communication**	**External**
Improvement of the relationship with the society	Improve communications with stakeholders		Use a standardized language that makes an effective link between them and their stakeholders: customers, suppliers, distributors and health institutions	Increase the communication in the food chain		
	Fewer customer audits			Reduce the number of audits		
	Acquisition of more up-to-date equipment and technology				**Technological improvement**	**Internal**
	Improvement of the firm's facilities					

Motivations

Portuguese food companies' motivations for ISO 22000 certification were from internal nature. The most common ones were "To guarantee the confidence of the consumers", "Customers requirement", "Market differentiation" and "Involvement and commitment of the food chain in the product safety". For the Portuguese food companies the main motivation is the improvement of consumers' confidence (Teixeira & Sampaio, 2011).

Păunescu *et al.* (2018) identified that the main reasons for the reluctancy to implement ISO 22000 in Romanian food companies were the lack of information, the costs involved and the demanding of a certification system. However, the main mentioned motivations to implement a certified system were the assured confidence of the consumers, the prevention of food hazards and the improvement company image.

In Greek food companies the participants indicated several reasons to implement a certified ISO system. Among the reasons, it stands out the control of safety on food products, the guarantee of a safe product and the improvement of the management system (Mamalis *et al.*, 2009).

The studies about Italy and Spain did not analyze the motivations of ISO 22000 implementation. Escanciano and Santos-Vijande (2014) pretend to identify the motivations to the implementation and subsequent certification of an FSMS in future work. However, this study pointed as reasons for an FSMS implementation the quality and safety of food products, the reinforcement of competitive position and the access to new marketers. Casolani *et al.* (2018) pointed internal and external reasons and that the implementation of a FSMS is a complex process.

Obstacles

The implementation of a FSMS is a process that is related to some difficulties detected by companies. Indeed, all the mentioned studies about ISO 22000 implementation refer the obstacles that companies face when they decide to undertake the process (Table 2).

The study performed for Portuguese food companies present as the most important difficulties factors like "Internal resistance to change", "Food safety management system implementation costs" and "Employees qualification" (Teixeira & Sampaio, 2011).

The Spanish study listed a total of 16 potential obstacles that may impede the implementation of the ISO 22000 standard. All the companies described difficulties and this result can be explained by the major presence of small firms in the sample which usually show issues to adopt quality standards. The analysis of the results also confirms that companies that are not ISO 9001 certified experiment greater difficulties to implement ISO 22000 (Escanciano & Santos-Vijande, 2014).

For the 20 catering companies in Greece the most important barrier of ISO 22000 implementation is the lack of employee training. Employees are not interested in implementing the necessary rules of hygiene. There is a lack of motivation while the supervision is not always efficient. Also, the time and effort are crucial parameters as most of the staff are part time employees and work seasonally (Mamalis *et al.*, 2009). Small producers are not certified with ISO 22000, so they cannot supply the enterprises with certified products.

Romanian companies state that the obstacles that should be prudently considered in ISO 22000 implementation were the employees' qualification, costs associated with the FSMS implementation and legal requirements, followed by internal opposition to change (Păunescu *et al.*, 2018).

Analogous to the literature, food Italian companies expose barriers to ISO 22000 implementation; the dominant issues were about the cost for certification, slower procedures, and lack of international consumer expectation (Casolani *et al.*, 2018).

Table 2 Obstacles from ISO 22000 implementation in Portugal, Spain, Greece, Romania and Italy.

Portugal	Spain	Greece	Romania	Italy	Factor
Lack of top management commitment	Weak commitment of management		Difficulty imposed by the managerial level, technical aspects and constraints within the organization.	Requires a different organization	
Internal resistance to change	Top management's resistance to change		Inexistent involvement and responsibility from the management part		
Lack of employees' motivation and involvement	Staff's resistance to change (lack of motivation)	Lack of training of Employees (employees are not interested in implementing necessaries rules of hygiene)	Employees' skills and reluctance to change	Adequate staff training	**Organizational resistance**
	Communication difficulties within the firm		Communication issues at the company's level		
Difficulty in the use of the food safety management system tools and methodologies	Difficulty workers have in accepting and adapting to the system	The food workers often lack interest and they often have a negative attitude toward food safety programs			
Time limitation	Excessive demands on time and resources	Time and effort to develop and implement the certification	Constraints imposed by time insufficiency	Slower procedures	
	The volume of documentation required	Excessive volume of Paperwork	Large number of documents needed		
Food safety management system implementation cost	High cost, financial constraints	Cost of Prerequisite programs		Cost for certification	**Bureaucracy and cost**
	Excessive formalism				
	Insufficient financial aid				
	Standard unrecognized by consumers and customers		No well-known standard	Lack of international consumer expectations	
Legal requirements	No legal requirement on the part of the government or public agencies				**Unfamiliarity**
Difficulty in the comprehension and interpretation of the standard requirements	Difficulty in interpreting the standard		Understanding and application of the ISO standard's procedures	Difficulty in understanding the procedure	

CONCLUSIONS

This literature review refers to the implementation of ISO 22000, the key benefits, motivations and obstacles in several countries, performing a comparative analysis between them. The study demonstrates that there are common factors among the countries for the implementation of standard ISO. The food companies from different countries reveal that size of firms and the existence of a previous certification influenced differently the application and the effect of the FSMS. Small and non-previous certified firms show more complications and barriers to the implementation of ISO.

The implementation of FSMS is a complex process and it was difficult to find quantitative studies that focus specifically on the ISO 22000 standard. Food companies must be conscious about the complications through the process however there are several benefits to the implementation of this certification. All literature reviewed infer that the implementation and certification of ISO 22000 provides consolidation and improvement of the FS chain. The main reasons for its adoption were to attain the consumer’s confidence, guarantee food security procedures and improve the company image. ISO certification also can be used as a marketing tool to help several firms, to differentiate their products and build an advantage in the marketplace. Managers need to be motivated and involved in the process to perceive the role of ISO certification and understand the future advantages that this certification offers to their companies. The decision of applying a FS management system commonly reveals prevalent difficulties such as high costs, skilled employees and legal requirements. Despite the obstacles, ISO application in food firms showed that a big range of benefits are responsible to high levels of customers and stakeholders’ satisfaction. The fact that the data are represented by personal opinions of managers and workers is a limitation of this study. It would also be interesting to know the point of view of companies that are no longer certified by ISO 22000. Likert scale used in the different analyzed studies reveal difficulties in data comparison; a distinct range of scores can demonstrate a lack of standard method.

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Lean Philosophy Applied to Gemstones Certification

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STRUCTURED ABSTRACT

The intention is to demonstrate advantages of using Lean philosophy tools in Gemstones' certification through a case study about the implementation in GemsValue´s training and certification center in Lisbon, specifically in the reports' production department. The problem that originated this study occurred because of the company´s growth, as more client orders came with a consequent need for rapid production increase, risking either not attending the client or lose quality. To prevent this from happening and since there was space for improvement, GemsValue decided to use Lean to achieve this goal. With this action, GemsValue improved the reports' production process in terms of waste reductions and quality results, allowing for an increase in production in the same available time without quality loss. The methodology focused on the reports' production process details, such as the process phases, the space cleanliness and organization, the time spent and the analysis of the report as it is the important final product that also had room to be improved. The results obtained were positive, as there was a reduction in the total time required to produce each report as well as an increase in daily production capacity without quality loss or major investments. Stakeholders were made aware of the advantages associated with maintaining the implemented measures, which brought understanding and satisfaction to all. In this way, GemsValue obtained a permanent improvement for the future in the Gemstones' certification process.

Keywords: Certification, Gemstone, Lean, Report.

Paper type: Research paper

INTRODUTION

This case study intends to demonstrate the advantages of Lean philosophy tools, through its application in a Gemological Center, analyzing and improving the Gemstones' certification process and the final product, the gemological report.

In terms of this paper´s organization, the abstract section intends to summarize the case study and the problem that originated the necessity to implement the Lean tools in the company. In the introduction section, it is explained with more detail the necessity that led to the study, the product object of analysis and Gemology's current world business situation using information about its evolution in the recent years. In the research methodology section, it is intended to explain the Lean philosophy tools used, the product and the process analyzed and improved. Two different situations are compared, namely the process and product without Lean and finally after Lean. Then the results are demonstrated, and conclusions are explained.

As an environment to perform the study, the center for training and certification of gemological materials, GemsValue, located in Lisbon, was chosen. GemsValue achieved accreditation, experts' recognition, clients' trust and satisfaction due to the hard work, accuracy, profound knowledge and mostly the passion to work with gemological materials. With the company´s growth came the necessity to improve productivity, be faster and more effective when it comes to delivering the product to the client. For this reason, the implementation of Lean tools was an advantage and brought the expected benefits to GemsValue, which were afterwards measured. As other organizations in early stages of development, GemsValue presented rapid growth, with the increase in clients' orders, which gave rise to the need to be faster and better and to maintain the business´s sustainability in terms of costs. For this reason, Lean was a smart and economic solution. Inside the laboratory environment, the stages where evaluated in a real daily situation, from the first contact from the client, who brings the necessity to GemsValue's laboratory, to the report delivered. For the process stages, room for improvement, according to Lean tools, was carefully looked out for, in terms of report layout, time spent, laboratory cleaning and organization.

GemsValue (Figure 1), works hard to innovate and grow in a competitive market. It finds its energy in the main purpose of sharing its knowledge across the Gemstones' world. Specialized in diamonds, precious stones, and organic Gems, it spreads gemological information and updates new criteria for quality graduation and Gemstones' laboratorial evaluation. According to GemsValue (2020), it detains a capital of knowledge, whose mission is to dignify jewelry in Portugal, guided by high standards of seriousness and credibility.

Figure 1 – Brand logotype (GemsValue, 2020).

Gemstones trade consists in an important matter all over the world. The Gemstones and jewelry extraction, as the subsequent commerce, represent a dynamic and constant business, being one of the values that makes the economy move between countries originating important money transactions. For the most important and famous type of Gemstones in the world, the diamonds, 142 million carats of these Gems were estimated to have been produced from mines worldwide in 2019. Major producing countries include Australia, Canada, the Democratic Republic of Congo, Botswana, South Africa and Russia. Worldwide reserves are estimated to be some 1.2 billion carats. Russia has the largest reserves, estimated at some 650 million carats, according to diamond industry (2020).

Gemstones, currently named precious stones, are generated by nature in its rough stage. After the extraction from the mines, they can be lapidated, traded, or subjected to various other changes that modify their appearance to a result far from the natural stage. The advantage of these actions to sellers is that they are more likely to achieve a selling process with an increase in the evaluation result or to make Gemstones suitable to be craved in jewelry.

The United States is one of the biggest consumers of Gemstones in the world. According to the U.S. Geological Survey (2020), in 2019 U.S. imports for consumption of gem-quality diamonds, were estimated to be about $23 billion, which was an 8% decrease compared with $25.1 billion in 2018. U.S. imports for consumption of natural, nondiamond gemstones, were estimated to be about $3.0 billion, which was a 14% increase, compared with $2.64 billion in 2018. U.S. synthetic gemstone production increased by 10% compared with that in 2018. Total world diamond production during 2019 increased slightly from 2018 levels. Production is expected to continue to remain steady in the near term and then decline slightly, until 2025, when several large mines are expected to reach the end of their life, and only a few new projects are being developed.

According to Rapaport Diamonds (2020), in Figure 2, the global diamond production will decrease in 2020. It is expected that the global rough production value will drop some 29% to around $8.6 billion this year, which would be its lowest level since 2009. This is the result of two factors, namely that some important mines are reaching the end of its life and the financial impact of Covid-19, which brought less capacity to invest in the extraction industry.

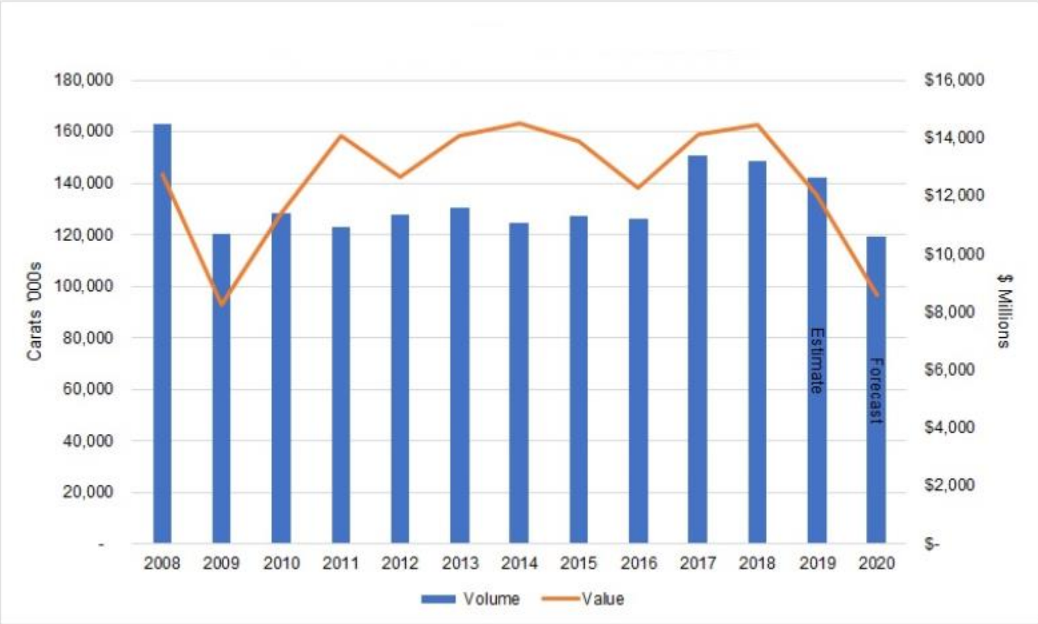

Figure 2 – Global diamond production (Rapaport Diamonds, 2020).

It is important to refer that, although Portugal is not one of the biggest consumers of Gemstones or Jewelry, it plays an important part because of its geographic location and natural language, representing a bridge, and a strategic location in terms of Gemstones' certification, with an ease communication for the Portuguese speaking countries to make business. For this reason, Portugal´s economy and Gemological companies also suffer with the aforementioned decrease in world production.

The Gemstone´s report (or jewelry report depending on what is been trading) can be decisive and represents an advantage to perform a secure and fair trade. There is no precise information of how much independent reports are produced across the world each year, as it is consumer demand, and laboratories belong to the private sector. Independent reports are not legally demanded for trades to be possible. Most Gemstone producers and traders make their own reports as a guaranty to the buyer, but this may represent a conflict of interests because they can benefit with the trade. For this reason, consumers started to value the necessity to have an independent laboratory that produces these documents without having any interested part in the business. The economic value of these beautiful objects is set by the present tabled stock exchange and its gemological characteristics, namely, its beauty, durability, and rarity, indexed to each type and quality of Gemstone. There are thousands of natural Gemstones and it is believed by specialists that there are more to be discovered in nature´s mineral exploration. For each type of Gemstone, there is also a large range of characteristics that define their economic value, and even for a natural Gemstone, the range can be enormous. For this reason, there is space for negotiation between a seller and a buyer, where both parts try to make the best deal. Sometimes the process can be slow and difficult. There can be attempts to trick, which once successful, may represent a great amount of business loss. These problems are originated by lack of gemological knowledge from the interested parts and lack of a specialist Gemologist to verify the authenticity, characteristics, and consequent fair Gemstone trade. There are also synthetic stones that imitate almost perfectly natural ones. Additionally, between natural Gemstones, there is also the risk of being tricked, because there are different types that present similar physical and chemical characteristics and also react to the laboratorial tests with the same manner, despite them not being the same and their market value differing. One example of this common confusion is between diamonds ad moissanites. Moissanites are also beautiful natural Gemstones, but much less valuable than diamonds. They can be easily confused, leading the buyer to believe he is buying a good diamond while he is buying a moissanite. Also, there are chemical treatments that can improve the appearance of Gemstones and induce a mistake, leading the buyer to believe he is buying a better example of a Gemstone. For this reason, there is a consumer need to document the trade and demand a credible, Government recognized Gemstone report, performed by an accredited laboratory, accompanying the item. There is also the possibility to ask for an expert Gemologist to certify the Gemstone before the trade is closed, this person also certified by the Government as a professional to evaluate Gemstones, and to produce a report. These actions add value and security to the business and to all involved parties. The certified expert Gemologist has the knowledge and knows which instruments he must use to discover what stone he has in hands and its current commercial value. As stated by Pinillos and Gavilenko (2009), the Gemologist can distinguish Gemstones, recognize the synthetic ones and the physical treatments that were applied using the laboratorial and technical equipment.

For thousands of years, Mankind uses Gemstones as an adherence or to decorate monuments and living spaces, to increase beauty, and as a symbol of richness and good fortune, as explained in Lino et al. (2020).

According to Webster (1987), the most correct analysis of Gemstones must be performed in a laboratorial environment, where the Gemstone´s physical and chemical properties are studied, such as crystallography, spectrophotometry, luminescence, specified weight, among others.

RESEARCH METODOLOGY

The methodology to approach this matter was designed to improve specifically the Gemstone´s report production, in GemsValue´s laboratory, by using some of the Lean philosophy tools, to bring benefits to the process for the future. The final goal was to save time and resources, allowing for an increase in the production of reports without major money investments.

It was necessary to comprehend some gemological concepts and designations. The report consists in the document that is produced in GemsValue's laboratory by one of the certified expert Gemologists, requested by the Gemstone´s owner with the propose of certifying the authenticity of the Gemstone, its value and rarity. In this study, the called "initial process" refers to GemsValue's process to produce a report before Lean application. The called "improved report" refers to the report with changes that come from the Lean philosophy tools applied to the initial process. In this study, the term item refers to the Gemstone and the term product refers to the report delivered to the client. The term layout or template refer to the standard design of the report. The Gemstone´s report production refers to the process that began with the order from the client and then has the report as the final product, which is delivered to the client.

After Lean tools were applied, an improved report for the same Gemstone was made, with the new process and the new layout for the same Gemstone presented in this study.

With the theorical and practical study of the initial process, it was possible to make an analysis and identify spaces available for improvement and application of Lean tools. Two Lean tools where carefully selected to fulfil the needs of the process. The PDCA cycle was also considered.

Lean philosophy tools used. The Lean philosophy tools were the seven lean wastes and the 5S methodology.

Lean philosophy had its origin in Japan, in the twentieth century, and was designed by Taichii Ohno, to improve productivity in the Toyota Production System, as mentioned in Ohno (1998).

Seven Lean wastes. According to Navas and Machado (2011), the seven Lean wastes tend to accumulate, creating a chain of wastes that can result in an enormous impact in the organizations. As mentioned by Ohno (1988), the seven Lean wastes are transport, stocks, unnecessary work, waiting, over-production, over-processing, and defects. As illustrated in Figure 3, the seven Lean wastes are a group of wastes that can exist at the same time in an organization.

Figure 3 – The seven Lean wastes (Lean Manufacturing Tools, 2020).

Transport. Refers to unnecessary movement of items that can be easily rearranged with a layout reorganization.

Stocks. Refers to a set of products that are produced but not yet delivered, resulting in maintenance that occur when, for example, over-production is performed. This brings an increase in costs for keeping and maintaining the products for a certain period.

Unnecessary work. Refers to steps of the project that don´t bring gains, so they should be removed or evolve to a less important stage so the organization can spend less resources with it.

Waiting. This type of waste represents the periods of time that don´t bring benefits to the product´s conception.

Over-production. Is the conception of unnecessary items. An alternative way to mitigate this waste, can be the just-in-time way of production, which means zero stocks and the production of the items only after the order comes.

Over-processing. Is the excess of the organization´s processing capacity, which results in an increase of defects.

Defects. Is a type of the seven Lean wastes that represents the products without the perfection needed and can result in waste of materials or the remake of the product from the beginning.

5S methodology. The 5S methodology was designed by Massaki, the founder of Kaizen Institute, with the propose to minimize problems in workplaces, reducing wastes and helping improve the productive process. According to Gapp Fisher and Kobayashi (2008), the advantages that 5S can bring to the process are: more efficient, organized, clean, productive and secure work places, better identification of problems, better planning of activities, increase of productivity, reduce costs, spaces, movements and brakes. As illustrated in Figure 4, the 5S organizational methods are sort, set in order, standardize, shine, and sustain. Each of these methods can be used individually or together to fulfill the propose of improvement.

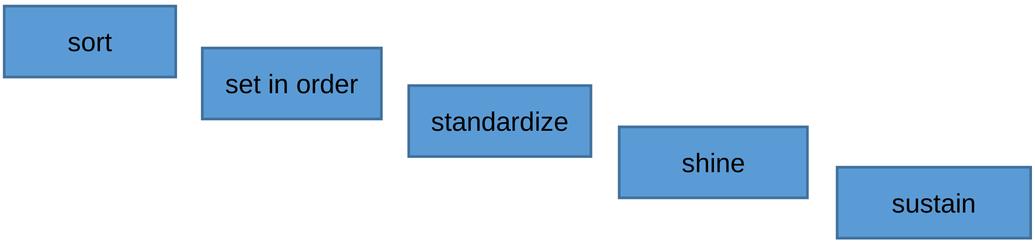

Figure 4 – 5S.

PDCA cycle. The PDCA cycle was developed by Shewart in 1930, and according to Falconi (2014), is a methodology to analyze and create solutions to perform a continuous improvement. As illustrated in Figure 5, it means Plan, Do, Check, Act, in this processual order. When implementing PDCA, as a first step it is necessary to plan and define the objectives and then implement the plan. After this stage comes the data analysis where room for improvement is detected and the decision to make changes to achieve better outcomes also is executed.

Figure 5 – PDCA cycle (Moen and Norman, 2006).

Report Process

Illustrated in Figure 6, in GemsValue the process to produce a report is organized in four different phases. As shown in the blue boxes, these phases are the negotiation, the gemological study, the report creation, and the final delivery. As shown in green boxes, each phase has internal sub-phases. Once well known the initial product and the process, the Lean tools were applied to create the improved step analysis. The study focused mainly on phases 2 and 3. For phase 2, the Gemological study, the initial and improved reports were separated in laboratorial steps, from A to L. The data analysis and the expert´s review was also studied to verify where there could be changes and application of Lean. All these steps were named with letters to facilitate Lean changes.

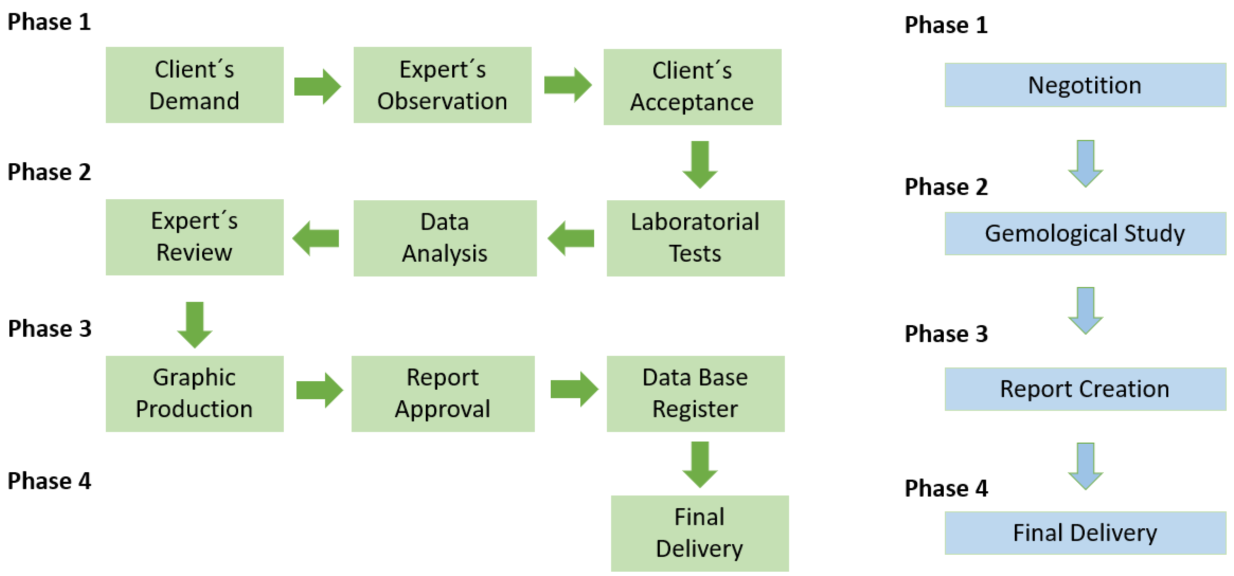

Figure 6 - GemsValue´s Report Process Production.

Initial Process Analysis. According to Figure 7, the study focused on phases A to J, of laboratory tests and calculations to obtain gemological Gemstone´s data and produce the report. Each of these lettered steps are described.

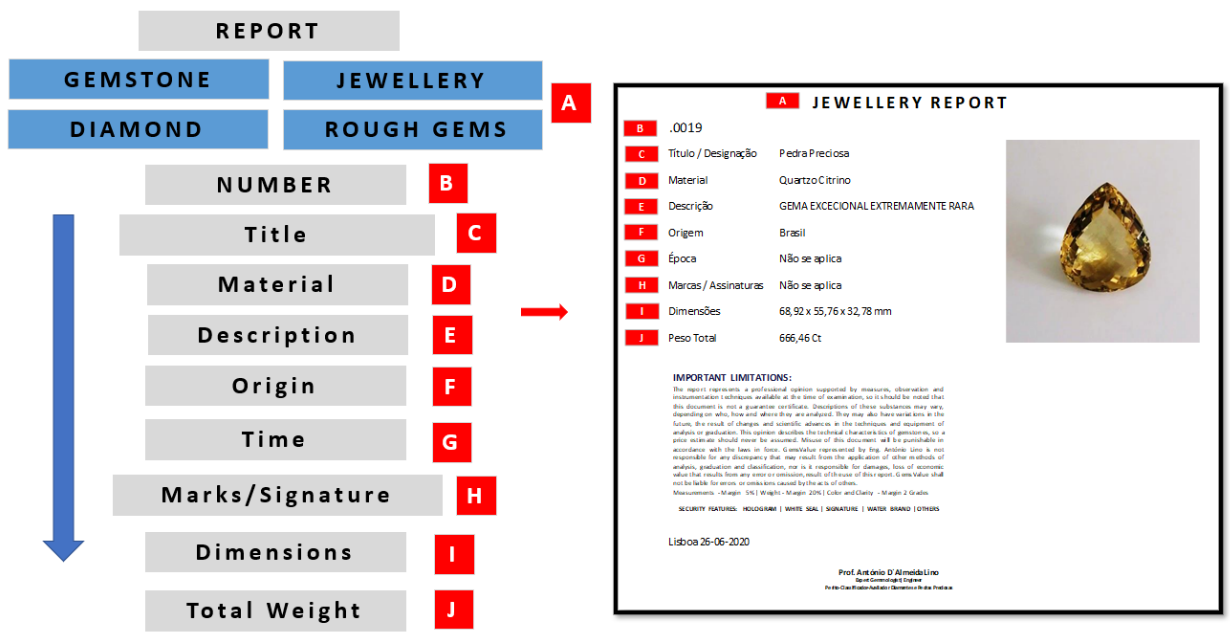

Figure 7 – Gems report elaboration - Initial Process (GemsValue, 2020).

The client´s request, could be solicited by several channels, such as, in a consulting appointment, by email, in GemsValue´s site, or by a phone contact. The client demanded a report of the item he possesses, so GemsValue tried to understand the necessity and the type of material the client has so the service could be customized as best as possible. For each new client GemsValue explained how the consultation and report delivery works, the information and security it contains, the advantages and how it could be used to perform the trade. It was also necessary to comprehend if the client had one item, a set of items for a single report, or a need for multiple certificates for different items. This information was essential to anticipate the time to deliver the product to the client and to put the task on the planning schedule chart. In a second step the client brought the item to the laboratory along with the legal documents. After the acceptance and scheduling the process of Gemological study began.

A step initial – Type of item. The process started with the laboratorial technique to recognize the category in which the item should be integrated. This information determined the main report´s title.

There could be four categories of reports, namely, Gemstone, jewellery, diamond, or rough diamond. This distinction was necessary because the evaluation and parameters differ, so the laboratorial instruments, techniques and calculations differ too. For example, for a jewellery, one of the differences was the necessity to analyse each stone that was craved, the metal´s alloy, would contrast, among others.

B step initial - Number. The number was a secure code created to the report to be linked to the stone in a sealed bag. The number stays in GemsValue´s data base so there can be no other report with the same number for a different item. This number was associated with the bar code. This technique allowed GemsValue to replicate reports for the same Gemstone, without the necessity to ask the client to bring it back to the laboratory and without loss of authenticity.

C step initial - Title. The title referred to the designation, the type of item and was wrote in the report. The title could be Gemstone, jewellery, diamond, or rough diamond.

D step initial - Material. The D step was the definition of the item’s mineral, which was one of the most important information’s of the report. For example, it certified that it was an actual natural diamond, natural ruby, natural sapphire, a synthetic diamond, natural emerald with treatment, among many others.

E step initial - Description. The description complemented the information provided in D step. It represented the evaluation of the Gemologist, which holds a high standard to add value in a trade, especially when the professional is highly recognized.

F step initial – Origin. The origin referred to the geographical mine location in the world where the mineral was extracted. This was not applicable for jewellery, and only made sense for natural precious stones.

G step initial - Date. The date was the time when the report was approved by the expert Gemologist. This was essential to make track of the report in the database and in case of new precious stones are discovered in the future and new laboratory techniques evolve.

H step initial – Marks/Signature. This field referred to marks that could be found when the item was analyzed with a magnifying glass or a microscope such as inclusions that appear in natural stones, clavation marks or would contrast marks in the jewellery items.

I step initial - Dimensions. The dimensions were the length, width, and height of the item. For example, for jewellery items, all Gems dimensions must be measured and referred in the report.

J step initial – Total Weight. The total weight was measured in a scale with a high precision. This information was essential because the commercial value of the Gemstone depends on its weight. This determines its interest to lapidation or carvery.

The initial report had a fine lighted photography of the item, where its transparency was visible. It indicated information of the report´s limitations, such as the information conditioned by the scientific knowledge in the gemological study at the time. Also, it referred the name of the Gemologist and his signature.

Improved Process Analysis. The diagram shown in Figure 8 represents the new process that results from the initial process shown in Figure 7 changed using Lean tools.

The reports were designed to be written in English instead of Portuguese, so they could be more global and attractive to other markets. Despite this, if the client ordered the report in the Portuguese language, that could also be delivered. For each new client GemsValue explained the security seals and codes, that were an upgrade in the improved product, and the advantages of trading a Gemstone with a report rather than a Gemstone without report. If the client had a set of items to certify, GemsValue could offer a discount, which was also an improvement.

Figure 8 – Gems report elaboration - Improved Process (GemsValue, 2020).

A step Improved – Type of item. As for the initial process, the improved process started with the identification of the item´s category. This information determined the report´s main title. As for the main title, it was upgraded to include the information that the report came from the accredited laboratory in Portugal, GemsValue.

The four categories remain the same, namely, Gemstone, jewellery, diamond, or rough diamond.

B step Improved - Number. Comparing to the initial process, for the improved process, GemsValue created a new coding, that was indexed to the bar code, the hologram and the QR code in GemsValue´s database. These number was more difficult to be faked and could be in no other report with the same number for a different item.

C step Improved – Species/variety. In the initial process, C step initial represented the title of the report, which was reconsidered. The C step improved to represent the information that was in the D step initial, namely, the material in terms of Gemological evaluation. This field informed if it was a natural or artificial Gemstone, and what type of Gemstone it was.

D step Improved – Shape and cut. The D step changed from the material to the shape and cut, which were more technical information's that could add more value to the report. The cut was the type of lapidation, and the shape was the form of the Gemstone.

E step Improved – Measurements. The I initial process had the item´s dimensions, that were moved to the E step in the improved process to appear before, because it also implicated the viability for craving in a jewel or to a new lapidation. Also, to link a report to a Gemstone, when verifying its authenticity, is an improvement which can help significantly.

F step Improved – Weight. The origin that appeared in the F initial process was removed to open space to the weight of the Gemstone to appear earlier in the hierarchy, so it was moved from the J step in the initial process to the E step. The Gemstone´s weight was an important feature to define its commercial value.

G step Improved – Grading Results. The date presented in the initial process was an unnecessary step because it also appeared in the end. In the improved process it was decided that it should appear only in the end. This field was replaced with the grading results, which were the results for grading, highlighted with the laboratorial techniques and gemological international standards, such as colour, cut, clarity and transparency.

H step Improved – Colour. In the improved process, colour was described in a single field, because it was one of the characteristics that was more important to the trading process and to recognize the authenticity of the report related to the Gemstone.

I step Improved - Cut. The cut was not applicable for rough Gemstones, because it represents the type of lapidation.

J step Improved – Clarity. The clarity means the inclusions observed and other marks inside the gem that could be seen in microscope.

K step Improved – Transparency. The transparency was the degree of light passage visible in the stone, according to the laboratorial tests and international range.

L step Improved – Comments. The comments were free writing, for the Gemologist to provide his conclusion and additional considerations to complete the report.

Application of the two Lean tools and the PDCA cycle. After observing the report´s elaboration and performing a detailed analysis of the initial process, the whole system was carefully analysed, each phase of the initial process was questioned and space to apply the Lean tools was searched for to change the report layout and the process stages, with the goal of improving GemsValue´s reports successfully and reducing waste.

Application of the seven Lean wastes. In terms of transport, GemsValue concluded that there was no need to move the item to the phase where the study of its origin was looked out for. This was important but not necessary and represented a waste of time in the search for this information. For this reason, it was dismissed and removed from the report. For stocks, GemsValue started to buy the laboratorial consumable materials in a just-in-time mode and started to deliver the certificates immediately after there were concluded. This action reduced the cost with materials per month, allowed the laboratory to remain more organized and opened more space to necessary movements. The report´s delivery was made more quickly, and the clients were more satisfied. GemsValue eliminated various stages that represented unnecessary work such as the photography stage´s mounting. Because there was no space to maintain the stage always ready, it was mounted and dismounted as it was necessary, which represented an enormous waste of time. With the Lean actions implemented, as removing the stock waste, the space was set free to allow the stage to be always ready. The time to product a report decreased.

For these reasons, GemsValue started to spend less time in report elaboration. Afterwards, it was verified that there were less defects, even when over-processing occurred in times of high demand. For this reason, GemsValue has grown stronger and more competitive, with an increased in productivity, defect reduction and increased client satisfaction. GemsValue also started to make just-in-time production to eliminate over-production. It implemented the early payment in the just-in-time mode also to guarantee that the process of payment occurred just-in-time and not a time latter. This eliminated the registration for client´s payments in fault.

Application of 5S. GemsValue also implemented the 5S. The laboratory was reorganized and the equipment was disposed in a strategic order to reduce time between the process movements of the specialist during the work. The space was cleaned, all the unnecessary materials were kept in a closet to reduce distractions and the laboratory tools were strategically placed to facilitate its use, also in a strategic order to be used according to the process. The space was set to be more attractive to work in it and it was maintained this way.

In terms of the report layout, the way of coding the report number was changed to be more normalized and sorted to be indexed to the report´s bar code. This made it difficult for the reports to be compromised and made it possible to be trackable and valid throughout the years. Additionally, GemsValue started to consider the coding by order of purchase and not by the type of Gemstone, which was much easier to track, in less time and with less defects, creating a more sustainable certificate. In terms of set in order, GemsValue dismissed the E step initial, the description, because it was considered to be too general and not specific enough. The Grading Results Field was created, where four important pieces of information appear in order of interest, namely, the colour, cut, clarity and transparency. GemsValue also created a field for comments in the improved stage of the report. This fulfils the lack of retreating the initial description stage and the marks/signatures that was also removed.

In the initial process there were several stages that could or could not appear depending on what type of report was needed, as example, for a jewel or a diamond they were different in many steps. The improved process and layout were more standardized and easier to fill, which eliminated waste of time.

Application of PDCA cycle. The PDCA cycle was applied in the process of transition from the initial process to the improved process of report elaboration. First, the plan was designed to evaluate the initial process, then it was evaluated and room for improvement was sought. The improved process was tested with the elaboration of experimental reports in the new template and the new layout of the process was tested as well. Once improved, the initial process and initial template where disregarded and the improved ones were implemented for future clients.

RESULTS

Figure 9 intends to compare the stages of the initial process and the stages of the improved process and show the gains from the changes made in each phase.

Initial process	Improved process	Principal Gain
A - type of item	A - type of item	none
B – number	B – number	none
C – title	C – species/variety	gemological info added
D – material	D – shape and cut	commercial utility info added
E – description	E – measurements	financial value highlighted
F – origin	F – weight	financial value highlighted
G – data	G – grading results	technical specifications
H – Mark/signature	H – colour	laboratorial result added
I – dimensions	I – cut	laboratorial result added
J – total weight	J – clarity	laboratorial result added
	K– transparency	laboratorial result added
	L - comments	space for more info added

Figure 9 – Comparison of initial process and improved process.

The improved report also brought more clients, client compliments and satisfaction, more orders, and good references for GemsValue´s brand in the market. For this reason, profits increased. The costs with the reports' elaboration decreased because of the more effective and efficient process, which was less expendable in terms of time required for the production of each individual.

The report gained a new, more attractive and refined face to the market where GemsValue wanted to be more competitive.

After analysing Figure 10, it was possible to see the more appealing image added to the product, in terms of technical, gemological, and commercial information, as represents the GemsValue´s report after Lean philosophy tools mentioned in this study were applied, showing the future organization´s certification process.

GEMS VALUE

INDEPENDENT ANALYSIS OF GEMSTONES
EDUCACIONAL PROGRAMS
- LISBON -

GEMMOLOGICAL LABORATORY
ANALYSIS & GRADING
A GEMSTONE REPORT

REPORT CHECK

B	REPORT NUMBER	201805540308
C	GEMSTONE	NATURAL QUARTZ
	SPECIES / VARIETY	CITRINE
D	SHAPE AND CUT	PEAR MIXED
E	MEASUREMENTS	68,92 x 55,76 x 32,78 mm
F	WEIGHT	666,46 CARATS
G	GRADING RESULTS	
H	COLOR	YELLOW BROWNISH [INTENSE]
I	CUT	VERY GOOD
J	CLARITY	INCLUSION(S) PATTERN [RARE]
K	TRANSPARENCY	TRANSPARENT
L	COMMENTS	EXTREMELY RARE EXCEPTIONAL GEMSTONE
	LISBON, 26/06/2020	

www.GemsValue.com

IMPORTANT LIMITATIONS:

The report represents a professional opinion supported by measures, observation and instrumentation techniques available at the time of examination, so it should be noted that this document is not a guarantee certificate. Descriptions of these substances may vary, depending on who, how and where they are analyzed. They may also have variations in the future, the result of changes and scientific advances in the techniques and equipment of analysis or graduation. This opinion describes the technical characteristics of gemstones, so a price estimate should never be assumed. Misuse of this document will be punishable in accordance with the laws in force. GemsValue represented by Eng. António Lino is not responsible for any discrepancy that may result from the application of other methods of analysis, graduation and classification, nor is it responsible for damages, loss of economic value that results from any error or omission, result of the use of this report. GemsValue shall not be liable for errors or omissions caused by the acts of others.
Measurements - Margin 5% | Weight - Margin 10% | Color and Clarity - Margin 2 Grades

SAMPLE

Prof. António D'Almeida Lino

SECURITY FEATURES: HOLOGRAM | WHITE SEAL | SIGNATURE | WATER BRAND | OTHERS

GEMMOLOGICAL LABORATORY
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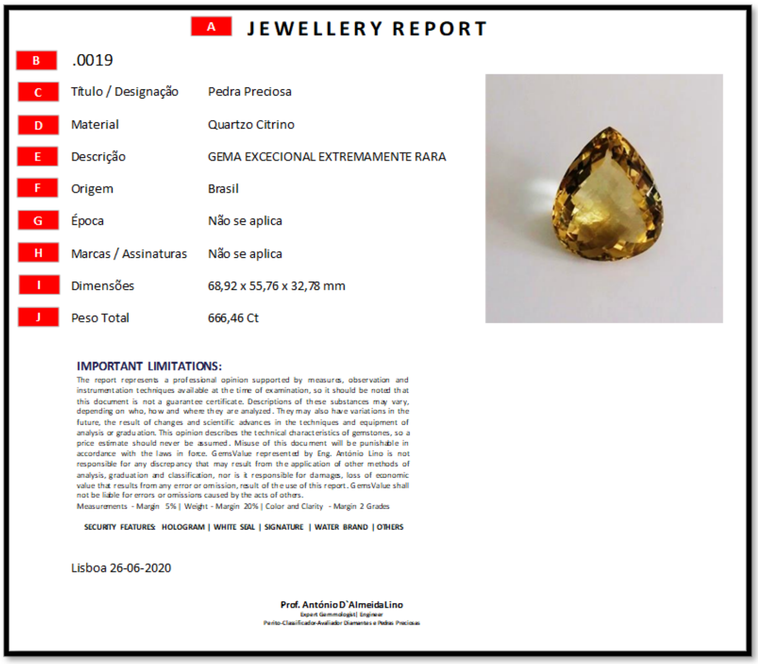
GEMS VALUE

Figure 10 – Gems report - Improved layout (GemsValue, 2020).

The initial report illustrated in Figure 11 was kept in the database as obsolete and for track of old reports if necessary.


A JEWELLERY REPORT

B .0019

C	Título / Designação	Pedra Preciosa
D	Material	Quartzo Citrino
E	Descrição	GEMA EXCECIONAL EXTREMAMENTE RARA
F	Origem	Brasil
G	Época	Não se aplica
H	Marcas / Assinaturas	Não se aplica
I	Dimensões	68,92 x 55,76 x 32,78 mm
J	Peso Total	666,46 Ct

IMPORTANT LIMITATIONS:
The report represents a professional opinion supported by measures, observation and instrumentation techniques available at the time of examination, so it should be noted that this document is not a guarantee certificate. Descriptions of these substances may vary, depending on who, how and where they are analyzed. They may also have variations in the future, the result of changes and scientific advances in the techniques and equipment of analysis or graduation. This opinion describes the technical characteristics of gemstones, so a price estimate should never be assumed. Misuse of this document will be punishable in accordance with the laws in force. GemsValue represented by Eng. António Lino is not responsible for any discrepancy that may result from the application of other methods of analysis, graduation and classification, nor is it responsible for damages, loss of economic value that results from any error or omission, result of the use of this report. GemsValue shall not be liable for errors or omissions caused by the acts of others.
Measurements - Margin 5% | Weight - Margin 20% | Color and Clarity - Margin 2 Grades

SECURITY FEATURES: HOLOGRAM | WHITE SEAL | SIGNATURE | WATER BRAND | OTHERS

Lisboa 26-06-2020

Prof. António D`Almeida Lino
Expert Gemmologist| Engineer
Perito-Classificador-Avaliador Diamantes e Pedras Preciosas

Figure 11 – Gems report - Initial layout (GemsValue, 2020).

The time spent producing a report was measured, considering one day before Lean and another day after Lean. Before Lean tools applied, the time to complete phases 2 and 3 was on average 30 minutes. before Lean applied, and after the improvements it changed to, on average, 20 minutes.

In a 4-hour laboratory work, in terms of Gemological time spent producing a report, the number of reports per day increased from 8 reports to 12 reports. Thus, GemsValue gained the capacity to produce 4 more reports per day, on average.

The number of reports previously dismissed due to errors was 20%, and it was decreased to 10%.

CONCLUSIONS

The objective was accomplished as production capacity increased using the same available hours per day, without major financial investments. GemsValue was able to produce 4 more reports per day, decreased the time to produce each report by 10 minutes. The two Lean tools, namely the seven Lean wastes and the 5S methodology, combined with the PDCA cycle, helped GemsValue improve the production process and the product as was expected. The report´s quality increased with a more appealing image and a decrease of 10% in report production errors was observed.

Comparing the two products, namely, the initial report and the improved report, which resulted from the application of Lean philosophy tools, there were several gains in terms of security code, normalization, technical information provided and gemological value that showed the fine laboratorial work that was executed behind each report. For this reason, the credibility of GemsValue´s reports increased, which brought good reputation, clients´ satisfaction, good publicity, and in consequence, the orders increased.

As the success of Lean philosophy tools were seen and recognized by the organization, GemsValue intended to maintain the implementation of these assets to other processes and products, in a creative and opened minded manner, always finding room for continuous improvement.

Additionally, it was verified that GemsValue started to be more organized, clean with a continuous care for this necessity, for this is essential to maintain the sustainable times to elaborate a report in a competitive way, without waste spent in obsolete tasks. A routine for this matter was also created.

Considering future growth, GemsValue still has room for more improvements, as it has the goal to continue to expand in a competitive and heterogeneous global market. Consequently, new challenges will appear. In the report department, for a future suggestion, GemsValue may apply the Kano model, which focuses on the client´s satisfaction, and may bring the tools to adapt the reports to a customized market. The road ahead is to apply Lean tools to the training department, which is another important product of this company and is also experiencing rapid growth. It would be interesting to apply Lean philosophy to one of GemsValue's training courses, the Gems Business Course, in the way of passing the knowledge to the students.

AKNOWLEDGEMENTS

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Develop the New Business Model for SME Manufacturer

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ABSTRACT

Purpose - In this new era, due to the market competition, there are a lot of pressures in the SME manufacturers. Most of the manufacturers are facing challenges, such as increasing product variety, small lot size and short delivery time, but there is lack of a suitable and practical methodology to solve such problems. This study is mainly based on drilling down into an SME manufacturer, exploring the limitation in its current business model and determining the boundaries of its operation process.

Design/methodology/approach - This research paper develops a new business model, two-phase operation process and standardization modular design to solve the above problems and then trial run the new business model in the SME manufacturing company.

Findings - The results prove that the new business model and the new operation process not only solve the problems in product variety, small lot size and short delivery time, but also create a synergic effect for transformation of the surplus to business opportunities, and improve the efficiency and effectiveness in the operation.

Research limitations/implications - This study only focuses on an SME manufacturer, so that the results and conclusions are limited. In the future, it would be interesting to collect data from other manufacturers and conduct a cross-country comparison study.

Originality/value – The study provides a clear roadmap for exploratory and cost-effective solutions for other SME manufacturers to achieve continuous improvement of their business model.

Keywords: Continuous Improvement, PDCA Cycle, Standardization.

Paper type: Research paper.

1. INTRODUTION

E-commerce is changing purchasing behavior from traditional channels to Omni-channels, many trading and manufacturers also run their retail business through the E-commerce. Due to the end customers frequently requesting products with personal characteristics, such as choosing products with specific colors, styles, or logos. Therefore, the business process in the manufacturer has changed from Mass Production (MP) to Mass Customization (MC) for mass product variety, small lot size, and short delivery time.

From the above, problems arise such as how to increase the product flexibility and variety; how to shorten the product delivery time; how to improve the surplus of the finished goods; how to improve the cost saving; and how to solve the limitation in production for MC products. These are the key factors those most manufacturers are facing.

There are a lot of external forces driving product variety, mass customization and short delivery time, but there are a lot of limitations in production in fulfilling such requirements, especially for Small and Medium-sized Enterprises (SMEs). According to James and Mondal (2019), setups are sequence dependent because they depend not only on the next job to be processed, but also on the previous job processed. The setup times cause a loss of valuable time and production efficiency due to a high variety of products in MC.

SMEs have been a crucial factor for growth in countries all over the world. According to the statistics from Mainland China, the European Union (EU), Hong Kong and the US, SMEs represent over 98% of all business units in their countries [11][12][13][14]. According to Radziwona et al. (2014), in the EU, SMEs provide approximately 20% of all jobs in industry, and the manufacturing activity represents about 21% of the total EU GDP. It has been shown that SMEs are not only contributing to employment but also economic development in the global and regional economic recovery.

The objective of this paper is to analyze the root causes and determine the key issues that need to be improved in the business model of the SME manufacturing industry when they are facing the change from MP to MC (product variety, small lot size and short delivery time). We develop a new business model and new operation process for the SME manufacturing industry by implementing has refined business model described in this paper.

2. LITERATURE REVIEW

2.1. From Mass Production to Mass Customization

The business process of manufacturing has changed a lot in the past few decades. It changed from MP to MC, then to small batch customization of products and short delivery time. MC is the rapid, low-cost production of goods that fulfill increasingly unique customer requirements. However, MC is not only about variety, but also about making precisely what the customer wants economically (Heizer et al., 2017). According to Graman and Bukovinsky (2005), MC implies the ability to customize a large volume of products and deliver them at close to MP prices, and it adopts the approach of creating variety and customization through flexibility and quick response. The revised system was redesigned and the product development, manufacturing and logistics were affected in order to provide modularity and flexibility (Traian and Aurel 2015).

2.2. Overview of different Business Models in Manufacturing

In the past, most of the manufacturers were using the Make-to-Stock (MTS) business model to handle MP. Due to the current market change from MP to MC, there are different business models in the manufacturing environment, such as Assemble-to-Order (ATO), Make-to-Order (MTO) and Engineer-to-Order (ETO) (Olhager, 2003) and Configure-to-Order (CTO) (Aqlan et al., 2014). The different of those models are related to different positions of Order Penetration Point (OPP), the OPP means the stage in the manufacturing value chain where the customized product is linked to a specific customer order (Olhager, 2003). OPP provides a way of distinguishing between manufacturing approaches, defining the point in the manufacturing process where a product is linked to a customer order (Haug et al., 2009). Figure 1 shows the OPP in five models, the dotted lines depict the production activities that are forecast-driven, and the straight lines depict customer-order-driven activities.

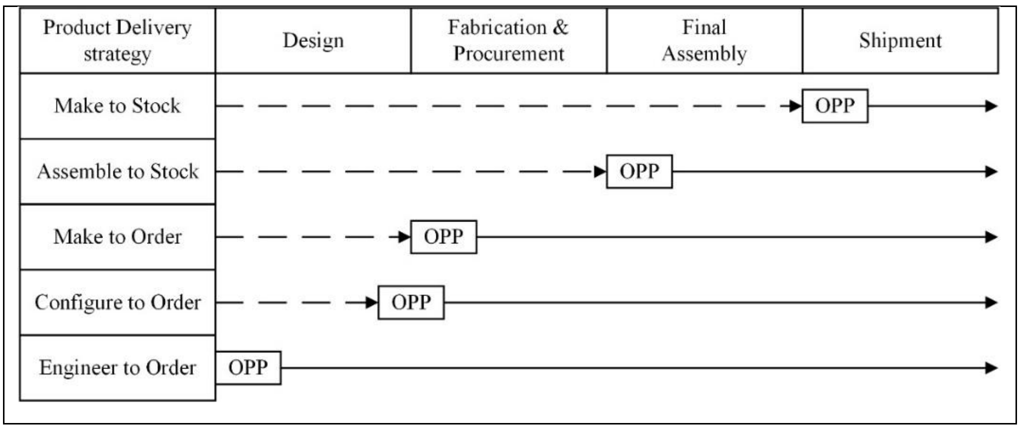

Figure 1. The OPP in MTS, ATO, MTO, CTO and ETO models

- Business model of Make-to-Stock

The MTS model is suitable to produce standard products in low variety and at high volume. The operations are not flexible but benefit from low operating costs (Graman and Bukovinsky, 2005). In the MTS model, products are created before receiving a customer order. The delivery time is short, but it needs to keep a lot of products. As shown in Figure 1, the OPP is located at shipment phase.

- Business model of Assemble-to-Order ATO

The ATO model produces the products by forecasting, but it will run the final assembly process after receiving the sales order. The advantage of the ATO model can produce a variety of products from limited components and it can start the final assembly process after receiving the sales order. As shown in Figure 1, the OPP is located at final assembly phase.

- Business model of Make-to-Order

The MTO model provides mass variety, high levels of customized product, but in high operating costs (Graman and Bukovinsky, 2005). Due to the raw materials will be purchased and produced after receiving a customer order, the delivery time is longer than using MTS and ATO models. As shown in Figure 1, the OPP is located at fabrication and procurement phase.

- Business model of Configure-to-Order CTO

The CTO model produces and keeps the components on a forecasted plan, then assembles the components after receiving the sales order. The advantages of the CTO model are the flexibility of mass customization, delivery time, and efficiency of mass production (Aqlan et al., 2014). In the ATO and MTO models, manufacturers can configure the products based on the customer order, in the CTO model, it allows customers to configure the finished product that they want to buy. As shown in Figure 1, the OPP is located between design and fabrication & procurement phases.

- Business model of Engineer-to-Order

The ETO model provides an environment with ultimate customization. The final product may not be modified the specifications but may be required to change the design and production methods. As shown in Figure 1, the OPP is located at the design phase, so that the delivery time will be very long which includes engineering design, material acquisition and manufacturing time (Akinc and Meredith, 2015).

2.3. *Overview of other methodologies for Mass Customization*

Time Postponement and form postponement are other methods of using inventory differentiation to solve the MC problems (Graman and Bukovinsky, 2005, Heizer et al., 2017). Time postponement delays the differentiation tasks of the operation tier as late as possible in the production flow process. Form postponement is to standardize the upstream stages as much as possible so that the product remains generic longer. Standardization of components effectively delays the point of product differentiation through increasing component commonality and modularization.

2.4. *Internet of Things and Cloud Manufacturing*

Internet of Things (IOT) and cloud manufacturing provide another direction to solve the customized / personalized products problem that used to be solved by the collective efforts from consumers, manufacturers and third parties (Yang et al., 2017). IOT provides real-time sensing and fast transmission capability of data, and can greatly facilitate remote operation in manufacturing activities and efficient collaboration among stakeholders. However, the method does not seems to provide communication among the machines in the production line and the cost of robots for the production line may not be affordable by SMEs.

2.5. *Cellular Manufacturing*

Cellular manufacturing involves using multiple cells in an assembly line, and each of these cells is made up of one or more different machines to complete a certain task. Usually the cells are arranged in a "U-shape" design whereby it can allow an inspector move less and more easily in observing the whole process. According to Torabi and Amiri (2012), cellular manufacturing focuses on shop floor control and it may be more effective in small and medium production sizes, and is suitable for products with steady demand. It may not be suitable for product with a high variation in demand or product mix.

2.6. *Flexible Manufacturing and Three Dimensional Printing*

According to Tien (2011), there are a number of technological advances that can better enable MC, such as flexible manufacturing and three dimensional printing. Flexible manufacturing, sometimes referred to as rapid prototyping, is a key MC enabler, and depends on advanced computer and communication technologies. In the current technology, Three Dimensional (3D) prototyping uses the Computer-Aided Design (CAD) software to develop Two Dimensional (2D) layers of discrete thickness products, such as dental parts, hearing aids, knee replacements and other replacement parts.

Although it can quickly develop customized models and eliminate the use of tooling or molding, the materials are limited to resins, thermoplastics, ceramics, composites or metal powders.

2.7. Limitation of Mass Customization

According to James and Mondal (2019), there are a lot of limitations in the real MC environment. They found out that MC decreased machine efficiency, due to a lot of parameters involved such as product variety, lot size, changes in product design, and complexity in business process etc.

2.8. Customer Behavior

For the customer, the advantage of MC is provided in the large product selection. Usually the price of MC is most likely lower and the delivery time is shorter than the full tailored product. According to Haug (2009) and Piller (2004), ‘‘Do customers need customized products?’’, ‘‘If yes, what prevents them from purchasing these offerings?’’, ‘‘Do we have the enabling technologies for MC?’’, and ‘‘why do many firms fail during and after the introduction of MC?’’. The motivation for a company to switch from MP to MC is to allow customers to join the co-design process but keep the costs of products close to those of MP. It will also improve the internal processes, and let the customers modify the existing products (Hsu, et al., 2014).

2.9. Research Gaps

Although there are a lot of SMEs in the world, many approaches to improving performance are not practical (Thürer et al., 2011). According to Hofmann and Rüsch (2017), the definition of the concept for Industry 4.0 is not clear in the existing academic literature, there are a lot of risks, costs and barriers when implementing Industry 4.0. It seems that IOT, cellular manufacturing and 3D printing are not suitable to solve the mass customization in SME. Therefore, in this project, we develop a new business model and new operation process for SME manufacturers to handle the product variety in small lot sizes and in short delivery time. Besides, it determines purchasing behavior in ordering customized products.

3. RESEARCH METHODOLOGY

This project analyzes the root causes and determines the key issues that need to be improved in the current business model of an SME manufacturer when they are facing the change from MP to MC, small lot size and short delivery time. The roadmap of the research methodology includes five phases for the implementation of the proposed framework, as shown in Figure 2.

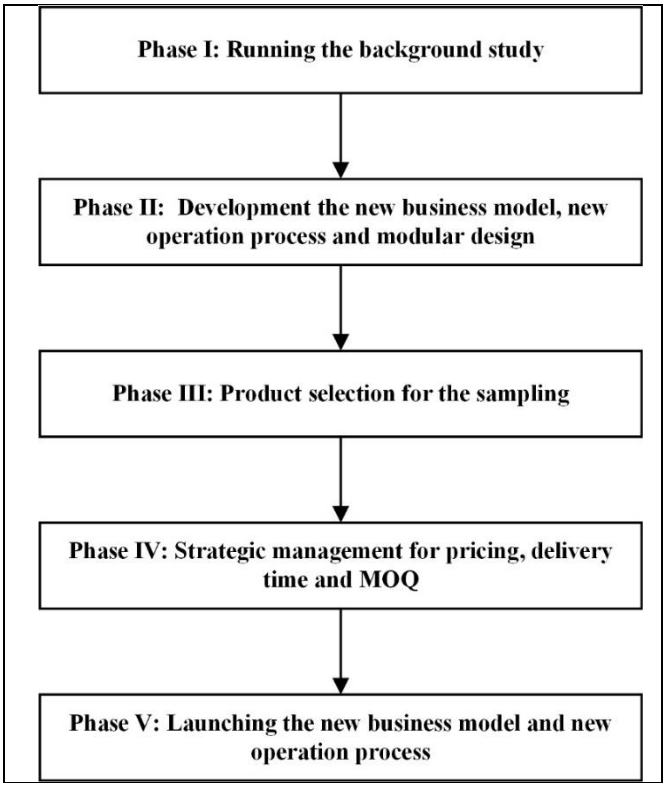

Figure 2. Roadmap of the Research Methodology

3.1. Running the Background Study

This project studies the current business models and operation processes, addressing the problems faced, the limitations of the production processes and the limitations of product design.

3.2. Development the New Business Model, New Operation Process and Modular Design

The project is based on the design of a new business model for the SME manufacturing industry and defining and identifying the criteria and Key Performance Indexes (KPI) to measure the improvement in the new business model. Further, the new operation process is also designed to run with the new business model, and restructured product design. The new business model is then fine-tuned and a feasibility study undertaken to ensure the requirements are fulfilled.

3.3. Product selection for the sampling

In the sample selection, all the samples of the standard products and customized products need to cover all kinds of models in the MTC. Therefore, the proportion in the sampling size is based on the ratio of each kind of product and those products need to be fulfill in some criteria.

3.4. Strategic Management of Pricing, Delivery time and MOQ

Strategy management for the selling price, delivery time, and MOQ is a hot topic in the marketing approach and in customer behavior. How to set the equilibrium point directly affects the result of the sales volume. Before implementing the new business model, the company should adopt strategy management for price setting, product delivery time and MOQ.

3.5. Launching the new business model and new operation process

The new business model and the Two-phase operation process will run for four months, all the sales and inventory data will be collected and analyzed. Then comparing the results between the current and new business models.

4. CASE STUDY

ABC Company Limited is a leading classic tin toy and gift company in Hong Kong and has the largest tin toy factory in Shanghai. Its activities include manufacturing, and wholesale and retail business. It has its own brand – Saint John - and its markets include China, Hong Kong, France, Spain and other countries.

4.1. Company Background and Current Business Model

ABC uses the MTS and MTO models to handle different kinds of business. Table 1 shows that ABC uses the MTS model to run new design products and current products for retail, Business to Customer (B2C) from the e-commerce and retail shop. One of the reasons is that the labor and material costs per Stock Keeping Unit (SKU) in using the MTS model are lower than for the MTO model, and the product delivery time is shorter than the MTO model. On the other hand, it uses the MTO model to produce all the customized products and current products for the wholesale business, thereby it does not need to keep a lot of finished products, and the delivery time in the wholesale business is sufficient for production and product delivery.

Table 1. Current business models

	Wholesale Business	**Retail Business**
New Standard Product	MTS	MTS
Current Standard Product	MTO	MTS
Customized Product	MTO	MTO

Table 2 shows the ABC operation process, it contains eight key phases: they are Product Design, Mold Making, Tinplate printing, QA & QC in Calibration, Tinplate Toasting, Tinplate stamping, Assembling & Packing, and QA & QC in Finished Goods.

Table 2. ABC operation process.

(Phase I) Product Design	(Phase V) Tinplate Toasting
(Phase II) Mold Making	(Phase VI) Tinplate Stamping
(Phase III) Tinplate printing	(Phase VII) Assembling & Packing
(Phase IV) QA & QC (Calibration)	(Phase VIII) QA & QC (Finished Goods)

As the customer requirement and ordering are changing from standard products to customized products, the business models MTS and MTO cannot fulfill the requirement for product variety, small lot size, and short delivery time. After examining the problems faced, it was found that there are specific limitations in the production processes and product design.

4.2. Limitation in Current Operation Process

There are totally three operation processes with limitations: tinplate printing, tinplate toasting and tinplate stamping.

4.2.1. The limitation in tinplate printing

Before running the tinplate printing process, the following steps are taken for printing materials. Figure 3 shows the procedure of tinplate printing. The key factors that need to be considered for tinplate printing are

- Time consumption during the machine setting
- Material wastage and labor time during the trial run and calibration

Therefore, ABC sets an economic lot size in tinplate printing as 1000 sheets.

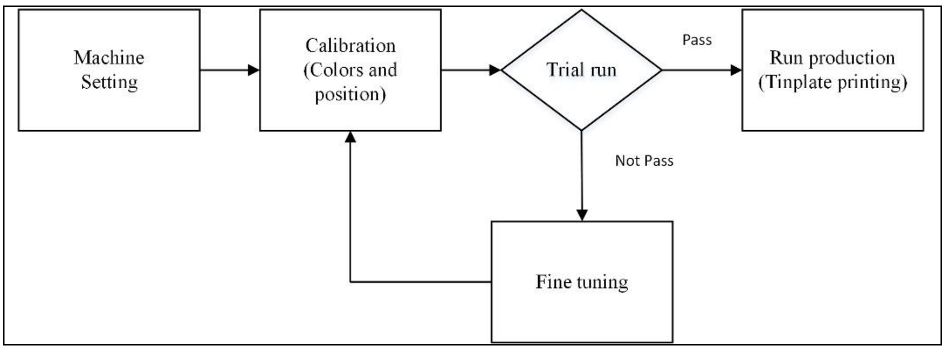

Figure 3. ABC operation flow of tinplate printing

4.2.2. The limitation in tinplate toasting

Same as tinplate printing, before running the tinplate toasting, the toasting machine needs to run a sequence of preparation procedures, as shown in Figure 4. The key factors that need to consider for the tinplate toasting are

- All the tinplate printing products must run the tinplate toasting within a short period
- Time consumption during the machine setting
- Resource (electricity) waste during turn start-up of the tinplate toasting machine to constant temperature and humidity

Therefore, ABC sets an economic lot size in tinplate toasting as 1000 sheets.

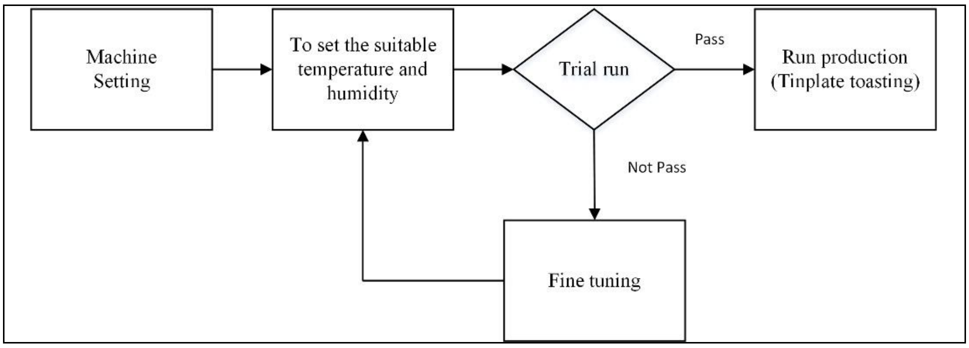

Figure 4. ABC operation flow of tinplate toasting

4.2.3. The limitation in tinplate stamping

ABC contains 12 sets of stamping machines in the production department, it could run 12 kinds of different parts concurrently. Before running the tinplate stamping, it needs to run a sequence of preparation procedures. Figure 5 shows the steps of preparation procedures. The key factors that need to consider for the tinplate toasting printing are

- Time consumption during the machine setting
- Material wastage during the trial run

Therefore, ABC sets an economic lot size in tinplate stamping as 500 sheets.

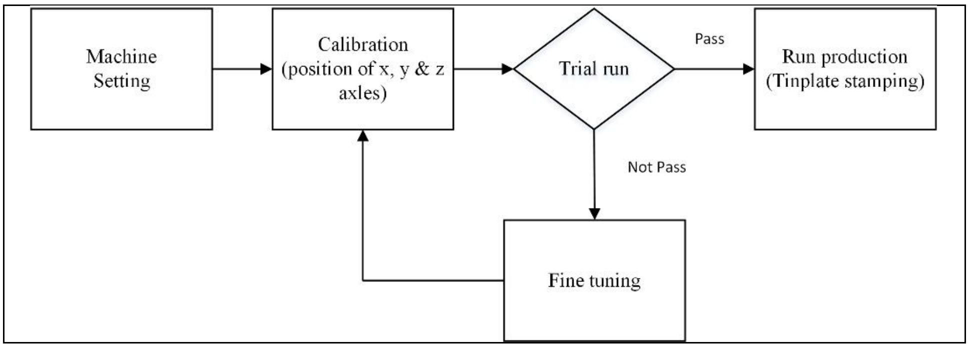

Figure 5. ABC operation flow of tinplate stamping

From the above limitation in the current business model and operation process, ABC sets the MOQ to 300 units per item for the current standard products and 1000 units for the customized products in the wholesale business.

4.3. Limitation in Product Design

The product design is based on the method of classic tin toy design so that most of the product designs do not consider product flexibility, mass variety, and standardization. Further, there are many products that do not have modular design or standardization thereby the parts in product A cannot be shared with product B. This is one of the reasons for the limited product flexibility and mass variety. Owing to the above reasons, the cost and the selling price of the customized products are very high, and the product delivery time of customized products is very long.

5. DEVELOPMENT THE NEW BUSINESS MODEL, NEW OPERATION PROCESS AND MODULAR DESIGN

5.1. Development the New Business Model

There are a lot of criteria and constraints that need to be fulfilled when developing a new business model for SMEs.

- *Limited Resources in SMEs*

Most SMEs have limited resources, so the initial and running costs of switching and applying the new business model should be as low as possible.

- *Easy to Switch from the Current Business Model to the New Business Model*

The new business model needs to be exchanged and implemented easily from the current one, so that the switching process could involve a seamless integration.

- *To Improve the Product Variety*

The new business model needs to be flexible and cost-effective to handle the product variety and customized products.

- *To Decrease the Order Quantity of MOQ*

The new business model can decrease the order quantity per item, so as to improve the sales order and sales quantity, but would not increase any surplus in the inventory control.

- *To Improve the Product Deliverability*

The new business model could improve the product deliverability and shorten the product delivery time.

- *To Improve the Inventory Control*

The new business model can improve inventory control and decrease the surplus in the warehouse.

To fulfill the above criteria, the new business model is developed (Figure 6) and named as Make to Customization (MTC). It breaks through the current business model from wholesale and retail to the degree of customization and short delivery time. It also improves the two independent MTS and MTO models to five integrated MTS, ATO, MTO, CTO, and ETO models.

In the MTC, the MTS model is only assigned to handle the short delivery time of the new standard products. The ATO model used to process the long delivery time of the new standard products, all the current standard products, and all the slightly different customized products. The MTO model is used to process partially different customized products, the CTO model is used to handle unique customized products, and the ETO model is used to run the almost different customized product. From the above, the MTC not only integrates five individual models but also has a synergic effect on the products.

	Delivery Time	
	Short	Long
New Standard Product	MTS	ATO
Current Standard Product	ATO	ATO

	Degree of Customization			
	Slightly different	Partially different	Unique	Almost different
Customization Product	ATO	MTO	CTO	ETO

Figure 6. New Business Model - Make to Customization

5.2. Development the Two-Phase Operation Process

To implement the MTC model, a new operation process was developed and named as "Two-Phase Operation Process" (Figure 7). In the current operation process, the MTS and MTO models are run separately, and in the new business process, five models are integrated using one intelligent business process. The principle of the Two-phase operation process is time postponement, and the mechanism separates the process of the whole production into two phases, phase I and phase II.

- Phase I

In phase I, the process is based on sales analysis and forecasting, and the minimum stock level to produce and assemble the parts, common-parts and standard products, and then transfer them to the warehouse. Besides, it will process the customized parts after receiving the sales order and using ATO, MTO, CTO, or ETO models for processing.

- Phase II

In phase II, it will run the final assembly and shipment process. This process will be run immediately after the Phase I process when using the MTS model; after receiving the sales order handled by the ATO model, or after completing the further process for customized component in Phase I when using the MTO, CTO and ETO models.

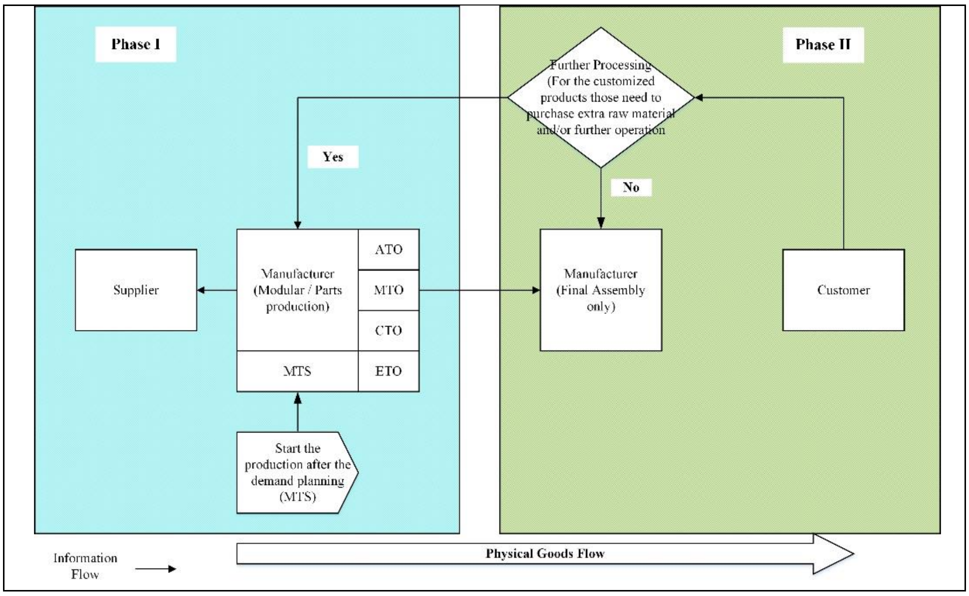

Figure 7. Two-Phase Operation Process

5.3. *Product Reengineering: Modular Design and Standardization*

To improve the efficiency and effectiveness of the new business model and the Two-phase operation process method, module design and standardization should be applied. Although module design is a general design method, it is new to the traditional or tin toy industry. Figure 8 shows the module design products of parts such as arm, head, and cap, could be interchangeable, thus they could use the ATO, MTO, CTO, and ETO models to produce different degrees of customized products. It can improve the product flexibility, variety, and shorten the production time.

Figure 8. Products with modular design

5.4. *Product selection for the Trial Run Sampling*

The new business model and the Two-phase operation process will run for four months, and all the selected products for sampling need to cover all kinds of models in the MTC. In the sample selection, all the samples of the standard products and customized products must include five different models, so there are 25 kinds of samples to be selected.

5.5. Strategy Management for Pricing, Delivery Time and MOQ

In order to determine the competition in customized products, the strategy is to set up an equilibrium point among the selling price, product delivery time and MOQ to avoid negative the customer buying behavior (Figure 9).

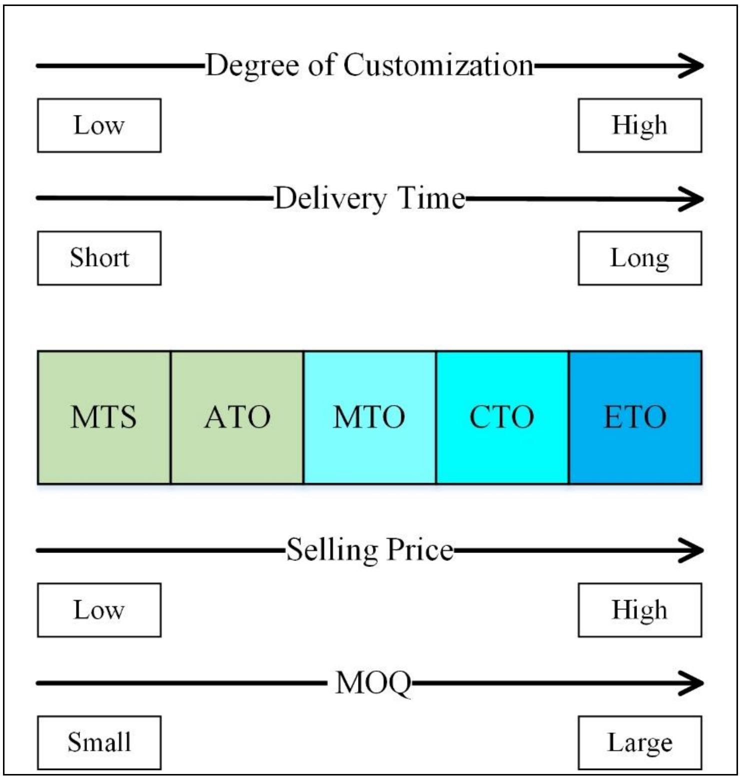

Figure 9. Strategy of the degree of customization, delivery time, selling price and MOQ

For the standard and slightly different customized products handled by the MTS and ATO models, due to the production cost and time being very close, then the selling price, delivery time and MOQ for those products will be the same. Besides, the MOQ quantity is reduced from 300 to 50 units per item, and the product delivery time is one day for delivery (Table 3).

For the partially different and unique customized products handled by the MTO and CTO models, due to the production cost and time decreasing, the selling price is set to around 20% more than the standard product, and the product delivery time is shorter than the current customized product, and the MOQ is reduced from 1000 to 200 units per item. Same as partially different customized products, the almost different customized products handled by the ETO model, the MOQ is reduced from 1000 to 300 units per item.

Table 3. Summary of the Pricing, delivery time and MOQ for different models

	Before		After				
	MTS	MTO	MTS	ATO	MTO	CTO	ETO
Degree of Customized Product	Standard Product	Customized Product	Standard	Standard /Slightly different	Partially different	Unique	Almost different
Delivery time	1 day	Longer than standard product	1 day		Shorter than current customized product		
Selling Price	-	Higher than standard product	Same		Lower than current customized product		
MOQ (Unit)	300	1000	50		200	300	

5.6. *Synergic Effect in the New Business Model*

Even the sales volume is less than 1000 units, due to the economic lot size in production is 1000 units per item, all the surplus in phase I (Figure 7) will be kept in stock. Then the surplus can provide more options for different degrees of customized products and shorten the product delivery time when using the ATO, MTO, CTO, and ETO models.

6. RESULTS

The proposed new business model with the Two-phase operation process and module design enables the manufacturer to solve the current problems in the market – mass customization, small in lot size, and short delivery time. After a trial run of the new method in the case company for four months, it was found that the sales quantity increased, and the number of inventory in the warehouse decreased.

Furthers, the MTC model can reduce the quantity of MOQ, and shorten the product delivery time for most of the customized products, so that it can improve the sales volume and decrease any surplus in inventory.

6.1. *Improving the Sales Quantity*

As customized products are controlled by the MTC model, the total sales volume is increased by 29%. Table 4 shows the comparison of the sales volume before and after the proposed model.

Table 4. Summary of four months sales quantity

Product	Before	After (Average in 4 months)	Percentage of Improvement
Standard	4,100	2,375	-42%
All Customized Product	1,500	4,875	225%
Total (Unit)	5,600	7,250	29%

Table 5 shows that sales volume of slightly different customized products is 41% of the total sales volume, highlighting the trend in the demand for different customized products, especially as the slightly different customized products is increasing rapidly, but standard products is seen reverse. In the past, the selling price of slightly different customized product was higher than the standard products, the delivery time was longer, and the MOQ was higher. After using the MTC model to produce slightly different customized products, the selling price, product delivery time, and MOQ are the same as for the standard product. This is the reason that the demand from the market is for slightly different customized products.

Table 5. Detail of four months sales quantity

Degree of Customized Product	Before	After (Average in 4 months)	Percentage
Standard	4,100	2,375	33%
Slightly different		2,975	41%
Partially different		350	5%
Unique	1,500	1,400	19%
Almost different		150	2%
Total (Unit)	5,600	7,250	100%

6.2. *Reducing the Surplus in the Inventory*

After using the MTC model, the percentage of all the finished goods in the warehouse is decreased by 62%. Table 6 shows the summaries of the finished goods in the warehouse. For standard products, the percentage of finished goods decreased by 74%. For all the customized products, as some items were using non-modular design products, so the surplus slightly increases 200 units.

Due to the economic lot size in production being 1000 units, all the surplus finished goods are kept in the warehouse. After using the MTC and the Two-phase operation process, the surplus for different customized products is improved. The MTC transforms the surplus to improve product flexibility and variety and shortens the product delivery time.

Table 6. Summary of the stock data (finished goods)

Product	Before	After (The end of last month)	Percentage of Improvement
Standard	6,000	1,550	74%
All Customized Product	900	1,100	-22%
Total (Unit)	6,900	2,650	62%

6.3. Shortening the Product Delivery Time

In the MTC, the ATO model meets the target – it could complete the final assembly process and start the product delivery within one day (Table 7). There is no doubt that the delivery time of the MTS model is the shortest, but it limits product variety and flexibility. The ATO model includes the advantages of product variety, flexibility, and shortens the product delivery time. It proves that the ATO model can replace the MTS model for handling all the standard and slightly different customized products in these four months successfully.

Table 7. Summary of the product delivery time for slightly different customized product

Product	Before	After
Current Standard Product	1 day	1 day
Slightly different Customized Product	Longer than 1 day	1 day

For the partially customized products, the product delivery time in using the new MTO model is faster than the current MTO model. For the unique customized products, the production time in using the CTO model with module design is 50% shorter than using the current MTO model without module design.

6.4. Decreasing the Minimum Order Quantity

By implementing the MTC model, it reduces the quantity of the MOQ for the standard products from 300 to 50 units, and customized products from 1000 to 50- 300 units. After running the revised MOQ for four months, there is not only an increase in the sales volume but also the redundancy of the final product was improved. Table 8 shows the MOQ for all products.

Table 8. Summary of the MOQ per item

Product	Before (Unit)	After (Unit)
Current Standard Product	300	50
All Customized Product	1000	50 - 300

7. CONCLUSIONS

In the ABC production line, the economic lot size for production is set to 1000 units so that the MOQ of the standard and customized products is set to 300 and 1000 units, resulting in a large surplus of the final products in the warehouse. After using the MTC model with the Two-phase operation process and module design for four months, even reducing the MOQ quantity, it remedies the surplus for different customized products and speeds up the delivery time for a modular design product. It turns out that after reducing the order quantity, increasing the product variety, and shortening the product delivery time, it can not only improve the sales volume and product flexibility but also decreases the inventory surplus.

It shows that customers prefer slightly different customized products compared to standard products, if the price, product delivery time, and MOQ between two kinds of products are the same. Otherwise, they prefer the standard product rather than the customized product. On the other hand, partially different, unique, and almost different customized products belong to the niche market, where most customers accept a higher selling price, longer delivery time, and higher MOQ.

In the current business model, with overstocking in the warehouse, it will affect the cash flow and the overhead costs in inventory control. In using MTC model, due to the five models being integrated, the whole operation process is split into two phases and adopt modular design product; therefore the surplus will create the synergic effect, and will transform the surplus to business opportunities and improve the operation efficiency and effectiveness.

As the MTC model and the Two-phase operation process have only ran for four months in an SME manufacturing company. In the future, it will collect data from other manufacturers and carry out continuous improvement through the Plan-Do-Check-Act (PDCA) cycle approach for improving the model and process.

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Quality as a driver for internationalisation of Chilean universities?

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ABSTRACT

Purpose – This work shows how internationalisation actions implemented by two Chilean universities have been driven by governmental policies oriented to improve the quality of higher education, and to what extend they influenced their strategic objectives.

Design/methodology/approach – The study starts with a systematic literature review from websites including internationalisation strategies, quality criteria, and policies. Qualitative and quantitative data was obtained from surveys applied to universities' authorities. Empirical analysis was used to identify quality drivers of internationalisation and to draw conclusions.

Findings – The study found that guidelines and policies for improving quality of education have been key drivers of internationalisation activities. Engaging key stakeholders and devoting attention to the necessity of developing an internationalisation strategy linked to the quality policy is a must.

Research limitations/implications – Further empirical research is needed to provide insight into other universities not included. The perspective of other keyholders could enhance the results.

Practical implications – Improving quality of higher education is vital for universities willing to excel; internationalisation might help speed up the process. International relations offices should make efforts focalising funds to develop strategies that support the internal quality system.

Originality/value – The influence that national quality policies have on internationalisation strategies taken by universities is a debate not discussed yet in Chile and scarcely, in the rest of the world.

Keywords: Internationalisation, Quality assurance, Higher education, Accreditation.

Paper type: Case study.

INTRODUCTION

Worldwide, higher education is facing challenges in a fast and ever-changing environment which sometimes, understands quality assurance and internationalisation as independent approaches (Komotar, 2018) instead of complementary ones, overlooking that both are key elements to the strategic development of universities. The main goal of Higher Education Institutions –HEIs– is to ensure quality of education, which in turn would result in proficient graduates able to perform adequately in a globalised world (Carnoy and Rhoten, 2002).

Accreditation is a traditional mechanism to ensure quality, a key element for internationalisation of universities in the current political and economic conditions (Robson *et al.,* 2017); and internationalisation is an essential component to enhance the quality of higher education (Gacel-Ávila and Rodríguez, 2018). As a consequence, it matters changing HEIs practices and undertaking self-assessment and control of quality (Jarvis, 2007). As governments highlight the benefits of accountability, international status, and prestige of their institutions, quality has been addressed by national policies in most countries through assurance agencies.

Most research is devoted to finding successfully implemented practices of quality assurance and internationalisation (Komotar, 2018), measuring the quality of internationalisation (Beerkens *et al*., 2010; LeBeau, 2018; Belarbi *et al.,* 2016; Stensaker and Maassen, 2015), national accreditation as a means to acquire international accreditation (Dotong and Laguador, 2016), or rankings and quality measurement (Blanco-Ramírez and Berger, 2014; Berbegal-Mirabent and Ribeiro-Soriano, 2015; Tutterow and Evans, 2016). Despite of the development of national quality assurance systems, to the best of the knowledge of the authors, no studies have addressed how national quality policies could have helped in determining internationalisation strategies of universities. Chilean research on both topics is scarce, and efforts to analyse strategies utilised by universities as a response to national quality policies and rankings, under one general and combined perspective are still missing. Therefore, questions are raised- Are quality assurance policies and rankings driving internationalisation strategies of Chilean higher education institutions? To what extend do policies and rankings influence institutional objectives?

Internationalisation's most accepted definition state it as "… the intentional process of integrating an international, intercultural or global dimension into the purpose, functions and delivery of post-secondary education, in order to enhance the quality of education and research for all students and staff, and to make a meaningful contribution to society" (de Witt *et al.*, 2015).

Even though internationalisation actions started earlier, it has evolved slower than quality assurance in Chilean institutions compared to other developed countries. Internationalisation of universities has resulted in a growing demand for accountability and transparency (Ryan, 2015), and while developing quality assurance systems, findings pointed to the equilibrium of continuous improvement and accountability (Danø and Stensaker, 2007). Three types of accountability systems do exist: fulfilling regulations; adherence to professional norms; and student learning outcomes (Anderson, 2005). Formulation of institutional policies built under accreditation standards could heighten the development of internationalisation actions (Dotong and Laguador, 2016). Since internationalisation is a process, it can be included as a component of the quality management system of an HEI.

The first internationalisation actions in Chile can be traced back to the fifties with the signing of international mobility agreements, which allowed academics to specialise in the United States and Europe (Didou *et al.*, 2014). Chilean quality assurance of higher education started in 1999, with the creation of the National Accreditation Committee for Undergraduate Programs. Internationalisation took a stronger role as universities had access to national initiatives such as the implementation of the Higher Education Quality Improvement Program financed by the World Bank and administered by the Chilean government. The program provided funds and encouraged universities to foster their international research partnerships, promote student and academic mobility, and sign international agreements. Internationalisation practices has not always been embedded in Chilean HIEs policies or strategic plans, but it has been a constituent of accreditation processes, both at the institutional and program level.

Later on, the wave of ranking's status has placed internationalisation on stage. Used appropriately, ranking indicators as well as accreditation processes, could help identify improvement areas (West *et al.*, 2019). Most extensively used World University rankings in Chile, are edited by Quacquarelli Symonds –QS–, the Academic Ranking of World Universities –ARWU–, Scimago, University Ranking by Academic Performance –URAP– and the Times Higher Education –THE–. On a lower scale, América Economía ranks Latin-American universities. On a domestic level, *Universitas - El Mercurio* and *Qué Pasa - La Tercera*, publish both yearly ranking of Chilean universities.

Using a case-study, this work explores how internationalisation of two Chilean universities might have been driven by governmental policies oriented to improve the quality of higher education. First, the methodology used is presented. Second, the perspectives of university's authorities are summarized and compared with other authors' findings, and quality criteria. Finally, discussions and conclusions are provided.

RESEARCH METHODOLOGY

This is a mixed qualitative-quantitative exploratory study aimed to understand and clarify concepts and ideas, in order to establish more precise problems for future investigation, considering the scarcity of research in this topic. A case study was selected to do an empirical research in order to analyse deeper the phenomenon in real context within Chilean higher education institutions and help answering the research question, given the fact the boundaries among phenomenon and context are not clearly defined (Yin, 2014).

Since this is a case study, it was designed to get input from institutions the authors are familiar with. Therefore, it included two historically prestigious regional universities located in located in the most undeveloped and poorest region of Chile, La Araucanía Region. The Subnational Human Development Index gives the region an index of 0.7770, the lowest in the country (Global Data Lab, 2019); and the Regional Development Index 2019 ranks La Araucanía at the bottom, with an index value of 0.458 (Vial Cossani, 2019). Universidad de La Frontera –UFRO– is a state public-owned institution with 45 undergraduate and 73 graduate programs, and over 10 000 students. Universidad Católica de Temuco –UCT– is a private university with 54 undergraduate and 16 graduate programs, and over 10 600 students. Both belong to the Council of Chilean Rectors, a well-established and recognised national organisation which groups 30 traditional universities. The differences among the institutions affect how they respond to national policies, decision-making processes, accreditation and ranking criteria, and strategic definitions reviewed for comparison purposes.

To identify similarities and differences between the written documents compared, a point-by-point comparative approach was applied (Ali *et al.*, 2018). After a thoughtful literature review was performed using journal indexed databases, quantitative and qualitative data was collected from various sources, both primary and secondary.

The secondary data was gathered through public government and HEIs websites regarding written documents on internationalisation and quality assurance policies, national laws and quality accreditation criteria, international and national rankings, and institutional strategic development plans. The national and international rankings included were those most commonly known in Chile. The units of analysis were quality and internationalisation indicators or objectives, and the phrases used to describe them. The coding was done manually.

The primary data was collected in person and/or via online surveys during 2017 and 2018 using a questionnaire with semi-structured and closed questions. The questionnaire was based on four areas: perceptions about internationalisation policies of the university; priorities on internationalisation; internationalisation networks and primary partners; and academic internationalisation. It was developed previously by a research group to which the researchers belong to, validated through expert judgement, and tested originally with partner universities of Chile, Argentina and Brazil. For the closed questions, a five-point Likert scale evaluated a set of attitude statements within the categories: very important, important, neutral, unimportant, and don't know. For his study, the questionnaire was applied to top and middle university authorities. Personal sessions were audio-recorded and transcribed in written form later. The level of responses was limited by the willingness to participate in the study. UFRO responses were 16, including deans, vice rectors, and the rector. UCT responses were 20, including top managers.

Data obtained was summarized in the form of spreadsheets of numerical data, and qualitative responses with an approach based upon the notion that policies should be considered as text and things (Ball *et al.*, 2012), within an institutional context. As some responses were semi-structured questions, patterns were identified. The documental analysis was consolidated in a database where it was reduced to quantifiable categories in the ranking and accreditation areas, incorporating elements for the components of internationalisation from the literature review and data provided by both institutions. Findings were validated, and discussion and conclusions drowned upon the results obtained.

RESULTS

Internationalisation and quality in Chilean higher education

UCT benefited from several Chilean Higher Education Quality Improvement Programs, which defined its internationalisation priorities and measurement, as the projects mainly centred on increasing the number of student and academic mobility, signing international partnership agreements, improving the community’s English skills, and designing programs to attract international students. As a result of those projects, the institution was able to create a student mobility office, to allocate funds for international mobility, specialisation and research, and to provide monetary support for international missions, which resulted in the signing of international collaboration agreements and partnerships. On the other hand, UFRO mainly allocated educational government grants for the internationalisation of doctoral programs, which centred its efforts on fostering joint publications, cooperative research and projects with international partners in order to increase the institutions international visibility, strengthening graduate student mobility, developing English skills, and signing double degrees and international partnership agreements. As a result, the quality of doctoral programs was increased, research publications mainly WoS and Scopus went up by 61% in a 5 year period, international partnerships added to over 250, two doctoral and two undergraduate programs were internationally accredited, and as of March 2020, 100% of the institution's doctoral programs were accredited, as mandated by the law, being one of the few HEIs in the country to achieve such accomplishment –compared to 69% of doctoral accreditation programs nationwide.

Both institutions include in their development plans (Universidad Católica de Temuco, 2010; Universidad de La Frontera, 2013) the need to strengthen their international relations, by creating alliances with institutions and organizations in order to increase the institutions development possibilities, to strengthen existing ties, and to increase the universities' participation in international networks.

Regarding management of internationalisation, UFRO declares internationalisation to be a key component of its institutional vision. Both institutions have objectives related to internationalisation on their strategic development plans. UCT has focused on student and academic mobility, research, and partnerships collaboration; and UFRO mainly aimed to research, ranking positioning, student and academic mobility, international accreditation, doctoral programs, and double degrees. Those actions could be related to some indicators associated to accreditation indicators such as: number of international partnerships and of related activities; number of students and faculty in outbound mobility; number of international visiting faculty; number of thesis with international co-advisor; number of international outreach activities where students participated, and number of international media engagement and number of students obtaining financial aid for international internship/assistance to write thesis (CNA-Chile, 2018a; CNA-Chile, 2018b).

Accreditation verifies that universities do accomplish what is stated in their mission and vision, as well as in their strategic plans: 72 % of Chilean universities have declared clear internationalisation objectives and goals, and 50% consider it a strategic goal. Those results are similar to 83% of Latin-American institutions surveyed, which mentioned internationalisation in their institutional mission and/or strategic development plan (Gacel-Ávila and Rodríguez-Rodríguez, 2018). So far, only three public state-owned universities –Universidad de La Frontera, Universidad de Santiago de Chile, and Universidad de Talca– have an internationalisation policy published on their websites, compared to 47% of Latin-American institutions (Gacel-Ávila, 2018). UCT is still developing it. However, results of the analysis showed that internationalisation strategies of both universities are not comprehensive, nor integrated in all institutional relevant policies.

Accreditation, certification and quality assurance are not synonyms, although some university authorities do believe so. Accreditation is the public guarantee that a university's educational project is being correctly accomplished, that systematic mechanisms have been performed, and that quality can be assured after complying with a set of criteria and standards. A Certification is usually related to an organisation's quality management system. Quality Assurance embraces activities defined to ensure the organisation's processes are efficient and effective. Most quality assurance approaches and instruments are criteria and standards verified by external peers, who either grants a certification or an accreditation level, most of them conducted by national accreditations bodies (Vettori, 2018) or quality assurance agencies.

The Chilean National Accreditation Committee has helped setting a framework for internationalisation since 2007, by including internationalisation's indicators among its criteria. There are 5 traditional areas of accreditation: two mandatory, management and undergraduate studies; and three voluntary, graduate studies, research, and outreach. However, internationalisation criteria and standards are only evaluated in voluntary areas. Both UFRO and UCT have experienced 4 institutional accreditation processes, being the latest in 2018 and 2019, respectively.

The Chilean government has promoted among HEIs, the development and offering of high-quality graduate programs in order to increase their number of international partnerships of scientific and innovation research. With the previous law, the accreditation of graduate programs was voluntary. However, they had to be accredited if national and international students wanted to apply to scholarship opportunities or funding by the Chilean government. The growing trend of institutional accreditation of voluntary areas is aligned with the use of rankings as a *proxy* of quality. Ranking positioning of HEIs and their graduate programs have turned out predominantly important for individuals willing to hold a degree from a recognised university, as the HEIs' prestige is perceived to increase graduates' qualifications and job opportunities (West *et al.*, 2019; Huang, 2007).

As of 2009, from a total of 61 universities, 47 were accredited, a 77%. Only 7 universities, i.e. 11% including UFRO, were accredited in all five areas. Regarding the accreditation of graduate programs, 78% of 157 doctoral and 22% of 804 master's programs were accredited.

Compared to December 2019, from 55 universities, 45 were accredited, representing 82%; 16 universities, i.e. 29%, were accredited in five areas included UFRO; UCT was accredited in four areas since it did not apply to the graduate studies' optional area. The growing trend of institutional accreditation of voluntary areas is aligned with the use of rankings as a *proxy* of quality. Ranking positioning of HEIs and their graduate programs have turned out predominantly important for individuals willing to hold a degree from a recognised university, as the HEIs' prestige is perceived to increase graduates' qualifications and job opportunities (West *et al.*, 2019; Huang, 2007).

Regarding graduate programs, 34% were accredited from a total of 1780. By type of program, it represents 69% doctoral, 28% masters, 33% medical specialties, and 9% dentistry specialties. A difference in the accreditation policy with respect to year 2009, is that doctoral programs, as well as medical and dentistry specialties, are currently mandatory to be accredited. The accreditation of graduate programs is consistent with the strategy followed by UFRO. Strengthening doctoral education and its close relationship with the research areas of a HEI is a proven approach for internationalising and improving the quality of higher education (Linhares Hostins, 2014). UCT has focused in developing undergraduate programs.

The study also discovered an inconsistency in what is considered to be relevant for accreditation purposes: the lack of a process for keeping accurate, complete and up-to-date internationalisation records, a fundamental activity for accountability of the HEIs. Since accreditation was not mandatory until the Chilean law of 2018, this could be one of the reasons this key element has not been addressed by internationalisation offices or included in their institution's quality assurance systems. This is a problem also for other Latin-America HEIs, considering that barely 29% recognised to have an internationalisation process established in their quality assurance, evaluation and monitoring system (Gacel-Ávila and Rodríguez-Rodríguez, 2018).

Concerning internationalisation's benefits, results obtained from a research including 377 Latin-American institutions (Gacel-Ávila and Rodríguez-Rodríguez, 2018) were confirmed by responses to this study: there is a strong perception that internationalisation activities can help developing the international and intercultural profile of students, increasing the prestige and profile of the institutions, and enhancing the quality of their programs. It was also mentioned that the main role of internationalisation offices at both universities were student and academic mobility –incoming and outgoing–, as well as the signing of international partnership agreements. See Table 1.

Table 1 – Results associated to institutional policies (% very important; % important).

Priorities	**UFRO**	**UCT**
TEACHING		
Outgoing int. student mobility	56%; 33%	62.5%; 37.5%
Faculty participating in int. seminars	56%; 44%	37.5%; 62.5%
Increasing the number of int. students	56%; 22%	25%; 75%
Visiting faculty teaching short courses	22%; 67%	25%; 62.5%
Double/joint international programs	22%; 44%	12.5%; 25%
RESEARCH		
Publications in int. scientific journals	78%; 22%	87.5%; 12:5%
Promoting int. faculty mobility	56%; 44%	37.5%; 50%
Participating in int. research projects	67%; 33%	62.5%; 37.5%
Belonging to international networks	67%; 33%	75%; 25%
INSTITUTION		
Signing international agreements	56%; 44%	75%; 25%
Positioning in int. rankings	67%; 33%	25%; 37.5%

Developing int. students' competencies	78%; 22%	50%; 37.5%
Increasing prestige	78%; 22%	62.5%; 25%
Participating in int. funds/grants	33%; 22%	25%; 25%
Strengthening international curriculum	67%; 33%	37.5%; 37.5%

Consistently with other HIEs' actions of establishing strategic partnerships with institutions abroad (de Witt *et al.,* 2005; Egron-Polak and Hudson, 2014), authorities of both institutions consider internationalisation opportunities a possibility to consolidate their universities. As well as in most countries (de Witt and Hunter, 2015), UFRO and UCT have focused on mobility, short term and long-term economic gains, recruitment and or training of talented students and scholars, and international reputation and visibility. As a consequence, the construction of partnerships, the development of international joint-double programs and research projects, and the participation in networks and consortiums, have been considered relevant activities. Those actions are consistent with the institutional accreditation criteria shown in Table 2.

Table 2 – Evidence for institutional accreditation related to internationalisation (CNA-Chile, 2014).

Area of accreditation	**Evidence**
Research	Participation in international competitive funds. Impact of research at international level. Resources assigned to international research. International accreditation processes.
Graduate programs	Institutional partnerships. Student and faculty mobility Visiting faculty. International thesis co-advisor.
Outreach and engagement	External outreach policy. Policies, mechanisms and their effectiveness in placing students and academic staff in international activities.

Some obstacles recognised by both institutions for one of the main accreditation indicators, outgoing mobility, are the lack of a second language and the scarcity of funds; both elements are consistent with barriers recognised by Latin-American institutions (Gacel-Ávila and Rodríguez-Rodríguez, 2018). The first one is related to socioeconomic background of students and staff, which is harder for both institutions, located in the poorest region of the country; the second one, to the resources assigned by the Ministry of Education.

Regarding strategies, authorities interviewed perceived internationalisation would help improving the quality of teaching and learning and preparing students to live and work in a globalised world; having regional and national level policies as key drivers and influencers of institutional policy on internationalisation; and increasing international –and especially outbound– student mobility. However, there is a lack of knowledge on how an internationalisation strategy must be carried out, thus limiting the articulation with the institutional vision and mission. Consequently, most of the time, internationalisation actions are misinterpreted with strategies.

Internationalisation and rankings: do they really matter?

Coincidentally, national and institutional strategies, as well as accreditation mechanisms, mainly focus on what is defined by: student and academic mobility; joint publications; and international rankings (Aerden *et al.*, 2013). Quality in higher education is synonymous of excellence, being usually related to a ranking position in HEIs' table leagues. This has contributed to the myth that international reputation is a *proxy* for quality. Although rankings encourage the behaviour of institutions and contribute to decision making (Berbegal-Miraben and Ribeiro-Soriano, 2015), they have been questioned as international quality practices (Blanco-Ramírez and Berger, 2013) and regarding their precision to measure how internationalised a university is, and even further, if the international dimension of an HEI is a strong indicator of quality (Knight, 2011), especially since each one uses a different method to create table leagues. The concept of excellence itself implies it should be more than a ranking number calculated through a formula (Grifoll, 2016). Nevertheless, rankings keep extending and being perceived by authorities of both institutions as an element of competitive advantage. A summary of rankings' criteria is shown on Table 3.

Table 3 –Criteria for Selected International and Chilean Rankings.

Ranking	**Metric or Criteria**
QS	Academic Reputation, Employer Reputation, Faculty/Student Ratio, Citations per Faculty, International Faculty Ratio, International Student Ratio
SCIMAGO	Research factor, Innovation factor, Societal factor
ARWU	Quality of Education, Quality of Faculty, Research Output, Per Capita Performance
THE	Research, Citations, Industry Income, International Outlook
América Economía	Quality of Faculty, Quality of Students, Infrastructure and Finance, Efficiency, Research, Inclusion and Diversity, Accreditation, Internationalisation, Community Outreach, University Life
Universtitas- El Mercurio	Students, Faculty, Teaching process, Institutional Governance
Qué Pasa- La Tercera	Quality Perception, Institutional Governance, Faculty, Students

Rankings are considered to influence national and institutional HEIs' policies (Blanco-Ramírez and Berger, 2013) and to be an essential driver for decision-making processes for at least 38% of Latin American HEIs (Gácel-Ávila, 2018), although the estimated effect of rakings on their performance is extremely small. Despite the wave of attention devoted by the general audience and academic press to rankings, one rank position only corresponds to 1% more applicants/students (Tutterow and Evans, 2016). In the last years, both institutions have publicly acknowledged their ranking positions through institutional news and social networks, especially during the time potential students are applying to tertiary education. The results of the latest ranking positions for UCT and UFRO are shown below in Table 4. Both have been scaling up the table leagues in the last years.

Table 4 – Latest ranking position among Chilean universities.

University	Ranking, position, year
Universidad de La Frontera	Scimago Chile, #9, 2020 QS Latin-America, #13, 2020 THE Chile, #7, 2020 URAP, #11, 2019 América Economía Chile, #11, 2019 Qué Pasa-La Tercera, #14, 2019 Universitat-El Mercurio, #9, 2019
Universidad Católica de Temuco	Scimago Chile, #25, 2020 QS Latin-America, #25, 2020 América Economía Chile, #26, 2019 Qué Pasa-La Tercera, #20, 2019 Universitat-El Mercurio, #21, 2019

Most of the top rankings of UFRO are related to quality of research, which is consistent with its graduate and research internationalisation focus, a high value for ranking indicators. The lower level of research and graduate programs measured by accreditation number of years of UCT, could be the reason its rankings positioning is modest.

Similar to what happens in Mexico, international offices of both institutions must comply with quality standards they might not be ready for, in an increasingly global and interconnected society that believes rankings are the force that will transform and internationalise universities (Bustos-Aguirre *et al.,* 2018). Although rankings can be seen as a means to keep information consolidated, do comparisons, and monitoring (Rindova *et al.*, 2017), redesigning the quality management system and documenting the processes that gather information and assess the data, could have greater impact: it should close gaps regarding the fulfilment of criteria for either ranking groups or accreditation agencies, given the fact that some rankings' criteria is similar to the one requested by accreditation processes.

DISCUSSION AND CONCLUSIONS

This study attempted to provide insights and deepen understand key stakeholders' views, strategies of internationalisation used, and their relationship to quality assurance criteria followed by two Chilean regional universities, in order to address the research problem being studied and to examine its complexity. The results allowed to have a broader perspective of the influence of national quality guidelines in decision-making processes.

Since accreditation indicators are used by both institutions, there is a tendency to focus more on quantitative than qualitative results, placing a lot of pressure to increase the numbers, more than the real impacts that quality or internationalisation may cause. Apart from being a very reduced vision regarding the modern perspective of internationalisation and quality assurance, focusing only on accreditation criteria is a quantitative form of measurement, forcing UFRO and UCT to devote its resources and efforts to actions, not strategies, such as increasing the number of international mobility, partnerships and research. Instead, they should focus on the impact internationalisation can have on the institution, to improve quality for their students as a whole, staff and faculty, as well as the community surrounding the universities. However, there is no clarity in how to articulate accreditation and internationalisation; no synergies have occurred yet.

Quality assurance policies have influenced the international activities of this two Chilean universities in the last few decades, which in turn aimed to fulfil accreditation criteria, and in some instances, national and international ranking indicators. As a result, universities have focused on single-dimensional actions, increasing their performance at the institutional and program levels. As suggested by the results, the focus on internationalisation of research and graduate programs, could have enhanced the quality of UFRO, which improved from 5 to 6 years of accreditation in all areas, and has been going up in rankings, especially those related to research. On the other hand, UCT has increased the number of areas (4) of accreditation and currently has 5 years.

Driving forces, policies and practices for the internationalisation of UFRO and UCT were influenced by the actions of international, regional or global organisations, as happened worldwide (Huang, 2007). For both institutions, quality is already a key element; however, only UFRO has developed a quality and internationalisation policies. The question remains, how internationalisation is revisited to improve further the quality of education. As observed, while strengthening higher education, national policies have been fundamental drivers to influence the institutional policies of both universities, same as happened in Brazil (Linhares Hostins, 2015).

Despite the fact that internationalisation is a priority for both institutions, from the data gathered and responses to questionnaires, it is implied that more efforts are needed to engage key stakeholders and to devote attention to the necessity of developing an internationalisation strategy which supports quality assurance; this would shift the current paradigm and involve all the units in international subjects. All internationalisation processes should be documented and handled under the quality management system structure, involving the design, planning, execution, control, evaluation, feedback, and performance improvement. As a result, the elements related to the corresponding accreditation or ranking criteria would be fulfilled in future processes or data submission of the universities, opening the door to establishing good internationalisation practices, that are effective and efficient for accreditation and ranking purposes. The internationalisation focus could be the source of further studies.

The scope of this study was limited to evaluating the perspective of two universities located in southern Chile and affected by harsh socioeconomic conditions; these conditions could bias the results. Since they are located in the same geographical region, results may be a poor fit to others located in more favourable locations. This situation raised the question if resilience of the institutions could play a role in their internationalisation and quality endeavours; therefore, it would be valuable to include universities from other regions or even other countries in further research, to deepen understand the interdependent relationship among quality assurance and internationalisation of higher education (Komotar, 2018).

The Chilean higher education sector could benefit from internationalisation in order to improve the quality of its education, as others have done (Belarbi *et al.*, 2016). When the leaders, governments, and university communities are educated properly, and are taught the benefits and forms of implementation of internationalisation strategies and policies, and how this can help improving the quality of higher education, a wider vision of how to reach the institutional goals could be achieved.

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Fire brigades - organisational assessment through excellence approach

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ABSTRACT

Purpose - This paper aims to report the first part of a research project to understand the implementation of the Common Assessment Framework (CAF) model to assist the management of fire brigades.

Design/methodology/approach - The paper involves a qualitative approach, a descriptive exploratory study that follows a case study method. The instrument used to gather empirical data was the CAF tool and involved four fire brigades. The study was anchored in the quality management literature and CAF model.

Findings - The results contribute to creating knowledge about CAF's role as a useful and important tool to help fire brigades, to improve the effectiveness and efficiency of their management through the process of self-assessment and implementation of improvement initiatives.

Research limitations/implications - The results need further validation in other fire departments. However, the results highlight the importance of implementing CAF to assist the management of fire brigades.

Practical implications - The results encourage fire brigade organizations to introduce self-assessment with CAF.

Originality/value - This investigation is a unique study, as it explores the use of CAF in fire brigades. The paper outline an analysis that does not exist in the literature, outside the scope of operational fire-fighting intervention, in particular the weaknesses and strengths regarding the management model, in its different domains: leadership, strategy, human resources, material resources, partnerships and process management of fire brigades.

Keywords: Common Assessment Framework (CAF), Excellence, Fire brigade, Quality management.

Paper type: Case study

INTRODUCTION

Public and private sector organisations use the European Foundation for Quality Management (EFQM) and Common Assessment Framework (CAF) as models of excellence, in order to assess the measurement of organisational performance and establish a diagnostic analysis, respectively.

The CAF model is inspired in the EFQM model, whose core goal is anchored in supporting organisational self-assessment according to the criteria established in the model, and in defining improvement initiatives. Given the type of approach proposed by the models, it would be helpful for the different models to be disseminated and implemented in all sectors of activity. Many organisations use the CAF model as a basis for developing and improving their services and the results of their operations.

This paper reports on the implementation of the CAF model in the fire sector and has been applied to four brigades that make up the case study. There are no references in the literature review to the use of CAF in fire brigades. In this sense, the results presented can guide the management of fire brigades and launch clues for future research, particularly regarding the understanding of the main barriers and constraints for the massification of the implementation of models of excellence in the sector.

The nature of the firefighters' activity, which includes functions such as the protection of human lives and property, as well as firefighting, makes them take on these functions as if it were a mission, focusing solely on helping others. These actors are essentially focused on ‘theatre of operations’, neglecting the planning and management activities of brigades. In Portugal, the fires of 2017 ended up acting as an impulse to rethink the whole Civil Protection system. Aware of these conditions, and the specific context, we took up the challenge of helping four fire brigades, from centre Portugal, to reflect on their organisation by promoting self-assessment and organisational diagnosis. For this purpose, we have used the CAF model of excellence.

From the literature review undertaken, we found that, in Portugal, the CAF model was implemented in 5 areas of the public sector and that it did not involve, neither the justice (courts, Public Prosecutor's Office, penitentiary service) nor the Defence, Public Policy and Security sectors (military forces, police) (Vrabková, 2013), subsequently extended to the Defence and security sector (DGAEP, 2020). Thus, it still does not include the fire brigades. The aim is therefore to make a contribution to research by presenting in this paper the results of the implementation of CAF in the fire services, which have not yet been studied.

Fire Brigades

Fire brigades are established and managed by humanitarian firefighters' associations, non-profit (collective) legal entities, of public utility, whose function is to ensure the protection of people and property, namely the rescue of the injured, sick and/or shipwrecked, and the extinction of fires. The brigades are part of a voluntary or mixed fire brigade, integrating salaried professionals. Firefighters are classified as 'civil protection agents' alongside security forces, armed forces, among others (article 46, no. 1, paragraph a) of Law no. 27/2006, of 3 July).

In accordance with no. 1 of article 5 of Decree-law no. 247/2007 of June 27, each fire brigade has its area of action, defined by the Portuguese National Authority for Civil Protection (ANEPC), after consulting the National Fire Brigade Council. The operation area of each fire brigade is corresponding to that of the municipality where it is located, if it is only one. In case there are several volunteer fire brigades in the same municipality, the different areas of operation tends to correspond to a parcel that coincides with one or more contiguous parishes. The humanitarian fire associations have a special duty to collaborate with ANEPC.

Purpose of the study

Many organisations, within and outside Europe, have already used the CAF model, such as organisations in the area of Education (EIPA, 2012), Social Services, Health, Transport and Infrastructure, Police (RCPAR, 2011) and even Churches, with central and local government organisations being the areas that have used CAF the most (Staes et al., 2011, 2016).

In Portugal, the CAF model was used by central, regional, local and public security public administration organisations, and still does not include the fire brigades (DGAEP, 2020). In Portugal, several public administration organisations (both central and local) have undertaken empirical studies using the CAF model (Figueiredo et al., 2005; Nogueiro, and Saraiva, 2008; Pedreira, 2008; Marques, and Saraiva, 2011; Cândido, 2014; Alves and Moura e Sá, 2018; DGAEP, 2020).

There is no publication that highlights the implementation of the CAF model in fire brigades, which reinforces the relevance of the goal of the study developed and the innovation of the paper presented here. Thus, this study is expected to contribute for the increase of knowledge about CAF implementation, quality management and continuous improvement in fire brigades.

Structure of the paper

After this present introduction, a review of the relevant literature focused on fire brigades, Quality and CAF is put forward. In Section 3 (method), we explain the undertaken fieldwork (case studies). In Section 4, we highlight the results of the empirical analysis and discuss the results from a theoretical and practical point of view. Finally, we sum up the main conclusions and the implications of the study for theory and practice, the study's limitations and future research.

CONCEPTUAL FRAMEWORK

Fire Brigades and Quality

Fire brigades are technically organized operational units, prepared and equipped to act in several missions and are usually recognized for their role in firefighting. However, they act whenever there is, in a generic way, a need to support and act in defence and rescue of people and goods due to diverse events such as calamities or even transport of sick or injured people. In their daily lives they provide essential services to the whole community. Thus, mainly because of the role they play, the processes of action of fire brigades are assumed of paramount importance for the whole of society.

Since quality is a crucial characteristic for a good performance of an organisation, it is important to define quality in the provision of services in fire brigades. Quality of service should be understood as a process by which customers compare performance with ideal standards or assess their perceptions of the quality of a series of attributes of a product or service (Zeithaml et al., 2006).

We understand that the concept of quality, applied to services, refers to a multidimensional global judgment, or attitude about the superiority of a service (García-Fernández, et al., 2014). Thus, in order to offer a quality service, there is a need for good interaction with clients, i.e., to strengthen the service monitoring, its results and proactively accept feedback from clients. In this sense, the quality of the firefighting service can be materialized in the public satisfaction considering the actions of the firefighters, that is, in addition to the operational aspects, assessment also comprises a performance perception factor, thus being dependent on a case-by-case assessment. It is thus considered that there is a need for an objective model of assessment and systemic implementation.

According to Deng et al. (2001), which focuses exclusively on the quality of service in firefighting, the quality of this service should include six main factors: the timely response in firefighting; the correct judgment of fire situations; the effective control of resources to be used in firefighting; the concrete actions in combat operations; the reduction in life and property loss and the various risks in the occurrence of a fire. The control of these six factors reduces the divergence between the performance of firefighters and the opinions of the public, thereby helping to establish a basis for firefighting management. Taking the quality of service of the brigade as a whole, the wide variety of people who render service, as well as the complex tasks that firefighters perform, present an opportunity for a more comprehensive assessment and the possibility of redesigning the way firefighting services are organized and function.

In a brigade there are essential requirements to achieve the pre-defined objectives, and it may choose to implement a Quality Management System (QMS), through the NP EN ISO 9001:2015 standard, to achieve compliance of its services, achieving better results and meeting the statutory, regulatory and citizens' requirements. However, the brigade can also follow the guidelines of Van Trijp (2013), which refer to using the EFQM Excellence model to develop an audit model and tools to assess and compare occupational safety and quality management at the strategic, tactical and operational levels, combined with a complete review of operational procedures. At the strategic and tactical level, this assessment is carried out using a self-assessment, a peer review and an organisational audit that results in a plan focused on continuous improvement, innovation and organizational sustainability.

Aiming at continuous improvement in the quality of services, the brigade should plan and define the strategic and operational objectives by reviewing and analysing them through the implementation of a model that develops a culture of excellence and good practices that lead to improved results (Tzelepis, et al., 2006; Evans, 2008; Ismail Sila, 2020). This model should link individual and organisational performance to knowledge management and evaluate all knowledge management processes and benefits resorting to an integrated system, involving employees and citizens.

Knowledge management in a brigade is based on good communication and cooperation between the various hierarchical levels. Commanders should promote an atmosphere of trust in the organisation and support the team, creating synergies for knowledge management, and facilitating the generation and implementation of innovative ideas, aligned with the purposes of the organisation (Afsari, 2017).

In the assessment report regarding the fires that occurred between 14 and 16 October 2017 in mainland Portugal, the Independent Technical Commission created by resolution of the Portuguese Parliament reports that it is essential to develop a work of rigorous identification of the current status of the fire brigades, so that, in a second moment, a strategy for strengthening them can be drawn (CTI, 2018).

Planning, executing, collecting results and acting are the key elements of modern and effective management. Strategic planning should serve as a guideline to direct efforts, combine synergies and avoid wasting resources, which are already so scarce.

This paper intends to contribute to knowledge creation using the self-assessment tool, CAF, based on benchmarks of organisational excellence, applied for the first time in fire brigades. The objective is also to initiate an exploratory study to validate the applicability of this instrument in these organisations.

Common Assessment Framework (CAF)

The CAF model was approved by the EU Council of Ministers to assist the quality management implementation in Public Administration, promoting the assessment of its organisational performance (Bouckaert, 2002; Staes et al., 2010). It is a self-assessment tool for public organisations (EIPA, 2012) that promotes the achievement of its objectives and allows each organisation to compare itself with another public organisation (Kalfa and Yetim, 2018). It is easy to use and helps to understand and implement modern management techniques (Engel, 2002).

The 2013 Model is currently used, adapted based on feedback received from national CAF correspondents and users of this model. The model is more robust and better prepared to support the public sector, allowing for the creation of new opportunities for the further development of organisations in this sector (CAF, 2013). In Portugal, the Directorate General for Administration and Public Employment (DGAEP) (Evaristo, 2010) is responsible for the dissemination of CAF.

Conceptually, this model consists of a holistic approach to analysing organisational performance based on the foundations of the European Foundation for Quality Management (EFQM). It aims to introduce organisations to the culture of excellence and principles of Total Quality Management, progressively guiding them towards a full cycle of PDCA (Plan, Do, Check, Act), acting as a catalyst for a process of organisational improvement. It assumes, as a principle, that excellent results in organisational performance, citizens/clients, people and society are achieved through strategies and planning of leadership, people, partnerships, resources and processes. It facilitates self-assessment of the organisation resulting in a diagnosis and definition of improvement actions and can serve as a bridge between the various models used in quality management.

They point out as benefits of the self-assessment promoted by CAF: the way to identify the information to be shared and enhance communication; the clear identification of strengths and areas for improvement; the possibility for employees to get to know the organisation and its problems better; the possibility for the organisation to identify, internally, several actions to be implemented; leveraging new ideas and new ways of thinking the organisation; employees express and share their opinions; means of promoting and encouraging a quality approach in employees; developing a strong interest in the organisation in employees, reinforcing their feelings of belonging (EIPA, 2005; Vakalopoulou et al., 2013; Wiśniewska and A. Szczepańska, 2014).

RESEARCH METODOLOGHY

This paper reports the first part of a research project that aims to understand the implementation of the CAF model to assist the management of fire brigades in Portugal.

A case study approach was adopted because it seeks to fully understand a poorly known phenomenon (Hoon, 2013). A qualitative, cross-sectional, descriptive exploratory study was used, since its purpose is to name, classify, describe, or contextualize a situation (Fortin 2000). An empirical strategy was used to investigate a contemporary phenomenon in its real-life context (Yin, 2009), adopting a holistic analysis, as complete as possible, which considers each social unit studied as a whole.

This case study has a multiple focus since studies involving four fire organisations are conducted simultaneously. In this sense, the comparative method of analysis was also used since the case study assumes that knowledge of the phenomenon studied can be acquired from the intense exploration of a single case. Thus, the comparative method of analysis allows one of the specific objectives outlined, which deals with the identification of differences and/or similarities between the four studied fire brigades.

Sample

A convenience sample was used, as the brigades involved are some of the elements of the population that were easily accessible to researchers (Saumure at al., 2008). Four fire brigades were studied from the central zone of Portugal, which for the sake of confidentiality we designated as brigades A, B, C and D.

Participants and data collection process

Data collection was carried out using direct observation and semi-structured interviews with key players in the brigades. The procedures were all approved by the researchers and the commanders of the fire brigades involved.

Four separate teams applied the CAF model, set up for this purpose, with junior researchers, who were given initial training to carry out data collection. Several meetings were held, coordinated by the researchers responsible for the study. This aimed to standardise the implementation process of the model by the four teams and also to ensure the reliability of the results obtained from implementation and higher fidelity of the CAF model. These meetings included support and training on the different tools and concepts encompassed by the CAF model, as well as how to implement the model in the organisations, which varied according to the needs of the team. Data collection was undertaken in each of the brigades involved and previously scheduled with those responsible for them.

After gathering data and obtaining the results (strengths, opportunities for improvement and scores), a self-assessment report was produced for each brigade. In order to ensure the necessary triangulation and validation of the results obtained by the implementing teams, the results expressed in the self-assessment reports were validated by the researchers and the fire brigades.

Instruments

The tools used were made available by the CAF group on the DGAEP website. The fine-tuned scoring was adopted to obtain more information on the status of the organisations within the PDCA cycle. The working procedure followed was the implementation methodology suggested in the CAF 2013 Manual.

RESULTS

The results obtained in the four fire brigades (A, B, C and D) are presented. The state of the art of the brigades regarding their maturity concerning excellence is presented according to the principles of the CAF model, based on the identification of strengths and opportunities for improvement. The score component is the one that best translates, in a quantified manner, the guidance to be followed as a starting point for improvement actions (DGAEP, 2017). The scores obtained, based on CAF fine-tuned scoring, are presented in tables 1 and 2.

The analysis of the scores obtained in the studied brigades unveils that: organisation D consistently presents the best results in the analysed criteria, all the brigades present the criterion related to processes as the one with the best assessment average (40.2 pts.), and all four brigades present the criterion related to strategy and planning as the one with less maturity (20 pts.). The remaining criteria appear in different positions depending on the organisation under study.

Enablers criteria

Analysing the Leadership criterion (Table 1), the results obtained, aligned with the strengths and opportunities for improvement identified in the self-assessment reports, show a relative homogeneity in the different sub-criteria.

However, the sub-criterion that stands out on the negative relates to “Provide direction for the organisation by developing its mission, vision and values” (20.3 pts.). This allows for verifying that the brigades sustain their orientations exclusively based on the legal diplomas, abstaining from a specific strategic formulation of the respective brigade, that frames in the mission, vision and other referential, the geographic, social, economic and even political specificity of the territory in which they act.

Table 1 - Enablers criteria score obtained by the brigades.

##	ENABLERS CRITERIA	Fire Brigades A	B	C	D	Average
	Criterion 1: Leadership	22.2	20.6	28.1	30.6	25.4
1.1	Provide direction for the organisation by developing its mission, vision and values	18.8	11.3	20.0	31.3	20.3
1.2	Manage the organisation, its performance and its continuous improvement	22.5	22.5	30.0	36.3	27.8
1.3	Motivate and support people in the organisation and act as a role model	20.0	21.3	32.5	27.5	25.3
1.4	Manage effective relations with political authorities and other stakeholders	27.5	27.5	30.0	27.5	28.1
	Criterion 2: Strategy and Planning	19.4	20.0	17.4	23.1	20.0
2.1	Gather information on the present and future needs of stakeholders as well as relevant management information	20.0	22.5	12.0	21.3	18.9
2.2	Develop strategy and planning, taking into account the gathered information	20.0	17.5	17.5	20.0	18.8
2.3	Communicate and implement strategy and planning in the whole organisation and review it on a regular basis	17.5	17.5	17.5	22.5	18.8
2.4	Plan, implement and review innovation and change	20.0	22.5	22.5	28.8	23.4
	Criterion 3: People	30.0	29.2	22.1	36.3	29.4
3.1	Plan, manage and improve human resources transparently with regard to strategy and planning	27.5	35.0	17.5	31.3	27.8
3.2	Identify, develop and use competencies of people aligning individual and organisational goals	30.0	28.8	26.3	47.5	33.1
3.3	Involve employees by developing open dialogue and empowerment, supporting their well-being	32.5	23.8	22.5	30.3	27.3
	Criterion 4: Partnerships and Resources	26.0	25.2	29.6	33.1	28.5
4.1	Develop and manage partnerships with relevant organisations	28.8	23.8	30.0	42.5	31.1
4.2	Develop and implement partnerships with the citizens/customers	22.5	12.5	18.8	35.0	27.2
4.3	Manage finances	50.0	46.3	50.0	50.0	49.1
4.4	Manage information and knowledge	16.3	15.0	22.5	20.0	18.4
4.5	Manage technology	17.5	25.0	25.0	17.5	21.3
4.6	Manage facilities	21.3	28.8	31.3	33.8	28.8
	Criterion 5: Processes	36.7	34.2	43.8	46.3	40.2
5.1	Identify, design, manage and innovate processes on an ongoing basis, involving the stakeholders	26.3	23.8	41.3	43.8	33.8
5.2	Develop and deliver citizen/customer-oriented services and products	38.8	42.5	43.8	48.8	43.4
5.3	Coordinate processes across the organisation and with other relevant organisations	45.0	36.3	46.3	46.3	43.4
	Enablers criteria score	134.3	129.2	140.9	169.5	143.5

Also, on the criterion Leadership and in opposite pole, one can identify the management of the relations of these organisations with the different political authorities and other stakeholders, of national and local territorial scope (28.1 pts) and the involvement of the leaderships to manage processes of continuous improvement for the operational increase of their organisations.

As for the Strategy and planning criterion, equal homogeneity is shown between the different organisations, namely in the different sub-criteria. The result obtained in the sub-criterion “Plan, implement and review innovation and change” is highlighted, consistent with the involvement of the leaderships for the modernization process, but also aligned with the strengths identified in the criterion Partnerships and Resources, sub-criteria “Manage technology” and “Manage facilities”. These are both associated with the criterion Partnerships and resources, specifically in the introduction of modern equipment and experimental computer tools to support the operation that has been benefiting the different brigades, depending on the increased investment in the sector. Data from the self-assessment reports show that the planning of these brigades is essentially operational, short-term, and there is no evidence of practices oriented to medium and long-term management, related to strategic thinking.

Regarding the criterion People, the score show that the sub-criterion “Identify, develop and use competencies of people aligning individual and organisational goals” presents the best average result (33.1 pts.), benefiting from the fact that the brigades have, with different maturities, maps of profiles and functions, firefighters' files that are being updated as they gradually participate in training actions mostly related to firefighting operations. In this sub-criterion, it was also identified the repeated practice of performance assessment of firefighters, even if the alignment with the strategic objectives of the brigades is omitted, due to their lack, as well as the absence of process assessment (check) and consequent improvement actions (act).

In the sub-criterion “Plan, manage and improve human resources transparently with regard to strategy and planning”, there are some exercises that help to predict the need to reinforce the number of firemen, however they are not based on strategic thinking for the brigade.

As regards the criterion Partnerships and resources, the sub-criterion “Manage finances” shows the best average result (49.1 pts.), highlighting a more mature approach from the point of view of planning, implementation and periodic assessment of practices. The sub-criterion also presents the best maturity regarding excellence compared against the other 27 sub-criteria - a fact to which the brigades are subject to scrutiny because of the public funding they receive.

The sub-criterion 'Manage information and knowledge” is less well-performing (18.4 pts.), not only under the criterion Partnerships and resources but also in comparison with the other sub-criteria linked to the Enablers criteria. From the reports analysed, it is clear, and common for all four organisations, the lack of consistent and systematic approaches that promote the identification, management and critical analysis of information relevant to the mission of the organisations, and there are no generally accessible knowledge repositories.

The proliferation of partnerships with public and local stakeholders supporting the mission of the brigades (31.3 pts.) is highlighted, lacking, in general, monitoring practices of these partnerships and the consequent systematic approach to increase them. Concerning the management of partnerships with citizens/clients (22.2 pts.), the reports highlight some partnership initiatives, which are not greatly enhanced by the persistent lack of systematic approaches, in the logic of the PDCA cycle, and which are not oriented towards deepening the services offered by the brigades.

Concerning the criterion Processes, the score of the different sub-criteria show more consistent approaches to operations related to fire fighting and other services provided in articulation with other stakeholders (hierarchical and other partners in the civil protection, health and social sectors, among others). However, these approaches lack more focus in the planning, monitoring and implementation phases of improvement. The criterion also benefits from the existence of procedure manuals, primarily associated with firefighting operations, financial management and patient transport.

Results criteria

The Results criteria (Table 2) show that the organisation D consistently presents the best score in the various criteria and sub-criteria and that the four brigades present as the criterion with the best assessment score, the criterion “Key performance results” (29.1 pts.) and the four brigades present as the criterion with the least maturity, the “Social responsibility results” (10.1 pts.).

Table 2 - Results criteria score obtained by the brigades.

		Fire Brigades				
##	RESULTS CRITERIA	A	B	C	D	Average
	Criterion 6: Citizen/Customer-oriented Results	15.0	10.0	12.5	25.0	15.6
6.1	Perception measurements	10.0	5.0	7.5	30.0	13.1
6.2	Performance measurements	20.0	15.0	17.5	20.0	18.1
	Criterion 7: People Results	20.0	21.9	11.3	23.8	19.2
7.1	Perception measurements	10.0	20.0	5.0	20.0	13.8
7.2	Performance measurements	30.0	23.8	17.5	27.5	24.7
	Criterion 8: Social Responsibility Results	12.5	9.3	6.3	12.5	10.1
8.1	Perception measurements	10.0	3.5	5.0	10.0	7.1
8.2	Performance measurements	15.0	15.0	7.5	15.0	13.1
	Criterion 9: Key Performance Results	32.5	23.8	20.0	40.0	29.1
9.1	External results: outputs and outcomes to goals	30.0	20.0	20.0	40.0	27.5
9.2	Internal results: level of efficiency	35.0	27.5	20.0	40.0	30.6
	Results criteria score	80.0	64.9	50.0	101.3	74.0

The analysis of the score obtained for the Results sub-criteria “Citizen/Customer-oriented”, “People results” and “Social responsibility results” shows a trend towards better approaches by the brigades to internal performance measurements as opposed to perceptions measurements. In fact, except for organisation D, for the case of Citizens/Customer-oriented results, there are only a few, non-systematised attempts to collect perceptions from citizens/clients, employees and partner entities.

The different self-assessment reports also show that the few existing performance measurement indicators are essentially associated with the operation, and no association is identified between these indicators and targets, as well as performance from previous years.

The analysis of the self-evaluation reports, complemented with the brigades' activity reports, confirms, as aforementioned, the idea of the existence of indicators related to organisational effectiveness and efficiency, although there is no monitoring against targets or performance in previous years.

Total Score

The total score (Table 3) show a low level of organisational maturity regarding excellence, supported by the low score obtained by the fire brigades in relation to the criteria of Enablers and Results criteria and consequently in the general framework.

Table 3 - Total score obtained by the brigades.

ENABLERS CRITERIA	Fire Brigades A	B	C	D	Average
Enablers criteria score	134.3	129.2	140.9	169.5	143.5
Results criteria score	80.0	64.9	50.0	101.3	74.0
TOTAL SCORE	214.3	194.0	190.9	270.7	217.5

The brigade that stands out in the scoring board and consistently presents better results in all criteria is the organisation D with 30.1% (270.7 pts.) of the total possible score (900 points), of which 169.5 pts. (62.6%) relate to the Enablers criteria. Organisation A has a total of 214.3 pts, and organisations identified by the letters B and C have similar results, 194.0 pts. and 190.9 pts., respectively.

PDCA phases

Given the score obtained in the different Enablers criteria and considering the use of the CAF fined-tuned scoring, it is essential to analyse the organisational maturity concerning the different phases of the PDCA cycle. Figure 1 represents the overall average of the 20 Enablers sub-criteria for each phase of the PDCA cycle.

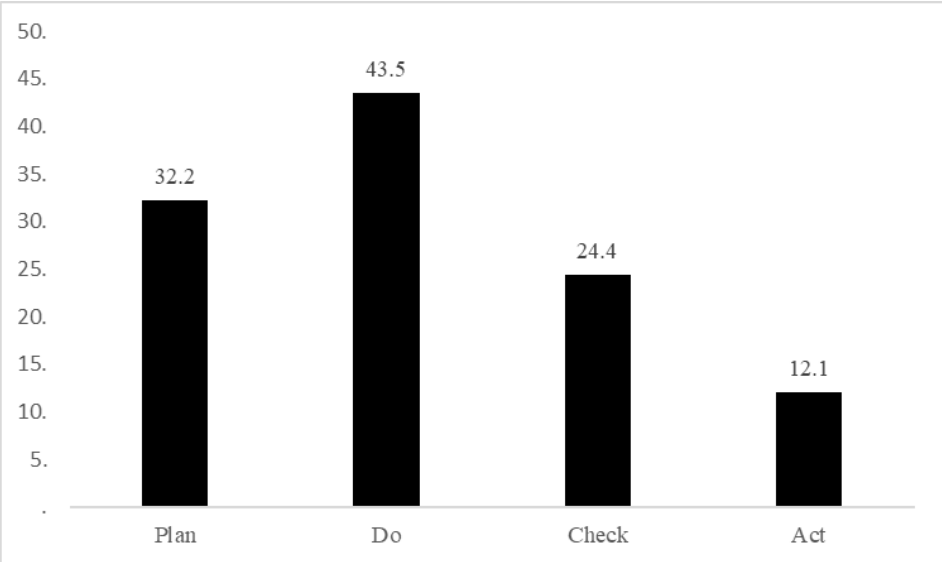

Figure 1 - PDCA phases score.

The Figure 1 confirms the idea, expressed throughout the work, of these organisations' willingness to undertake numerous initiatives in line with the different examples proposed by the CAF model; however, the scores obtained in the planning, monitoring and improvement of practices reveal weaknesses.

About the Plan phase (PDCA), as presented in figure 2, an analysis of the 20 Enablers sub-criteria shows that the sub-criteria with the highest planning maturity are: “Manage finances” (57.5 pts.) of the criterion Partnerships and resources; “Coordinate processes across the organisation and with other relevant organisations” (50.0 pts.); and “Develop and deliver citizen/customer-oriented services and products" (47.5 pts.) of the criterion Processes. The sub-criteria with the lowest values are "Communicate and implement strategy and planning in the whole organisation and review it on a regular basis" (20.0 pts.) of the Strategy and planning criterion and "Manage information and knowledge" (20.0 pts.) of the Partnerships and resources criterion.

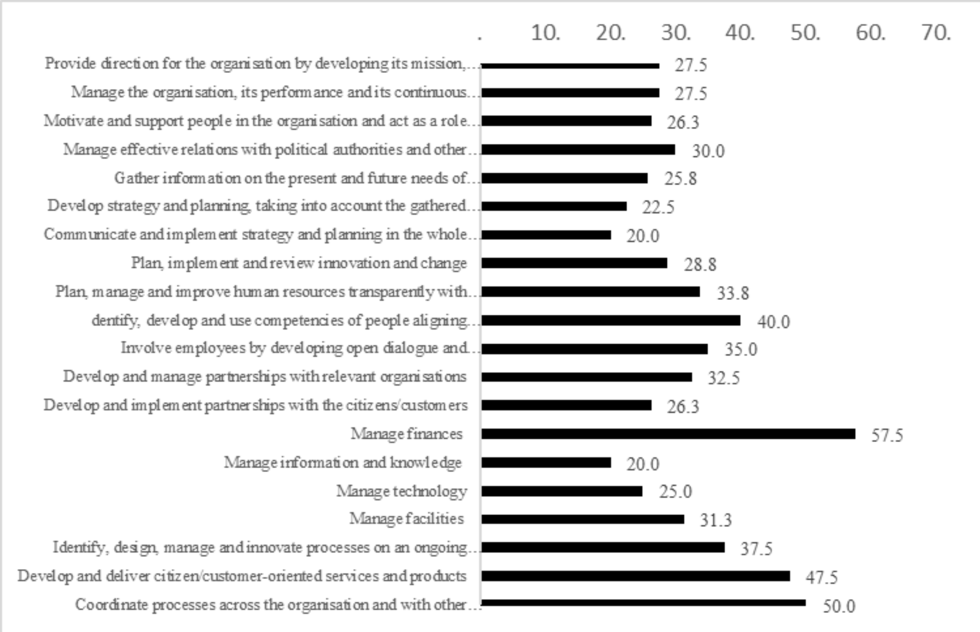

Figure 2 – Phase 'Plan' (PDCA) score.

For the Do phase (PDCA), as presented in figure 3, the sub-criteria that are more mature in planning continue to present better results during the implementation phase, namely "Manage finances" (63.8 pts.), "Develop and deliver citizen/customer-oriented services and products" (67.5 pts.) and "Coordinate processes across the organisation and with other relevant organisations" (67.5 pts.). The lowest value is presented for the sub-criterion "Gather information on the present and future needs of stakeholders as well as relevant management information" (27.0 pts.) of the Strategy and planning criterion.

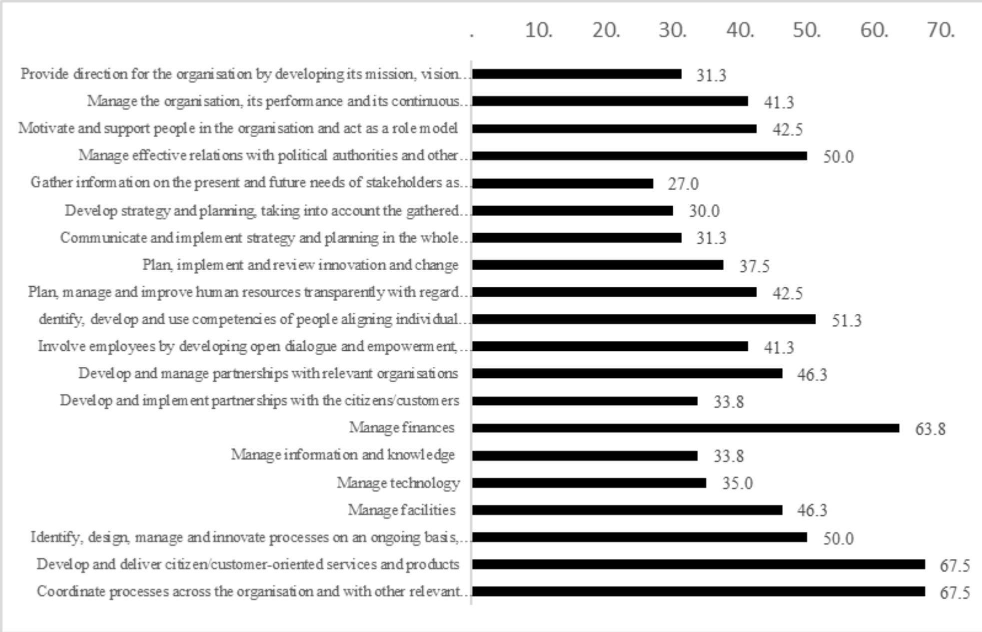

Figure 3 – Phase ‘Do’ (PDCA) score.

Concerning the Check phase (PDCA) and figure 4, it can be seen that the sub-criteria for the Enablers, which have better approaches in the planning and implementation phase, still score better with respect to the approaches adopted in the assessment phase. The lower-rated sub-criteria “Gather information on the present and future needs of stakeholders as well as relevant management information” (13.8 pts.) and “Develop strategy and planning, taking into account the gathered information” (15.0 pts.) both of the Strategy and planning criterion and “Manage information and knowledge” (15.0 pts.) of the Partnerships and resources criterion.

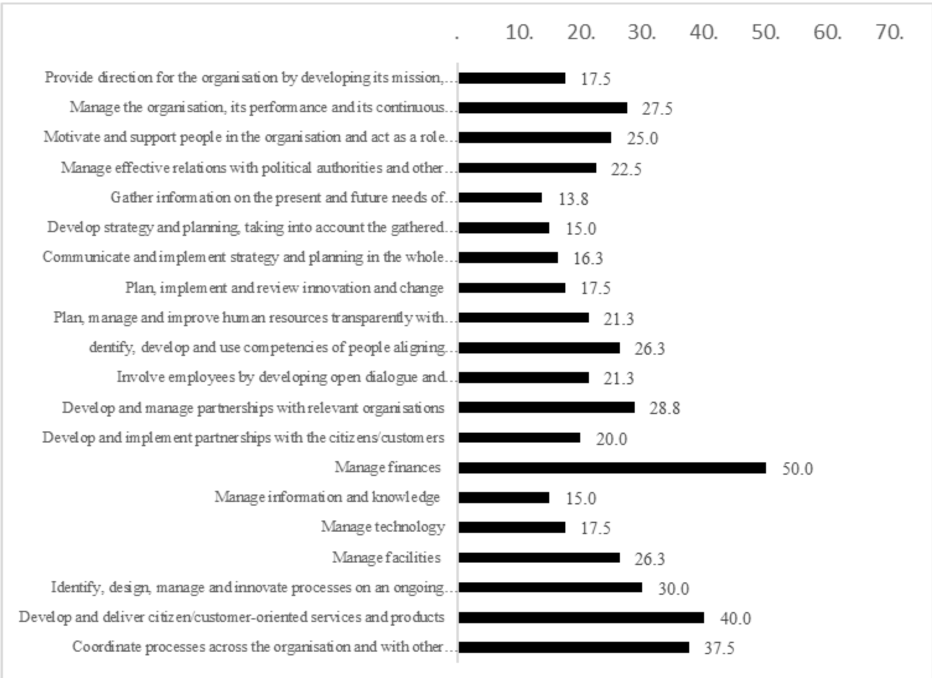

Figure 4 – Phase ‘Check’ (PDCA) score.

As far as the Act phase (PDCA) is concerned (see figure 5), an analysis of the assessment results of the brigades' practices shows a tendency to obtain better scores for those sub-criteria, which up to the Check phase also presented better approaches, namely “Manage finances” (25.0 pts).), “Coordinate processes across the organisation and with other relevant organisations” (18.8 pts.) and “Develop and deliver citizen/customer-oriented services and products” (18.8 pts.); the lowest scores being associated with “Manage information and knowledge” (5.0 pts.) and “Provide direction for the organisation by developing its mission, vision and values” (5.0 pts.).

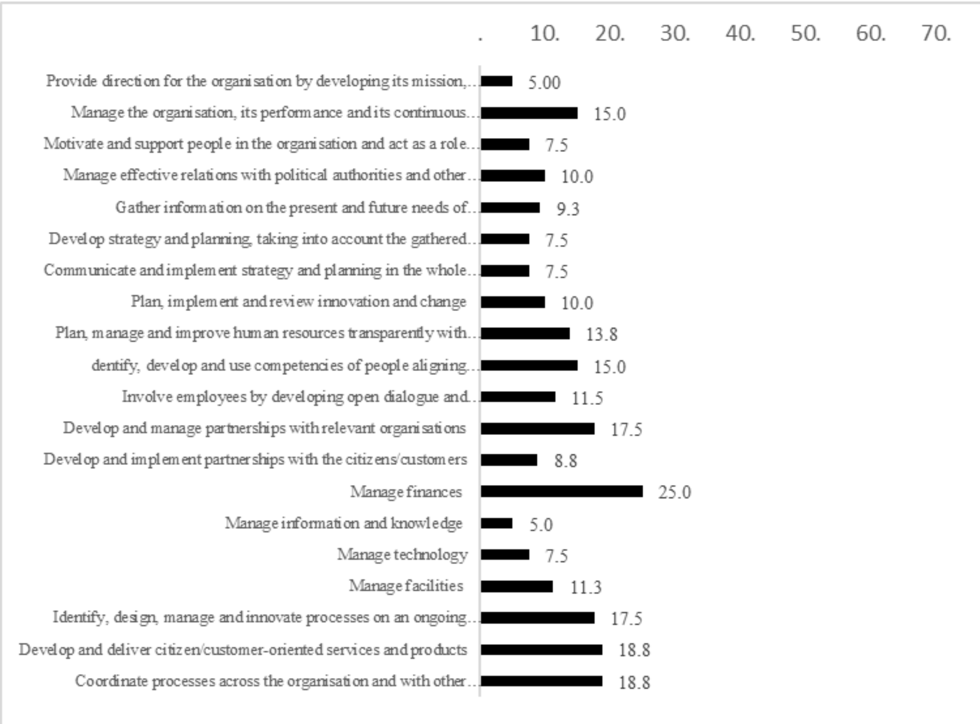

Figure 5 – Phase ‘Act’ (PDCA) score.

CONCLUSIONS

The conclusions are presented in two distinct perspectives, on the one hand concerning the state of the art of fire brigades and, on the other, concerning the implementation of the CAF model.

Regarding the state of the art of the fire brigades included in the study, the implementation of the CAF model made it possible to identify, in general terms, the fragile approach of leadership in terms of the formulation and promotion of the organisation's benchmarks (mission, vision and values), despite its involvement in the modernization of practices and adoption of technologies necessary to strengthen management skills and operational capacity (Leadership). Weak management skills are found essentially in strategic planning, relegating the action of these organisations almost exclusively to short-term operational management. Besides, the observed scarcity of use of management tools oriented to the analysis of organisational and operational reality, make it difficult to be proactive in introducing innovative practices that leverage performance improvement (Strategy and planning).

It was observed that the more mature approaches to excellence coincide with the sub-criteria for which there is a greater focus by the sector at all stages of the PDCA cycle, namely “Manage finances” (criterion Partnerships and Resources), “Coordinate processes across the organisation and with other relevant organisations” and “Develop and deliver citizen/customer-oriented services and products” (criterion Processes).

The low number of indicators was also evident, with those available being essentially short-term oriented, often lacking association with targets to be met or comparison against previous performance levels.

The results show a low level of organisational maturity regarding excellence, supported by the low score obtained by the fire brigades in relation to the criteria of Enablers and Results criteria and consequently in the general framework.

Regarding the implementation of the CAF model, based on the results obtained, we highlight, on the one hand, the innovative character of the implementation of the model to fire brigades and the feasibility of the use of the quality concepts, and in particular excellence, in the context of fire brigades. On the other hand, the fulfilment of the purposes of the CAF model when implemented in the fire brigades, namely, to serve as a basis for self-assessment and organisational diagnosis processes. However, it is not easy for users to understand some references and terms in the context of the fire brigades.

As practical implications, this study has served as an exploratory tool for future action, namely, to analyse the improvement proposals identified in order to develop good practices programmes in the field of fire brigade excellence.

On the basis of this case study and in line with the recommendations of the Independent Technical Committee, namely the need to carry out work to rigorously identify the current status of the fire brigades, the conclusions produced here should be taken into account for the reflection process, expected to be broad, for launching a programme oriented towards the management of fire brigades.

Limitations

First of all, the lack of studies with similar objectives to the present study and with the same target population is highlighted. The exploratory nature of the study limited the literature review and the comparison of the results against those of other studies. Another limitation is related to the case study method and the comparative study, since they should not have the pretension of allowing for an absolute analysis of the studied organisations, but rather recognize their limitations and seek a holistic view that can stimulate new studies to fill the existing knowledge gaps.

Future research directions

The results of this study reinforce our conviction on the need to deepen the theme of quality and excellence in fire brigades. Therefore, the scientific community associated with management and, more specifically, quality sciences, should carry out new studies by extending the sample to other fire brigades.

A further complement to this study could translate into the collection of the perspective of key actors in the brigades, namely top managers, regarding the model implementation process in order to identify strengths and opportunities for improvement, as well as the impacts arising from the implementation of improvement initiatives on organisational performance and the strengthening of their operational capacity. Studies to assess the impact of the model's implementation can also be promoted in the context of the brigades, after the implementation of the improvement proposals.

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Classification of Improvement Project Selection Methods

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ABSTRACT

Purpose – The aim of the paper is to identify and evaluate the current state of the art of research into methods for improvement project selection so as to: 1) elaborate an Improvement Project Selection Methods **(**IPSMs**)** summary taking into account different types of these projects, 2) propose a classification of Improvement Project Selection Methods, 3) determine possible gaps, issues and opportunities for further studies.

Design/methodology/approach - This paper reviews the extant literature on the theory and application of.

Findings – The main contribution of the paper is the classification of IPSMs. The classification is based on four types of methods: 1) scoring and ranking, 2) multiple criteria decision-making (MCDM) methods, 3) hybrid multiple criteria decision-making (MCDM) methods, 4) other methods. The analysis has indicated that the main area of research related to the development and application of IPSMs is Six Sigma project management. The classification fills a research gap in the subject of theory related to the selection of improvement projects.

Research limitations/implications - The main limitation is the analysis in the scope of topic "improvement project selection" including the Thompson/Reuters Web of Science.

Practical implications - the proposed combination of methods and their classification may be used among the managerial staff when choosing the selection method of improvement projects in enterprises.

Originality/value - The review fills a research gap by providing researches and practitioners with an overview IPSMs and their classification. Moreover, it takes into account various types of projects and presents the current state of research in terms of their application.

Keywords: Improvement project (IP), Project Selection, Improvement Project Selection Methods (IPSMs).

Paper type: Literature review

INTRODUTION

Currently it is very difficult to build a high level of organization performance without a key ingredient that is Continuous Improvement (CI) (Fryer and Ogden, 2014). According to Bhuiyan and Baghel (2005) the best known of CI methodologies are: Lean Manufacturing, Six Sigma, the balanced scorecard and Lean Six Sigma. Their implementation constitutes a sequence of unique, complex and related tasks with a common goal. An organization operating in line with the CI concept quite often implements several improvement projects (IPs) simultaneously. The performance of a single project influences the final outcome of several related projects within a company Martinsuo and Lehtonen (2007). The traditional approach to project management is to consider corporate projects as being independent of each other. However, research in this field has shifted towards Project Portfolio Management (PPM) owing to its many benefits (Padhy, 2017). The most common errors during project improvement plans related to poor selection of projects, insufficient project resources and too broad a scope (McLean et al., 2017). The problem of poor choice of improvement projects may be rooted in their incorrectly conducted assessment or a large number of them. This, as a consequence, significantly hinders and/or prevents the assessment of the possibilities of achieving project objectives and the scale of potential benefits. That is why it is important to pay special attention to this issue.

It is also worth paying attention to the results of the research which show there to be considerable dissatisfaction with project and portfolio selection amongst practitioners. Organizations do not use the most appropriate structured tools to select their project portfolios. Tools such as brainstorming, which are advocated by the popular press, are not appropriate for project selection and prioritization (Kornfeld and Kara, 2013). In the study by Banuelas et al. (2006) was indicated that brainstorming was the predominant method for identifying projects among the surveyed companies in UK.

In the scientific literature, the classification IPSMs are presented, but they only apply to selected groups of projects. Substantial researchers have accentuated the significance of the Six Sigma project selection, and numerous methods have been presented in the literature. For example, Arafah (2015), Banuelas et al. (2006), Padhy (2017) and Yousefi and Aqamohammadi (2014) summarized the common methods used for the Six Sigma project selection. Kalashnikov et al. (2017) focuses only on Lean Six Sigma projects (LSSs). Kornfeld and Kara (2011) have developed a list of IPSMs recommended in the literature, but without division into types of improvement project. Obviously, the list includes methods developed before the year 2011.

Thus, there is a lack of a full classification and presentation of scientific achievements which have been achieved in this area, taking into account latest research results. There is no consistent statement of Improvement Project Selection Methods regarding different types of projects for which they have been developed. To meet this research gap, the authors took up the development of coherent classification methods for project selection, considering various types of improvement projects.

Identification of the research gap prompted the authors to pose the following research questions:

- RQ1. What methods are proposed in literature for selection improvement projects?
- RQ2. What is the share of project selection methods in different types of improvement projects in the last 15 years?
- RQ3. What groups of selection methods concerning improvement projects can be distinguished?

The aim of the paper is to identify and evaluate the current state of the art of research into methods for improvement project selection so as to:

- elaborate an Improvement Project Selection Methods summary taking into account different types of these projects,
- propose a classification of Improvement Project Selection Methods,
- determine possible gaps, issues and opportunities for further studies.

The remainder of this paper is organized as follows: section 2 reviews the pertinent literature. Section 3 describes the research methodology. Section 4 contains presentation of research results and focuses on the classification of Improvement Project Selection Methods. Conclusions and future research opportunities are addressed in the final section.

LITERATURE REVIEW

Improvement project

According to Aleu and Van Aken (2016) examples of three common types of Continuous Improvement Projects (CIPs) include: Kaizen Events (KEs), Six Sigma projects (SSPs) and Lean Six Sigma projects (LSSPs). However, CIPs are also projects related to other CI techniques, especially Quality Improvement Projects (QIPs), Quality Circles (QCs) or projects resulting from the operation of suggestion systems. It was assumed that an improvement project is a unique undertaking, aimed at achieving the goal of improving the organisation and its processes; it is a sequence of completed and related activities. It is planned in time and has allocated resources necessary for its implementation.

Considering IP initiators, improvement projects were divided into three groups (Kucińska-Landwójtowicz et al., 2019) (Figure 1).

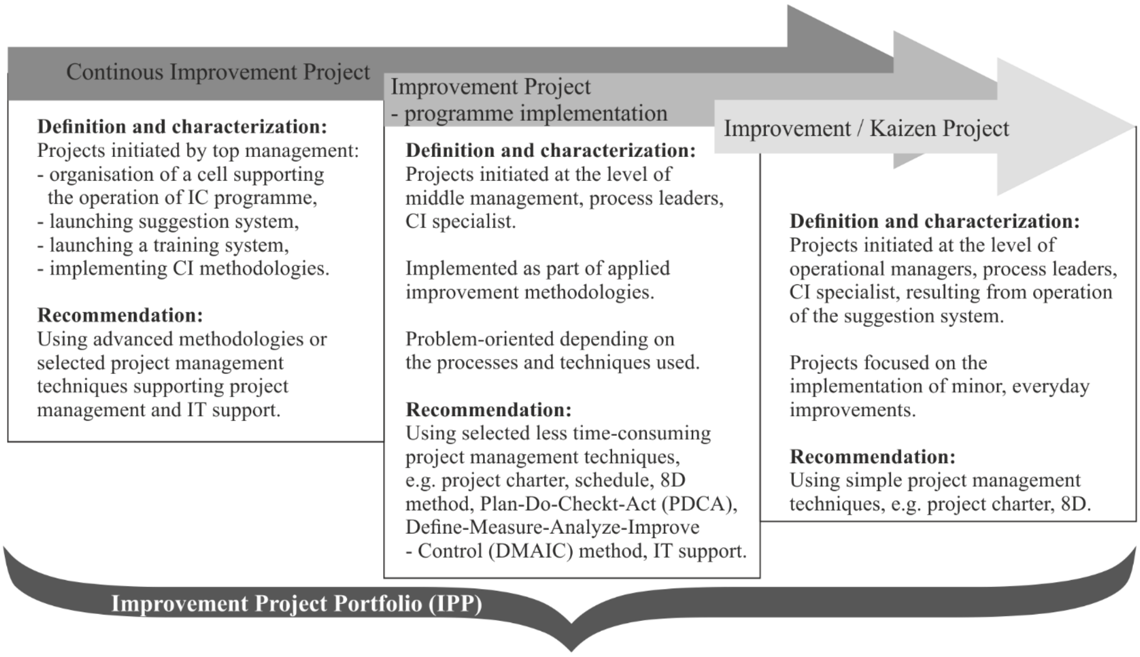


Figure 5 – Improvement projects characteristics (authors).

Improvement project selection

Project selection is recognized to be a critical success factor in Continuous Improvement by researchers Antony and Banuelas (2002), Su and Chou (2008). Project selection is the process of evaluating individual IPs as well as choosing a subset of them to be implemented so that the objectives of the organization will be achieved (Padhy and Sahu, 2011). Improvement project or portfolio selection is a complex and multi-faceted decision-making activity that becomes increasingly complicated as organization size and the number of potential projects increases (Kornfeld and Kara, 2011). According to Zhang et al. (2008) strategic portfolio selection and project management can positively impact organizational performance, and decision-making during this part of the process can have a substantial impact on whether strategic outcomes are successfully realised. The appropriate selection and staging of tactical actions – in this case improvement projects – are critical factors in successful strategy execution. Project portfolio selection is a decision problem faced by many organizations which carry out activities through projects with the aim of attaining an appropriate balance of cost, reward, and risk (Salo et al., 2011). The choice of the project means deciding which projects are to be implemented and in what order. It involves assessing them and bestow priority onto them. It also requires to define the criteria for their assessment, which allow organization managers to prioritize improvement projects. According to Kalashnikov et al. (2017) the literature classifies project selection methods into two groups: simple approaches and complex approaches. In this research Improvement Project Selection Methods are defined by authors as a set of tools, the use of which enables project evaluation and prioritization based on adopted evaluation criteria and a dedicated calculation algorithm.

METHODOLOGY AND DATA

The research was conducted using the literature review method. The essence of a systematic literature review is to reflect the state of knowledge in a given subject on the basis of methodical behavior promoted by Tranfield et al. (2003). This approach has since been adopted by a many author in management research. The method bases on the deliberate literature selection and its distinguishing feature is the use of quantitative techniques, which are describing and analysing literature. A literature review seems to be a valid approach because it is a necessary step in structuring a research field and it advances our understanding of any emerging area of research (Easterby-Smith et al., 2002). A literature review also helps to identify the conceptual content of the field and can contribute to theory development (Seuring and Müller, 2008). It can also be a relevant step to review and understand the theory-practice gap. A structured approach has been adopted for surveying the literature. The research was carried out according to defined stages:

1. Selection of databases that have been searched.
2. Bibliometric analysis:
   - development of a publication databases and selection of publications,
   - data analyses.
3. Content analysis.
4. Developing a list of the improvement project selection method considering different types of these projects.
5. Developing classification improvement project selection method.
6. Discussion of results.
7. To determine possible gaps, issues and opportunities for further studies.

As the object of exploration, the literature of the subject was taken under consideration, which is placed in the universal Thompson/Reuters Web of Science database (WofS). It bring a wide range of journals from relevant publishers that provide a global access point to most of the scientific literature published internationally. At this stage of the research, the focus was on the indicated database, which is a limitation of the conducted analysis. Nevertheless, it allows to state that the analyzed issue is an important topic for researchers and practitioners. The literature review will be extended to include new databases at a later stage of the research.

The review was limited to the literature which has been published since 2005, which is going to allow the analysis of publications in the span of the last 15 years. All searches were conducted using the databases advanced search function. The bibliographic databases were queried adopting the following keywords: “project selection”, and then the search was narrowed down to “improvement project selection”. The search was narrowed down to several WofS categories: “Management, Computer science information systems, Operations research management science, Computer science interdisciplinary applications, Computer science artificial intelligence, Computer science software engineering, Business”. The search resulted 394 publications. From 2005 to 2020, the number of publications found in the topic “improvement project selection” has a growing trend to 43 publications in 2019 year. As for the sum of Times cited by year, the trend is clearly growing, the number of citations was the highest in 2019, these were 594 citations. The summary of information related to the bibliographic analysis indicates a total sum of the Times Cited equalling 3896, with the Average Quotations per Item equalling 9,89, and the h-index equalling 31. The narrowing allowed enabled the preparation of a literature database with a number of articles which is sufficient to permit an individual analysis of particular publications, as well as excluded publications distantly related to the subject of the analysis. The analyzed articles concerned the selection of improvement projects, including the methods used to evaluate them. This issue was the subject of content analysis. After verifying the abstracts only 31 publications directly or partially related to the topic were selected. Therefore, content analysis has been expanded to include leading references, systematically recurring in the selected publications.

RESULTS

The literature analysis showed that there are various methods available and applied for improvement project selection. Scientists' work focuses on developing new solutions that will allow unbiased assessment and prioritization of projects. They are increasingly focused on Project Portfolio Management. The analysis of the articles' content enabled the identification of particularly important studies carried out in this area. Therefore, the results of the article content analysis refer to the scientists' achievements accomplished before 2005. The conducted analysis permitted the identification of 32 improvement project selection methods. The research identified 6 groups of improvement projects. Each of the methods was developed for one of six types of projects (Table 1).

Table 1 – List of type of IP with number of elaborated IPSMs (authors).

Type of Improvement Project	**Number of adopted/elaborated IPSMs**
Six Sigma Projects (SSPs)	23
Lean Projects (LPs)	4
Lean Six Sigma Projects (LSSPs)	3
Quality Improvement Project (QIPs)	1
Kaizen Events (KEs)	2
Improvement Projects (IPs)	2

The literature review reveals that researchers paid the biggest attention to the methods used in selecting Six Sigma Projects (23 scientific papers, the first published in 2000).

The list of Improvement Project Selection Methods, taking into account their types, along with the indication references are presented in Table 2. The table also includes brainstorming, which is often used in practice ((Kornfeld and Kara, 2013), (Banuelas et al. (2006)). Comparison of three techniques for QIPs (Mittal et al. (2017)) selection was also included. The list is prepared chronologically.

Table 2 – Improvement Project Selection Methods, type of IPs and references

Method/Tools	**References**	**SSPs**	**LPs**	**LSSPs**	**QIPs**	**KEs**	**IPs**
Project Selection Matrix	Pande et al. (2000)	e					
AHP and QFD	Chuang (2001)	e					
Project Ranking Matrix	Kelly (2002)	e					
Pareto Analysis	Larson (2003)	e					
Pareto Priority Index (PPI)	Pyzdek (2003)	e					
Project Assessment Matrix	Pyzdek (2003)	e					
Cost-Benefit Analysis	Hira and Parfitt (2004)	e					
Cause-and-Effect Matrix	Tague (2005)	e					
Process Simulation	Abdulmalek et al. (2006)		e				
TOPSIS	Cheng et al. (2006) Kumar et al. (2009)	e					
AHP	Mawby (2007) Kendrick and Saaty (2007)	e					
Project Categorization	Jung and Lim (2007)	e					
DEA	Kumar et al. (2007) Alinezhad et al. (2013) Yousefi and Aqamohammadi (2014)	e					
Linear Programming/ Integer Programming	Kumar et al. (2007)	e					
Simulation and AHP	Evans and Alexander (2007)	e					
Fuzzy AHP	Kahraman and Büyüközkan (2008) Huang et al. (2009) Bilgen and Şen (2012)	e					
AHP and FMEA	Su and Chou (2008)	e					
Goal Programming	Hu et al. (2008)	e	e				

PROMETHEE and AHP	Anand and Kodali (2008a)		e				
ANP	Anand and Kodali (2008b)		e				
AHP and Project Desirability Matrix	Kumar et al. (2009)	e					
Delphi Fuzzy Multiple Criteria Decision-Making method (FMCDM)	Yang and Hsieh (2009)	e					
ANP and DEMATEL	Büyüközkan and Öztürkcan (2010)	e					
Dynamic Stochastic Programming	Tkáç and Lyócsa (2010)	e					
0-1 Integer Linear Programming	Padhy and Sahu (2011)			e			
ANFIS and Fuzzy Weighted Additive Goal Programming	Saghaei and Didehkhani (2011)	e					
DEA	Yüksel (2012)	e					
ANP	Wang et al. (2014)					e	
Multi-DEA Unified Scoring Framework	Arafah (2015)	e					
Fuzzy ANP	Altintas et al. (2016)	e					
0–1 Bi-objective Quadratic Programming	Kalashnikov et al. (2017)			e			
Interval neutrosophic Fuzzy TOPSIS	Otay and Kahraman (2018)	e					
Modified Common Weight DEA	Wen et al. (2018)	e					
Combination of PFMEA, PDM and PICK Chart	Kovach and Ingle (2020)						e
VSM – Fuzzy TOPSIS	Kumar et al. (2018)			e		e	
Brainstorming	Practitioners' approach Kornfeld and Kara (2013) Banuelas et al. (2006)						e
Cost of poor quality/ Conditional Probability/ Fuzzy TOPSIS - comparison	Mittal et al. (2017)				e		

Description:

AHP – Analytic Hierarchy Process; QFD – Quality Function Deployment; TOPSIS – Technique for Order of Preference by Similarity to Ideal Solution; ANP – Analytic Network Process; DEA – Data Envelopment Analysis; FMEA – Failure Mode and Effect Analysis; PROMETHEE – Preference Ranking Organization METHod for Enrichment Evaluations; DEMATEL – Decision Making Trial and Evaluation Laboratory; ANFIS – Adaptive Neuro Fuzzy Inference System; PFMEA – Process FMEA; PDM – Precedence Diagram Method; PICK – Possible Implement Challenge Kill; VSM – Value Stream Mapping.

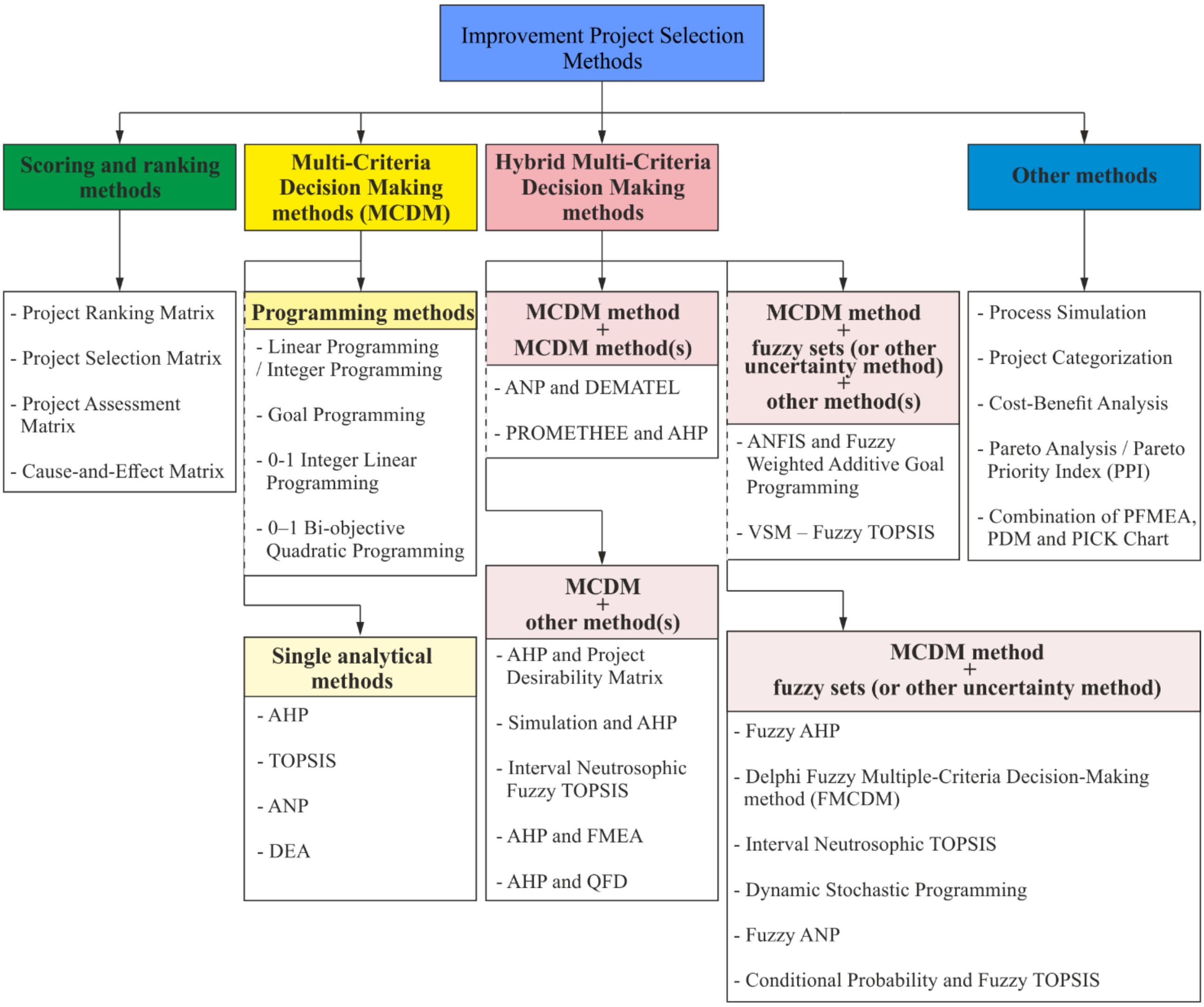
An in-depth analysis of selected articles has allowed the selection of the following types of Improvement Project Selection Methods (Figure 2):

1) scoring and ranking,

2) multiple criteria decision-making (MCDM) methods,

3) hybrid multiple criteria decision-making (MCDM) methods,

4) other methods.



Description:
AHP – Analytic Hierarchy Process; QFD – Quality Function Deployment; TOPSIS – Technique for Order of Preference by Similarity to Ideal Solution; ANP – Analytic Network Process; DEA – Data Envelopment Analysis; FMEA – Failure Mode and Effect Analysis; PROMETHEE – Preference Ranking Organization METHod for Enrichment Evaluations; DEMATEL – Decision Making Trial and Evaluation Laboratory; ANFIS – Adaptive Neuro Fuzzy Inference System; PFMEA – Process FMEA; PDM – Precedence Diagram Method; PICK – Possible Implement Challenge Kill; VSM – Value Stream Mapping.

Figure 2 – Classification of Improvement Project Selection Methods (authors).

Scoring and ranking methods

Scoring and ranking methods are group of multi-criteria approaches to assessment and prioritization of the projects. They can be also named as matrix-based techniques such as the Ranking Matrix, the Selection Matrix or the Assessment Matrix. Using scoring methods, projects are selected or compared based on decision matrix i.e. ratings assigned to each project for a proper criterion. Generally, each criterion is assigned a weight relative to the overall objective as an impact of each criterion to assessment. The scoring methods force a decision maker to attempt to maximize the expected utility (Kim et al., 2009). Scoring methods have been found to be easier to use and have lower cost than the other methods (Souder, 1972), because most often the final score is calculated by additive (multiplicative) methods or weighted additive (multiplicative) methods.

Multi-Criteria Decision Making methods (MCDMs)

MCDM methods are group of methods which use multiple conflicting criteria in selection projects. Term conflicting criteria refers to different types of criteria: cost and profit. For example, in project portfolio selection, we are interested in select project with the high efficiency rate (profit criteria) but also with the lowest risk (cost criteria). The difficulty of this methods originates from the exist of more than one criterion, so a unique optimal project can't be able to be found. The methods precise a set of nondominated projects. It means, that we can't choose the other set of the best projects without removing some of criterion.

Depending on the method, there are different approaches to calculating final project assessments. In general, two groups of this methods can be distinguished: programming methods (basic methods) and single analytical methods. In the first group of methods the calculations determine a set of nondominated projects, considering organization objectives, constraints related to resource limitations, and interdependencies among projects. In this approach, the projects are not specified before the using the method, only using the method results in optimal project assumptions. In the literature, we can distinguish selection project with single- and multi-objective. Among the methods used for IPSM are Linear Programming (Kumar et al., 2008), (Padhy and Sahu, 2011), Integer Programming (Kumar et al., 2008), Goal Programming (Hu et al., 2008) and Quadratic Programming (Kalashnikov et al., 2017).

The second group of methods contains single analytical methods. These methods cover the problems of assessing and prioritizing a finite number of improvement projects. Based on project assessments against the specified criteria and the important of these criteria, the final scorings of IPs are calculated. A lot of techniques have been proposed for the analysis and synthesis of discrete multi-criteria problems. Among the IPSMs, the most common approaches are based on Analytic Hierarchy Process (AHP) method (Kendrick and Saaty, 2007) Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method (Cheng et al., 2006), (Kumar et al., 2009), Analytic Network Process (ANP) method (Anand and Kodali, 2008b), (Wang et al., 2014) and Data Envelopment Analysis (DEA) method (Kumar et al., 2007). The AHP method, based on pairwise comparisons of criteria with each other and IPs due to subsequent criteria, create a scale vector whose components allow the evaluation and ordering of projects. The TOPSIS method calculates a synthetic score that expresses the comparison of the analyzed project with the abstract weighted projects: ideal and anti-ideal. The ANP method is a development of the AHP method, with the possibility of relationships between criteria and projects. The relationships between the components are represented by a network. While, the DEA method can be used to evaluate the relative performance of projects by combining the multiple inputs and outputs that affect the performance of projects (Xu and Yeh, 2011).

Hybrid Multi-Criteria Decision Making methods (MCDMs)

The hybrid approaches group includes IPS methods that combine two or more MCDM methods (e.g. ANP and DEMATEL methods, AHP and PROMETHEE methods), MCDM method with uncertainty method, MCDM method with other type of method(s) and their hybrid (MCDM method plus uncertainty method plus other method(s)). Uncertainty methods usually use the fuzzy set theory based on the Zadeh approach (Kahraman and Büyüközkan, 2008, Huang et al., 2009, Bilgen and Şen, 2012, Yang and Hsieh, 2009) or the neutrosofic set theory (Otay and Kahraman, 2018) or the theory of probability (Mittal et al., 2017). Inclusion of uncertainty methods in the assessment of IPs allows for taking uncertain data processing and risk into account. In other groups, MCDM methods or fuzzy MCDM methods are most often combined with methods that are tools in project or quality management. For example in paper Su and Chou (2008), an Analytic Hierarchy Process (AHP) model is implemented to evaluate the benefits of each project and a hierarchical failure mode effects analysis (FMEA) is developed to evaluate the risk of each Six Sigma Project from which the priority projects can be determined.

Other methods

The last group of methods is quite diverse in terms of the range of proposed selection techniques. Cost/benefit analysis identifies the improvement projects with the highest expected financial return (Hira and Parfitt, 2004). Pareto analysis identifies the most important focal point(s) of an improvement projects. The Pareto Priority Index is a related approach that considers an improvement project’ s return on investment adjusted for probability of success.

In this group of methods using PFMEA analysis were also distinguished. The combination of a modified form of PFMEA with a standardised version of a project desirability matrix (PDM) and a possible, implement, challenge, kill (PICK) chart was developed. According to Kovach and Ingle (2020) it provides a rigorous yet flexible and easy-to-use method for improvement project identification and prioritisation/selection.

A simulation model was developed to contrast the “before” and “after” scenarios in detail, in order to illustrate to managers potential benefits resulting from the introduction of lean techniques (Abdulmalek and Rajgopal, 2007).

The project categorization proposed by Jung and Lim (2007) also applies to Six Sigma Projects. According to this approach a particular project can be defined and categorized by using two process performance indicators: capability and controllability. In the next step, projects are prioritized for selection.

CONCLUSIONS

The review of the literature is carried out according to strictly defined research methodology. Quantitative research permitted to reflect the state of knowledge in a given subject. The growing trend the number of publications concerning “improvement project selection” and the number of citations has been indicated. The analysis of the number of annual publications after verifying the abstracts revealed that only part of the publication were directly and partly concerning the issue. Content analysis was carried out on the basis of 31 publications selected based on the verification of abstracts.

Content analysis has shown that research on IPSM focuses on six types of projects: SSP, LP, LSS, QIP, KE, IP.

The analysis has indicated that the main area of research related to the development and application of IPSM is Six Sigma project management. A relatively small number of methods have been indicated, which are dedicated to the selection of other groups of projects.

The main contribution of the paper is the classification of IPSMs. The classification fills a research gap in the subject of theory related to the selection of improvement projects. In relation to the classifications contained in the literature ((Padhy, 2017), (Yousefi and Aqamohammadi, 2014), (Kalashnikov et al., 2017), (Kornfeld and Kara, 2011)), we propose a more detailed division of the methods concerning these methods. The classification is based on four types of methods: 1) scoring and ranking, 2) multiple criteria decision-making (MCDM) methods, 3) hybrid multiple criteria decision-making (MCDM) methods, 4) other methods.

Among the IPSMs, one can notice the quantitative advantage of MCDM approaches and their hybrids, especially MADM methods. This is due to the fact that project selection and prioritization is usually a discrete area of research with a wide range of analyzes, which in turn may indicate a multi-criteria approach in making decisions regarding IP assessment and prioritization.

In the methods analyzed, no approach was taken into account that includes psychological conditions of project managers (experts) during assessing and prioritizing IP. This approach could provide more objective and rational decision-making (Deptuła and Rudnik, 2018).

The conducted analysis allows to indicate further research directions. It is worth continuing them in order to indicate the advantages and disadvantages of the indicated methods.

The main limitation is the analysis in the scope of topic “improvement project selection” including the Thompson/Reuters Web of Science. This is the first stage of a literature review that will be continued including the results from the Scopus database.

The presented classification is an introduction to carry out a characteristics/comparison of individual methods and indication of their advantages and disadvantages.

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Small and Medium Enterprises Pursuing Organizational Excellence: A Toolkit for Improvement

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STRUCTURED ABSTRACT

Purpose - This paper presents the development of a new organizational excellence tool specifically for use by small and medium-sized enterprises (SME) while implementing business excellence models. A literature review was conducted to analyse the current state of business excellence models and their content and application around the world, including the identification of key principles that drive their creation and implementation. In this paper, we present a framework that has been validated by an Expert Panel of Organizational Excellence Professionals, considering the unique characteristics of SME and their industry contexts. It is hoped that this toolkit will allow these companies to strive for organizational excellence through a framework that is better suited to their context and needs.

Design/methodology/approach - An initial extensive literature review was conducted on the topics of Excellence Frameworks, Excellence Programs, Excellence Awards and the different contextual environments between LE and SME. Based on the literature review, we began by reviewing several scientific articles aimed at understanding the different contexts of LE and SME. From this point of view, and with a focus on small and medium-sized enterprises, we emphasized the themes that offered a better fit to the needs of these organizations and that, as a result, should be integrated into this framework. The Quality and Organizational Excellence Framework for Small and Medium Enterprises (QOE-SME) was built based on the weaknesses and shortcomings found in the use and implementation of SME's excellence models. The model was then validated by a group of quality experts through an online survey. This group was chosen based on criteria for reaching out to people who, in both academia and industry, have carried out significant and appropriate research in the field of organizational excellence and/or in the field of quality promotion and superior performance in SME.

Findings - Organizational excellence programs have created a catalyst and frameworks for improved success and productivity within large organisations. However, small and medium-sized organizations often try to achieve the same results using these same structures. However, evidence suggests that some of these frameworks are seen as unrealistic and difficult to implement. These implementation levels and records of positive implementation of OE models in SME are still small. The question is seen by both practitioners and researchers because of the various implementation difficulties faced by SME. Such perceived difficulties contributed to the development of the QOE-SME Framework.

Keywords: organisational excellence, excellence frameworks, small and medium enterprises.

Paper type: Research paper

INTRODUCTION

Small and Medium Enterprises (SME) operate in an extremely competitive market environment, often dealing with the same challenges as Large Enterprises (LE) while having more limited resources. Despite these limitations, and in order to compete in increasingly complex markets, SME must continue to adapt and improve in order to remain relevant. In the face of this reality, SME are becoming increasingly aware of Organizational Excellence (OE), recognizing it as a pathway for achieving competitive edge (Foote, Gaffney and Evans, 2010), and adopting existing Excellence models to guide them in achieving the benefits of organizational excellence (Arif, 2007).

However, while reports show that Excellence models can play a big role in maintaining an SME's competitiveness (Bauer, Falshaw and Oakland, 2005), several studies also show that SME often find it difficult to deploy and implement these models (Murphy, 2016; Wilkes and Dale, 1998). In fact, the truth is that most Excellence models have been designed for LE (Dahlgaard *et al.*, 2013; Olaru *et al.*, 2010; Armitage, 2002; McAdam, 2000; Ghobadian and Gallear, 1996), making it challenging for SME to successfully implement and efficiently use them to their full potential (Dahlgaard *et al.*, 2013). Although shorter or adapted approaches have been developed with a focus on SME, this does not seem to be enough to fully align with the needs of SME (Olaru *et al.*, 2010). SME comprise more than 80% of worldwide companies, but LE continue to be the drivers of new Quality and Excellence initiatives (McAdam, 2000). Consistently, there are also reports that some SME find OE programs and models too complex and decontextualized from SME's reality and market (Armitage, 2002; Ghobadian and Gallear, 1996).

Based on these somewhat conflicting reports, we believe the negative views may point towards a gap between the formulation of OE strategies and their deployment. Accordingly, there is a clear need for a review of the different dimensions that influence the deployment of Organizational Excellence strategies. To help SME overcome these challenges, it is important to highlight the criteria and strategic items that, in the face of the current market landscape, are vital for the successful implementation of an OE Model. As a result, we have designed a conceptual framework that lists the different factors - with different levels of detail - that potentiate a successful pursuit of Excellence. By doing so, we hope to help guide SME as they look to more efficiently implement Organizational Excellence initiatives.

QOE-SME Framework Development

The QOE-SME framework proposed here is based on a detailed review of four existing and internationally recognized Quality and Organizational Excellence frameworks. They are (1) the Shingo Model, (2) the ZED Program, (3) the EFQM and (4) Baldrige Excellence Framework. The study reviewed these frameworks since they combine a high rate of acceptance, application in industrial contexts, and focus on the necessary elements considered vital for a company's success. These elements are identified as (1) culture, (2) sustainability, (3)/(4) processes and (3)/(4) leadership/strategy.

In the design and development phase of the QOE-SME framework, we strived to ensure a simple and succinct representation. The design of the model was inspired by Hofstede's cultural model presented as concentric rings, since the research team concluded this would be the easiest and clearest way of presenting the toolkit. This simplicity of design was identified as a key need through the literature review – a common concern was that OE frameworks were complicated and not easy for SME to implement as they had greater constraints than larger companies. The QOE-SME framework is a result of an extensive literature review into excellence frameworks and their impact / application in SME.

Framework Validation

While the model for SME proposed by the research team and described in this article is still undergoing its initial practical validation, it was developed with a strong practical knowledge base including a research team with vast experience consulting dozens of organizations, both on professional and academic projects, in both the US and Europe. In addition, the model, including the dimensions, criteria, and tactical elements found within, were reviewed by a panel of 20 Organizational Excellence and SME experts. This panel consisted of both academics and industrial practitioners that work directly with SME and with representatives from countries around the world, namely: Brazil, China, Italy, Japan, Portugal, Spain, and the United States.

The panel was asked about their perceptions in different domains, resulting in six multiple choice statements based on a 5-point Likert scale- Table 1.

Table 1 – Statements evaluated by the expert panel.

Statements	The model presents a logical evolution through the different levels (dimension→criterion→item).
	The ontology used to define each level was well chosen (dimensions, criteria, items).
	The criteria are well organized according to the respective dimension.
	The model fits the reality/environment of SMEs.
	The QOE-SME Framework will be useful and able to be implemented by SMEs.
	The QOE-SME Framework is innovative in the organizational excellence models' literature field.

Results showed that in all 6 domains approximately 82% of the experts perceive the model positively, as indicated by a score equal to or greater than 4 out of 5. The version of the model presented in this article already reflects the iterations with the panel. Figures 3 to 8 summarize the experts' perceptions regarding the QOE-SME framework presented to them.

Figure 1 shows the distribution of the responses according to the perceptions regarding the logical evolution of the model's levels (Dimensions → Criteria → Items). The results show a high agreement with the evolution adopted, with approximately 89% of the experts agreeing with it. On the other hand, only 5.56% disagree with the suggested evolution and 5.56% maintain a neutral stance concerning the labels suggested.

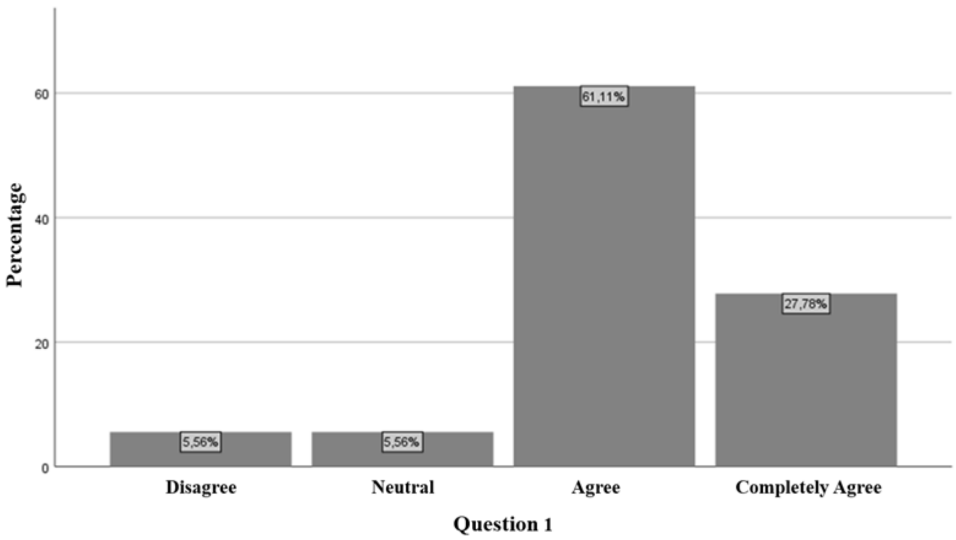

Figure 1. Perceptions regarding the logical evolution of the levels.

In addition, 94% of the respondents agreed with the ontology, leaving only a small portion (5.56%) that remains neutral on this question (Figure 2).

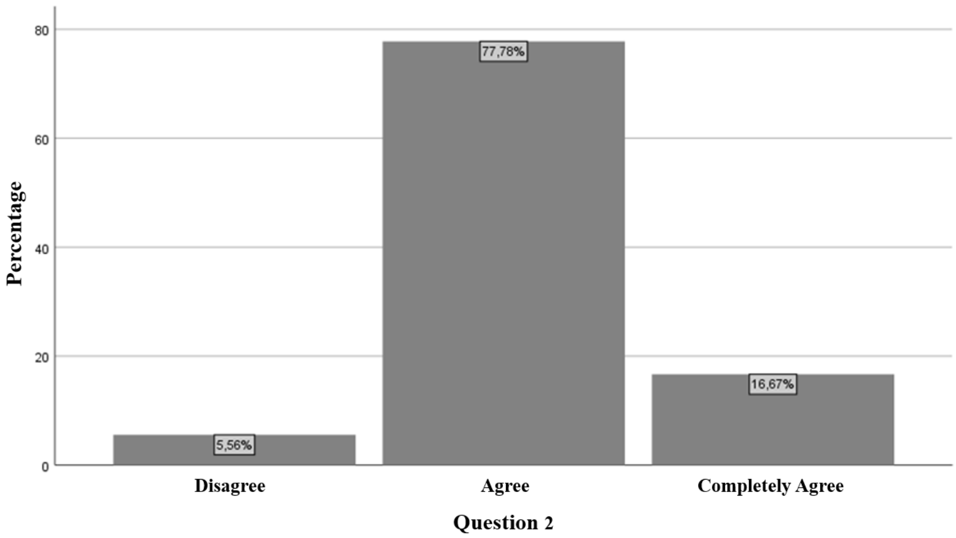

Figure 2. Perceptions according to the ontology used.

When asked about the distribution of the criteria by the different dimensions (Figure 3), 88.89% of the experts agree with the proposed work - only 11.11% answered 'neutral' which reveals a small level of uncertainty regarding this topic.

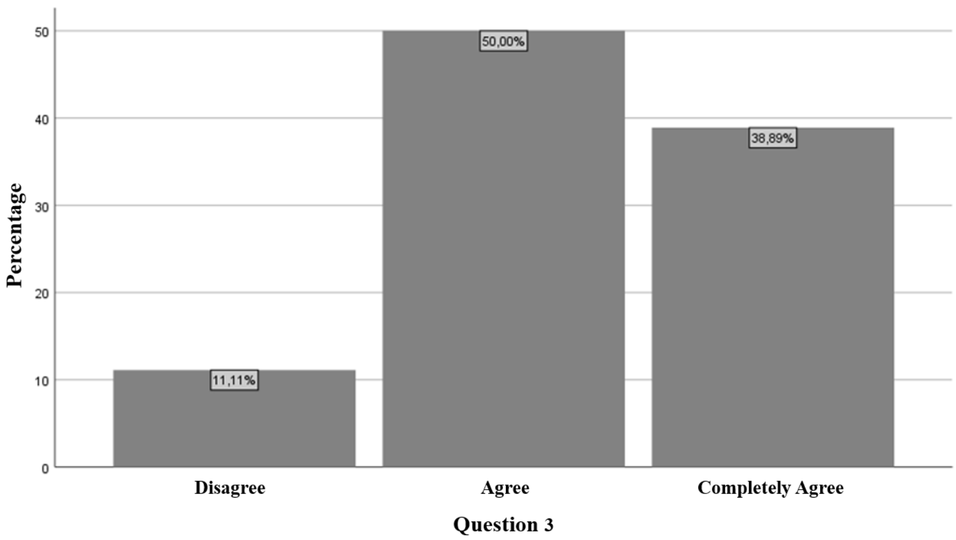

Figure 3. Perceptions about the fit between criteria and dimensions.

Figure 4 shows the distribution of the responses relative to the perceptions regarding the suitability of the model for use in SME. Approximately 78% of respondents believe that the model will succeed when implemented in SME, since it considers their reality of action. However, one should not disregard the 11.11% who disagree, this being an indicator of the importance of industrial implementation and testing of the model through actual application within case companies.

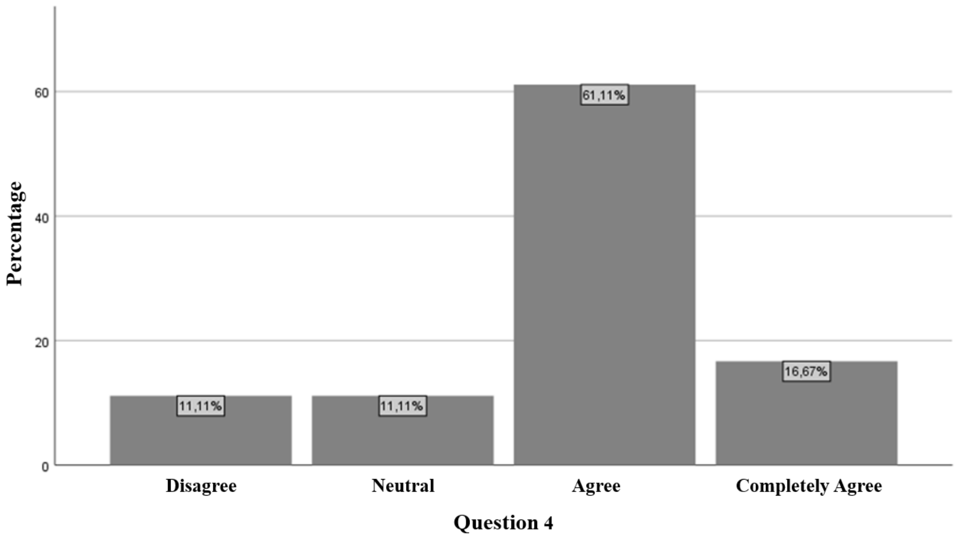

Figure 4. Perceptions regarding the suitability of the model to the reality of SME.

Regarding Figure 5 and its concerns - perceptions regarding the usability of the model in SME - about 67% of the experts believe that, in addition to being implementable, the model will be useful to SME in the quest for organizational excellence. On the other hand, 33.33% of the experts show some uncertainty regarding this topic. This uncertainty should once again be considered as a priority and supports the need to verify the usefulness of the model through implementation via case studies.

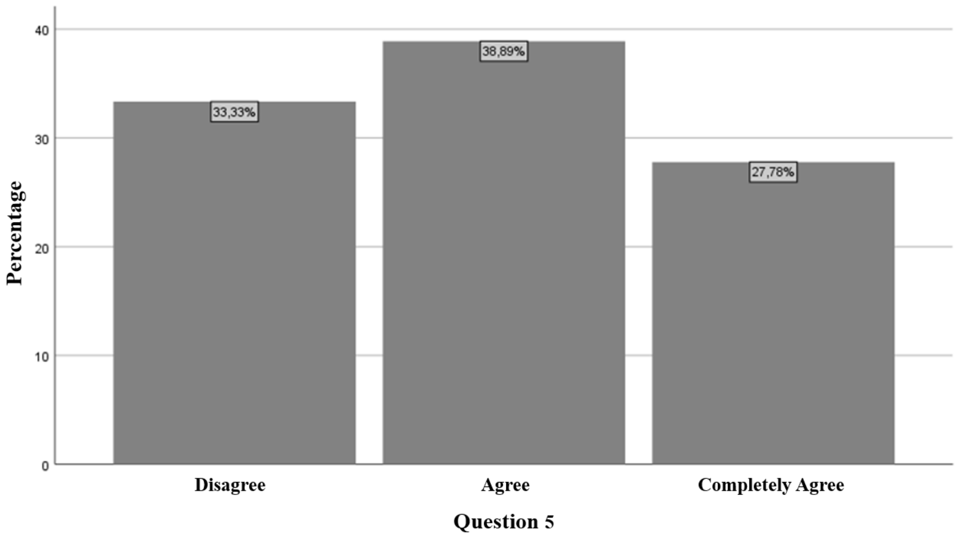

Figure 5. Perceptions about the usability of the model in SME.

Finally, when asked about their perception of the model with respect to its innovative aspect, about 72% of the specialists believe that it is a model that presents innovation with those already existing in literature (Figure 6).

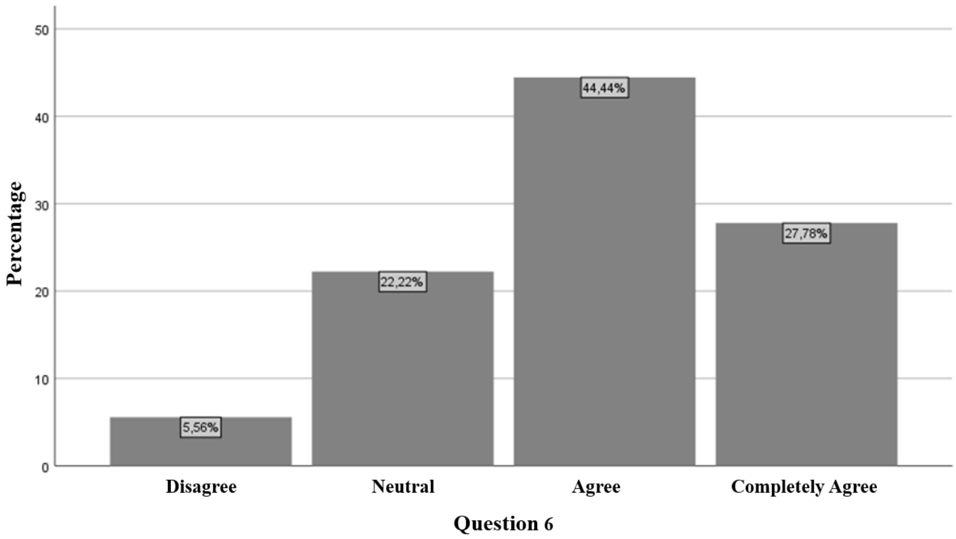

Figure 6. Perception regarding the innovation of the model in relation to the existing ones.

After treatment of qualitative data from the answers provided by the 20 experts, the QOE-SME framework was improved. This toolkit underwent through changes in the three levels, namely: (a) replacement of items by other important ones in the context of an SME (Example: Insertion of the Innovation item), (b) level change between leadership and management, considering the opinions presented and new literature and (c) reconstruction of the third level of the model.

The QOE-SME Framework

The purpose of offering a conceptual model is to promote an understanding of the key dimensions, criteria and tactical elements that are vital for the successful implementation of Excellence initiatives in SME.

The Quality and Organizational Excellence Model for Small and Medium Enterprises (QOE-SME Model) presented in this article is divided into three distinct levels, each level providing more tactical detail than the last. Accordingly, while designing the QOE-SME Model, focus was first put on identifying the dimensions that are particularly critical for enabling SME to reach their Excellence potential. These were identified by researching various excellence models and comparing their defined dimensions, enablers or critical success factors with the limitations and constraints reported by SME worldwide. Internationally recognized Quality and Organizational Excellence models reviewed include (a) the Shingo Model, (b) the Zero Effects, Zero Defects (ZED) Program, (c) the European Foundation for Quality Management (EFQM) Model and (d) the Baldrige Excellence

Framework. These models were selected because they each not only combine a high rate of global acceptance and have application in industrial contexts but also because some of them already focus on the pursuit of Excellence for SME. We now intend to further discuss this topic, by making public information that may help SME to better understand how they can achieve OE through these frameworks.

In its first and highest level (Figure 7), the QOE-SME model defines its dimensions. Dimensions, in this context, represent the main domains that OE models often deploy in order to achieve excellence. As a result of an extensive literature review, a set of core dimensions were identified by the team as the main contributors specific to an SME's success regarding OE (Talwar, 2011; Kumar, 2007). These are (a) Values, (b) Leadership, (c) Strategy, (d) Culture and (e) Stakeholders.

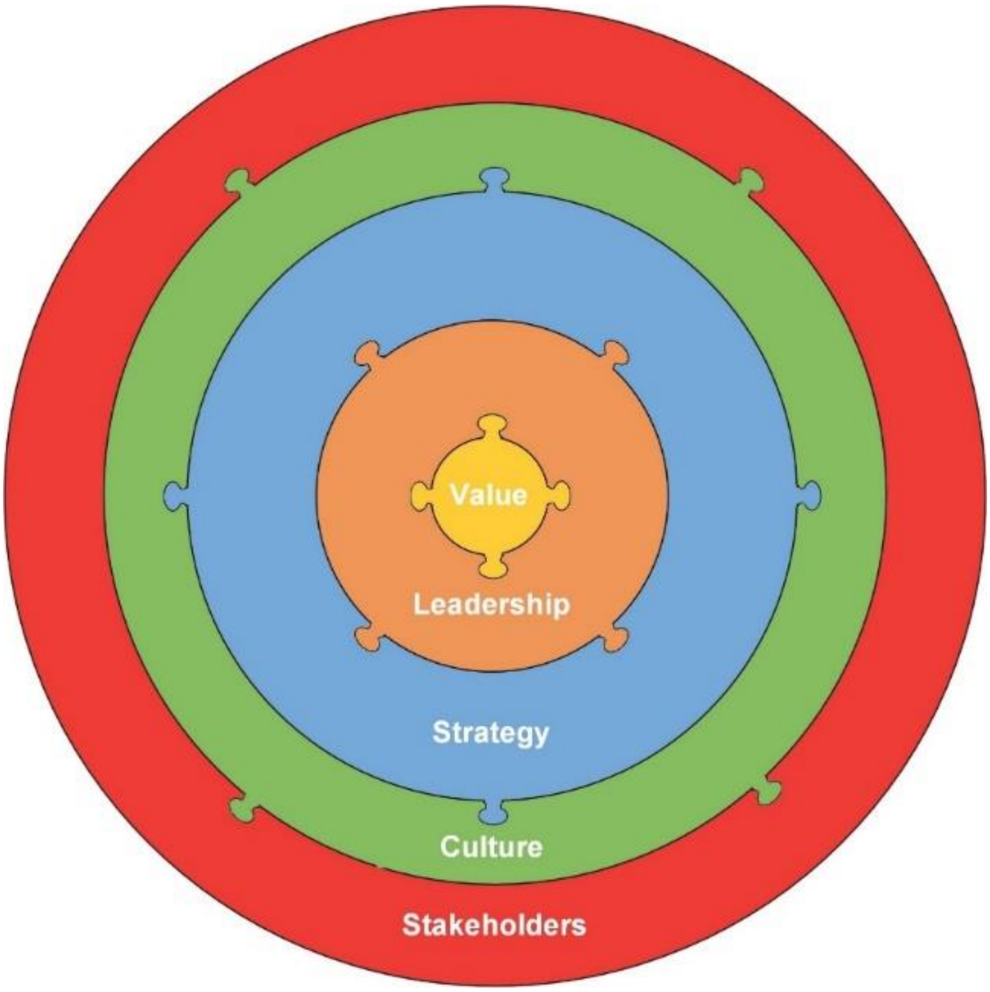

Figure 7 - First Level of the QOE-SME Conceptual Model (Dimensions).

These dimensions foster the basis of the QOE-SME model and its definitions can be found in Table 2.

Table 2 - Dimensions of the Conceptual Model.

Dimensions	Value
	Leadership
	Strategy
	Culture
	Stakeholders

As we begin our dive into these dimensions, adding the first level of detail to the model, the target criteria for SME striving to reach Excellence becomes better defined. The model's center criteria, Value, is defined as providing Products or Services that costumers recognize as being worth the price, they pay for them. Leadership is broken into sociotechnical perspectives that, much like excellence criteria from EFQM and MBNQA, includes the involvement of Top (1) Management, the engagement of (2) People and a clear focus on (3) Processes. The strategy criteria are further segmented into three key differentiated strategic approaches that allow organizations to leverage the opportunities and meet the needs of not only current but future market demands: (1) Digital Transformation, (2) Sustainability and (3) Agility. Culture includes (1) Behaviors, (2) Principles and (3) Artifacts. While behaviors and principles may be observable, they are not always tangible. Artifacts are typically physical items that reveal valuable information about an organization and its culture and can include evidence such as infrastructure, dress codes, documents, language or communication formats. Defining culture from these three perspectives is essential to ensure leaders do not simply define what they want their culture to be but also seek evidence, through observed behaviors, recognized principles and visible artifacts, of what their culture actually is (Carvalho *et al.*, 2017; Schein, 1983). Finally, Stakeholders highlight (1) Customers, (2) Partners and (3) Society, since interests in companies come not only from our costumers but also from others with a real or perceived interest in our organizations.

These criteria can be seen in Figure 8. This visual representation allows SME to successively understand the intermediate level of the model and its connection with the dimension level. Criteria are listed in Table 3.

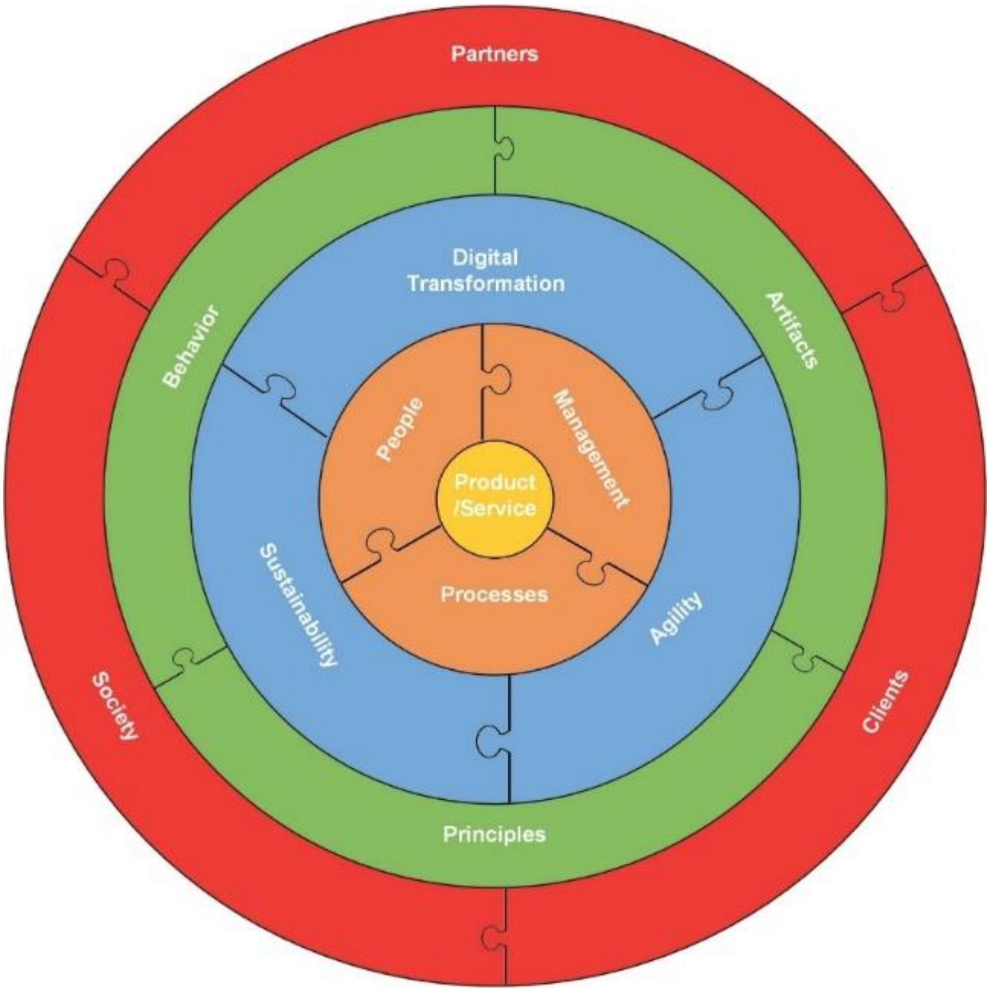

Figure 8 - Second Level of the QOE-SME Model (Criteria).

Table 3 - Dimensions: deployment by criteria.

Value	Product/Service
Leadership	Management
	People
	Processes
Strategy (new strategic areas)	Digital Transformation
	Sustainability
	Agility
Culture	Behaviors
	Principles
	Artifacts
Stakeholders	Costumers
	Partners
	Society

Each criterion identified in the intermediate level was segmented to provide additional details. This leads us to the final level of the model, which follows the purpose of enabling SME to assess in detail the more tactical elements that will influence their performance, processes, and results (see Table 4).

Table 4 - Criteria: deployment by items.

Product / Service	**Meeting Deadlines**	Continuous compliance with deadlines, establishing a reliable reputation and promoting customer loyalty.
	Conformity	A measure of how the product and / or service meets the criteria planned and expected by the customer.
	Delighted Costumer	Promotion of a high sense of customer satisfaction, achieved by the immediate fulfillment of their needs when those are more desirable.
Management	**Effective Communication**	The perceived organizational goals and, consequently, the efficiency and effectiveness of its communication through the organization.
	Team Enthusiasm	A team's satisfaction with the interactions that they establish among themselves and with other teams of the organization, promoting an increase of joint work.
	Alignment (of business strategy and processes)	Process alignment that consists of a progressive and extremely dynamic phenomenon, allowing the achievement of goals in all divisions of the organization.
People	**Training**	Continuous development of employees.
	Motivation	Maximizing productivity and increasing organizational efficiency through Motivation.
	Employee Satisfaction	Maintaining positive emotional responses regarding the products or services that an organization provides.
Processes	**Innovation**	Creating a single network processed conferring advantage to the organization.
	Mapping	Maps of the core processes, having a higher level of abstraction and illustrating these organizational processes.
	Continuous Improvement	Continuously monitoring the processes and avoiding waste due to non-compliance with customer specifications.
Digital Transformation	**Use of technology**	Acquisition and use of technology, finding positive and consistent associations with a better organizational performance.
	Systems Integration	Use of existing data and functionalities in the organization or in the various linked systems, making it not necessary to use specific programs or databases to access certain information.
	Digitalization and Connectivity	Systems that connect the virtual and physical worlds.
Agility	**Flexibility**	The degree that an organization has in management capacity, and also the speed with which that capacity can be activated, in the sense of increasing the adjustment control of its internal environment to respond to changes in the external environment.
	Team Dynamics	Teams with high levels of performance, in order to understand the critical success factors in teamwork.
	Decision-making Process	The process of selecting an alternative among a set of several others, promoting the achievement of organizational objectives and goals.
	Operational Development	A set of goals, looking for future's vision based on organizational sustainability.
Sust aina bilit	**Sustainable Use (of natural resources)**	The responsibility that society expects companies to have regarding the use of natural resources and other environmental impacts generated by their activities.

	Organizational Transparency	The importance of opening the flow of information.
Principles	**Organizational Values**	Abstract rules that can be applied to several organizational experiences.
	Individual Behavior	Understanding the values and their implications in the actions of the employees of a given organization.
	Norms	Expectations and rules by which a culture guides the behavior of all its members in any situation.
Behavior	**Commitment**	The vision of the organization as an element that provides the possibility of union among all employees in the organization.
	Cooperation	The improvement of diverse characteristics such as communication, participation and effectiveness through Cooperation.
	Multidisciplinary	Teams that comprise members of various functions and have demonstrated positive results for the organization and are recognized for their value in the decision-making process.
Artifacts	**Organizational Orientation**	The importance to consider the ability to proceed to a clear definition of organizational culture to diagnose problems and develop better cultures.
	Documents	Effective document development and management.
	Infrastructures	Essential operating components such as policies, equipment, data, human resources and other external components.
Clients	**Client' Satisfaction**	It must be recognized that these are the main stakeholders, and, at the same time, their satisfaction is the main concern of the organization.
Partners	**Loyalty**	Loyalty is more profitable than the search for new customers.
	Strategic Partnerships	Organizational integration of external sources and Strategic Partnerships that positively influence their performance.
Society	**Benchmarking**	Management techniques used to identify performance failures and to improve organizational performance.
	Social Responsibility	Integrating organizations as part of solving major social and environmental problems.

This level is designed to give leadership a more tactical level of focus to drive the implementation of OE, with each item acting as a fundamental piece of a puzzle (Figure 9). Completing the puzzle results in progress regarding OE within an SME. Removing any element from the model may lead to an incomplete implementation, making it potentially difficult to achieve the full results of the OE strategies.

Figure 9 - Third Level of the QOE-SME Model (Tactical Elements).

CONCLUSIONS

Literature suggests that there is a gap between existing OE models and their successful deployment by SME (Murphy, 2016; Wilkes and Dale, 1998). While no OE model is perfect for all organizations, different models have shown to provide positive results for some smaller organizations. However, most SME still find it difficult to achieve OE as they consider that the adaptations made to OE models for LE to meet SME needs still do not provide enough information for their own environment (Olaru et al., 2010; McAdam, 2000; Armitage, 2002; Ghobadian and Gallear, 1996).

Thus, with this paper we intend to provide further information so OE can be met through easier and adapted techniques for SME. Accordingly, the Quality and Organizational Framework for Small and Medium Organizations provides an approach to support SME in efficiently implementing Organizational Excellence initiatives. The goal of this framework is thus not to compete or replace existing excellence models, but to help organizations in self-assessing their capabilities in a series of different dimensions. The strategic items included help close the gap in implementing excellence initiatives. This new toolkit was designed based on a strategic implementation of OE for SME and organizing the items that support it, which will help guide SME as they further seek to improve and to adapt to the demands of the ever-complex markets in which they compete

Despite all efforts, the model presents some limitations. In the first place, it will have a greater value for organizations that are already embedded in a quality culture, since these will more easily understand its applicability and importance. Secondly, some SME may find some complexity in the model because literature reports they seek prescriptive models, and in its domain – Organizational Excellence – prescription is not the suitable method. Finally, most SME focus their efforts on financial metrics, and the model proposed focus on several areas that are crucial for OE, which may result in some resistance to change. However, having in mind the feedback that the research team already received from the experts consulted, we truly believe that amazing results will be achieved through this work and soon will be presented to the scientific community.

ACKNOWLEDGMENTS

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DFMEAs with the New AIAG/VDA FMEA Handbook

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STRUCTURED ABSTRACT

Purpose

This paper provides guidance in using the recently released *AIAG/VDA FMEA Handbook* for performing a DFMEA for a component, assembly, or complete system.

Design/methodology/approach

This paper goes through the seven steps for performing a DFMEA per *AIAG/VDA FMEA Handbook* and provides guidance.

Findings

Guidance is provided for using the *AIAG/VDA FMEA Handbook* when performing a DFMEA.

Practical implications

The guidance in this paper can be used when conducting a *DFMEA. AIAG/VDA FMEA Handbook* requires the use of AP in place of RPN, which is a new approach and the use of AP requires the use of a table to derive the AP value. The *AIAG/VDA FMEA Handbook* provides a table; however, it is cumbersome to use. For ease of use, an organization should create a matrix based on the AP table and this paper provides an approach for doing so.

Originality/value (Mandatory)

The *AIAG/VDA FMEA Handbook* was released in 2019 and is not yet fully implemented across the automotive industry. Being a new standard with a heavily revised approach to DFMEAs, there is little guidance available relative to more traditional DFMEAs. This paper seeks to fill the gap in the literature.

Keywords: DFMEA, Standard, Design, Failure

Paper type: General review

INTRODUTION

The first standard for FMEA was MIL-P-1629 Procedure for performing a Failure Mode, Effects and Criticality Analysis (Design Failure Modes and Effects Analysis) (Carbone and Tippett 2004). Overtime, various industries developed new FMEA standards and several standards appeared for the automotive industry. The AIAG's (Automotive Industry Action Group) fourth Edition of the FMEA Manual and VDA's (German Association of the Automotive Industry) VDA Volume 4 governed FMEAs for many automotive industry suppliers. American OEMs (Original Equipment manufacturers) required the AIAG standard while German OEMs required the VDA standard. This was a problem for suppliers delivering the same part two German and American customers; they may need two separate FMEAs for the same product to meet their customer's requirements.

To alleviate this problem, a joint standard for was released by AIAG and VDA FMEAs in 2019; the *AIAG/VDA FMEA Handbook* (AIAG/VDA 2019). In addition to combining aspects of the AIAG and VDA standards, the new standard replaced the RPN (Risk Priority Number) with AP (Action Priority) and offers a new form suitable for both AIAG and VDA requirements (Barsalou 2020).

The standard covers both DFMEAs (Design Failure Modes and Effects Analysis) and PFMEAs (Design Failure Modes and Effects Analysis); however, this paper will be limited to discussing and explain DFMEAs per the new standard.

RESEARCH METODOLOGHY

As the standard is new, there is little research or case studies on the standard and this paper is a general review paper; therefore, it is of a descriptive and instructional nature and not an actual research paper. The AIAG/VDA FMEA Handbook has three phases with a total of seven steps for completing a DFMEA (AIAG/VDA 2019). This paper walks the reading through the steps in the order in which they are meant to be performed.

Planning and Preparation

A DFMEA per the AIAG/VDA FMEA Handbook begins with the Five Ts, consisting of determining the intent of the DFMEA, establishing the timing for the DFMEA, identifying team members, determining which tasks will be performed, and identifying which tool or software program will be used. Once a project plan is established, a baseline DFMEA, if available, should be evaluated as an older DFMEA may exist if the product is based on an older product. (AIAG/VDA 2019). Details pertaining to the DFMEA are listed in the form's header such as the one shown in Figure 1.

Design Failure Modes and Effects Analysis					
Planning and preparation					
Company		**Subject**			
Location		**Start date**		**DFMEA number**	
Customer		**Revision date**		**Responsibile**	
Model year & program		**Team**		**Confidentiality**	

Figure 1 - DFMEA form header

Structure Analysis

A new aspect of the *AIAG/VDA FMEA Handbook* is the structure analysis where system levels are identified. Three system levels are considered in the DFMEA form as shown in Figure 2. The focus element is the component, assembly, or system that is being evaluated. The next higher level would be an assembly if the focus element is a component and the end user if the focus element is the complete system. It may be advisable to include the next direct level and the end user as the consequence of a failure happens at the next higher level and is assessed from the view of the end user.

Structure analyis		
Higher level	**Focus element**	**Lower level or characteristic type**

Figure 2 – Structure analysis in the DFMEA form

The next lower level would be a component if the focus element is an assembly. The lower level can be a characteristic if the focus element is a component with no lower level component. For example, a surface roughness can be listed as the lower level for when the focus level is a component.

Previously, the AIAG recommended a boundary diagram be created when forming a DFMEA. A boundary diagram, also known as a block diagram, helps to identify the scope of the DFMEA (Carlson 2012). The components and assemblies of a system are listed in blocks and a box with dotted lines represents the limits of the system; interactions are depicted with the use of arrows which may be color coted or might use different lines types to represented different things such as heat transfer or physical touch conditions. An example of a boundary disarm is shown in Figure e3.

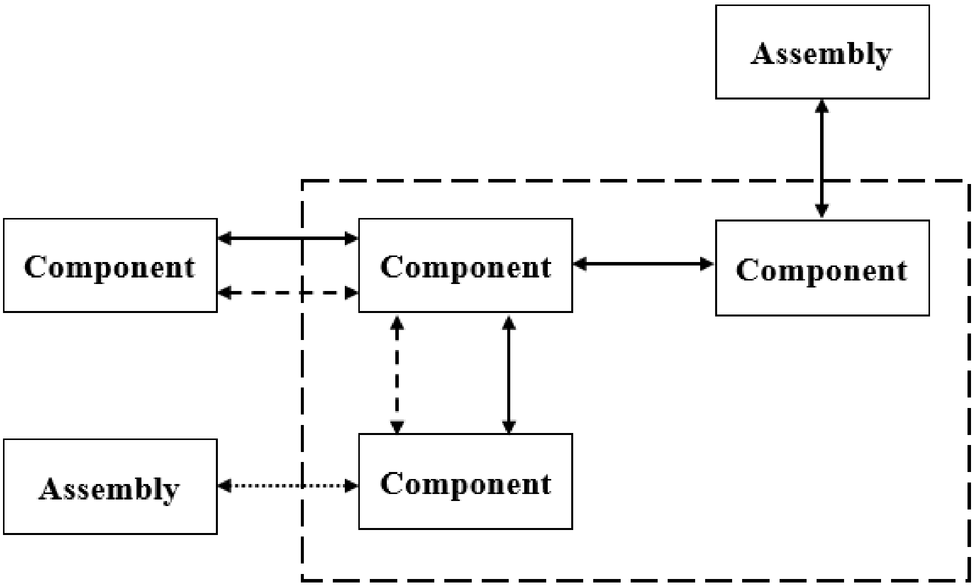

Figure 3 – Boundary diagram

A structure tree was used for VDA style DFMEAs (VDA 2003). Here, the relationship between components and assemblies in a system are graphically depicted such as in the example in Figure 4. In VDA style DFMEA, the structure tree was typically achieved though the use of a DFMEA software program.

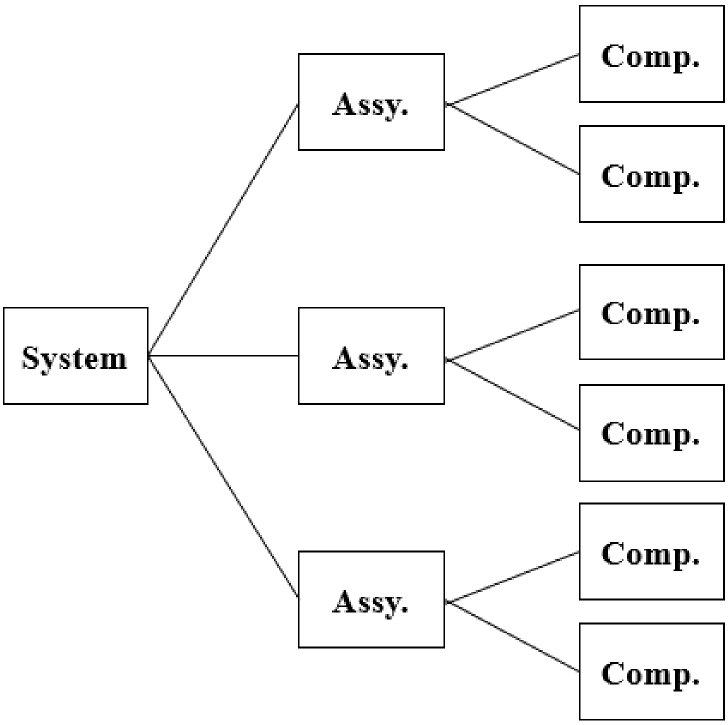

Figure 4 –Structure tree

With the harmonized standard, either a boundary diagram or a structure tree can be used (AIAG/VDA 2019). This makes it easier for an organization supplying both German and American companies to conform to the standard without the need to create separate DFMEAs for the same product.

Alternatively, an organization is free to use both a boundary diagram and structure tree as the two are not mutually exclusive.

Function Analysis

The function analysis is performed once the structure analysis is completed. Here, functions and requirements are assigned to the focus element, higher level, and lower level system elements. The functions are derived form requirements or specifications and describe what the system element must do. One system element may have multiple functions such as provide stability and resist corrosion. Functions should be described in represent tense using an action verb and a noun. The function analysis section of the DFMEA form is depicted in Figure 5.

Function analysis		
Higher level function and requirement	Focus element function and requirement	Lower level function and requirement or characteristic

Figure 5 – Function analysis in the DFMEA form

To assist with identifying functions, the new standard offers a P-diagram (parameter diagram), which graphically depicts inputs and outputs, control factors, error states, and noise factors (Yang and Basem 2009). The noise factors in a P-diagram are uncontrollable influences such as variation between parts, changes over time, the way in which the end user uses a product, the environment, and interactions with other system.

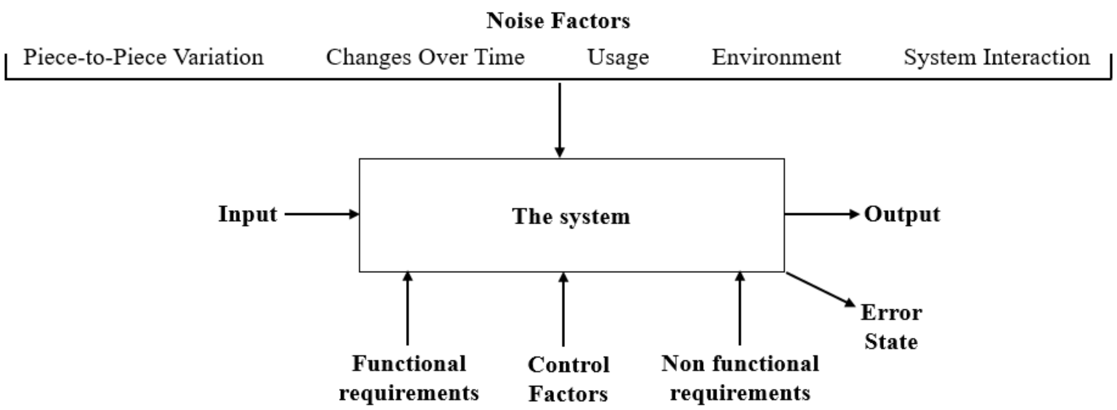

Figure 6 - P-diagram

Failure Analysis

The failure analysis is where failure effects, failure mode, and failure cause are identified and the severity of the failure effect is rated. An example of the DFMEA form is depicted in Figure 7.

Failure analysis			
Failure effects	Severity	Failure mode	Failure cause

Figure 7 – Failure analysis in the DFMEA form

When viewing the entire system, failure effect, failure mode, and failure cause are relative and the labels are assigned based on the focus element. A failure mode is at the focus element, failure effects are at higher level system elements, and failure causes are located at lower level system elements. This means that if a component is the focus element, the failure mode is at the component and the component has a failure effect at the higher level assembly and a cause at a lower level component or characteristic; however, if the assembly becomes the focus element, the former failure effect becomes a failure mode and the component's failure mode becomes a failure cause. This aspect of the standard originated in the VDA standard.

A failure effect is the consequence of a failure and the failure effect takes place at the next higher level system element and/or at the end user. This is not actually a significant change as previously a failure effect could happen at a component or assembly, at the entire system or the end user or a government regulation (Stamatis 2003). Now, One way to list failure effects in eth DFMEA form would be to list the failure effect of a component failure at the assembly and also list the final failure effect of a failure at the system level from the customer view. The effect of the failure on the end user is what is used to asses severity, which is rated using a table with a scale of 1 to 10 (Breyfogle 2008).

The failure mode describes how a component, assembly, or system fails to perform the required function (Pillay and Wang 2003). Failure modes should be written in technical terms such as component rusted.

The root cause of a failure mode is the failure cause (Daydem Press 2003). An example of a failure cause is wrong material specified for the intended use. The noise factors in the P-diagram should be observed and considered as some may potentially be failure causes.

The severity of the failure effect is rated on a scale of 1 to 10 using a table (Breyfogle 2008) with higher numbers indicating a more severe consequence of a failure. For example, a severity of 10 is often used when there is risk of injury or death and a severity of 9 is used when there is a violation of legal requirements.

Risk Analysis

The risk analysis is where current prevention and detection actions are listed. The risk assessment also takes place during this phase. Figure 8 shows the risk analysis section of the DFMEA form with fields for listing the current controls for prevention and detection, which must be identified here.

Risk analysis					
Current prevention control	Occurrence	Current detection controls	Detection	AP	Filter Code

Figure 8 – Risk analysis in the DFMEA form

Current controls are actions that will be taken; these may be ensured through currently existing procedures, process descriptions, or test plans. Prevention actions are taken to ensure the failure cause does not occur. Typical design controls include following a design guideline or performing a tolerance stackup calculation. Prevention actions are intended to detect either the failure mode or the failure cause if the failure should occur. Typical detection actions include functional testing and durability tests.

Once prevention and detection actions are identified, they are rated. The occurrence rating in a DFMEA is the chance of a failure cause occurring is rated on a scale of 1 to 10 (Borror 2009) and the likelihood of detecting the failure or the failure cause is rated using a detection table with a scale of 1 to 10 (Tague 2005). The standard provides assessment tables for both occurrence and detection and organization specific examples may be added to the tables.

For over half a sentry, risk prioritization in FMEAs was based on the PRN number (George et. Al 2005). The RPN is determined by multiplying severity times occurrence times detection (Stamatis 2015). Potentially the most significant change with the new standard is replacing RPN with AP. An

AP is determined though the use of tables with severity carrying more weight than occurrence and occurrence carrying more weight than detection.

Use of an RPN number for prioritization is intended to prioritize higher risks over lower risks; however, an RPN number alone could result in prioritizing improvement actions for a failure mode that could result in fatal consequence over a failure mode with minimal impact such a moderately objectionable visual blemish. For example, a severity of 3 with an occurrence of 10 and a detection of 4 has an RPN of 120 while a severity of 10 with an occurrence of 4 with a detection of 2 has an RPN of 80. In this example, a frequently occurring failure with minimal impact on the end user is prioritized over a rarer failure with a threat to the safety of the end user. Prioritizing with AP would result in an L for the former and an H for the latter.

Although the use of AP has advantages over RPN, the use of the table is more complicated than simply multiplying three numbers together. The table consist of over 100 cells and occupies 2 pages of the standard. As an alternative to the AP table, an organization should consider creating an AP matrix such as the one shown in Figure 9.

		Severity 1	Severity 2-3				Severity 4-6				Severity 7-8				Severity 9-10			
Occurrence	8-10	L	L	L	M	M	M	M	H	H	H	H	H	H	H	H	H	H
	6-7	L	L	L	L	L	L	M	M	M	M	H	H	H	H	H	H	H
	4-5	L	L	L	L	L	L	L	L	M	M	M	M	H	M	H	H	H
	2-3	L	L	L	L	L	L	L	L	L	L	L	M	M	L	L	M	H
	1	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	M	H
		1-10	1	2-4	5-6	7-10	1	2-4	5-6	7-10	1	2-4	5-6	7-10	1	2-4	5-6	7-10
		Detection																

Figure 9 – AP matrix

The new form has a column called filter code, which is a replacement for the column that would have one listed special characteristics, which are no longer required to be listed in the DFMEA. This optional column can be used to highlight special risks as inputs for the PFMEA.

Optimization

Actions must be identified for all items with an AP of H and can be identified for items with an AP of M. Here, resources should be considered. Ratings of M should be improved if there are sufficient time and resources available and resources are not pulled away from ratings of H. The optimization section of the DFMEA form is shown in Figure 10.

Optimization										
Prevention action	Detection action	Responsible person	Target completion date	Status	Action taken with evidence	Completion Date	Severity	Occurrence	Detection	AP

Figure 10 – Optimization in the DFMEA form

Improvement actions in the DFMEAs are now referred to as optimization actions. These actions can be taken for the prevention actions or the detection action. A change in the severity rating would have the greatest impact due to severity carrying more weight in the AP table; however, Severity can only be changed if the design is changed or the intended use is changed (Sheehy et. Al 2002). Better actions for preventing to detecting a failure have no impact on the severity of the failure if it should occur. For example, suppose a type of coolant that can't legally be released into the environment is used in a system. A leakage would have a severity of 9 as it would result in a violation of legal requirements; increasing wall thickness of a component may reduce the change of failure occurring, but the consequences would remain unchanged. Replacing the coolant with an environmentally friendly substitute would reduce the severity; however, the new concept should be assessed for additional risks.

Identified optimization actions are listed in the DFMEA form and a person must be designated as being responsible for the action. Avoiding assigning reasonability to those who are not members of the DFMEA team when the actions will be performed by somebody outside of the DFMEA team such as a supplier or customer. In such situations, a member of the DFEA team should be designated as responsible for informing those who will perform the actions and this individual should report the status of the action to the DFMEA form.

A target date and status must be given. The three recommended status are open for when no action has been defined, completed for finished actions that have been verified and documented as effective, and not implemented for when an action has been identified, but when a decision not to implement the action has been made. There are also two optional statuses; decision pending for when the decision to implement it has not yet been made and implementation pending for when a decision to implement an action has been made, but the implementation is not complete.

Upon completion, the actions taken are described and supporting evidence is listed. A completion date is then given and the severity or occurrence is reassessed and a new AP is determined. If necessary, additional optimization actions can be defined.

The implemented optimizations can be transferred to the current controls section of the DFMEA if they will be standard actions in the future and the DFMEA will be used as a template for future projects. However, the original DFMEA should be left as-is as a record of actions taken and the transfer from optimization to current controls should only happen in DFMEAs used for future projects.

Results Documentation

The seventh and final step of performing a DFMEA per the new standard is the documentation of results. Here, actions taken are to be documented and records showing the reduction of risks are to be saved. The results of the DFMEA are also to be communicated. An FMEA report can be used for communicating the content of the DFMEA; the exact content of the report is an individual organization’s choice; however, the report should contain a detailed summary of the DFMEA including the scope pf the DFMEA, participants, a summary of how the functions were identified and a summary of high risks as well as actions taken to address the high risks.

RESULTS

Over the next few years, automotive industry suppliers must convert to the DFMEAs per the new standard. Although the revision is extensive, the changes are not insurmountable. The main changes are the layout of the DFMEA form, potentially new optional tools, and use of AP in place of RPN.

CONCLUSIONS

For suppliers delivering per the old AIAG, the use of the structure tree is new. However, use of the structure tree is optional and the basic concept is not so far removed from how thing were previously done; for example, a failure mode at a component would generally have a failure effect at the assembly or system level and a cause at a characteristic.

For suppliers that have delivered per VDA requirements, the structure tree is nothing new and the boundary diagram and p-diagram are additional non-mandatory tools. Although not required, they could both be beneficial for gaining a better understanding of the system when performing a DFMEA.

The new standard is intended for the automotive industry and only time can tell if any aspects of the standard will be carried over to outside of the automotive industry. Even without use of the new form, implementing the concept of AP in place of RPN would be an improvement to DFMEAs. Therefore, although specific to the automotive industry, the information presented here can be applied across industries.

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Leadership in the current Quality Management paradigm

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STRUCTURED ABSTRACT

Purpose: The current Quality Management (QM) paradigm, designated as Emergency, instigates a quality culture with openness to change in which leadership is essential due to its role in the change process. This work aims to portray the state of the art that combines QM and Leadership that could ground a proposition that leadership has an increasingly important role in the current QM paradigm. It also pretends to identify the main theoretical foundations (concepts, models, measuring instruments, interrelationship studies) to understand the role of transformational leadership in QMS maturity to overcome the changes resulting from the current context´s pressures.

Design/methodology/approach - A Systematic Literature Review was performed following the steps suggested by Denyer and Tranfield, (2009). The analysis was supported by the content analysis methodology (Strauss and Corbin, 1990) (Strauss and Corbin, 1990), clustering four main themes: Publications, QM approaches, Leadership Approaches and Relationship between QM and Leadership.

Findings –The results indicate that the interest in leadership and QM has been manifested more expressively in the research field, with broad practical implications reflected in several sectors of activity. It presented a collection of studies with different perspectives and approaches related to leadership and QM, pointing out conceptual models and measuring instruments as guidelines to deepen the role of leadership on QMS maturity.

Research limitations/implications - The sample was supported only on Scopus database, other multidisciplinary databases can be integrated to extend the results.

Originality/value – This research's novelty is the combined interest of transformational leadership and QMS maturity and to relate them with the challenger dynamic current context.

Keywords: Quality Management, Leadership, Systematic Literature Review, Change Management

Paper type: Literature review

INTRODUTION

Organizations face an increasingly complex and demanding context, so to meet the stakeholders' needs and expectations systematically becomes a significant challenge. Thus, companies must deal with changes, both into their structures and processes, procedures, and products.

The knowledge and understanding of the current and future stakeholders' needs, as well as the ability to develop solutions for their fulfillment, is an essential challenge Customer satisfaction is the focus of Quality Management (QM), which is considered an option for organizations to achieve competitiveness (Gunasekaran, Subramanian and Ngai, 2019). Integrated into this dynamic context, featured by flexibility, innovation and risk, a new QM paradigm flourishes with a culture more open to changes and based on networks (not only internal but also external) (van Kemenade and Hardjono, 2019). Therefore, the implementation of QM, namely through Quality Management Systems (QMS), has changed leading organizations to respond effectively to political, economic, and social changes. Organizations expect to recognize the value of the QMS, hoping that its mechanisms (tools, practices, procedures, and processes) support them to overcome the challenges imposed by the current context.

Does it mean that any company with a QMS is prepared to manage the changes arising from the external context effectively? It will depend on the QMS development level, designated as maturity. The maturity models describe the degree of consolidation of the practices adopted by an organization, highlighting good practices and a progressive trajectory in organizational development (Silveira, 2009). Some authors (Nascimento *et al.*, 2016) set that the highest stage of maturity is when the QMS support innovative planning able to adapt to environmental changes.

Nowadays, it is essential to be prepared for the constant mutation and growth and "following procedures is not a solution." Competencies such as "intercultural capabilities, adaptability, flexibility , and the ability to create synergies" are essential for leaders to conduct QMS (Van Kemenade, 2014). However, changes mean resistances and obstacles to overcome and the leadership is decisive in this change process. Leaders point out directions that inspire changes throughout the organization. The involvement of everyone in the change process minimizes the resistance resulting from the modifications (Randeree, 2008). Consequently, leadership plays a key role in QM maturity, namely in setting goals and strategies to achieve them through the involvement of all employees (Nguyen, Phan and Matsui, 2018).

In sum, the current most significant challenge is the change management where risk management, innovation, adaptability, and flexibility are key elements for the organization´s competitiveness. The QMS could support the overcoming of this challenge. However, it depends on the QMS maturity level, and leadership could be an essential factor in this progress.

Thus, the need to study together QM and Leadership in the current context is highlighted. Some authors identify as future research areas the relationships between leadership styles and the different stages of quality development, because various situations require different leaders (Pires and Saraiva, 2019).

A research project has been designed based on the proposition that leadership has an increasingly relevant role in the current QM paradigm, both for its importance in the evolution of QMS moving it to higher maturity levels, as well as for its role in managing change. It starts from the hypothesis that transformational leadership leads QMS to higher maturity levels and, therefore, prepares better organizations to change management resulting from the current context´s pressures. This paper describes the first project step proposing a systematic literature review to portray the state of the art that combines Quality Management and Leadership, unveiling the approaches followed, theoretical models in both areas, and different aspects of the interconnection between these two areas. It is also intended with these previous results to find academic support to the initial hypothesis and outline the future project research steps.

Thus, a section is presented with a literature review that summarizes and characterizes the theoretical constructs to underpin the research methodology conducted by a systematic literature review (SLR). In the last two sections, the results and conclusions are presented and discussed.

LITERATURE REVIEW

To support the primary theoretical constructs applied in SLR, this section fits the QM in the current paradigm, discusses the concept of maturity of QMS, and presents a succinct description of the theoretical leadership models.

Quality Management (QM) in the current paradigm and Quality Management Systems (QMS) Maturity

QM is one of the most important areas of discussion in modern management, being recognized by organizations as a strategy to pursue in the current competitive context. Kemenade and Hardjono, (2019) identify four quality management paradigms in the literature: The Empirical, the Reference, the Reflective, and the Emergency:

- In the Empirical Paradigm, quality is seen as “compliance with requirements,” it is objective and focuses on rules. The problems are technical and solved through science. The interest of this paradigm is the optimization of the material, financial and technological resources;

- However, as not everything can be measured through parameters, the Reference Paradigm emerges and provides models and guidelines instead of rules. It promotes continuous improvement and quality awards.

- The third paradigm, the Reflective, assumes that there is no universal reality, each person can have their perspective. It is a paradigm that promotes the sharing of views, it is subjective and based on aspects that cannot be observed.

- A fourth paradigm flourishes designated as Emergency and is still under development. This new paradigm is based on creating networks, both internal and external, fostering a culture of quality with openness to change. This paradigm bets on leadership, which is fundamental in implementing quality management systems and developing an effective organizational environment to involve all employees to pursue quality goals. The Emergency paradigm defines quality holistically, once considers all stakeholders´ needs and expectations and, therefore, adapt the way to solving problems considering each reality (Barbosa, Gambi and Gerolamo, 2017).

To achieve this last paradigm, organizations need to transfer QM to their strategy, structures, processes, and products. For this, organizations have relied on the implementation and monitoring of QMS. A QMS can be defined as a set of practices and techniques to minimize or prevent defects or gaps in an organization to improve its efficiency and pursue the organizational objectives (Barbosa, Gambi and Gerolamo, 2017). However, QMS cannot be closed or static, contrariwise, needs to be adaptable and flexible to respond to the pressures of the external context, showing the capability to face the Emergency paradigm mentioned above. QMS, through the involvement of all stakeholders and the development of a quality culture, contributes to the construction of open organizations aware of constant changes arising from external pressures. A QMS should bring together "self-regulation, learning, adaptation, and evolution" (Arif, 2016).

The QMS´ ability to adapt and evolve is designated as maturity. The maturity models describe the consolidation degree of the practices adopted by an organization, highlighting good practices and pointing a progressive trajectory in organizational development (Silveira, 2009). The concept of QMS maturity is referred in literature with several interpretations, being defined according to the number of the years of QMS´s implementation and certification (Sousa and Voss, 2009) or by the relationship with the best practices used (Patti, Hartman and Fok, 2001), or even associated with the assessment of quality perceived by customers and the effectiveness and efficiency of process management (Rosnah and Wan, 2010). Three perspectives can be found in the literature:

- Maturity Perspective: it is associated with the temporal dimension or age, indicating a more advanced state over the years (Fraser, Moultrie and Gregory, 2002; Sousa and Voss, 2009);

- Capability Perspective: it is the full development of a process or activity, ready to start the continuous improvement process (Nascimento *et al.*, 2016).

- Evolution Perspective: it defenses the evolutionary notion, advocating the adoption of good practices combined with adaptation to the context in which the organization operates (Lahti, Shamsuzzoha and Helo, 2009).

Higher degrees of predictability, capacity, control, effectiveness, and efficiency will correspond to each maturity level. Several contributions are found in the literature to support the assessment of maturity management practices. The authors Nascimento *et al.*, (2016) compile a set of approaches classified in maturity models, quality awards, and standards, as shown in table 1:

Table 5 – Classification for Maturity Approaches (adapted from Nascimento *et al.*, 2016)

Class	**Approach**
Maturity models	Crosby's Quality Management Maturity; Maturity continuous improvement Bressant, Caffyn and Gallagher; Erasmus University (Netherlands); Montgomery control model; CMM-Capability Maturity Model; Documentation Process Maturity; Human Factors Integration Capability Maturity Model; SCPM3 (Supply Chain Process Management Maturity Model); OPM3 (Organizational Project Management Maturity Model); PMMM (Project Management Maturity Model); MMGP (Maturity Model Project Management).
National Quality Awards	Deming Prize (Japan); Award Malcolm Baldrige National Quality Award (USA); National Quality Award (PNQ - Brazil); European Foundation Quality Management (EFQ – European Community) German National Quality Award (German Society for Quality Germany)
Standards	ISO 9004 - Managing for the sustained success of an organization- A quality management approach (2010); JIS Q 9005 - Quality Management System - guidelines for sustainable growth (2005);

The same authors (Nascimento *et al.*, 2016) have developed a maturity measuring instrument that encompasses the most emerging issues. It was supported on the Crosby Maturity Grid (Crosby, 2016) the National Quality Award PNQ (FNQ, 2011) and the JIS Q 9005 Standard – Quality (JIS, 2005). On table 2 are described five levels of maturity.

Table 2 – Level of Maturity (Nascimento *et al.*, 2016)

Level of Maturity	**Planning**	**Results**
1	There are flaws in the design or plan is not executed as planned.	The expected results are not produced. Lower results than competitors.
2	Procedures for ISO 9001 requirements are established and implemented.	The expected results are usually achieved. Similar results are comparing to competitors. The company is certified to ISO 9001.
3	The organizational profile is clearly established, and planning is effective, facing identified as actually needed items.	Expected results are always achieved. Similar results to competitors.
4	The organizational profile is clearly set against the competition. Planning is effective and efficient, facing important and necessary and fully implemented items.	Expected results are achieved efficiently. Better results than the competition.
5	Innovative planning able to adapt to environmental changes. Everyone shares lessons learned in the organization.	The expected results are produced efficiently and sustained in the organization, regardless of management and the environment. It is considered a model of excellence by competitors and customers.

Level 1 is characterized by poorly defined and contains unstructured practices resulting in unpredictable performance and high costs. Functional cooperation and customer satisfaction levels are low. At the second level, defined as basic in QMS, the organization prepares and documents its processes and performance is more predictable than the first level. At this level, ISO 9001 certification occurs, resulting in better customer satisfaction, albeit at a high cost. At the third level, the processes management is enhanced, with greater cooperation between organizational departments, suppliers, and customers, resulting in the hight level of customer satisfaction. At the fourth level, suppliers and customers strategically cooperate with the organization and the assessment of performance activities takes place widely, resulting in better monitoring and drastic cost reduction. Customer satisfaction, as well as team spirit, becomes a competitive advantage. At the final level, the company's quality management becomes a benchmark for competitors. The organization becomes more efficient and can adapt to the changes imposed by the organizational environment.

This maturity measuring instrument (Nascimento *et al.*, 2016) integrates a set of criteria from different individual models, and at level 5, it includes a stage of QMS able to plan innovative responses to the challenges of the context.

For the level escalation, there are several factors: structural, technical, technological, and behavioral. Focusing on the last factor, as already mentioned in the introduction, leadership plays a vital role in the involvement of all employees and the change process (Nguyen, Phan and Matsui, 2018). The next section contextualizes some concepts and leadership models.

Leadership

Leadership approaches are associated with variables that impact the changes that lead to organizations' success by fulfilling the objectives (Chiavenato, 2004). Leadership can be defined as personality characteristics that influence others to pursue the organization's goals, following their customers' needs and expectations (Barbosa, Gambi and Gerolamo, 2017). The influence process can be understood as dynamic and interactive, so leaders and followers have mutual influence and involve social exchanges (Yaghoubipoor, Puay Tee and Musa Ahmed, 2013). "A charismatic leader gains the trust of his followers, establishes a vision for the future and is respected" (Barbosa, Gambi and Gerolamo, 2017).

Contemporary leadership approaches seek to identify a leader as an agent of change and transformation. Bass and Avolio (2003) defend three leadership models: transactional, transformational, and non-transactional or laissez-faire.

Transactional leadership is based on an exchange of rewards for the effort and goals achieved. Leaders use incentives and their power of persuasion to achieve high levels of performance. However, this is not only translated into benefits, so punishments are also attributed to mistakes and failures committed.

Transformational leadership is built on the transactional model, but it goes further and achieves better results in terms of change. The focus is on developing team members and recognizing the individual needs and desires of each one. These leaders encourage employees to solve problems in different ways, promoting growth and quality. According to Bass (1995), four dimensions of transformational leadership can be distinguished:

- Idealized influence: Leaders assume the objectives of the organization and employees, demonstrating a spirit of sacrifice for the common goal, not expecting to be recognized or idolized;

-Inspirational motivation: leaders focus on the development of employees with concerns of ethics, truth and harmony;

- Intellectual stimulation: leaders admit that differences stimulate a critical spirit in finding solutions;

- Individual consideration: leaders encourage employees to succeed, helping and supporting them.

This leadership model is also very focused on change, which can be an asset for organizations in the current dynamic scenario (Xu, 2017);

In non-transactional or laissez-faire leadership, there is passive behavior. The leader avoids commitment and intervention in the organization's activities (Hirtz, Murray and Riordan, 2007). This type of leader usually does not establish goals and objectives for his workers, which difficult to organize work and continuous improvement (Barbosa, Gambi and Gerolamo, 2017).

Despite the advanced knowledge of leadership, the research focused on leadership continues to increase, mainly by its association with other areas (Pires and Saraiva, 2019). Top management leadership has an indirect effect on performance through its influence on QM practices, such as process management. Thus, these indirect and interactive relationships between leadership and QM performance lack widespread agreement among researchers, being an exciting field for the research field (Nair, 2006).

RESEARCH METODOLOGHY

To exhibit state of the art with scope both in Quality Management and Leadership, a Systematic Literature Review was performed, following the steps suggested by Denyer and Tranfield,(2009) structured on figure 1:

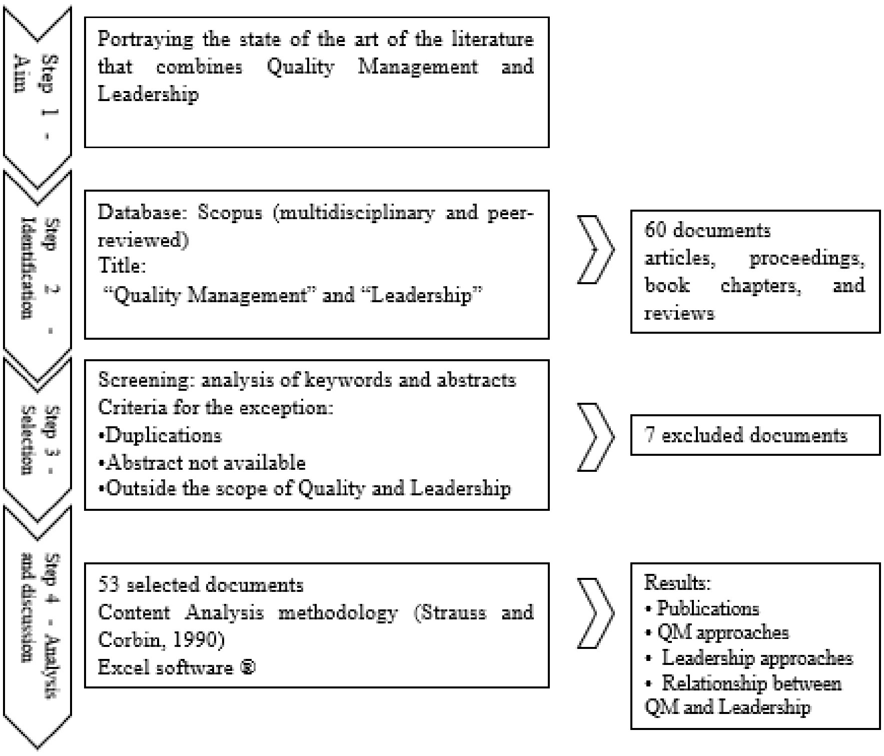

Figure 1 – Steps of Systematic Literature Review

Step 1 – Setting the aim.

It is intended to characterize studies that combine Leadership and Quality Management, trying to understand the evolution of the theme up to the present moment by the number of publications, practical applications, theories, and models more adopted to merge both, contributions, as well as the kind of relationships established between Leadership and QM.

Step 2 – Identification of studies.

A sample of articles was collected in the scientific database Scopus since it is one of the largest multidisciplinary global databases with abstracts available, citations, and peer review. A literature search was performed on May 2020 using the search path [(Leadership) AND [(Quality Management)] in the title field, without any date restriction. The choice of the title field aims to collect a sample of studies more focused on the combination of leadership with the QM. The preliminary result returned 60 documents, including 42 articles, 14 conference papers, 3 review articles and 1 book chapter.

Step 3 - Selection

The keywords and abstracts of all articles were considered. Seven articles were excluded (two due to their duplication, two due to lack of leadership focus, and three whose abstract was not available in the database), resulting in 57 relevant articles for analysis.

Step 4: Results and Analysis

The analysis followed the qualitative approach with the organization, categorization, and coding of the data. Inspired on Barratt, Choi and Li, (2011) this process was supported on the Excel ® software, building a database structured in the following coding criteria (table 3).

Table 3 – Coding criteria

Coding Criteria	**Description of coding**
Publication year	The year in which the article was published
Contribution	A short description of the content in terms of contributions
Type of article	Empirical, conceptual, or review
Methodology	For example, case, survey, experiment, action research, review, or interview study
Research strategy	Quantitative or qualitative
Results	The outcomes of the articles, such as models, frameworks, propositions
Quality Management Focus	Identification of the main QM approaches, such as TQM, QMS, principles, tools and practices, performance and maturity
Leadership Focus	Identification of the main leadership approaches
Interrelationship between QM and leadership	Analyzing how the relationship between these two areas has been researched

RESULTS AND DISCUSSION

By the content analysis were clustered four main themes to portray the state of the art that joint Leadership with QM: Theme I – Publications; Theme II – QM approaches (to understand which QM areas are more addressed to study this interrelationship); Theme III – Leadership approaches (which leadership areas are addressed in this sense); and at the ending Theme IV – Relationship between Leadership and QM.

Theme I - Publications

The first database article was published in 1990 (Gibson, 1990), and the number of publications had a significant increase in recent years. It should be noted that although this survey was carried out in May 2020, the current year presents the highest number of publications, with seven documents already published in this sample, as shown in figure 2.

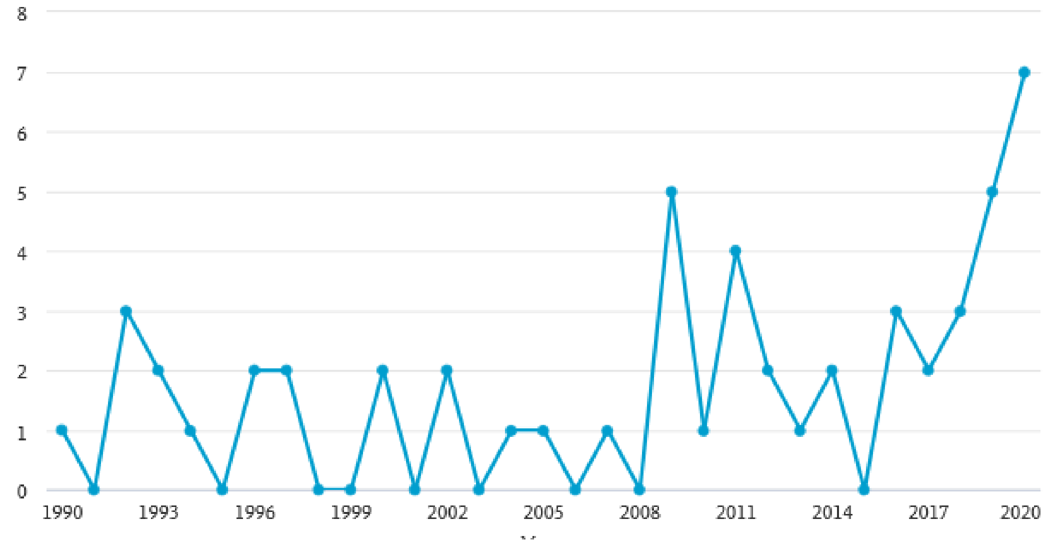

Figure 2 - Timeline of analyzed articles.

However, during this period, the published articles were changed considering the contributions and the methodologies, hence until 2000, 80% of the articles were reviewed with only 10% were surveys- From 2000 to 2020 there was an apparent inversion, highlighting the empirical works with a quantitative investigation strategy structured in surveys (59.5%) and only 14.8 % were review articles.

The subject areas highlighted were business, management and accounting (29.1%), then social sciences (17.4%), and engineering (15.1%).

The results presented above show that the research on Leadership and QM simultaneously is an emerging area, with a broad practical implication present in industry, education, and health sectors. In the industry field, were identified studies in several sectors, such as food (Walaszczyk and Polak-

Sopinska, 2020), oil (Wagimin *et al.*, 2019), automotive (Rosenkrantz, 2011), construction (Farooqui and Ahmed, 2009). In the education area, the works were more focused on higher education (Anyamele, 2005; Gowen, Henagan and McFadden, 2009; Papadimitriou, 2011; Aldaweesh, Al-Karaghouli and Gallear, 2013; Holt *et al.*, 2014). However, this area has also raised interest in secondary education (Sfakianaki *et al.*, 2018) as well as in primary education (Aksu, 2009). The healthcare performance was interlinked with leadership from different perspectives (Bäckström, Ingelsson and Johansson, 2016), and at different functions, like as nurses (Barlett and Kelly, 2009) or executives (Gowen, Henagan and McFadden, 2009).

Theme II - QM approaches

Considering the quality management area, there were found studies focused on quality practices (Laohavichien, Fredendall and Cantrell, 2011; Chan *et al.*, 2016),quality tools (Rosenkrantz, 2011), quality principles (Mlkva, Paulova and Ruskova, 2011; Ololube, Agbor and Agabi, 2016; Barbosa, Gambi and Gerolamo, 2017), and quality management systems standards such as ISO 9001 (ISO, 2015), models of quality management like as Total Quality Management (TQM) (Krumwiede, Sheu and Lavelle, 1996; Chen, 1997; Trofino, 2000; Osayawe Ehigie and Clement Akpan, 2004; Farooqui and Ahmed, 2009; Saiti, 2012; Aldaweesh, Al-Karaghouli and Gallear, 2013; Soliman, 2018; Chen, Lee and Wang, 2020; Rahman *et al.*, 2020), quality management maturity models for example quality management systems index (QMSI) (Clay-Williams *et al.*, 2020), Malcolm Baldrige National Quality Award (Chen, 1997) or European Foundation for Quality Management Excellence Model (EFQM) (Anyamele, 2005, 2007; Quddus and Ahmed, 2017), world-class (Trofino, 2000), Hayes' six stages of quality system implementation (Rosenkrantz, 2011; Kharub, Mor and Sharma, 2019; Walaszczyk and Polak-Sopinska, 2020).

Theme III - Leadership approaches

Within the scope of the leadership models referenced in the literature review section, the most significant emphasis was placed on transformational and transactional leadership (Trofino, 2000; Gowen, Henagan and McFadden, 2009; Rosenkrantz, 2011; Chan *et al.*, 2016; Barbosa, Gambi and Gerolamo, 2017; Wagimin *et al.*, 2019; Chen, Lee and Wang, 2020; Clay-Williams *et al.*, 2020; Rahman *et al.*, 2020). Some instruments were referenced to assess the leadership profiles, such as Multi-Factor Leadership Questionnaire (Avolio and Bass, 2004), Leadership Profile Questionnaire designed by Sashkin and Rosenberg (Aksu, 2009) and The Myers-Briggs Type Indicator (MBTI) (Krumwiede, Sheu and Lavelle, 1996). Other leadership approaches are also the object of study in the interrelation with Quality Management, such as leadership turnover (Leggat and Balding, 2019), Competing Values Framework leadership model (Barbosa, Gambi and Gerolamo, 2017)

Communicative leadership (Bäckström, Ingelsson and Johansson, 2016) and Feminist leadership (Lewis Lanza, 1997).

Theme IV - Relationship between QM and Leadership.

The studies dedicated to the relationship between QM and Leadership try to understand the role of each area. Thereby, some authors choose to study the effect of several factors together, such as quality management, leadership, and knowledge management. This perspective is often followed since it intends to understand the impact of Quality Management and leadership practices on the organization's management processes and performance (Saiti, 2012; Aldaweesh, Al-Karaghouli and Gallear, 2013; Mukwakungu *et al.*, 2019). Chen, Lee and Wang,(2020) supported on the input -process -output (IPO) approach, advocate that TQM should be considered as an input, transformational leadership as a mechanism (process) that allows the coordination of internal and external elements for the organization to reach sustainable competitive advantage (output).

Some correlational studies were focused on the impact of different leadership styles on quality management performance (Chan *et al.*, 2016; Barbosa, Gambi and Gerolamo, 2017; Soliman, 2018; Chansatitporn and Pobkeeree, 2019; Zhang *et al.*, 2020). The interest in measuring the influence of several factors on the employees' performance leads to the development of studies that intend to understand the relationship of transformational leadership, transactional leadership and TQM (Wagimin *et al.*, 2019). However, other studies were designed to determine the effect of ISO 9001 (ISO, 2015) on the Top Managers' responsibility to manage the organization's resources and processes. The comparative study shows that top management's commitment was higher in organizations that had implemented the ISO 9001 for more than seven years (Walaszczyk and Polak-Sopinska, 2020).

There are studies in both directions, the impact of leadership in Quality Management and the reverse. The results were consensual with statistical evidence of the impact of leadership in Quality Management (Chan *et al.*, 2016; Chansatitporn and Pobkeeree, 2019), and a significant effect of charismatic leadership in TQM implementation (Wagimin *et al.*, 2019). Other results indicate that leadership is an essential element of QM and human resource management practices, which affects the core quality practices (such as statistical process control and other QM techniques) and, consequently, the quality performance (Laohavichien, Fredendall and Cantrell, 2011). Some authors set QM as a mediator of transactional and transformational leadership influence on employee performance (Wagimin *et al.*, 2019). Chen, Lee and Wang, (2020) argue that transformational leadership and the managers' skills (executives) have a mediating effect in the interrelationship between TQM and sustainable competitive advantage. Leadership is also recognized as a "facilitator" element in following the organization's mission and vision (Quddus and Ahmed, 2017).

Were also found some studies that present conceptual models for the effective integration of leadership and QM. Farooqui and Ahmed, (2009) proposed a model designated Leadership-based TQM to assess the role of leadership in organizations that have implemented or have a plan to implement the TQM program. Aldaweesh, Al-Karaghouli and Gallear, (2013) developed a framework for the adoption of TQM and the leadership.

Table 4 presents in detail the cross-tabulations of the main topics of QM and Leadership.

Table 4 – Cross-tabulation of QM and Leadership Studies

Leadership / **Quality**	**Transformational**	**Transactional**	**Laissez-faire**	**Styles and Behaviors**
TQM	Chen et al., 2020, Rahman et al., 2020			Chen et al., 2020 Clay-Williams *et al.*, 2020 Soliman, 2018 Aldaweesh et al., 2013 Waldman, 1993 Saiti, 2012 Osayawe et al. 2004 Marco Perles, 2002 Savolainen, 2000 Krumwiede et al., 1996 Van Allen, 1994 Gibson, 1990 Levin, 1993
QMS	Gowen et al., 2009			Clay-Williams et al., 2020 Walaszczyk et al., 2020
QM Principles	Barbosa et al., 2017	Barbosa et al., 2017		Mlkva et al., 2011
QM Tools and Practices	Chan et al., 2016	Chan et al., 2016	Chan et al., 2016	Kharub et al., 2019 Mukwakungu et al., 2019 Chansatitporn et al., 2019
Performance				Zhang et al., 2020
Maturity	Rosenkrantz, 2011	Rosenkrantz, 2011		Quddus et al., 2017 Anyamele, 2007 Anyamele, 2005 Chen, 1997

Although the significant part of the studies refers to quality management in general, even so, it was possible to allocate a set of works to Quality ´s specific topics, such as TQM, QMS, QM principles, QM tools and practices, performance and maturity. There is an emphasis on studying the leadership associated with TQM and then with the QM maturity. The transformational leadership model has been selected in researches related to TQM, QMS, Principles, Tools, Practices, and Maturity. These studies were performed in the last 11 years, which may indicate that this leadership model has raised more interest in QM research in the current context.

CONCLUSIONS

As mentioned, this study intended to feature state of the art with scope in leadership and QM simultaneously. From the results, this research area has been increasing in the last decade, with broad practical implications reflected in several sectors of activity, both in industry and in services. The research interest in what is the role of leadership in QM has been manifested more expressively. These results reinforce the initial proposition that leadership has an increasingly important role in the current QM paradigm, the emergency, both for its importance in the evolution of quality management systems, and its role in change management. As defended by Chiavenato (2004), leadership approaches study the variables with an impact on the changes for the organizations ‘success. Xu, (2017) defends that the transformational leadership model is also very focused on change, which can be an asset for organizations in the current scenario of constant change.

Analyzing now the hypothesis, “Transformational leadership leads QMS to higher levels of maturity and therefore preparing better organizations to change management resulting from the current context´s pressures.” For the literature review, it was found that the most recent contributions on the QMS maturity cover aspects related to change management, pointing out the highest QMS maturity level promotes innovative planning able to adapt to environmental changes. The measuring instrument developed by Nascimento *et al.*, (2016) added items to assess change management capability.

Results shown in table 4 revealed that QM maturity had been investigated jointly with the leadership, including the transformational leadership. These results gave indications to proceed with the research project, once they were identified theoretical constructs that strengthen the initial research proposition and hypothesis. The results identified theoretical models, namely the leadership-based TQM (Farooqui and Ahmed, 2009) and the framework for the adoption of TQM and the leadership (Aldaweesh, Al-Karaghouli and Gallear, 2013). Also, were reported some measuring instruments, such as the Multi-Factor Leadership Questionnaire (Avolio and Bass, 2004) and the measuring instrument developed by Nascimento *et al.*, (2016) to assess QMS maturity. The future steps of this research project will evaluate the QMS maturity in the companies located in Portugal to understand how QMS supports them in the current context. Then, it will develop a correctional study between leadership models and the level of QMS maturity. Finally supported in results, the future research pretends to give organizations some practical implications to develop their leadership models to achieve higher levels of maturity QMS.

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FCT Fundação para a Ciência e a Tecnologia

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Quality Management System according to Quality 4.0 guidelines

Loureiro, F.G. [1)]

[1)] Sonamet Industrial

ABSTRACT

The purpose of this paper submission its to present a practical application of the topic related with a "Quality Management System" defined and implemented according to the future of quality and Quality 4.0 guidelines, mentioned by Paulo Sampaio at the APQ conference "the leader of quality 4.0" on the 17 July 2020.

In Sonamet (a big company of EPCI – Engineering, Procurement, Construction and Installation, of mega-structures for the Oil&Gas sector, such as oil platforms), the Quality Management System (QMS) is fully integrated into the organization, use the same language of the C-Suite level, and is seen as a core area, which ensure the alignment and operationalization of the management system, processes, departments and employees with the aspects defined by the CEO (namely, the purpose, context, policies and interested parties needs and expectations and strategic objectives) and the world trends and best practices [Industry 4.0 (data analysis, predictive quality models and mindset, digitalization, best practices sessions), purpose and value added culture, the future of quality concept (do it well X do it better X do it differently).

Keywords: Quality Management System, Quality 4.0, Industry 4.0, Leadership.

Paper type: Case Study.

INTRODUCTION

Joseph Juran, referred that "the 21st century will be the century of quality" and some authors, such as, Pedro Saraiva (for example, in the APQ webinar held on 17/6/2020 on the theme "Master Class - Quality: and now? ") and Paulo Sampaio (for example, in the APQ webinar held on 17/7/2020 on the theme" the leader of quality 4.0"), have been looking at what the role of quality will be or should be, in the 21st century and how to adjust quality to new contexts.

This paper refers to a practical example of a quality management system, implemented taking into account some of these guidelines, namely, in bringing top management to quality issues, who see quality as a core area, that speaks the same language as the C-Suite level and is aligned with market trends and best practices (example, Industry 4.0 guidelines).

QUALITY MANAGEMENT SYSTEM (QMS) INTEGRATED INTO THE ORGANIZATION, USING THE SAME LANGUAGE OF THE C-SUITE LEVEL, AND SEEN AS A CORE AREA

Based on these premises we have created a unity of purpose and direction, so that the processes and employees understand how their duties are aligned with aspects defined by the CEO (described above), and how they can create a unity of purpose and increase value (see table 1).

Table 1 – Quality Management System Structure

Inputs	**Purpose**	The purpose of the Quality Management is to ensure the alignment and operationalization of the: **1.** Management system **2.** Processes **3.** Departments **4.** Persons With the aspects defined by the CEO (market trends and with the world best practices)
	Context (see table 12)	
	Interested parties (see table 13)	
	Policies	
	Strategy + Objectives	**Strategic Map** (see table 2) ► **SAP 2018** (see table 3)
	Processes	AFC **Area Action Plan** (see table 4) ► Accounting **Department Action Plan** (see table 5)
	Functions	Accounting Responsible **Performance Evaluation** (see table 6) Accounting Technician **Performance Evaluation** (see table 7)

Table 2 – Strategic Map (part of)

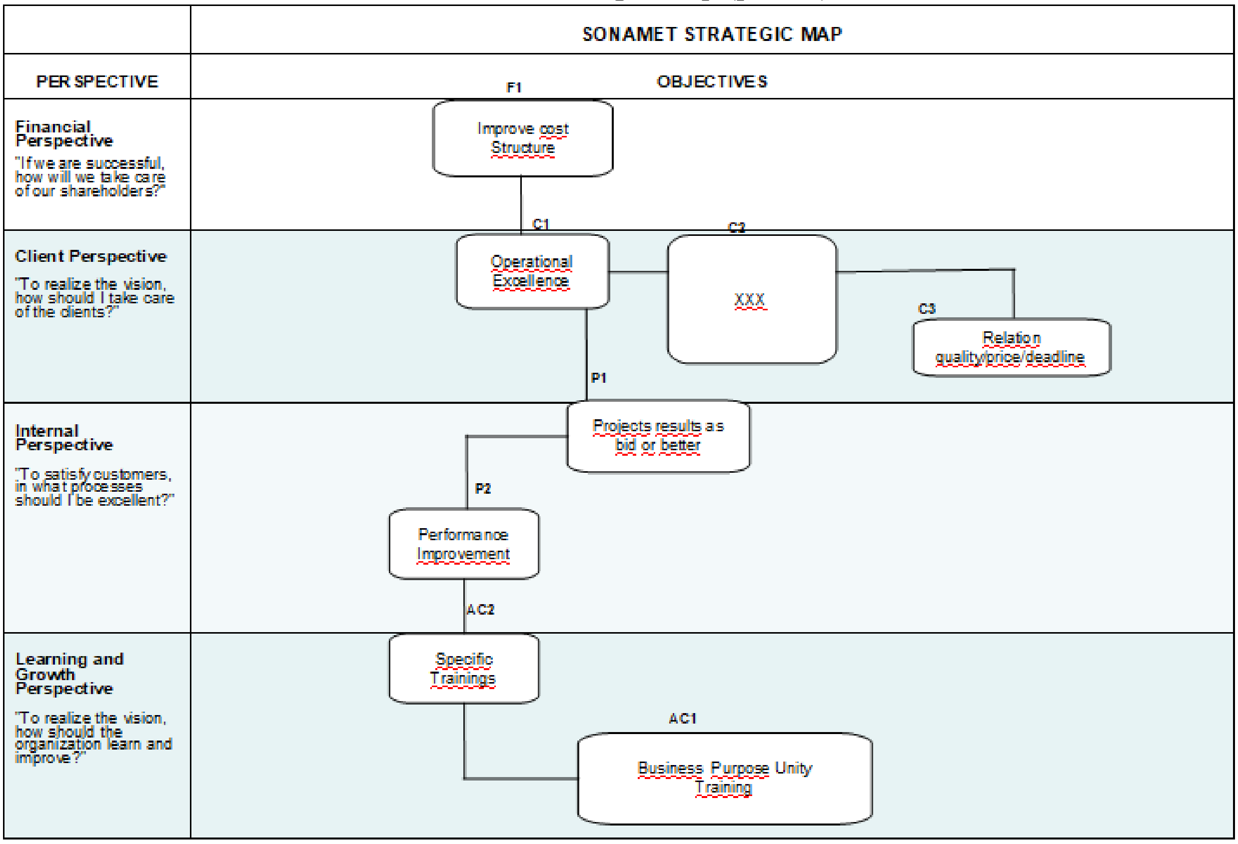

Table 3 – Sonamet Action Plan (SAP)

Sonamet Action Plan (SAP)					
Ref[a]	**Objective Description.**	**Completion Date**	**Committed Processes**	**Measures And KPIs**	**Initiatives**
F1	Improve cost structure	Q4 2018	AFC	Reduce costs with stocks and consumptions	Conduct an inventory and redefine the stock. Have consumptions adjusted to the project needs.

Table 4 – Area Action Plan (AFC)

Area Action Plan (AFC)					
SAP Ref.	**Objectives**	**Key Actions**	**Resp**	**Indicator**	**Progress**
F1	Improve cost structure	Conduct an inventory and refine the stock. Have consumptions adjusted to project needs.	DAF	$ xxx M stock balance at Yard. $ xxx K cost monthly stock consumption.	X %

Table 5 – Department Action Plan (Accounting)

Department Action Plan					
SAP Ref.	***Objectives***	**Key Actions**	**Resp.**	**Indicator**	**Progress**
F1	Improve cost structure	Improve the cost of structure - monitor the correct valuation of stocks in all warehouses and ensure the redefinition of stock practices. Complete reconciliation of balance sheet accounts.	CONT	The total value of stocks must be less than USD xxx million	X %

Table 6 – Performance Evaluation (Department Responsible)

Performance Evaluation		
Function:	Accounting Responsible	
Business objectives agreed for this year		
SAP Ref.	**Description**	**Measure of Sucess**
F1	Improve the cost of structure - monitor the correct valuation of stocks in all warehouses and ensure the redefinition of stock practices. Complete reconciliation of balance sheet accounts.	Total value of stocks must be less than USD XXX million. Prepare reconciliation of balance sheet accounts with warehouses.

Table 7 – Performance Evaluation (Technician)

Performance Evaluation		
Function:	Accounting Technician	
Business objectives agreed for this year		
SAP Ref.	**Description**	**Measure of Sucess**
F1	Track stock accounts. Material in transit from all warehouses.	Present the monthly reconciliation of stock reports with financial reports.

We can have a management system that allowed us to have a unity of purpose and create value, but if we don't have the involvement of people and a company methodology that allows us to be agile to respond to changes and best practices in the market, what kind of results can we expect?

<u>What new skills could we acquire to allows to continue work and be agile?</u>

Leadership

The first step was to involve people at all levels of the organization so that they are committed to create and add value. We conceive a Leadership training (see tables 8 and 9) and tools (see tables 10 and 11), in order to create a climate for action, motivating and leading people.

What is motivation? It is everything that drives the person to act.

How does the process work?

Table 8 - Create a climate for action, motivating

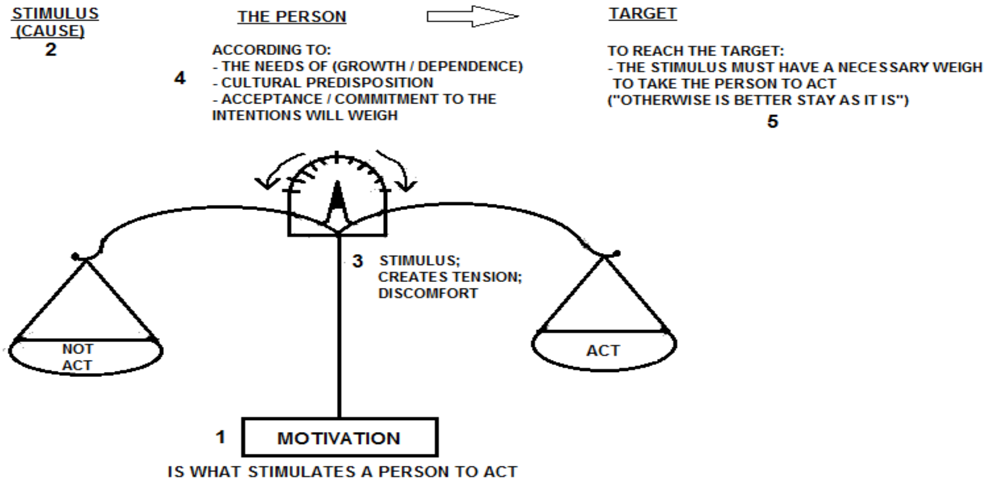

Table 9 - Motivation and Leadership

Motivation	Extrinsic	Intrinsic	Transcendental
Definition	**External Motivation** It is linked to the environment, to the situation and external factors	**Internal Motivation** It is linked with personal interests (and only may be altered by personal choice).	**Transcendental Motivation** Lign up the interests and motivation of employees with the company interests and motivates him to act and contribute.
Objectives	**Conformity ►** 1st level of leadership	**Empowerment** 2nd level of leadership	**► Unity of Purpose** 3rd level of leadership
Example	Monetary awards, hollydays.	Enjoy learning and continous improvement. Mentoring / Coaching.	Commitment to the mission, ethic, values, objectives and the satisfaction of interested parties. Volunteers.

Table 10 - The dimension of Leadership in the management

Exercise1 –The dimension of Leadership in the management
1 What are the main obstacles that I could avoid, in such way that the subordinates act for Transcendental motives? 2 How to show the real value of their actions and teach them how to evaluate the consequences of their own actions can affect other people? 3. What are the main examples of acting by transcendental motives, that I should give ? How can I work to develop continuously these aspects?

Table 11 - Authority Development

Exercise2 – The strategic and executive dimension of management
What are the core capabilities? 1 Strategic (Discover opportunities to apply the productive capabilities of the organization, that increase the income and / or decrease the resources necessary to reach them, assuring the revenues that the organization needs to continue to exist).

2 *Executive*
(Capability to discover, use talents, skills and stimulate the people you lead. Define functions and / or tasks that appeal to intrinsic and transcendent motives. It is important that the order is accomplished, either by internal or spontaneous acceptance by the executor).

On which they must work, to demonstrate the confidence to subordinates?

How should I work them?

Agile

A second step was to create a mechanism for the Board, periodically monitor the aspects of internal and external company context (see table 12) and the needs and expectations of the interested parties (defined in the QMS) (see table 13), that had changes in that period and implications in the company strategy. Once we have a mechanism that allow us to deploy the strategy at the process and functions levels (see table 1), we can automatically know the implications of that changes at those levels, and prepare functions/people and processes affected, to give a people and organizational agile response.

Table 12 – Context

CONTEXT
Internal Factors
1. Slowdown in the learning curve (loss of experienced professionals during low production).
External Factors
1. Monitorization of quality standard between facilities fabricated in Angola and in abroad.

Table 13 – Interested parties needs and expectations

Interested parties					
Type	**Classification**	**Designation**	**Requirements**	**Monitoring and Measurement**	**Process**
Costumers	Internal	Shareholders	Comply with the strategy, macro objectives and planned financial results	Minutes of meeting of the quarterly operational committee	MGT
Costumers	External	Project Owner	Compliance with contract requirements and customer specifications	Correspondence register, NCR (non-conformance report) register; site observation registers and satisfaction survey	Yard
Competitors	Direct competitors	Competitor 1 Competitor …	Define and effectively operationalize a strategy that offers to customers a value proposition	Results of the achievement of the strategic objectives. Man-hours compared to competition.	MGT

Future of Quality Concept

Another step was to reflect the quality concept and how it can be integrated with the business sustainability. It originated all aspects previously spoken and the concept "Future of Quality = do it well X do it Better X do it Differently", was reflected in the company's strategic map (more precisely, in the strategic objectives of the balanced scorecard - customers perspective). Quality has been identified as "Do it differently from the competitors and adding value for the customers". In practical terms, in the company, this aspect is represented in the "client perspective, in the strategic map", as: "relation quality/price/deadline" and "operational excellence" (see table 2).

Industry 4.0

In addition to the good practices previously mentioned, such as, unity of purpose and added value, leadership, agile, future of quality concept, we now mention the aspects related to_Industry 4.0 (in this specific case of this article, we refer to best practices sessions, data analysis, predictive quality models and mindset and digitalization).

2. Best practices sessions

Began with Top Management, followed by Quality Champions (process representatives at QMS) and focused essentially on the following topics: industrial management systems (from the 80s, 90s and since 2015) (see table 14), focused in particular on financial measures (80's), operationalization of the strategy (90's) and industry 4.0 (since 2015), as well as on Leadership, and the creation of a culture of unity of purpose and added value.

Table 14 – Industrial Management Systems

Industrial Management Systems

Years	Focused in:	Sonamet Management System
80´s	**$** Financial Measures	➢ Context ➢ Interested Parties ➢ Policies
90´s	**Strategy** Operationalization of the Strategy	Strategy
2015	**Industry 4.0** Added Value (for the: Interested Parties and Business)	Management System (SAP) and Processes (Area Action Plan) **Added Value** (Satisfy Interested Parties and Business Sustainability)

The sources of information used were essentially, Bibliography on the BSC (balanced scorecard), strategic intelligence on industry 4.0 from the WEF (World economic forum), Mckinsey & Company (Oil & gas) publications, OilPrice.com newsletters, ISO 900 standards, IESE Business School bibliography.

3. Data Analysis, Predictive Quality Models and Mindset, Digitalization

In the audit plan for each of the processes, a point was contemplated to verify, what data existed in the process, how they were analyzed and evaluated, to try to identify possible improvements related to data analysis, predictive models and digitalization. As an example, we can mention the following opportunity of improvement identified in the audit report of the Financial Direction "hold a project closing meeting to identify future learnings and prevent future scenarios (eg, sensitive analysis of a new project, risks and contingency plans)". This would help us in assessing the riskiness of a strategy and to predict the outcome of a decision if a situation turns out to be different compared to project key predictions and can be optimized with a project sensitivity analysis software (eg, sensitivity analysis software for Oil&Gas design optimization – Sensitivity Manager, from DNV GL).

CONCLUSIONS

In the practical example of implementation of the quality management system presented in this paper, in order to guarantee that the Quality Management System (QMS) is fully integrated into the organization, use the same language of the C-Suite level, and is seen as a core area, were defined with top management: the purpose, the aspects of the organization's internal and external context, to be taken into account, the needs and expectations of the stakeholders and the policy.

Based on these aspects, the company's 5-year strategic plan was defined (see table 2) and the SAP (Sonament Action Plan) (see table 3) is prepared annually, where an annual objective is defined for each strategic objective. These objectives are deployed at the directors (see table 4) and Departments (see table 5) levels and at the functions level (see table 6 and 7). This ensures the alignment and operationalization of the management system, processes, departments, and employees with the aspects defined by the CEO.

We can have a management system that allowed us to have a unity of purpose and create value, but if we don't have the involvement of people and a company methodology that allows us to be agile to respond to changes and best practices in the market, what kind of results can we expect?

The first step was to involve people at all levels of the organization, so that they are committed to create and add value. In this sense, was conceived a Leadership training (see tables 8 and 9) and tools (see tables 10 and 11), in order to create a climate for action, motivating and leading people.

A second step was to create a mechanism for the Board, periodically monitor the aspects of internal and external company context (see table 12) and the needs and expectations of the interested parties (defined in the QMS) (see table 13), that had changes in that period and that have implications in the company strategy. Once we have a mechanism that allow us to deploy the strategy at the process and functions levels (see table 1), we can automatically know the implications of that changes at those levels, and prepare functions/people and processes affected, to give a people and organizational agile response.

In relation to Industry 4.0 (in this specific case of this article, we refer to best practices sessions, data analysis, predictive quality models and mindset, digitalization) we started with good practice sessions for Top Management, followed by Quality Champions (process representatives at QMS). In the audit plan for each of the processes, a point was contemplated to verify, what data existed in the process, how they were analyzed and evaluated, to try to identify possible improvements related to data analysis, predictive models and digitalization. As an example, of an opportunity of improvement to be implemented, we identified at the project level a mechanism that would help us in assessing the riskiness of a strategy and to predict the outcome of a decision if a situation turns out to be different compared to project key predictions.

Based on the practical application described in this paper, it was found that as important as defining a quality management system that ensure the alignment and operationalization of the Management system, Processes, Departments and Persons with the aspects defined by the CEO, market trends and with the world best practices, are the aspects related to Leadership, in order to create a climate for action, motivating and leading people, so that they have a unity of purpose and an add value culture.

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Internal Strategic Alignment: Exploring the Concept

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Purpose - The literature points to the importance of alignment and its relationship to organizational performance. The concept, however, is multifaceted and it has been applied with different terms and in different contexts. The main objective of this article is to analyse how the strategic alignment concept has been considered in the field of strategy research and provide a classification.

Design/methodology/approach - The basis of this research was a systematic literature review (SLR) carried out in three stages: (1) planning the review, (2) conducting the review and (3) planning and dissemination. A search was conducted in the ISI Web of Knowledge (Web of Science), applying specific words, resulting in a sample of 256 documents.

Findings – We provide a classification of studies that can be a guide for future studies in the field, making it easier to find the right authors and the appropriate content according to the area of interest.

Research limitations/implications- The number of articles analysed can be expanded and other databases can be included.

Originality/value - The research contributes to a more broadly vision of how the alignment concept has been applied in the context of business strategy.

Keywords: alignment, strategic alignment, strategy implementation, literature review.

Paper type: Literature review

INTRODUCTION

The connection between alignment and organizational performance was established by contingency theoreticians and it is almost a common sense that lead to satisfactory organizational performance.

Miles and Snow (1984) successful organizations make strategic adjustments to their competitive environment and support the strategies with suitable management structures and processes. Less successful organizations typically display poor external and internal adjustment.

In the field of strategy studies, alignment is a central concept. For the proponents of the strategy with emphasis in the market alignment falls primarily on external factors, demanding a definition of a strategy that will enable the company to adapt to the structure of the industry, and secondarily on the arrangement of the activities internal to the strategy. For the proponents of the resourced based view (Barney, 1991; Collis and Montgomery, 1995), the emphasis of alignment falls primarily on the internal resources, such as competencies developed and controlled by the company. These resources will support decisions to face the challenges of the external environment.

In the field of organizational management, the theme can be found in disciplines of management organizations, such as Management by Objectives - MBO, also known by its original names: Hoshin Kanri or Policy Deployment, in the Quality Management field.

Despite the importance of the theme, there have been barriers for its operationalization (Prieto and Carvalho, 2018; Sabherwal *et al.*, 2019). The concept itself is useful in different fields of study and multiples terms are applied to define it.

In this context, the main objective of this article is to analyse how the strategic alignment concept has been considered in the field of business strategy research and provide a classification.

BACKGROUND OF THE STRATEGIC ALIGNMENT CONCEPT

Alignment is a central theme in operations management research (Cao, Baker and Hoffman, 2012; Kathuria, Joshi, and Porth, 2007; Schneiderjans and Cao 2009). Nevertheless, significant variations can be found in this area in what it refers to the terminology and constructs used in its operationalization (Hill and Brown, 2007; Venkatraman and Camillus, 1984). The terms most commonly applied are strategic fit, strategic alignment and strategic consensus, which are used in the sense of fit, cohesion, adjustment and congruence among different dimensions. Each organizational dimension must be consistent not only with the strategy but also with other internal dimensions (Galbraith and Kazanjian, 1986; Park et al, 2017).

The theoretical bases outlined and the main variables for internal and external alignment are distinct (Schniederjans and Cao, 2009; Venkatraman and Camillus, 1984). External alignment considers the perspective of strategy formulation and, above all, the adjustment of strategy to environmental variables. In contrast, internal alignment focuses on the implementation and adjustment of strategy to internal variables.

Vertical alignment has received considerably more attention in the literature than horizontal alignment (Kathuria, Joshi, and Porth, 2007).

According to the Internal Strategic Alignment Model (ISA model) proposed by Prieto and Carvalho (2018), vertical alignment is conceived as a set of actions required to implement the strategy, from the formulated strategy up to its deployment at all the levels of the organization. It is posited that the factors involved in vertical alignment are the comprehensiveness of strategy formulation, management capabilities for strategy implementation, and people's involvement with the strategy. Horizontal alignment involves understanding customer needs and aligning processes (cross-functional) able to deliver the respective necessities. The factors involved in horizontal alignment are process orientation and customer orientation.

Alignment is seen as a dynamic process in which the manager will simultaneously considers environmental variables and organizational resources (Zajac et al., 2000). Changes in exogenous variables, such as consumer preferences, government policies, competitors' actions, etc. may create new demands, opportunities or restrictions to the current position. The organization's performance is dependent on both internal and external alignment and the process of achieving alignment is dynamic (Prieto and Carvalho, 2011; Siggelkow, 2001). However, the effect of external alignment on performance has received more attention from the researches.

The main strategic alignment concepts are summarized in the Chart 1.

Alignment: agrupamento, coesão, ajuste, congruência entre diferentes dimensões. **Strategic Alignment:** both a process and a result - a dynamic for adjusting the organization to its external and internal environment. **External Alignment:** adjustment of the organization to its external environment through the strategy formulation. **Internal Alignment:** alignment of the organization in both dimensions: vertical and horizontal. **Vertical Alignment:** Set of actions required to implement the strategy, from the strategy formulation to its deployment through the organizational levels. **Horizontal Alignment:** it involves an adjusting between the client's needs and the processes (cross-functional) able to deliver it. **Internal Aspects of the Organization:** Refers to the elements to be aligned, such as, strategy, structure, process, people, clients, leadership, information systems, human development systems, management capabilities. Each dimension needs to be consistent with the strategy and with each other.

Chart 1. Strategic alignment: main concepts

RESEARCH METODOLOGHY

The basis of this research was a systematic literature review (SLR) carried out in three stages as recommended by Tranfield et. al (2003) and summarized by Morioka and Carvalho (2016), which are: (1) planning the review, (2) conducting the review and (3) planning and dissemination.

In the first stage an exploratory literature overview was conducted trying to choose the better key words to be applied, mainly considering how broad are the terms in use. As a result of this phase it was perceptible the dominance of the papers in relation to the system information area. It was decided to delimitate the sample to the alignment of business strategy in the context of internal strategic alignment.

The second stage pointed out by the cited authors represents the review itself. The basis of this research was a search in the ISI Web of Knowledge (Web of Science). It was applied the key words *"strategic fit"*, *"strategic alignment"* or *"strategic consensus*" in the topic. The search was refined by the areas of interest: management, business and industrial engineering. Were collected 256 articles.

The articles were exported to the Mendeley. The first reading of them was restricted to title and abstract with the objective of identifying those that referred to the business strategy implementation. Those who encompassed vertical or horizontal alignment or internal aspects to be aligned (see Chart 1) were selected. At the end of this stage, the final sample consisted of 108 papers.

The articles were recorded in an electronic spreadsheet. It was collected dates about the authors, publication, methodology, objectives and main results. Then the articles were classified according to the theme of strategic alignment.

RESEARCH RESULTS AND DISCUSSION

The articles were collected following the procedures described in the Methodology section. They were distributed according to the strategic alignment research area as represented in Figure 1.

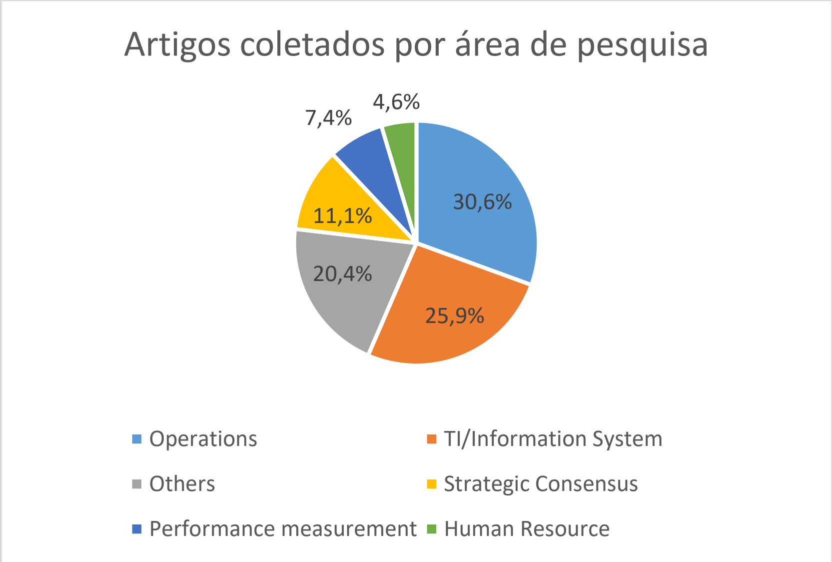

Figure 1 – Distribution of the articles collected by research area

The major number of the studies refers to the Operations/Supply Chain area (30,6%), following by Technology Information/Information Systems area (25,9%), Strategic Consensus (11,1%), Performance Measurement (7,4%), Human Resource (4,6%) and Others subjects (20,4%), including Project Portfolio, Innovation and Multinational Companies.

The articles were analyzed and classified according to the concept of alignment adopted, which are summarized in Chart 2 and will be explained following.

Alignment between business and operations strategies	
Alignment among competitive priorities of manufacturing	Joshi, Kathuria and Porth (2003)
Alignment between operations and marketing	Rhee and Mehra (2006)
Alignment between business and purschasing strategy	Baier, Hartmann and Moser (2008)
Alignment of competitive priorities in supply chain	Vachon et. al (2009)
Alignment between market, operating strategy and service delivery system	Hill and Brown (2007)
Alignment between three types of service strategies and determinants for service innovations.	Lightfoot and Gebauer (2011)
Strategic alignment between competitive priorities in the automotive supply chain	Garo and Guimaraes (2018)
Alignment of human resources to the strategy	
Alignment of human resources to business strategy	Boswell (2006)
Leadership effects in the strategic commitment	Ates et al (2020)
Human resource development (IHRD) and ecosystems research.	Garavan et al (2019)
Middle management role in the strategy implementation	Floyd and Wooldridge, 1992
Configurational alignment	
Alignment between systems of activities	Siggelkow (2001)
Alinhamento configuracional	Siggelkow (2002)
Interações entre elementos intangíveis	Carmeli and Tishler (2004)
Covariance perspective	Prieto and Carvalho (2018)
Configurational alignment	Al-Surmi et. al (2020)
Strategic Consensus	
Vertical Communication	Rapert et al (2002)
Communication ability of managers	Garretson, 2002

Manager's ability to negotiate the strategy	Hambrick and Cannella, 1989,
Management capabilities for strategy implementation	Prieto and Carvalho, 2018
Dynamic Alignment	
Impact of organizational resources on alignment	Zajac, Kraatz (2001)
How environmental contingencies influence alignment	Zajac, Kraatz and Bresser (2000)

Chart 2 - Summary of applications of strategic alignment concept

Alignment between business and operations strategies

In the operations and service area the authors investigate the alignment between competitive priorities of business strategy and its respective areas. Joshi, Kathuria and Porth (2003) and Rhee and Mehra (2006) pointed that there are few studies in the operations area and a lack of them examine the relationship with organizational performance.

Literature is relatively sparse on describing how companies should align their elements in the service area. Lightfoot and Gebauer (2011) explore the alignment between three types of service strategies and determinants for service innovations. Prieto and Carvalho (2011) and Hill and Brown (2007) provide strategic profiling managerial framework that enables businesses to show visually the level of internal strategic fit in their organizations and compare the results with the demands of the external environment.

Alignment of human resources to the strategy

The vertical dimension represents alignment between strategy and people and its proposal is communication of the strategy to all the levels of the organization (Labovitz and Rosansky, 2012; Prieto and Carvalho, 2011). In this sense, the role of human resources is broadly discussed in the strategic alignment literature.

It is considered that the role of middle management goes beyond the traditional provision of input information and overseeing of the implementation process, since it also includes regular influencing of the strategy and providing the impetus for new initiatives (Ates et al., 2020, Floyd and Wooldridge, 1992).

However, the real commitment to the strategy depends on how managers perceive that the strategy is aligned with the organization’s interests and with their own interests (Stepanovich; Mueller, 2002; Walter et al. 2013).

Another aspect is about the conditions necessary to promote behavior aimed at the achievement of objectives and goals, encompassing human development practices for motivation and reward (Boswell, 2006; Garavan et al., 2019).

Configurational Alignment

The studies under the configurational category define alignment from the holistic perspective or from that of covariance (Venkatraman, 1989, p. 435; Venkatraman and Prescott, 1990). Prieto e Carvalho (2018) consider that internal alignment is the result of interaction between vertical and horizontal alignment and propose a model to integrate all the elements. Al-Surmi et. al (2020) investigates the performance impact of triadic strategic alignment among business, IT, and marketing strategies while simultaneously considers strategic orientation of firms. These studies include multiple factors to explain the alignment while many studies apply a pairwise approach, which can only partially explain the nature of strategic alignment (Prieto and Carvalho, 2018)

Strategic Consensus

Consensus improves coordination and cooperation and can be defined as the agreement between top management, middle and operational managers regarding the organization's priorities (Floyd and Wooldridge, 1992, Walter et al., 2013). The literature presents vertical communication as the tool to establish consensus (Rapert, Velliquette, Garretson, 2002). It also highlighted the role of managers of building and maintaining the necessary support for the implementation of the strategy amid the resistance that naturally arises due to the interest of the stakeholders in upholding the old strategy, or because they do not understand the changing proposal (Hambrick and Cannella, 1989, Prieto and Carvalho, 2018).

Dynamic Alignment

Alignment is seen as a dynamic process in which the manager will simultaneously consider environmental variables and organizational resources (Nadler and Tushman, 1992; Zajac et al., 2000). There is the challenge of foreseeing which changes in the organizational environment are relevant and require changes in strategy. Zajac et al (2000) propose an approach whereby for each business segment there is a set of factors that determine its success and that should, in theory, define the strategic alignment. Kraatz and Zajac (2001) present an approach to identify changing environmental that can predict realignment of the strategy. Dynamic alignment was applied to analyze changes in the medical diagnostic sector (Prieto and Carvalho, 2011) and to confront the strategy adopted, the environmental conditions and the business performance.

CONCLUSIONS

This research conducted a systematic literature review (SLR), aiming at analyzing how the strategic alignment concept has been considered in the field of strategy research and provide a classification.

The initial research on Web of Science database resulted in a sample with 256 papers. The research was refined to collect the articles most adjusted with the alignment of business strategy.

The final sample consisted of 108 papers. Maybe this difference can be explained by the use of the terms *“strategic fit”*, *“strategic alignment”* or *“strategic consensus* indistinctively, without reflecting the concept. The reading of the abstract and of the parts of the article was crucial, in many cases, to identify the meaning of alignment that had been applied.

As a result of the research, the articles were classified according to their research themes around the concept of BSA, which are: Alignment between business and operations strategies, Alignment of human resources to the strategy, Configurational Alignment, Strategic Consensus and Dynamic Alignment. The article provided an explanation about each of the groups.

For future studies it is recommended to conduct the research of how the strategic alignment concept has been considered in each of the research groups identified in this article. A deeper understanding of the concept, type of research, research methodology and the evolution of the researches can be obtained.

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Intellectual Property Crime and Business Excellence Frameworks - Dubai Police Case study

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ABSTRACT

Purpose: As Intellectual Property (IP) criminal activities are increasingly complex, they require more than just technical skills to carry them out. IP Criminal entities are using emerging technologies to build networks and organisations to undertake complex transactions and multi-faceted transnational crimes. The remote and borderless nature of the internet, its global reach and the speed of technological uptake and change make cybercrime among the most pressing issues for Police force. In this research paper, the context IP crime in Dubai is being discussed. A closer look into literature review on IP has led to study how and in which conditions they are applied in Police Forces. Moreover, the impact of Business Excellence Frameworks (BEF) like Malcolm Baldrige and European Foundation for Quality Management (EFQM) on helping the performance of Dubai Police. Business Excellence Frameworks are used by organisations to assess and improve their work practices and performance. In order to respond to the highly competitive external environment Dubai Police systematically search for new effective approaches to enhancing their management capabilities such as Business Excellence Frameworks.

Design/methodology/approach: A case study from Dubai Police is analyzed and discussed in order to integrate the Intellectual Property Crime into Business Excellence Framework.

Keywords: *Intellectual Property, Crime, Business Excellence Framework, Dubai Police, Malcolm Baldrige, EFQM,*

Paper type: Case study

1. INTRODUCTION

Intellectual property (IP) is a growing concern in both the criminal and civil justice systems due to the growing number of products that can be reproduced quickly and inexpensively with little chance of detection and deterrent punishment. The economic impact of the misuse and theft of intellectual property is far-reaching (Nasheri, Hedieh.,2005).

Globalization continues to link societies across the primary domains of social or personal interactions, business dealings and governmental structures. The use and role of technology has permeated most aspects of our daily lives and has generated greater efficiencies and interconnectedness. (National Research Council, 2008). The spread of technology is often widely accepted and adopted before criminal vulnerabilities or counter measures have been identified and managed. Connectivity means greater productivity, but also increased vulnerability. While globalization and technological progress are largely positive advancements, they also bring new threats to UAE´s security and exacerbate pre-existing ones.

IP refers to any product that results from the creativity and innovation of the human mind and the original expression of those ideas. (Piquero, N. 2005). In other words, IP covers about every possible idea or invention from the arts and literary fields (i.e., books, photographs, recordings, choreography, etc.) to science and technology. (Canadian Intellectual Property Office, 2012). According to the World Intellectual Property Organization (WIPO), "intellectual creation is one of the basic prerequisites of all social, economic, and cultural development".

As criminal activities are increasingly complex, they require more than just technical skills to carry them out. Criminal entities are using emerging technologies to build networks and organisations to undertake complex transactions and multi-faceted transnational crimes. Counterfeiting and piracy are lucrative criminal activities, while at the same time generating relatively low detection risks. Criminal sentences for counterfeiting are also considerably lower than for many other criminal activities, such as drug trafficking. (Aeschlimann, Y. 2009). Globally, organized crime groups have become increasingly involved in the production and distribution of counterfeit and pirated goods and have adopted increasingly sophisticated and complex modi operandi, facilitated by technological advancements and complex global distribution channels. Online marketplaces are increasingly becoming an important source of income for criminal groups engaged in the sale of counterfeit and pirated goods. (EUROPOL, 2019).

The main aim of public performance management is to make performance, resources, and objectives more clear; to integrate nonfinancial and financial information; to improve accessibility, quality, and the content of information on the management information; and to integrate budget cycle and policy

(De Waal, 2010). Governments as part of public sector are responsible to enhance and increase the overall performance for the sake of satisfying and meeting the needs of their customers, transparency, combat and prevent corruption, accountability, and strengthen integrity (Ashour, 2004).

In order to respond to the highly competitive external environment Dubai Police systematically search for new effective approaches to enhancing their management capabilities such as Total Quality Management (TQM), Business Excellence Frameworks (BEF), Business Process Management (BPM), Organizational Change Management (OCM) etc. Among these various approaches, TQM and Business Excellence Frameworks have been among the most popular ones in the past two decades. Today, more than 90 national and state/regional awards base their frameworks upon the Malcolm Baldrige National Quality Award (MBNQA) criteria or the European Foundation for Quality Management (EFQM)/ European Excellence Award criteria (Mann R, 2011), and around 30,000 European organizations were using the European Excellence Model in 2006 (Heras-Saizarbitoria, 2012).

A case study will be included in section 8 to show how the suggested overall BEF may work in a specific context as a complement to an existing quality tools illustrating how a company has adapted a BEF to its specific context. The case is about Dubai Police which was a recipient of the 2018 EFQM winner in “Prize Winner in Succeeding through the Talent of People & Sustaining Outstanding Results”. The article will end up in section 8 with a short conclusion and implication section.

2. LIMITATIONS OF BUSINESS EXCELLENCE FRAMEWORK

The literature on implementation of BEF program has identified a wide range of barriers which also may explain the variation/ inconsistencies. These barriers are among others: Lack of top management commitment, limited resources, fear of change, work overload, lack of comprehensive quality improvement education, lack of staff involvement (Corbett & Angell, 2011).

One research category regarding potential limitations of existing BEFs is related to the poor performance of past Malcolm Baldrige National Quality Award in USA, winners such as Cadillac, Federal Express, Wallace and Motorola. Such examples have led some management experts and professionals to question the value of such awards. The responding argument is very simple and hence do not need much discussions. Even if the use of BEFs can produce both financial and non-financial benefits to an organization it is evident that a National Quality Award cannot be a guarantee for long-term success (ex. Wisner & Eakins, 1994; Powell, 1995; Melnyk & Denzler, 1996; Fisher et al., 2001; Evans, 2012). Another research category points to the potential weaknesses related to the operations of self-assessment in relation to award applications (Miller, 1993; McTeer & Dale, 1994; Wilkes &

Dale, 1998; Lee et al., 2006). Weaknesses include too sophisticated assessment criteria, excessive paperwork, cumbersome procedures, lack of infrastructure, excessive bureaucracy, time consuming, and a lack of focus (Main, 1991). A case study will be included in the section 8 on how Dubai Police adopted different BEF such as: EFQM, Baldrige and Dubai Government Excellence Program (DGEP).

3. BACKGROUND

The United Arab Emirates is formed by a federation of seven emirates Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah, and Fujairah which adhere to the federal laws, observe a centralized Constitutional structure and unified international policy, meanwhile each emirate handles its governance on its own following the federal rules. Furthermore, the country has a well-formulated legal system that offers protection for its citizens, residents and organisations while enforcing it effectively through governmental agencies and Ministries. Additionally, the free zones in the UAE have played an essential role in accelerating trade, innovation and the country's economy. (UAE National Archives, 2020). The Constitutional of UAE has passed federal laws which protect the Intellectual Property rights in the country, and these are laws are pieces of federal legislation that apply throughout the Emirates. These laws are assigned to be enforced by the designated Ministries according to its authority, where the patents, designs, copyrights and trademarks are held responsible by the Ministry of Economy.

The UAE’s Vision 2021 national agenda centers on the UAE transitioning to a knowledge-based economy. The national agenda includes a set of national indicators in the sectors of education, healthcare, economy, police and security, housing, infrastructure and government services. The goal is to become a competitive economy that is driven by innovation, research and development and strengthening the regulatory framework to encourage high value-adding sectors. As a measure of performance and outcomes, these indicators are long-term and generally compare the UAE against global benchmarks. As a global transit hub, the UAE faces increased risk of counterfeit goods entering the market, which causes reputational damage as a provenance economy of counterfeit goods. According to Ibrahim Behzad, Director of Intellectual Property Rights at Dubai Department of Economic Development, most of the counterfeit goods.

Intellectual Property (IP) is comprised of such things as inventions (protected under patent law); literary and artistic works, such as books, musical compositions, movies, computer programs, and other creative expressions (protected under copyright law); distinctive symbols, names, and images which distinguish the goods or services of one undertaking from those of others in the marketplace (protected under trademark and consumer protection laws); and confidential business information, including formulas, practices, processes, or methods that are not generally known. IP is found everywhere in the economy, and IP rights are relied upon by and support virtually every U.S. industry. IP-intensive industries represent a major, integral, and growing part of the U.S. economy. (U.S. House of Representatives, 2003). The Department of Commerce has reported that IP-intensive industries directly account for 27.9 million American jobs, and indirectly support an additional 17.6 million jobs. Together, this represents approximately 30 percent of all jobs in the U.S., with the total value added by IP-intensive industries amounting to 38 percent of U.S. Gross Domestic Product (GDP).

4. DATA

The report was drafted by a team of analysts and specialists from Dubai Police Criminal Investigation Department (CID)- Anti-Economic Crime. The team from Anti-Economic-Crime uses the operational data covering IP crime available at Dubai-UAE and the Business Excellence Framework to guide and evaluate their performance. This includes data on large operations coordinated or supported by Dubai Police. Finally, where appropriate and verified, open source information has been used to complement the primary data.

5. SCOPE AND IMPACT OF THE PROBLEM

Global intellectual property (IP) filing activity continues to grow at a rapid pace, setting new records in 2018. Patent filings around the world exceeded 3.3 million, representing a 5.2% growth on 2017 figures. Trademark filing activity totaled 14.3 million, up 15.5% on 2017. Industrial design filing activity amounted to 1.3 million. Applications for utility models grew by 21.8% to reach 2.1 million applications, while plant varieties filings reached 20,210 in 2018. China has been the main driver of global growth in IP filings in recent years and it was once again the main source of growth in worldwide IP filings in 2018. Filing activity in China grew by 11.6% for patents, 28.3% for trademarks and 12.7% for industrial designs. The IP office of China now accounts for 46.4% of patent filings and more than half of global trademark (51.4%) and industrial design (54%) filing activity. (WIPO, 2019)

Based on the available evidence, the piracy and counterfeiting problem in Dubai comprises two substantial elements: the cross-border importation of counterfeit goods such as Luxury products (Hand bags & watches), Vehicle parts, Cosmetics and Mobile Phones. Several overseas studies have reported that there is growing evidence that transnational and organized crime groups are increasingly involved in IP crime, some of it to finance other crime activities. There is a substantial quantity of international literature (including Organization for Economic Cooperation and Development, United States Department of Justice, Federal Bureau of Investigation and Interpol reports) asserting links between IP crime and organized criminal networks. Some IP rights holders highlighted particular cases of professional criminals being involved in copyright infringement. It is likely that such activities will have an increasing impact on Dubai in the years ahead. Lt General Abdullah Khalifa Al Marri, Commander-in-Chief of Dubai Police, stated: *"Strengthening the role of police at the level of international cooperation is crucial to enhancing law enforcement effectiveness in the region and beyond, and to preserving cultural, technological, intellectual and scientific achievements."*

The criminal networks behind trafficking in illicit goods and counterfeiting are complex and pervasive, reaching far beyond national borders. These criminals constantly find new and increasingly creative ways to manufacture and distribute fake goods. Naturally, this causes huge harm to the reputation and revenues of legitimate companies but this is by no means the only way in which this phenomenon affects the world's citizens. (OECD/EUIPO, 2016).

6. ECONOMIC IMPACT

Infringements of IP rights reduce the revenues of the affected businesses. The resulting adverse social and economic effects include the loss of jobs and livelihoods. IP rights infringement concerns content owners, law enforcement authorities and society at large because it results in negative business, legal and social impacts. (Grabosky, P, Smith, R and Dempsey, G 2001).

The OECD reported that: The effects of counterfeiting and piracy on economies and society as a whole are far greater than initially thought. The scope is broad; infringing products are no longer limited to falsely branded items such as fashion clothes, luxury watches and designer sunglasses, but nowadays include a growing number of common food, pharmaceutical, chemical, electronic and household products. In addition to the economic effects on holders of intellectual property rights, such illicit practices increasingly pose threats to the health and safety of consumers. Moreover, the production of counterfeit and pirated goods has also become more sophisticated, with organized criminal groups playing an increasingly important role. For example, in US, The FBI reports that IP theft robs of 'hundreds of thousands of jobs and as much as a billion dollars a year in lost tax revenues' (FBI 2003).

The European Commission show a number of more than 27 million articles suspected of violating intellectual property rights Statistics published on 19 September 2019. In 2018, almost 70.000 detention cases were registered by Customs. As far as the detained articles are concerned, the value of the equivalent genuine products is estimated to be over 740 million euro. The top categories of detained articles were cigarettes, which accounted for 15% of the overall number of detained articles. This was followed by toys (14%), packaging material (9%), labels, tags and stickers (9%) and clothing (8%). Products for daily personal use in the home such as body care articles, medicines, toys and electrical household goods accounted for nearly 37% of the total number of detained articles. (Intellectual Property Rights, 2018).

China continued to be the main source country for goods infringing intellectual property rights. North Macedonia was the main provenance for counterfeit alcoholic beverages. Turkey was the top source for other beverages, perfumes and cosmetics. EU customs saw a high number of fake watches, mobile phones and accessories, ink cartridges and toners, CDs/DVDs, labels, tags and stickers from Hong Kong, China. The main source for computer equipment was India, Cambodia for cigarettes and Bosnia and Herzegovina for packaging material. (Chang, L. 2012)

Economic Impact in Dubai

In Dubai, crimes have become increasingly involved in the production and distribution of counterfeit and pirated goods and have adopted increasingly sophisticated and complex modi operandi, facilitated by technological advancements and complex global distribution channels. Online marketplaces are increasingly becoming an important source of income for criminal groups engaged in the sale of counterfeit and pirated goods.

The Commercial Compliance & Consumer Protection (CCCP) sector in Dubai Economy witnessed 63% year-on-year increase in trademark files registered on its 'IP Gateway' portal during the first six months of 2019, indicating a high level of confidence in the emirate's ability to protect intellectual property (IP) and enable local as well as global businesses to grow sustainably. Trademark owners worldwide registered 4,735 brands on the portal while commercial agencies registered another 29 during the first half of 2019. The Intellectual Property Protection section in Dubai Economy also resolved 186 cases relating to trademark infringement in H1, 2019, a 23% increase compared to the 151 cases registered during the same period in 2018. Commercial agencies brought forth 16 cases of trademark infringement in the first six months of 2019, which also marked a 33% increase over the same period in 2018.

Year	Number of Cases	Number of Individual Accused	Number of Seized Counterfeit products	Estimated Value (AED)
2016	275	275	549.527.69	1.878.323.739
2017	287	300	1.223.048	496.989.242
2018	290	299	3.036.207	1.286.569.746
Until June 2019	169	170	1.373.931	245.240.135

Fig.1 Shows the number of cases and estimated value (AED) in Dubai

The following are some of the negative economic impacts of piracy and counterfeiting:

- Reduced sales of goods and services with an IP component, as legitimate items are forced to compete with lower-priced pirated copies
- Reduced rates of return available to IP rights holders, thereby reducing incentives for innovation and further investment in the production of goods and services with an IP component (OECD 2006)
- Long-term effects, including reduced economic growth, reduced taxation collections, reduced employment levels in industries focused on the production of goods and services with an IP component (OECD 2006)
- Increased national trade and balance of payments deficits, especially if the IP industries detrimentally affected by piracy are export industries (OECD 2006)
- Reduced direct investment in creative industries – pirates 'do not invest in recorded music' (Sean A. 2017).

Key Products Sector

Impact of intellectual property crime

The negative impact of IP crime includes adverse effects on business, the national economy, and consumer health and safety. Consumers who knowingly purchase counterfeit products are unlikely to have purchased genuine equivalents and often do so because the counterfeit versions are much cheaper. This means that legitimate companies face competitors that steal their IP without paying taxes or complying with the regulations and quality standards that the former do.

Such unfair and illegal competition displaces legitimate business activity, with clear negative knock-on effects for consumers, governments and economic growth. A recent ICC Business Action to Stop Counterfeiting and Piracy (BASCAP) study estimates that in 2013 between US$470 billion and

US$597 billions of genuine economic activity was displaced by counterfeiting. Counterfeiting is also estimated to cost up to 2.6 million jobs with projected job losses estimated to be between 4.2 and 5.4 million by 2022.

Year	Luxury Products (Handbags, Watches, Jewelry)		Vehicle Parts		Cosmetics		Mobile Phones	
	No. of pieces	Estimated Value (AED)	No. of pieces	Estimated Value (AED)	No. of pieces	Estimated Value (AED)	No. of pieces	Estimated Value (AED)
2016	249,903	527,725,676	15,517	473,600	217,927	11,607,222	2,843	1,735,505
2017	256,244	406,425,129	45,720	1,292,400	339,186	13,192,436	344,294	6,132,093
2018	294,709	1,145,753,368	195,038	936,205	1,013,824	23,041,722	569,763	50,475,321
Total	800,856	2,079,904,173	256,275	2,702,205	1,570,937	47,841,380	916,900	58,342,919

Fig.2 Estimates of the loss to various sectors in Dubai

7. BUSINESS EXCELLENCE FRAMEWORKS

Organizations need to assess and evaluate its performance regularly to ensure quality and continuous improvement. Decision makers adopt some business excellence frameworks such as Malcolm Baldrige and European Framework for Quality Management (EFQM).

The value is that Baldrige and EFQM frameworks are intentionally non-prescriptive. It does not tell leaders how to manage their organizations. There are no two organizations alike – organizations operate in different environments, even in the same industry or market, are pursuing different strategies; they have different core competencies; and they are addressing different strategic challenges.

Some research indicates that organizations implementing TQM/ BEM will obtain significant benefits including both increased financial profit (Hendricks & Singhal, 1996; Hausner, 1999; Hendricks & Singhal, 2000; Hansson & Eriksson, 2002; Jacob et al., 2004; Boulter et al., 2013) and non-financial outcomes (GAO, 1991; Powell, 1995; Curkovic et al., 2000; Hoisington & Huang, 2000; Douglas & Judge, 2001).

Baldrige Model Structure

The system of assessment to apply for the Baldridge Award is based on the response to the implementation of the criteria, segmented in two dimensions, “processes”, and “results”. The “processes” category refers to the methods that the organization uses to implement criterion 1 to 6;

and the "results" category, to demonstrate the achievements obtained in the sub-criterion listed in category 7. It is worth mentioning that Baldrige demands for the "results" (7) category, five years of positive trends for each of the sub-criterion of results. (Miller, J., & Parast, M. 2018). The Malcolm Baldrige framework is basically based on the following principles and values, concepts that have been observed in high-performance organizations that successfully implemented them:

- Leadership with visionary skills
- Client-oriented
- Organizational and personal learning
- Appraisal of employees and partners
- Business agility
- Long-term planning (future)
- Continuous improvement and innovation
- Management by facts
- Social responsibility
- Results and value creation approach
- Systematic perspective

These principles and values are set out in three large blocks that support the Baldrige framework structure. The Malcolm Baldrige excellence framework is built on a holistic and systemic view, with a strong emphasis on the causal and dynamic relationship between the leadership, the staff, and the results.

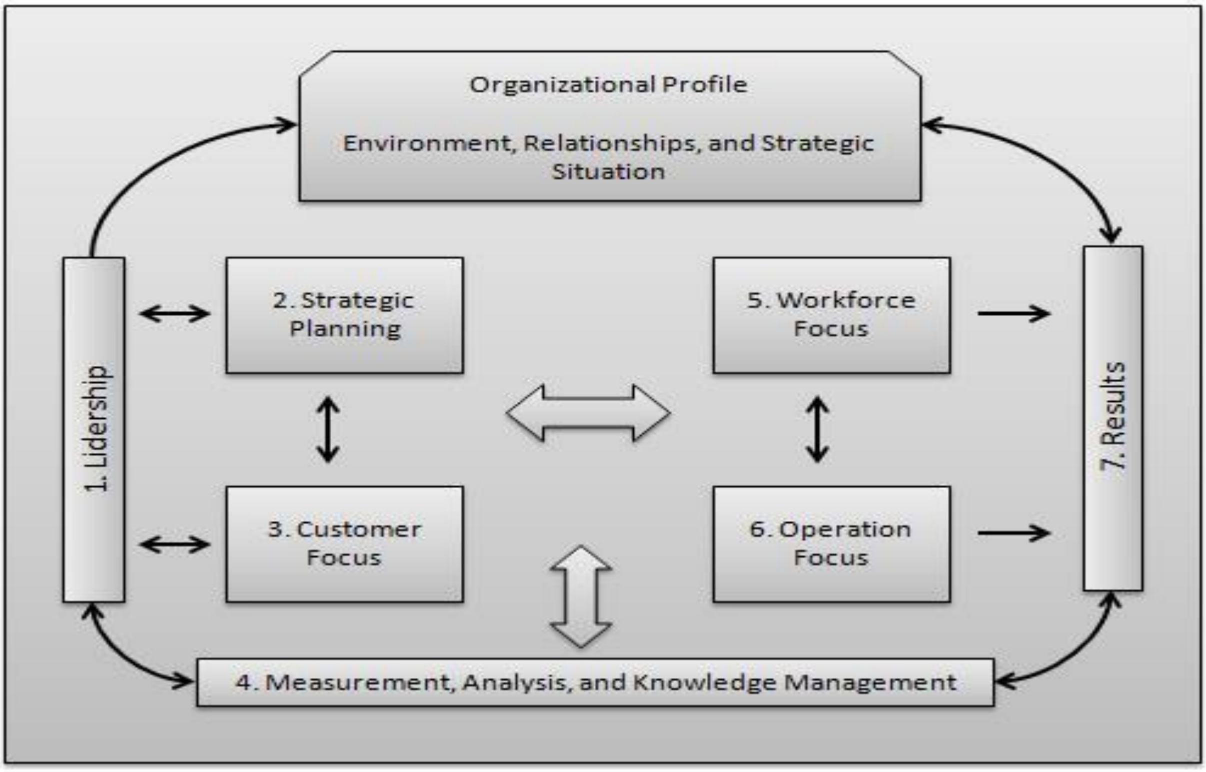

Figure 3: Malcolm Baldrige Framework

The other business excellence model that Dubai Police used is the European Framework Quality Management (EFQM). It is a business excellence model to meet the sustainability of the stakeholders of an organization. EFQM self-assessment can be applied in different sectors such as education information technology.

EFQM framework is made up of the following main principles: Result orientation, customer orientation, leadership and consistency of objectives, management by processes and facts, the development and involvement of people, the development of partnerships and the social responsibility of the organizations. (Jaeger, A., and Matyas, K. 2016)

To implement these principles, we need three phases: Initiation phase, realization phase and maturity phase. EFQM has nine criteria divided into two categories, which are enablers and results. Enablers' criteria are responsible for key activities management. On the other hand, results criteria are responsible for the way the results of an organization are achieved. These criteria include Leadership, Strategy, people, alliances, resources, processes, products, and services.

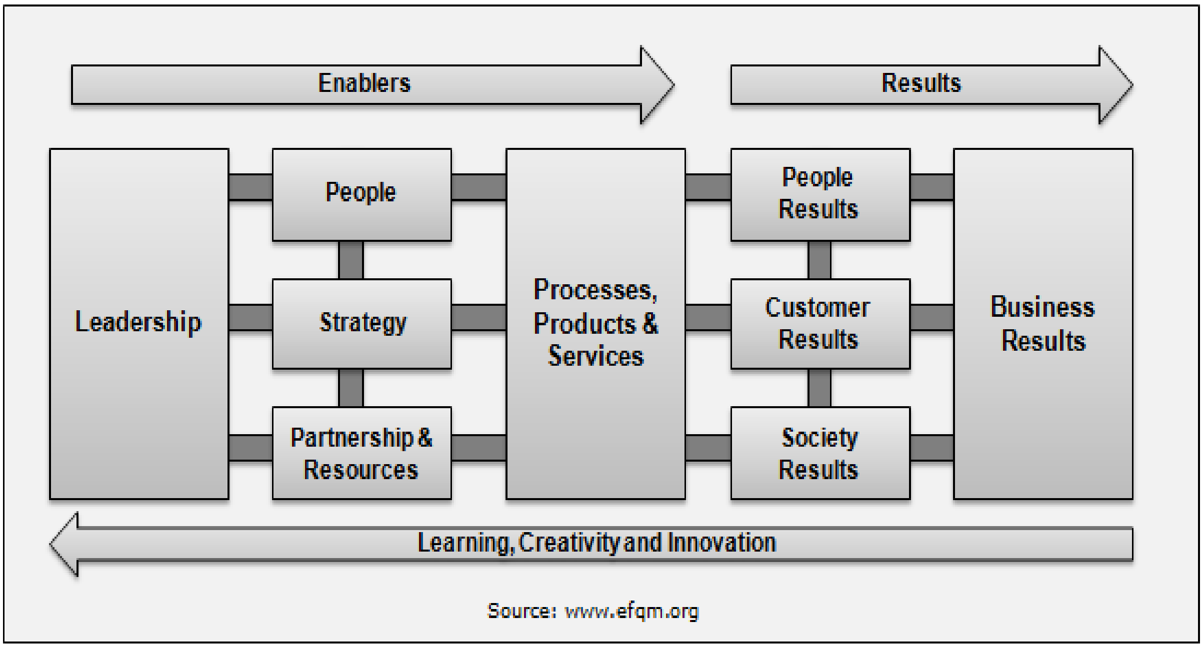

Figure 4: EFQM, 2013 Framework

Figure 4 shows the EFQM 2013 version, framework and its criteria, which are grouped into enablers and results. The latest version of EFQM is represented by Figure 5. It has three main dimensions with seven criteria. The dimensions are direction (why to implement the new framework), execution (how to implement), and results (what is obtained as an outcome). (Nenadál, J. 2020).

Figure 5: New EFQM Framework

The framework consists of seven criteria: purpose, vision and strategy, organizational culture and leadership, engaging stakeholders, creating sustainable value, driving performance and transformation, stakeholder perception, strategic and operational performance.

The excellence models provide a well-defined structural reference framework, which is based on the best practices to implement a corporate governance, oriented to processes and results (integrated corporate management system). The excellence models contribute as well with the definition of metrics (quality standards) and provide a scoring system to assess the organizational performance in all the dimensions required by the stakeholders.

8. DUBAI POLICE – CASE STUDY

The Dubai Police (DP) force was founded on the 1stof June 1956 in Naif, a historic neighborhood located in the Deira side of Dubai-UAE. The force grew from 29 members in 1956 to 25,000 in 2018. We cover an area of 4,114 square kilometers and a population of more than 4.7 million people in a city that has seen tremendous economic growth and a high level of urbanization. We come under the jurisdiction of the ruler of Dubai and we follow the motto of "Smart Secure Together" to reflect our core belief that technology, openness and tolerance are the corner stone of our identity. We provide service to a highly-diversified population that includes more than 200 nationalities. The Smart Police Station (SPS) is an integrated interactive self-service police station (without human interaction). It is the first of its kind, which allows the community members to apply for DP services that are provided at traditional police stations. (Román, J. 2019)

DP´s headquarters is located in a central area of the city of Dubai to allow easy access to both our employees and members of the community. Designed to fit the developing architecture of surrounding Dubai, our headquarters building features a modern architecture with a state-of-the art facility that features the latest technology trends in terms of fighting crimes and predicting new threats while serving our community with ease. DP were the first to create a Smart Police Station (SPS) to provide excellent and seamless service without the need for face- to-face interaction. DP aims to provide quality services to all segments of society by winning their satisfaction and exceeding their expectations. DP uses the Business Excellence Framework (EFQM, Baldrige and Dubai Government Excellence Program) and formal benchmarking (TRADE Methodology) to assess their performance in order to offer outstanding service to its stakeholders. In 2018 EFQM recognized Dubai Police with a prestigious International Award: "Prize Winner in Succeeding through the Talent of People & Sustaining Outstanding Results" (first Police Force in the World to achieve this prestigious award). In order to become an award winner, Dubai Police has put significant efforts to improve its performances. This great achievement of sharing knowledge among each department is one of the most important reason to applied and understand the main value of the Business Excellence Frameworks. Examples of Dubai Police´s efforts for winning EFQM are improvements of leadership, employee´s commitments and skills, vision and tangible strategies and good relationships among the main stakeholders.

Since 1997, 2.656 Dubai Police´s employees for all the departments have been trained in quality tools like: Business Excellence Frameworks (Dubai Excellence Government Program (4G), EQFM, Baldrige), Benchmarking (TRADE Methodology), Total Quality Management (TQM), Lean Management, Six-Sigma, ISO Standards, etc.

Dubai Police using the guidelines of Business Excellence Framework helps to identify the strength and the opportunities for improvements (OFI´s). These models guide the successfully performance for all the departments at Dubai Police. Criminal Investigations departments had been using the DGEP (4G) assessment to performance better and to improve the results in all of the departments like anti-economic fraud, cybercrime, Interpol, etc. The success of the Intellectual Property Crime in Dubai presented in this paper it´s based on the guide that the Business Excellence Framework 4G Dubai Government Excellence Program (DGEP). Also, DP assess their systems and performance against BEFs. The three ways that DP used assess are:

1. A pro forma approach. This involves forms being designed for all of category items. Each form requires DP to record how it addressed that particular item, its strengths, weaknesses, and actions for improvement.

2. A workshop approach. This approach involves a Dubai Police senior leaders gathering data and evidence to present to peers at a workshop. At the workshop (twice a year), performance against the model is scored and action plans (Dubai Police improvement plans, aligned with Dubai Vision 2021).

3. An award approach. This approach involves writing a full submission document based on the evidence within the submission document and supporting evidence from a site visit, internal or external assessors evaluate the organization and provide feedback. For example: EFQM, DGEP, Global Performance Excellence Award from APQO, among others.

Dubai Police’s services not only maintain security and stability, but try to exceed these and cover all of the requirements of Dubai’s society. The DP’s strategic plan contains objectives that meet or exceed the expectations and aspirations of its customers and guarantees their satisfaction, all of which stems from the strategic plan of the government of the Emirate of Dubai. DP has always strived to maintain the highest levels of comfort, security, and safe living for the emirate's visitors and residents. The fact that 97.6 percent of the people feel it is safe and secure to walk out at night in the UAE has helped rank the country as the world's second safest place. UAE's policies and strategies were behind that achievement. (Gallup Organization. 2018).

Globalization continues to link societies across the primary domains of social or personal interactions, business dealings and governmental structures. The use and role of technology has permeated most aspects of our daily lives and has generated greater efficiencies and interconnectedness. The spread of technology is often widely accepted and adopted before criminal vulnerabilities or counter measures have been identified and managed. Connectivity means greater productivity, but also increased vulnerability. While globalization and technological progress are largely positive advancements, they also bring new threats to Dubai's security and exacerbate pre-existing ones. As criminal activities are increasingly complex, they require more than just technical skills to carry them out. Criminal entities are using emerging technologies to build networks and organisations to undertake complex transactions and multi-faceted transnational crimes. The remote and borderless nature of the internet, its global reach and the speed of technological uptake and change make cybercrime among the most pressing issues for the Dubai Police.

Dubai Police continues to evolve and adapt to emerging criminal challenges by embracing technology to counter criminal threats. This has involved: participation in cybercrime initiatives, identifying innovations, and working with the private sector and government specialist units to build capabilities and networks for detection and response. This collaboration is central to developing technical capabilities to ensure criminals do not place themselves beyond the reach of law enforcement. Technical advances in policing require specialist skills and research, collaboration with international partners, often legislative reform, the development of procedures and appropriate evidentiary standards as well as consideration of disruption and prevention approaches to threats. Such work often takes time to develop and implement. The Business Excellence Frameworks described in previous sessions has been helping the Criminal Investigation department to continues improve, daily basis, the process of investigation base on the guideline of the assessment process. In every project or initiative, DP use the Business Excellence framework to evaluate the process and the results and to build the Business Improvement Plan.

9. CONCLUSION

By analyzing Dubai Police case it has been demonstrated that the analyzed world class organization not only uses a BEF (Baldrige, EFQM, Dubai) to guide the operations (CID Intellectual Property

Unit) of the company but also uses a variety of management tools and techniques in its operation. Besides the BEF it has been demonstrated that the company uses specific mechanisms (Criminal Investigation in Intellectual Property) and characteristics towards excellence. The case study has illustrated that Dubai Police using the Business Excellence Framework improved the performance of the organization and help the different department to performance better using the guidelines of BEF.

The problems for content users as a result of IP crime include poor quality products, with possible health and safety impacts. The problems for the Dubai Government and the new challenges for Dubai Police as a result of IP crime include forgone taxation revenues and reduced economic growth which, in turn, impact on employment levels. It is clear that IP crime causes serious problems, and in recent years' governments have devoted significant resources to enforcement activities and legislative amendments.

Dubai Police (DP) use the Business Excellence frameworks (BEF) embrace the same principles, a holistic and systemic approach, process, and result. With the description and analysis of these frameworks, we can conclude that BEF is absolutely integrated with all of the works that Dubai Police do in daily basis, because it focuses on an approach for integrating the process criteria of the frameworks, for example DP used the Baldrige Criteria it integrated with the 6 processes criteria with the core of Business Process Management. These frameworks are "non- prescriptive", that is, they enable the organizations to have a generic structure to design their own "corporate process-oriented management system". However, it is important to follow the core principles and values over which these excellence frameworks rest. Considering the above, both models (Baldrige and EFQM) provide an excellent reference framework to introduce "Process-oriented Management (BPM)" and integrate it with the "Business Excellence Frameworks (BEF)".

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World Intellectual Property Indicators (WIPO): Filings for Patents, Trademarks, Industrial Designs Reach Record Heights in 2018

Reduced Energy Consumption Using Lean Six Sigma

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ABSTRACT

Purpose - This research aims to use Lean Six Sigma in a project that aims to reduce the consumption of electricity in a manufacturing company.

Methodology/approach - The method used was the case study, whose nature is classified as applied, and the article was started with a bibliographic search. The procedures of the case followed the steps of the DMAIC cycle (Define, Measure, Analyze, Improve, and Control) with the support of quality tools and use of software to assist in organizing the data. In addition to identifying the departments with the highest consumption, were realized a series of measurements on the main electrical equipment. With the causes of the problem identified, actions were taken.

Findings: After performing the actions and analyzing the consumption averages, the monthly reductions were 23% during off-peak hours and 39% during peak hours. Exceeding the goals defined at the beginning of the project and culminating in an average monthly savings of R$15,270.60. The research showed the efficiency and effectiveness of the application of Lean Six Sigma, since the results obtained provided significant savings after implementation.

Limitations: This study has the limitations are non-probabilistic samples and dependence on perceptions. These characteristics of the study constitute a bias for the analysis.

Practical Implications: The Lean Six Sigma management strategy allows organizations to succeed in projects. In addition to achieving results with efficiency and reliability.

Originality/value: This study case study generates a scientific contribution, in addition to condensing information that is relevant to companies as a whole. This research also fills gaps in the scientific literature regarding the use to reduce electricity consumption.

Keywords: Lean, Reduction, Consumption, Energy

1 INTRODUCTION

In the current world scenario, with the development of different products and services, as well as more demanding customers, competitiveness among organizations increase both in national and international markets. Which requires a search for greater efficiency in operations and management processes, working in several variables such as costs, quality, time, flexibility, and innovation (Santos et al., 2015). Thus, the integration of strategies such as Lean Manufacturing and Six Sigma are highlighted, which has generated a positive impact on business performance (Endler et al., 2016).

Lean Six Sigma incorporates Lean Manufacturing and Six Sigma techniques to improve processes. Lean Manufacturing uses techniques for immediate action on identified problems working on the improvement and speed of processes contributing to the reduction of lead time. Six Sigma, on the other hand, provides tools capable of transforming data into numbers and statistics, focusing on reducing variability and achieving goals, implementing structured methods (Pereira et al., 2017).

The possible weaknesses of one are filled with the attributes of the other, becoming together, a powerful tool that generates a positive impact on the performance of processes.

Lean Manufacturing increases speed, efficiency and elimination of waste. Six Sigma proposes improvement actions to combat variations, aiming, in this way, to reduce waste in its most different aspects (Morais, 2014). This combination promotes quality.

For Deming (1990), any effort to improve the product from the customer's point of view can be considered quality. And quality is directly related to the effect that product improvement has on customer needs. According to Oliveira (2014), currently the quality of products, services and processes is not just a factor of competitiveness. Quality is an essential and mandatory tool that the organization must develop to remain firm in the current globalization of markets.

The evolution of organizations has led to the emergence of problems whose degree of resolution requires the support of methods and techniques. These methods are able to assist in the identification of causes and decision making. In view of this, quality tools were developed to solve problems efficiently through the analysis of facts and data. Oliveira (2014) highlights that quality tools enable, in a simple and direct way, the verification, interpretation and solution of quality problems at different levels.

For Ishikawa (1997), 95% of the problems can be solved when the seven quality tools are used. Since, when grouped and analyzed, irregularities can be highlighted and the causes related to their effects.

The Lean Manufacturing and Six Sigma philosophies, despite having particular characteristics, are used in an integrated manner (Dias, 2011). Lean Six Sigma has been gaining prominence not only in the theoretical scope, but also in practical applications in products and services companies (Endler et al., 2016; Pinheiro et al., 2013).

Unlike Total Quality, developed by technicians, Six Sigma emerged from executives as a way to make a business successful. To achieve these results, this methodology was used in conjunction with the Total Quality tools appropriate to each type of problem to be solved (Fernandes, 2005).

The use of Lean Six Sigma in the company under study is justified by the results already achieved with its application in the most diverse sectors. The research refers to the project to reduce electricity consumption, to promote improvements in the production process. The main objective of this work was to reduce electricity costs, a high rate that outweighed the company's costs.

Management through Lean Six Sigma facilitated the development and completion of the project, as its tools were structured to achieve the established goals and were essential in collecting data and preparing the action plan. It was also possible to measure the financial return after the project was applied.

2 RESEARCH METHOD

It is a case study, which according to Yin (2015), is a strategy in which it has an emphasis on contemporary phenomena included in a real-life context. The nature of this research is classified as applied, as it covers practical situations that occurred in the company under study.

The proposal is based on exploratory research, which, as Martins et al. (2014), is used when it is intended to test hypotheses, procedures, and instruments in relation to events that have little knowledge about a certain phenomenon. For Ganga (2012), the focus of exploratory research is not to test or discover particular concepts but to actually explore the phenomenon, aiming at the search for information hitherto unknown.

A quantitative approach was used in the present study, which, according to Ganga (2012), aims at the ability to quantify and statistically confirm cause and effect relationships. This relationship occurs between the researches variables, seeking to explain the factors that influence certain phenomena. For Miguel et al. (2010), in this type of approach, the way in which variables are measured is of paramount importance, and the researcher should be concerned with the reliability of the measuring instrument.

As a basis for the case study, initially, a search was carried out on books, periodical websites, and main published articles. These articles have as theoretical subsidies the bibliographic research, which according to Ganga (2012, p. 212) "seeks to know and analyze the cultural and scientific contributions of the past, existing on a certain subject, theme or problem".

To contribute to the reach of the proposed objectives, the project team was defined, chosen in such a way that all components were directly involved in the process. Furthermore, This team must be competent to carry out the activities.

Subsequently, historical data were collected in relation to expenses with electricity and the goals that should be achieved were defined. An inventory of the most consumed electrical equipment was also carried out, through daily measurements carried out with the aid of watt pliers, in addition to the analysis of documents and catalogs to seek quantitative and accurate technical information about this equipment. The information was collected and stored in spreadsheets, which were also used for calculations, graphs and tables.

The project was carried out following the steps of the DMAIC with the help of Quality tools. These steps were followed in order to develop a diagnosis of the situation studied and outline suggestions for intervention and implementation actions.

3 CASE STUDY

The company's headquarters began to transfer its production from Campinas - SP to the region in 1997. This installation was due to an invitation from the government of the state. This state offered tax incentives and the availability of resources such as labour and raw materials.

The company started about 160 years ago when the first product was patented. Throughout its trajectory, the company has been gaining space in the market and acquiring a considerable share of customers. The company became known worldwide and became the largest manufacturer in its product line, standing out mainly for the quality offered.

The company has, in addition to the unit under study, a factory in China and another factory located in São Paulo, as well as offices in several countries. The company has 249 employees. Of these, 197 are permanents staff, 11 apprentices, 11 from conservation and cleaning services, nine employees from the collective restaurant, nine from outsourced security services, two from medical and health services.

In addition, there are 10 interns from different areas such as production engineering, environmental engineering, administration, economics, information systems, and human resources. In addition to this staff, technicians from vocational high schools are selected annually to compose the various sectors. The company is responsible for monitoring the professional development of these students.

The work hours consist of three shifts each with eight hours a day from Monday to Friday. The operation of the 2nd and 3rd shifts occurs only in the plastic injection department where the demand for production is high. The company controls the entry and exit of employees through turnstiles and markings on time clocks that read and record the codes of each badge in the system.

If an urgent production order occurs, an extra two hours are added to the commercial shift. With that, he finishes the day at 19h18min or can still work on Saturdays.

The company has three distinct product lines X, Y, and Z, where they are subdivided into several models, each with a specific eight-digit code that differentiates one from the other. As for the physical characteristics, vary according to the model and country of destination, in addition to presenting differences in relation to voltages and features. In addition to household appliances, the company produces store replacement items for both import and export.

The company also produces boxes and lids, injected in the plastic injection department. These sets are used as packaging for accessories produced by the factory itself and at other company headquarters. There has been a significant increase in the production volume of this product in the past two years. This explains the fact that the company operates the three shifts since most of the items injected in the second shift and third shift are made up of boxes and lids, due to their high demand.

3.1 Production Process

The factory has two assembly lines for product X and two for product Y each with a production capacity of 350 machines per day, in addition to the product line Z whose daily capacity is 64 machines. The annual production capacity of the box and lid set is 2,500,000 units.

The production system adopted by the company is per batch, in which the production planning and control department receive a monthly program. This department specifies the model, quantity, and sequence in which the machines will be produced. Planning is divided into weekly programs per assembly line. This line may undergo changes in the production order due to unforeseen circumstances, as long as it does not delay the delivery of the order to the customer.

3.2 Company analysis and diagnosis

The company has eighteen departments, including the productive and auxiliary departments. With this number of active departments, the number of electrical equipment that must be in operation is big. Therefore, electricity consumption is quite high.

Thus, the high consumption and costs with electricity will directly affect the cost of the product. Therefore, the company realized the need to start a Lean Six Sigma project. With the aim of searching for ways to improve the production processes to guarantee optimization of the use of electric energy, as well as to seek the factory's awareness about waste.

4 PROJECT LEAN SIX SIGMA

For the development of the study, two hours of the daily working day were considered, outside peak hours and peak hours. As defined by the National Electric Energy Agency (ANEEL) in Normative Resolution No. 479, of April 3, 2012, chapter 1, article 2, item LVIII, peak rate or peak time refers to the period of the day that consumption of electricity tends to be higher and consequently the value of the electricity tariff and demand is also higher. These hours are defined by the local energy distributor and approved by the national electric energy association, considering the system load curve. On the other hand, hours outside peak hours are the total of consecutive daily hours that complement those not included in peak hours.

Also according to the national electric energy association, different consumption rates are applied, according to the time of day. During peak hours, the rate charged is higher than that charged outside peak hours. In Ceará, peak hours are considered from 5:30 pm to 8:30 pm, with the exception of Saturdays and Sundays and some national holidays.

4.1 Define

The first step in preparing the Lean Six Sigma project was to define precisely and clearly, what would be done, establishing an objective. Therefore, at the beginning of the project, metrics were defined, where the primary goal was to reduce the plant's electricity consumption. The target for peak hours was relatively higher because the monthly fee charged for these hours were bigger, as will be shown.

The definition of such targets was made based on a survey of the electricity bill data from January to July 2018. They were used to identifying consumption in kilowatt-hours (KWh) at the tip and outside the tip, in addition to the values account and fees charged in those months. Production data were also collected during this period. In addition to calculating the amounts spent in kilowatt-hours per unit of manufactured product and in monetary units per unit of manufactured product, as detailed in Table 1.

Table1 – Electric consumption history

Month	Production	Off-peak eletricity consumption (Kwh)	Peak time eletricity consuption (Kwh)	Total eletricity consuption (Kwh)	Energy bill amount (R$)	Off Peak fare (R$)	Peak fare (R$/Kwh)	R$ per machine produce	KW/off-peak machine	KW/peak machine
January	8.312	126.117	7.023	133.140	73.967,14	0.40	1,75	8,9	15,17	0,84
Febuary	9.240	153.012	8.772	161.784	84.690,23	0,38	1,7	9,17	16,56	0,95
March	9.474	148.093	10.329	158.422	86.201,40	0,38	1,71	9,1	15,63	1,09
April	9.472	152.409	12.770	165.179	95.454,16	0,40	1,77	10,08	16,09	1,35
May	7.957	145.080	7.501	152.581	87.208,82	0,41	1,80	10,96	18,23	0,94
June	6.586	152.669	7.479	160.148	97.992,54	0,47	1,85	14,88	23,18	1,14
July	6.819	135.709	9.332	145.041	96.819,50	0,41	1,83	14,2	19,9	1,37
Aerage	**8.266**	**144.727**	**9.029**	**153.756**	**88.904,83**	**0,41**	**1,77**	**11,04**	**17,82**	**1,10**

Figures 1, 2, and 3 below show the graphs with consumption at peak and off-peak hours in kilowatt-hours and expenditures in the analyzed period.

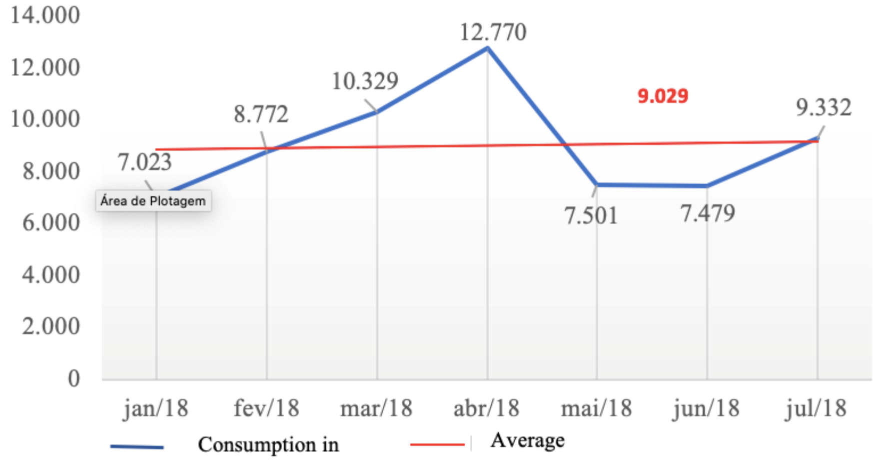


Figure 1- Monthly consumption during peak (KWh)

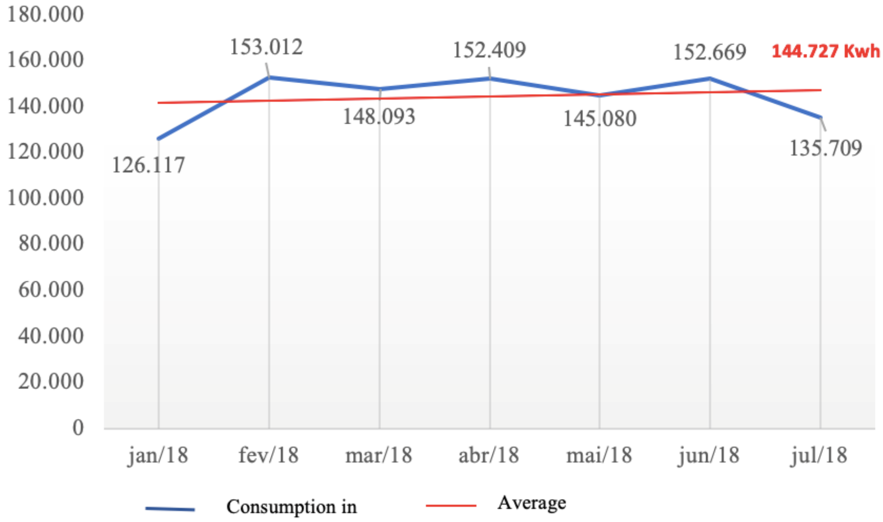


Figure 2- Monthly consumption Off-peak (KWh)

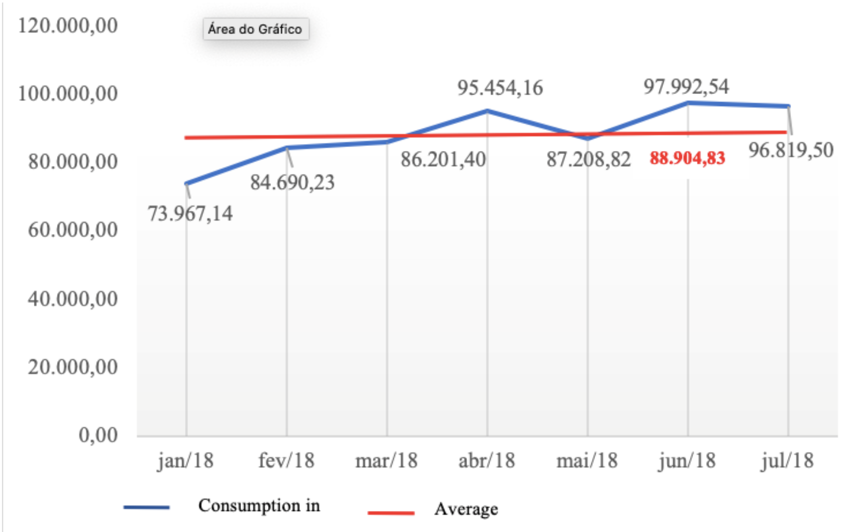


Figure 3- Electricity Expenditure History (KWh)

It can be seen from the graphs shown in the figures that there were some fluctuations regarding the consumption of electricity at peak and off-peak times. However, as shown in Figure 3, over the months there was a significant increase in the value of the electric bill.

Based on these data, the possible gains were estimated, if the reduction targets were reached, in which July's tariffs were considered in the calculation. Table 2 shows these estimates.

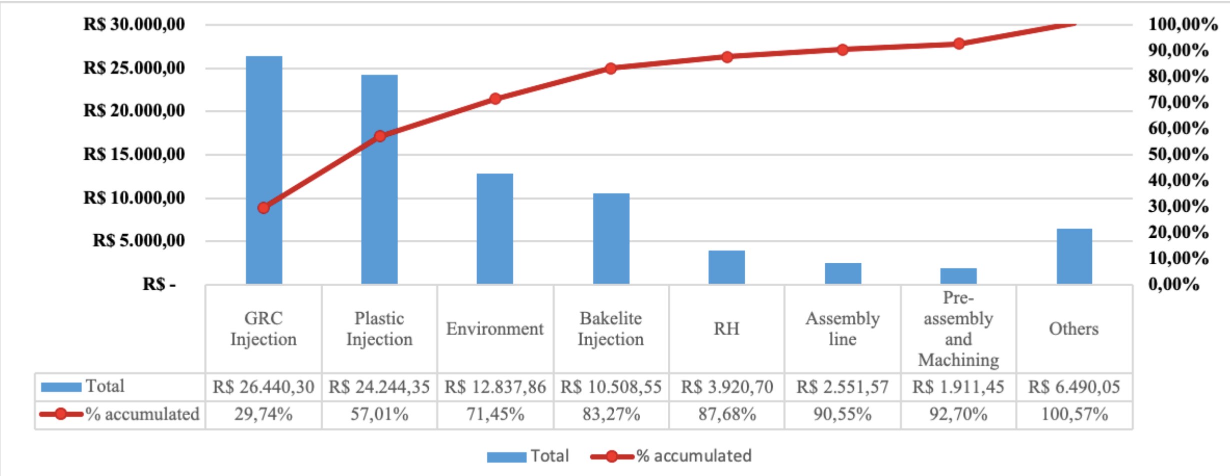
Table 2 - Growth expectations

	Peak time	Off peak time	Total
Fare (July-2018)	R$1,83316	R$ 0,41182	-
Average consumption (KWh)	9029	144727	153756
Reduction targets	30%	4%	-
Estimated monthly consumption reduction (KWh)	2708,83	5789,08	8497,91
Estimated monthly savings	**R$ 4.965,72**	**R$ 2.384,06**	**R$ 7.349,78**
Estimated annual savings	**R$ 59.588,59**	**R$28.608,71**	**R$ 88.197,30**

4.2 Measure

After defining the focus of the project, the next step was Measure. In this, the objective was to make several measurements to identify how critical the problem was and to understand its causes.

During this stage, we sought out the departments that had the highest consumption of electricity. The data were obtained through software that the company uses, SAP, where it has the cost center with all the company's expenses. In this system, the electric power bill to be paid monthly is launched through an apportionment made by the cost center between the departments. In which the highest values are launched for the departments with the highest installed power. In view of this, Figure 3 shows the graph that was used to facilitate the identification of the departments that had a higher expenditure compared to the average for the period from January to July 2018.



	GRC Injection	Plastic Injection	Environment	Bakelite Injection	RH	Assembly line	Pre-assembly and Machining	Others
Total	R$ 26.440,30	R$ 24.244,35	R$ 12.837,86	R$ 10.508,55	R$ 3.920,70	R$ 2.551,57	R$ 1.911,45	R$ 6.490,05
% accumulated	29,74%	57,01%	71,45%	83,27%	87,68%	90,55%	92,70%	100,57%

Figure 4 - Higher Consumption Departments

We can see in Figure 6 that 83.27% of the electricity expenses are concentrated in the GRC injection, plastic injection, environment, and Bakelite injection departments. Therefore, the focus will be given to these four departments initially.

After this stratification, the first step was to list and measure the actual consumption in the practice of the main equipment of these departments. For data collection, a verification sheet was created, identifying the department, the equipment, the consumption value in kilowatt per hour. In addition to the time needed in hours when such consumption occurs and the date of measurement.

To obtain the data, the *Wattímetro Minipa ET-4050* Pliers were used and data were searched in the equipment catalogs. During this process, a maintenance technician and another engineering technician were assigned.

In order to measure consumption, three measures were taken into account: the consumption of equipment in the normal operation, equipment maintaining heating and equipment heating. The consumption of equipment in the normal operation takes into account the period in which the equipment is producing, excluding, in this case, intervals (coffee, workplace exercise, lunch, dinner). The consumption of the equipment keeping the heating takes into account the time necessary for the electrical resistances to remain warm. This occurred after the weekend and during the breaks of the day. The consumption of heating equipment, on the other hand, considers the time necessary to heat the electrical resistances after they are turned off. This happened on Saturdays and Sundays since there was no production.

4.3 Analyse

In this step, the results of the data obtained in the measurement were analyzed in order to find causes and possible solutions to the problem. With the analysis of the data, it was possible to identify that the plastic injection presented the highest monthly consumption, according to Table 3.

Table 3 - Summary of actual consumption in practice

	SCHEDULE	
Departments	Off_Peak	Peak
	52705.0 KW	2996.4 KW
Plastic Injection	21704.97	R$ 5,492.88
	45326.4KW	0
GRC Injection	R$ 18,666.31	
	19404.0 KW	0
Environment	R$ 7,990.96	
	5019.5 KW	172.0 KW
Injection Bakelite	R$ 2,067.14	314.57

Brainstorming was carried out with all team members, to identify the causes of the high consumption of the four departments under review. During the meeting, several suggestions were discussed and analyzed in order to obtain viable solutions.

Subsequently, a cause and effect diagram (Ishikawa diagram) was developed. With that, it was possible to identify the main causes of the problems that occurred in the departments and the entire company

Through the diagram, it was possible to list points that can be worked on to reduce consumption:

- The electrical resistance of the plastic injection department are switched on 24 hours a day, from Monday to Friday;

The time required for heating electric heaters after the weekend is long;

- The 2nd shift could be eliminated if the daily demand was met in the 1st and 3rd shift;
- Working with a compressor smaller than the current one;

During the work, the fans are all connected to the work stations and, it is not possible to turn them off individually

There are no meetings with employees to discuss the plant's electricity usage.

4.4 Improve

According to the analyzes made in the previous step, with the aid of the cause and effect diagram. An action plan was drawn up to detail and direct improvement interventions. The plan consists of the following items: description of the problem, what should be done, who will be responsible for doing it, until when it should be done, and how much it will cost. The summary of the suggested actions follow.

As for the consumption of the environment department, after the measurements, it was possible to notice a high consumption of the compressor in operation. However, the air demand necessary by the company does not require a compressor with such high power.

As a first proposal for improvement, in this case, a budget was made with suppliers for the possible purchase of a new, smaller compressor that consumes less electricity. Feasibility calculations were made to analyze the investment required for the acquisition; however, the company decided that it would be unfeasible due to the investment value. This action was to be implemented in the near future.

Regarding the waste generated in the assembly and pre-assembly lines, the improvement implemented was in relation to the functioning of the fans. The method used to turn the fans on and off was only by a circuit breaker together, making it impossible to turn them on and off individually. As a result, budgets were made for the purchase of switches. Subsequently, the company's maintenance team installed an individual switch for each fan.

Evaluating the data, it was possible to realize that it was necessary that many of the equipment remains connected at this time. However, the GRC and bakelite injection departments, which did not work at that time, remained with all lamps turned on, unnecessarily. Thus, it was decided that, at the end of the work hours, the lamps would be turned off and on only the next day, thus reducing the waste generated. In the plastic injection department, as the 2nd shift was eliminated, it was also unnecessary for the lamps to stay on during this period, until the start of the 3rd shift, where they would be on again.

In the weekly meetings of the departments, one of the points that were discussed was about the waste that can be avoided, such as: turning off the machines that could be turned off during the lunch break, turning off lamps and fans during the lunch breaks, workplace exercise, and coffee.

4.5 Controle (Control)

In this stage, means were sought to control the actions implemented. In the plastic injection department, after the implantation, difficulties arose on the part of the employees of the third shift in the process of turning the electrical resistances on and off at the times defined in the project. To solve this problem, a control board was created to be attached to the department. The control board will be filled out of the schedules and those responsible for carrying out the operation.

The process will be monitored continuously, aiming to control the consumption of electricity. For this, monthly, an indicator with the results already obtained with the application of the project will be updated with future values. Then, sudden changes that may occur in consumption will be monitored by Industrial Engineering. To check the effectiveness of the project, a comparison was made before and after its implementation. Thus, it is possible to verify the reduction in consumption during off-peak and peak hours, in addition to the reduction in the value of the electric bill. Figures 5, 6, and 7 show the graphs that will be used as indicators for the control, in addition to the detailed results.

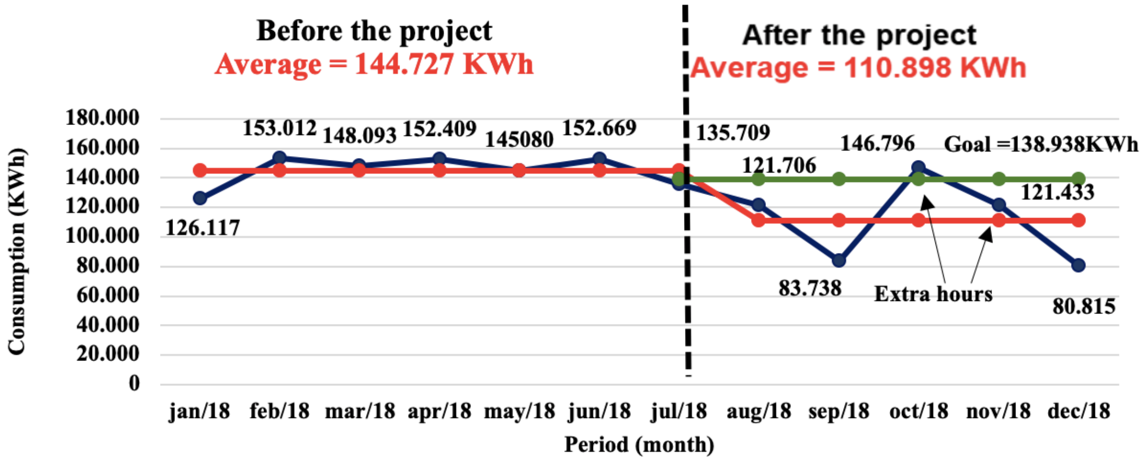


Figure 5 - Evolution of Consumption in Off-Peak Hours (before vs after)

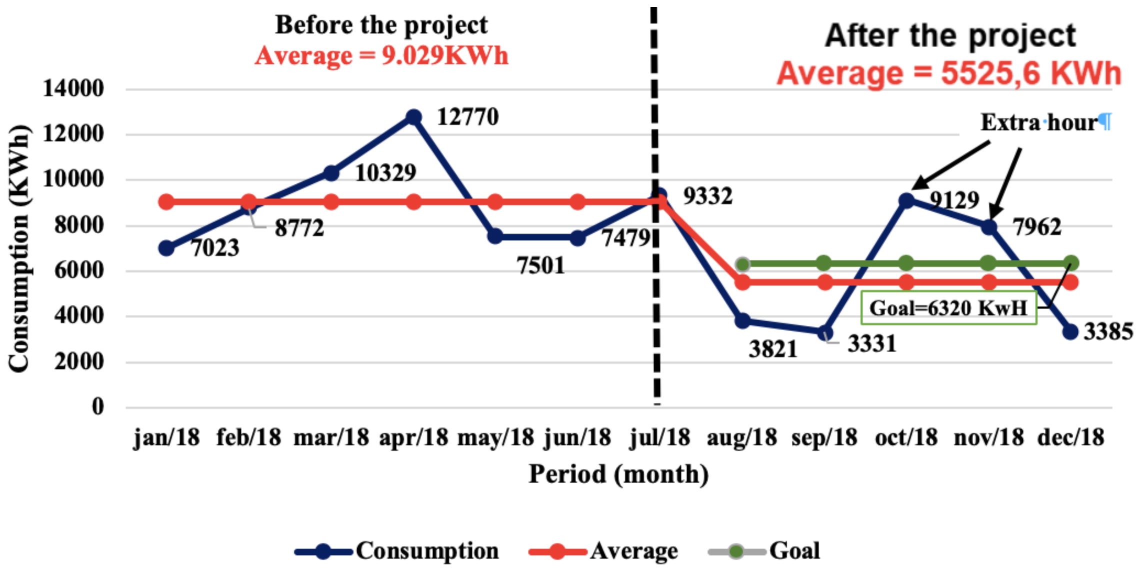


Figure 6 - Evolution of Consumption in Peak Hours (before vs after)

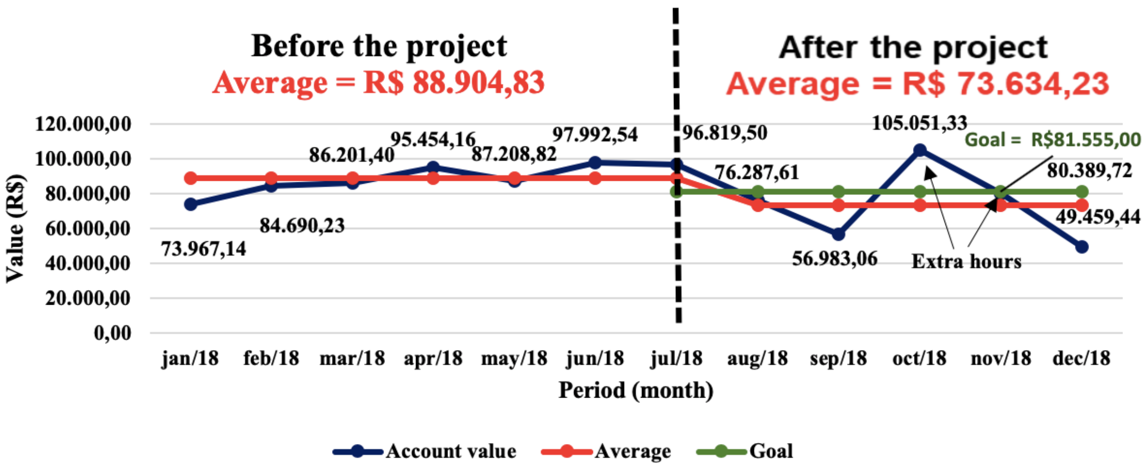


Figure 7 - Evolution of the Electric Bill (before vs after)

According to the data shown, it can be seen that there was a significant reduction in the average consumption of electricity after the start of the project (Figure 5). The figures show an increase only in the months of October and November. This increase is justified by the fact that the company received an order for production above its daily capacity. In addition, this order needed to be delivered urgently, so it was necessary to work overtime. The employees worked during the month of October and part of the month of November, from Monday to Friday from 5:18 pm to 7:18 pm and on Saturdays from 7:30 am to 4:18 pm.

5 RESULTS

As noted in the previous section, there was a significant drop in electricity consumption after the start of the actions. Checking the high acceptance rates in the results achieved. The following table shows the monthly averages of consumption in kilowatt-hours and expenditures in monetary units before and after the implementation of the project.

Table 4 - Average Monthly Consumption Before and After the Project

Off-peak time		
Period	Before the project	After the project
Average monthly consumption	144,727	110,898 KWh
Average monthly Reduction	33,829 KWh	
Pecentage Change	-23%	
Peak time		
Period	Before the project	After the project
Average monthly consumption	9,029 KWh	5,526 KWh
Average monthly Reduction	3503	
Percentage change	-39%	
Electric bill value		
Period	Before the project	After the project
Average monthly consumption	R$ 88,904.83	R$ 73,634.23
Average monthly Reduction	R$ 15,634.23	
Percentage change	-17%	

Assessing the values shown in the table, it can be observed that comparing the averages of monthly consumption before and after the execution of the actions. With these results, it can be seen that there was a reduction of 33,829 kWh per month in consumption during off-peak hours. This figure represents a drop of 23% and exceeding the goal defined at the beginning of the project, which was to reduce consumption by 4% at that time. At peak times, we also obtained positive results, with an average reduction of 3,503 kWh per month. This result represents a fall of 39%, also exceeding the goal established at the beginning of the project, which was to reduce consumption by 30% at that time.

As noted in Table 4 and Figure 7, the reduction in electricity consumption was achieved, representing an average monthly savings of R$ 15,270.60. These results are considered satisfactory since the improvement actions were implemented.

6 CONCLUSION

The objectives of this work were achieved, which focused on using the tools and methods of the Lean Six Sigma management strategy. Through this method, it was possible to reduce the consumption of electricity, eliminate losses, and optimizing the production methods used by the company.

The stages of the project took place according to the DMAIC cycle (Define, Measure, Analyze, Improve, and Control) linked to the use of some quality tools such as the Pareto Graph, Cause and Effect Diagram, 5W2H, Brainstorming and Check sheet. These tools helped define goals, collect and structure data, and to identify and solve problems.

In the Define stage of the DMAIC, the problem and goals were defined. Then, in the Measure step, a survey was made of the departments that had the highest consumption of electricity. With this information, several measurements were made of the main equipment that makes up these departments. In the Analyze stage, it was possible to identify root causes and point out solutions to the problem. In the Improve was the phase of suggesting and implementing viable improvements. In the last step, Control, it was possible to accurately visualize the results achieved and create ways to control them.

Applying Lean Six Sigma, the company was able to reduce electricity consumption more than expected, reaching the lowest values of 2018. In relation to the average of the first seven months before the project, an average monthly reduction of 23% was achieved (energy consumption during off-peak hours). This value exceeded the defined target of 4%. During peak hours, the average monthly consumption dropped by 39%. These results exceeded the goal established at the beginning of the project, which was to reduce it by 30%.

The research demonstrated the efficiency and effectiveness by using Lean Six Sigma, in which it made explicit the excellent results achieved, demonstrating clarity, security, and organization. Thus, the Lean Six Sigma allowing the development of practical actions based on tools, calculations, and methods that are easy to conduct.

It is not new that the company under study adopts Lean Six Sigma as a management strategy in its projects for quality, process, and cost reduction improvements. The development of this research provided significant savings after its execution, reducing waste and costs, and making the company more competitive in the market.

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Operational Excellence Using Gap Analysis: UAE IT Centers Case Study

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ABSTRACT

Purpose: There is a high demand on distance learning due to COVID 19 pandemic. As a result, the information technology centers of any educational institution are playing important role in maintaining the quality of education. It is very vital to assess and enhance the IT service performance. The motivation behind this research paper is to measure the operational excellence by applying gap analysis technique. The SERVQUAL tool is used in this research study in the information technology centers in three universities in United Arab Emirates.

Design/methodology/approach: The research study is conducted by calculating the perception and expectation scores (performance-based model). The gap scores (expected scores minus perceived-based model) are examined using SERVQUAL tool. The methodology is using survey questionnaire to collect data from 200-250 users of IT service centers from each university. The questionnaire has 22 questions, which represent the 22 items of five SERVQUAL dimensions. The survey participants concluded that the SERVQUAL is a useful tool for IT center service quality in the three educational institutions presented in this paper.

Findings: The SERVQAUL identified the gaps in service quality of IT centers for these institutions. The perception and expected scores of SERVQUAL in three IT centers of these institutions are also illustrated. The perception results are tabulated versus the expected results as well as the gaps are calculated. Moreover, we demonstrated the comparison between the average perception and the expected dimension scores results for each university. As a result, the averages of each dimension's items is calculated and the benchmarking between universities is done in terms of average expected and perception scores.

Research limitations/implications: We can conclude that the three universities should focus on the responsiveness dimension as it gets the lowest average gap scores. This study is cross sectional that is done on the users only. In addition, the decision makers' and service providers' feedback can be studied and more elaborated.

Originality/value: These scores can be used in business excellence models' criteria. Some of these models can be Malcolm Baldrige or European Foundation for Quality Management (EFQM). SERVQUAL can be integrated within the Malcolm or EFQM to enhance performance and continuous improvement.

Keywords*:* SERVQUAL, Excellence Models, Gap Analysis, Malcolm Baldrige, EFQM, Perception.

Paper type Research paper

INTRODUCTION

Due to the latest pandemic of COVID 19, the distance learning is adopted by most educational institutions. This leads to the increased demand on the IT departments. IT department in each educational institution is playing a vital role in the distance learning and maintaining the quality of education. For example, educators and students are using the web-based applications, online videos, emails, online exams (Beard and Humphrey). As a result, the business excellence models like Malcolm Baldrige and EFQM can be applied to assess and achieve higher and more accurate IT performance and continuous improvement.

Services in any organization should be assessed. We refer to service quality tools like gap analysis to examine and assist service quality in any sector. SERVQUAL is a gap analysis tool, which is used in this study to examine IT service quality in three universities in UAE where the perception and expected values for users are measured. The gaps (perceptions – expectations) are calculated for each item in each dimension. The average of gaps in each dimension is also calculated. In addition, te radar charts are used to benchmark the averages of each item in the three universities.

Service quality is considered a new subject in the field of management. It goes back to 1980's, where authors identified service quality as the comparison between customer's expectations and their perception of the company's service (Sayareh et al., 2016). Various definitions about service quality are introduced in literature by many authors. Gronroos identifies service quality as "an activity or series of activities of more or less intangible nature than normally, but not necessarily take place in interaction between the customer and service employees, and/or physical resources or goods and/or systems of the service provider, which are provided as solutions to customer problems." (Sayareh et al., 2016). Crosby states “quality is conformance to requirements.” (Hong et al., 2020). Those requirements must be defined in a measurable and clearly stated term (Hong et al., 2020). Moreover, Juran defines quality as “fitness for use” (Hong et al., 2020). Moreover, service quality is defined as the difference of consumers’ perceptions and their expectations of a certain service in a particular firm (Parasuraman et al., 1988). They argue that service intangibility represents a difficulty for firms to understand the way that customers perceive and evaluate service quality (Parasuraman et al., 1988). Lewis and Booms state that “service quality is a measure of how well a service level delivered matches customers’ expectations. Delivering quality service conforming to customer expectations.” (Brueckner and Flores-Fillol, 2020). Finally, in manufacturing, service quality is “making it right the first time” (Brueckner and Flores-Fillol, 2020).

GAP ANALYSIS AND SERVQUAL TOOL FOR MEASURING SERVICE QUALITY

Measuring service quality can be achieved by using different models and theories. Multidimensional model is the widely used model. Gronoos is considered the first to measure service quality. He found out that service quality can be divided into functional quality, technical quality, and corporate image (Ladhari, 2009). Parasuraman et al used dimensions of total quality and discovered the basic framework for measuring service quality, which is the Gap model.

Gap analysis is “the formal means to identify and correct gaps between desired levels and actual levels of performance.” (Ladhari, 2009). There are 22 items, which can be rated in gaps model. These items are divided into 5 dimensions:

- ✓ Tangibles (Items 1-4).
- ✓ Reliability (Items 5-9).
- ✓ Responsiveness (Items 10-13).
- ✓ Assurance (Items 14-17).
- ✓ Empathy (Items 18-22).

Parasuraman et al were the first to develop SERVQUAL (Parasuraman et al., 1994). It is an advancement of Gap model. Previously, SERVQUAL had 10 dimensions that were reduced to five (i.e. tangibles, reliability, responsiveness, assurance and empathy) with 22 items for measuring service quality (Parasuraman et al., 1994). SERVQUAL identifies gaps between customers’ expectations of the service and their perceptions of the actual performance (Markovic´ and Raspor, 2010).

This research paper measures the Gap analysis using SERVQUAL tool to measurement service quality in IT services centers in three higher educational institutions. The comparison between expected and perception average dimension scores is demonstrated for each university.

LITERATURE REVIEW

SERVQUAL is a gap analysis research instrument created by Parasuraman, Zeithamel, and Berry (Parasuraman et al., 1988). It is introduced in 1988. It has five gaps and five dimensions. All gaps are represented in the following figure (Brueckner and Flores-Fillol, 2020).

- ✓ **Gap1 (Knowledge Gap):** The difference between actual customer expectations and management's idea or perception of customer expectations.
- ✓ **Gap2 (Policy Gap):** Mismatch between manager's expectations of service quality and service quality specifications.
- ✓ **Gap3 (Delivery Gap):** Poor delivery of service quality.
- ✓ **Gap 4 (Communication Gap):** The difference between service delivery and external communication with customer.
- ✓ **Gap 5 (Service Quality Gap):** The difference between expected and perceived Quality. This GAP will be calculated and analyzed in this paper as shown in figure 1.

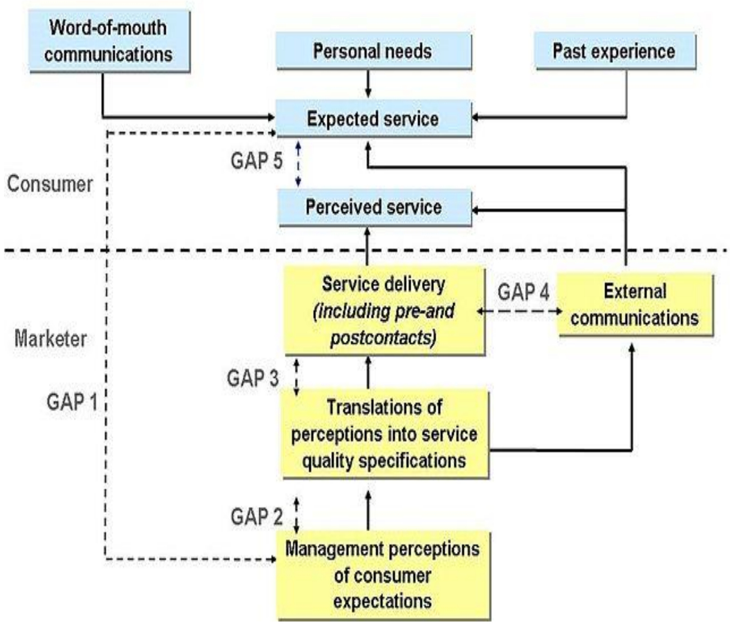

Figure 1: SERVQUAL Gaps (Ladhari, 2009)

On the other hand, Gronroos identified six dimensions, which are professionalism and skills, reliability and trustworthiness, attitudes and behavior, accessibility and flexibility, recovery, and reputation and creditability for service quality management (Brueckner and Flores-Fillol, 2020). In this research paper, Gap 5 is being analyzed for IT services for three higher education institutions.

Moreover, Woodruff and Gardial developed the expectancy disconfirmation model. This model allows customers to compare their perception of service quality with their standard of expected performance. This comparison can be positive or negative (Brueckner and Flores-Fillol, 2020).

SERVQUAL has been used in many industries such as education, hospitality, healthcare, telecommunications, retailing, public services, transportation and shipping.

Although this model has become widely used by researchers, SERVQUAL model has faced some criticism. SERVQUAL mainly focuses on the service delivery process. Some researches had doubts about its dimensionality, other argued about its measurement of perception and expectation (Brueckner and Flores-Fillol, 2020).

The SERVPERF model is similar to SERVQUAL. It explains more about the variation in service quality than SERVQUAL. It has an excellent fit in all industries and it contains only half the number of items that must be measured. These results were interpreted as additional support for the superiority of the SERVPERF approach to the measurement of service quality (Brueckner and Flores-Fillol, 2020).

Despite all these criticisms, SERVQUAL remains a useful and powerful tool for researchers in domain of service quality measurement. According to Parasuraman et al (Badri et al., 2005), SERVQUAL can be applied for evaluating service quality in any service sector.

Each organization has its vision and mission. Business excellence frameworks help in achieving these goals. Furthermore, IT management and governance need continuous improvement and applying excellence models such as Malcolm Baldrige or EFQM will enhance the performance of IT management (Duhamel et al. ,2017), (Usrey and Radhakrishnan, 1999). For example, Malcolm Baldrige is applied in educational sector and it has effect on the results of student learning and process, customer, workforce, leadership and governance as well as financial and market results (Badri et al., 2005), (Miller and Parast, 2018).

Malcolm Baldrige business excellence criteria include leadership, strategic planning, customer and market focus, management, analysis and management of knowledge, human resources focus, process management and business results (Miller and Parast, 2018), (Rao Tummala and Tang, 1996). Malcolm Baldrige framework is applied to different industries and in different countries worldwide. First few years from 1987 to 1992, Malcolm was widely applied in the manufacturing industry (Miller and Parast, 2018). It is also applied in education (Belohlav et al., 2004), healthcare (Edi Wahyudi and Yulianty Permanasari, 2018), (Goldstein and Schweikhart ,2002), (Lee and DePue, 2010) , hotel

(Markovic´ and Raspor, 2010) and airline industry (Hong et al., 2020), (Brueckner and Flores-Fillol, 2020).

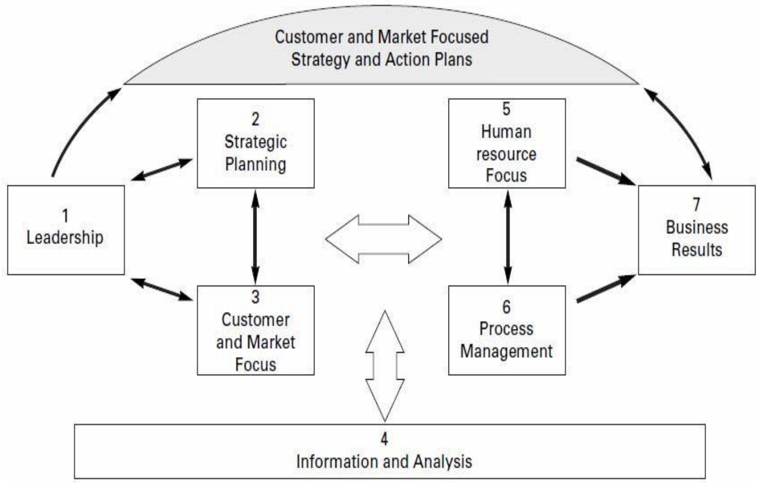

Figure 2: Malcolm Baldrige Framework (Miller and Parast, 2018)

The other business excellence model that can be used is the European Foundation for Quality Management (EFQM). It is a business excellence model where the organizations applying it meet the sustainability of the stakeholders (Arezki and Elhissi, 2018). It can be used in different sectors like education and information technology (Arezki and Elhissi, 2018), health care, construction (Hıdıroğlu, 2019).

EFQM framework is made up of the following main principles as described in (Shahin et al.,2014):

- ✓ Result orientation.
- ✓ Customer orientation.
- ✓ Leadership and consistency of objectives.
- ✓ Management by processes and facts.
- ✓ Development and involvement of people.
- ✓ Development of partnerships.
- ✓ Social responsibility of the organizations.

To implement these principles, we need three phases: Initiation, realization and maturity (Arezki and Elhissi, 2018). EFQM has nine criteria divided into 2 categories, which are means and results. Enablers’ criteria are responsible for key activities management. While results criteria are responsible for the way the results of an organization are achieved. This can be shown in figure 3. The criteria include leadership, strategy, people, alliances, resources, processes, products and services (Arezki and Elhissi, 2018). EFQM can be also applied to many domains like the education (Arezki and Elhissi, 2018), banking, construction like the case done in Turkey (Hıdıroğlu, 2019), hotels, and public sectors.

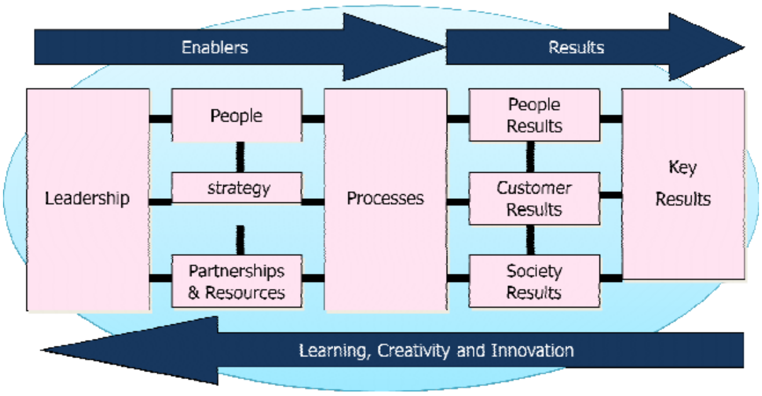

Figure 3: Old EFQM Framework (Arezki and Elhissi, 2018).

The latest version of EFQM is represented by the figure 4 (Nenadál, 2020). It has three main dimensions with seven criteria. The dimensions are direction (why to implement the new framework), execution (how to implement) and results (what is obtained as an outcome) (Nenadál, 2020).

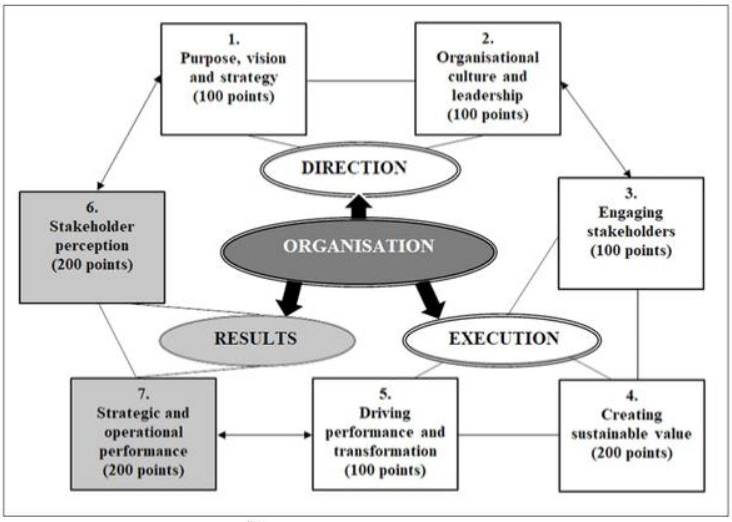

Figure 4: New EFQM Model (Nenadál, 2020).

There are several advantages of the new EFQM model implementations (Nenadál, 2020).. It maintains sustainability. The cause and effect relationships are more obvious and accepted by managers and academics. Moreover, the results regarding stakeholders' perceptions are concentrated on criterion 6, rather than scattered in three results criteria (Nenadál, 2020).

METHODOLOGY

SERVQUAL service quality measurement tool is used to measure the perception and expectation of users regarding IT service quality in three IT centers in three higher educational institutions: University X, University Y and University Z.

A questionnaire was distributed and collected in the three institutions. This questionnaire includes all 22 items of SERVQUAL model, which are grouped into 5 dimensions: Tangibles, reliability, responsiveness, assurance, and empathy. There are 22 questions in the questionnaire, which represent the 22 items of the five dimensions of SERVQUAL gap analysis tool. These questions are mentioned in the following the table. In each university, the questionnaire is distributed to 225 user participants, which used in the analysis using figure 5 SERVQUAL methodology framework.

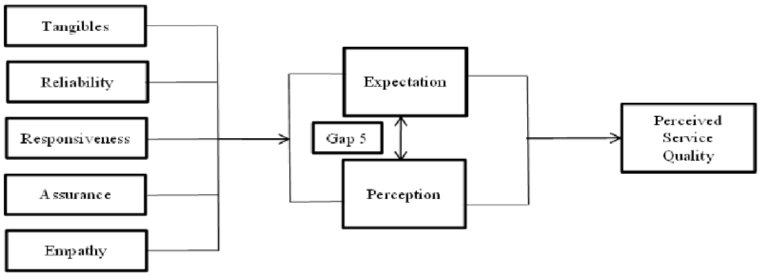

Figure 5: Research Methodology Framework (Badri et al., 2005).

In the expectation and perception parts of the questionnaire, each participant was requested to indicate the level of agreement regarding the expected and perceived service quality from IT services centers in a modern university. Participants ranked their opinion from 1 (not important at all) to 7 (extremely important) (Badri et al., 2005). Averages of these ranking for each item are recorded in the below table.

Gaps were calculated by subtracting the perceived results minus the expected. Negative gaps may appear, which mean that the perceived results didn't reach yet the expected score.

In addition, the radar charts (or spider web) in excel were used to compare between the expected and perception results in the three universities. As a result, we performed the benchmarking between the three universities.

RESULTS

Table 1 shows the results of expected, perception and gap results of users in the three universities. The expectation and perception results are obtained by getting the average of the scoring of users on each item. For example, the average of expected values for the 5 items for the tangibles dimension is (6.31+5.02+6.04+5.82)/4 =5.7579. This average score is included in the second table 2. Moreover, the gaps are calculated by subtracting perceived from expected scores. Scores go from 1 (strongly disagree to 7 strongly agree). Negative gap scores indicate that there are gaps between perceived and expected results, which means the expected results are not reached yet.

Table1: Expectation, Perception and Gaps for IT Center Users for University X, University Z and University Y (Badri et al., 2005).

	University X			**University Y**			**University Z**		
Items	**Expected**	**Perceived**	**Gap**	**Expected**	**Perceived**	**Gap**	**Expected**	**Perceived**	**Gap**
Tangibles Dimension									
1-Up to date hardware and software	6.31	6.22	-0.09	6.36	6.03	-0.33	6.43	6.11	-0.32
2-Physical facilities that are visually appealing	5.02	5.59	0.57	5.18	5.67	0.49	5.14	5.66	0.52
3-Employees that are well dressed and neat in appearance	6.04	5.98	-0.06	5.65	5.51	-0.14	6.10	5.89	-0.21
4-Will have physical appearance that keeps up with the kind of services provided	5.82	5.26	-0.56	5.87	5.41	-0.46	6.59	5.38	-1.21
Reliability Dimension									
1-Promising to do something	5.77	5.08	-0.69	5.74	5.16	-0.58	5.42	5.11	-0.31

by certain time and doing so									
2-Showing a sincere interest in solving user' problems	6.24	6.40	0.16	6.26	5.87	-0.39	6.31	5.78	-0.53
3-Being dependable	6.53	6.20	-0.33	6.78	6.19	-0.59	6.54	5.89	-0.65
4-Providing their services at the time they promise to do so	6.44	5.96	-0.48	6.18	5.17	-1.01	6.32	5.29	-1.03
5-Insisting on error free records	4.95	5.27	0.32	4.91	5.29	0.38	5.26	5.05	-0.21
Responsiveness Dimension									
1-Telling users exactly when services will be performed	6.24	5.7	-0.54	6.17	5.53	-0.64	6.36	5.62	-0.74
2-Their employees giving prompt service to users	5.83	5.68	-0.15	5.93	5.38	-0.55	5.96	5.47	-0.49
3-Their employees always willing to help users	6.05	5.69	-0.36	5.99	5.04	-0.95	6.06	5.54	-0.52
4-Their employees	6.27	4.36	-1.91	6.19	4.68	-1.51	6.18	4.16	-2.02

never being too busy to respond to users' requests.									
Assurance Dimension									
1-The behavior of their employees instilling confidence in users.	6.53	6.12	-0.41	6.39	5.03	-1.36	6.28	5.20	-1.08
2-Users feeling safe in their transactions with their employees	6.27	6.10	-0.17	6.32	5.79	-0.53	6.34	5.83	-0.51
3-Their employees being consistently courteous with users.	6.13	5.65	-0.48	6.24	5.50	-0.74	6.22	5.10	-1.12
4-Their employees having the knowledge to do their job well.	6.42	6.18	-0.24	6.36	5.50	-0.86	6.38	5.62	-0.76
Empathy Dimension									

1-Giving users individual attention	6.23	5.39	-0.84	6.21	5.34	-0.87	6.19	5.36	-0.83
2-Having operation hours convenient to all their users	5.43	5.30	-0.13	5.66	5.07	-0.59	5.46	5.04	-0.42
3-Having employees who give users personal attention	6.20	5.41	-0.79	6.12	5.30	-0.82	6.14	5.37	-0.77
4-Having the users' best interest at heart.	6.11	5.30	-0.81	6.12	5.11	-1.01	6.20	5.04	-1.16
5-Their employees understanding the specific needs of their users.	5.97	5.16	-0.81	5.93	4.91	-1.02	6.05	4.82	-1.23

Regarding users in University X, the highest gap was (-1.91) in the fourth item in the responsiveness dimension "Their employees never being too busy to respond to users' requests". The item with the highest positive gap (0.57) means that this item is the most to satisfy the expectation. This was in the second item in the dimension tangibility "Physical facilities that are visually appealing." 19 item out of 22 where perception results were less than expected (negative gaps). The highest expectation scores were assigned for responsiveness and assurance.

Individual expected and perceived scores were taken for items in the empathy and responsiveness dimensions

Regarding University Y, the following conclusions can be drawn. The fourth item in responsiveness dimension had the highest gap for University Y (-1.51). Out of 22 items, 20 have gaps, and 5 out of the 20 had gaps above 1.0. The item with the highest acceptance score (positive gap) was for the 2nd item in the tangibility dimension: "Physical facilities that are visually appealing." The highest expectation scores were assigned to assurance in University Y.

Regarding University Z, the following observations can be drawn. University Z experienced the highest gap (-2.02) in the fourth item in the responsiveness dimension compared to University X (-1.91) and University Y (-1.51). Out of 22 items, 21 have gaps, 7 out of the 21 are above 1.0. The item with the highest positive gap or acceptance score in University Z was for the 2nd item in the tangibles dimension. Highest expectation scores were assigned for assurance dimension in University Z.

A sample of expected versus perceived value is plotted for the empathy dimension (first item: giving users individual attention), responsiveness dimension (last item: employees never being too busy to respond to users), and tangibles dimension (4th item: employees are visually appealing).

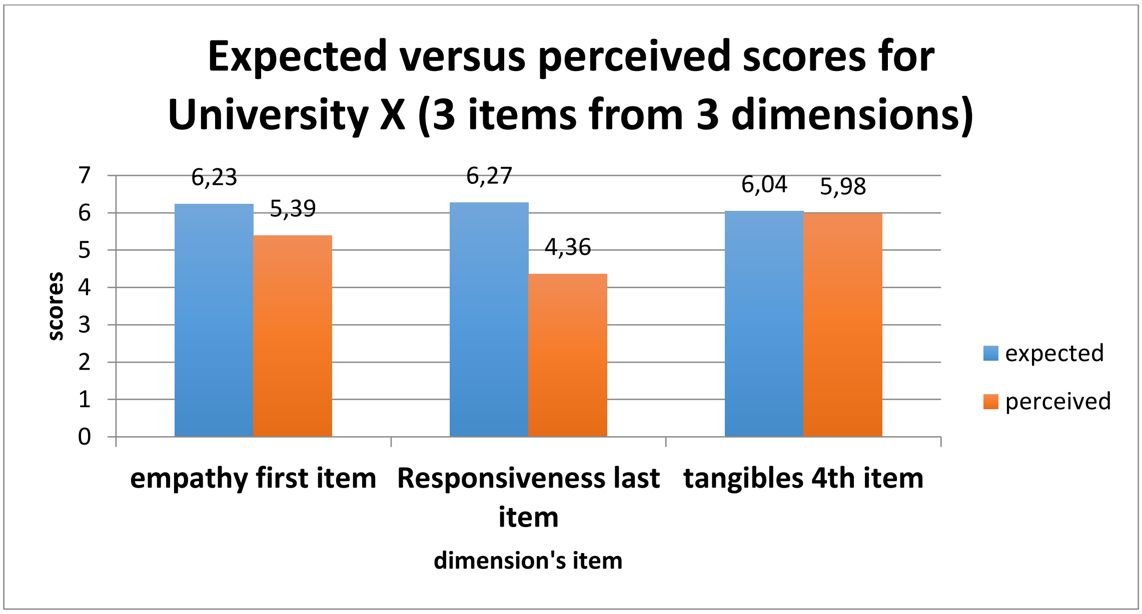

Figure 6: sample of expected versus perceived scores for University X

Figure 6 shows a sample of expected scores versus perceived cored for the most significant items of empathy, responsiveness and tangibles dimension. It is shown that University X should enhance on the item of giving users individual attention of empathy dimension. Moreover, the last item of the responsiveness dimension should also be improved to reach the expected value. Any improvement can be done using the any operational excellence framework (Malcolm or EFQM). The fourth item of the tangible dimension of University X shows almost same values of expected and perceived scores which leads to negligible gap (-0.06).

The values in table2 are the averages of the items of each dimension. The average was done on expected, perceived and gap values for each university.

Table 2: Average for Expected, Perception, Gap Scores for Each Dimension in Three Universities

Item	University X			University Y			University Z		
	Expected	**Perceived**	**Gap**	**Expected**	**Perceived**	**Gap**	**Expected**	**Perceived**	**Gap**
Tangibles Dimension									
Average	5.7975	5.7625	-0.035	5.765	5.655	-0.11	6.065	5.76	-0.305
Reliability Dimension									
Average	5.986	5.782	-0.204	5.974	5.536	-0.438	5.97	5.424	-0.546
Responsiveness Dimension									
Average	6.0975	5.3575	-0.74	6.07	5.1575	-0.9125	6.14	5.1975	-0.9425
Assurance Dimension									
Average	6.3375	6.0125	-0.325	6.3275	5.455	-0.8725	6.305	5.4375	-0.8675
Empathy Dimension									
Average	5.988	5.312	-0.676	6.008	5.146	-0.862	6.008	5.126	-0.882

In University X, Table2 shows the highest average expected score was for assurance dimension and minimum expected average score was for tangibles dimension. So, University X can use operational excellence models to try to eliminate the gaps in the tangibles dimension to enhance its business excellence performance.

The highest average perception score was for assurance dimension and the lowest was for average perception score for empathy dimension.

The highest gap between average perception and average expectation scores was for the average responsiveness dimension gap (-0.74) and the lowest was for the tangibles dimension (-0.035). This means that average expected and perceived scores of tangibles are almost met. However, the largest gap was between expected and perceived average scores of responsiveness dimension.

It is recommended that these responsiveness gaps are used as inputs for Malcolm criteria and EFQM models to evaluate and enhance the performance and continuous improvement. In this study, these models can be applied by universities to enhance the gaps in the SERVQUAL dimensions within their IT sector.

The radar chart of figure 7 was established to compare between expected and perception average scores for University X.

Figure 6 shows the comparison between expected and perception average scores for IT center in University X. It is shown that tangibles and reliability dimensions have close expected and perception average scores which gave low gaps (-0.035 and -0.204 respectively). On the other hand, the highest gaps were in the empathy and responsiveness dimensions where the expected and perception average scores are far away.

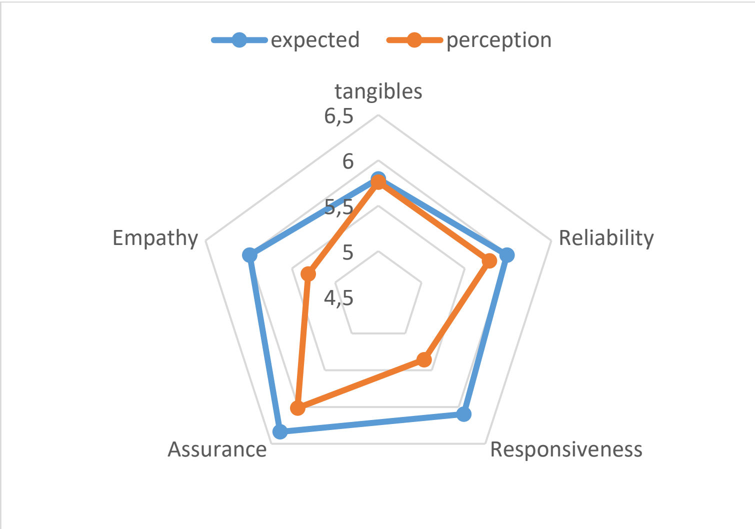

Figure 7: Expected Versus Perception Average Scores for University X

When comparing expected and perceived results for university X it is found out that there was a big gap in the empathy and responsiveness dimensions. It is suggested that this university apply one of the excellence models (Malcolm or EFQM). This will help in decreasing the gaps and enhancing the performance in IT sector of university X.

Radar chart for University Y comparing expected and perception average scores by users.

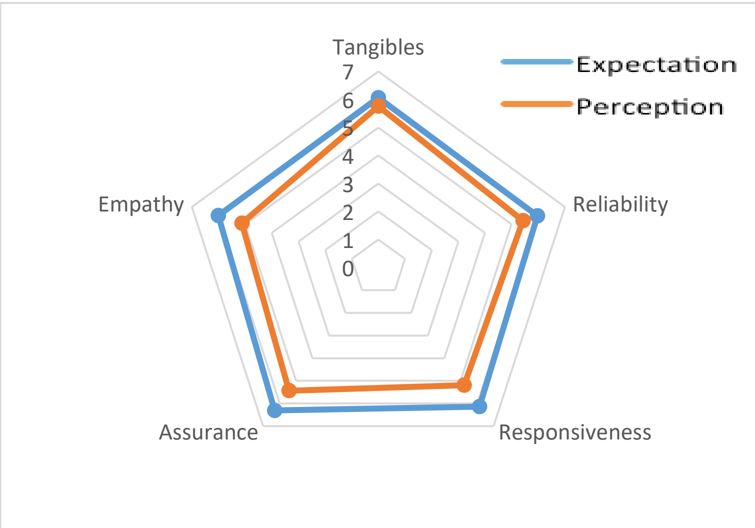

Figure 8: Expected Versus Perception Average Scores for University Y

Figure 8 shows the comparison between expected and perception average scores for IT center in University Y scored by users. It is shown that tangibles and reliability dimensions have the smallest gap were expected and average scores are close to each other. While larger gaps are in the responsiveness and empathy (-0.9125, -0.8725 respectively) where expected and perception average scores are farther apart.

The results in table 1 shows the highest expected average dimension score was for assurance dimension (6.3275) and minimum expected average dimension score was for tangibles dimension (5.765). The highest average perception score was for tangibles (5.655) and the lowest was for empathy dimension (5.146). The highest gap was for average score of responsiveness dimension (-0.9125) and the smallest gap was for average score of tangibles dimension (-0.11).

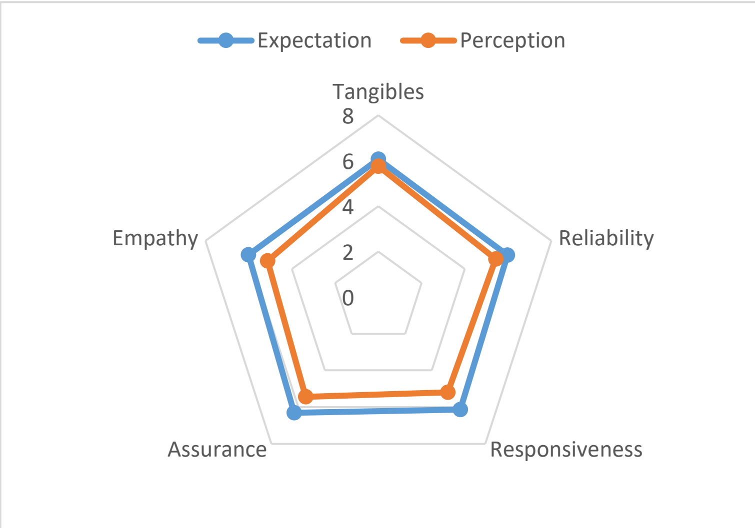

Figure 9: Expected Versus Perception Average Scores for IT Center in University Z

While figure 9 shows the comparison between expected and perception average scores in IT centers in University Z scored by users. It can be noticed that in the three institutions the expected and perception average scores for tangibles dimension were the closest so the gap was small (-0.305). While the expected and perception average scores for the responsiveness an empathy dimensions were the farthest away, so the gap was the largest. (-0.9425, -0.882 respectively). In University Z (referring to Table2), the highest average expected score was for assurance dimension (6.305) and the minimum expected average score was for reliability dimension (5.97)

The highest average perception score was for tangibles dimension (5.76), and the smallest average perception score was for empathy (5.126). While, the highest average gap was for responsiveness dimension (-0.9425) and the lowest average gap was for tangibles (-0.305).

If a comparison of average expected scores by users in the three universities is carried out, the following result can be obtained.

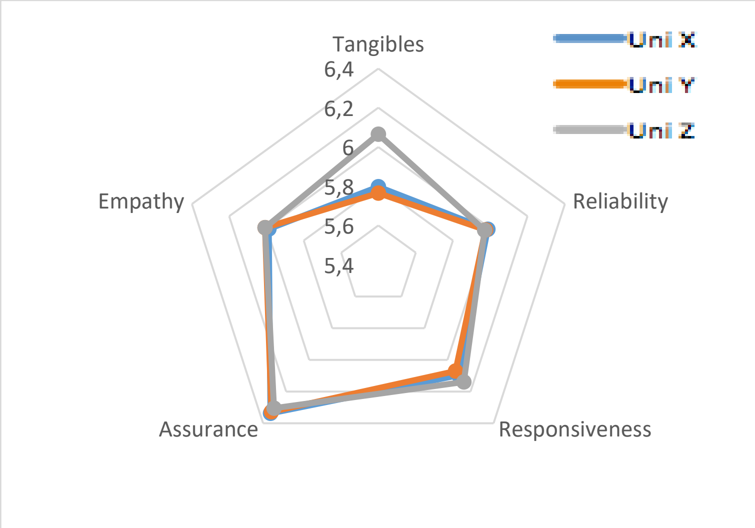

Figure 10: Comparison of the Average Expected Scores by Users in Three Universities

Figure 10 shows Comparison in the average expected scores by users in University X, University Y, and University Z. The 3 universities have approximately close average expected scores, except for the tangibles dimension where University Z showed the highest average expected score in the tangibles dimension. The strength point was for University Z in the tangibles dimension (6.065). It is suggested that University Y and University Z to adopt a business excellence model like Malcolm Baldrige or EFQM to enhance their average expected scores by users and consequently enhance their IT operational excellence.

A study of the average perception scores by users in the three universities is also done.

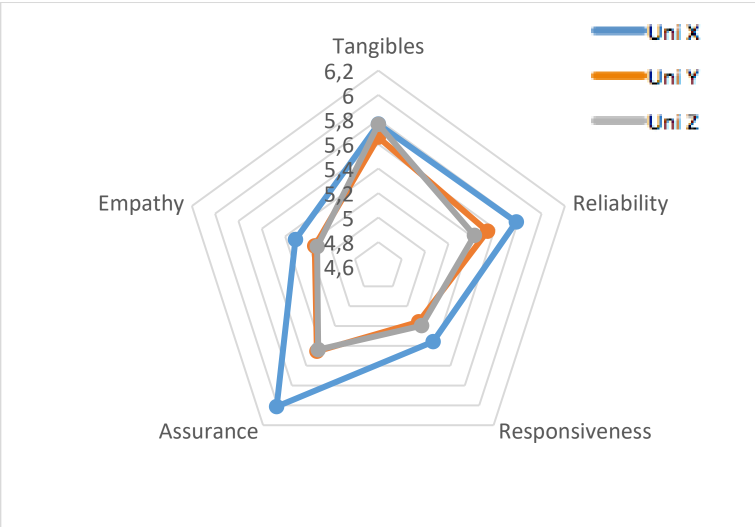

Figure 11: Comparison between Average Perception Scores by Users in the Three Universities

Figure 11 shows the comparison results between average perception score by users in University X, University Y, and University Z. It is obvious that University Y and University Z have almost the same scores for all dimensions. It can be seen that University X got the highest perception scores by users and its strength was in assurance dimension (6.0125).

It is seen from the figure above that University X and Y should adopt an excellence model (Malcolm or EFQM) to increase the average perceived score in the assurance dimension. Studies applying Malcolm Baldrige showed that this framework can be applied more than once (Rahayu et al., 2019), (Belohlav et al., 2004). These studies suggested and validated that after applying Malcolm Baldrige framework, the organizations' performance improved. It is also validated that the sectors getting the lowest scores from the first time applying Malcolm Baldrige framework are the most expected sectors to increase their quality and scores if Malcolm Baldrige is further applied. Furthermore, it is found that the manufacturing sector was the most influenced by Malcom Baldrige framework (Miller. and Parast , 2019).

DISCUSSION

Table 3 represents a summary of the average gap results for the three universities. It is clearly shown that these universities should work on the responsiveness item since it has the lowest values followed by the empathy and assurance items. However, due to the highest gap values results, it can be deduced that University X is the best performer among the three universities.

Table 3: Summary of Average Gap Values for each Dimension of SERVQUAL.

Dimensions	Average of each dimension items' gaps for University X	Average of each dimension items' gaps for University Y	Average of each dimension items' gaps for University Z
Tangibles	-0.035	-0.11	-0.305
Reliability	-0.204	-0.438	-0.546
Responsiveness	-0.74	-0.9125	-0.9425
Assurance	-0.325	-0.8725	-0.8675
Empathy	-0.676	-0.862	-0.882

It is recommended that all three universities should work more on the negative gaps to reach the perception score and to be greater than or equal the expected scores. It is also advised that the three universities put more efforts on the responsiveness dimension to increase the perception scores to reach or exceed the expected scores. This can be done via the aid of operational excellence models like Malcolm or EFQM.

Research can be also done on decision makers and service providers in the IT centers in these three universities. Future studies should try to find out causes and solutions for the gaps. Furthermore, future research should examine the relation between service quality gaps and its effect on performance in terms of number of failures and customer satisfaction. Moreover, longitudinal studies may take the gap analysis results and apply them into business excellence frameworks for several times and compare it with the initial results. These studies may conclude which dimension improved the most using the frameworks. Moreover, the following research questions could be part of future work and potential new research area for researchers

1- How business excellence models support IT service in UAE in practical and efficient way?

2- How can some business excellence frameworks solve the gaps of quality and risk management of IT sector in UAE having a good value for money?

Furthermore, the results shown that Malcolm excellence model or EFQM can be integrated with SERVQUAL service quality model.

The items' scores can be classified among the criteria of EFQM or Malcolm frameworks. A further study then can be conducted of the impact of these SERVQUAL scores on business excellence models. Shahin A., Jamkhaneh H worked on integrating SERVQUAL gap analysis tool with the EFQM model to get EFQMQual in Isfahan Province Gas Company using with respect to different viewpoints of senior and middle managers and senior experts. These include perceptions of goals, expectations of goals, perceptions of assessment and expectations of assessment (Shahin et al., 2014).

CONCLUSION

This paper studied the gaps between perception and expected scores by users in IT centers in University X, University Y and University Z in the UAE. For this purpose, we used the SERVQUAL tool to conduct the gap analysis. Key dimensions were identified for each educational institution to focus on the weakness points for future improvement. The gap analysis examined the 22 items in all dimensions in a questionnaire, which is given to users of IT centers in the three institutions. The analysis determined specific items where the IT center was successful and others where a change was required. In most of the studied items, the perception scores did not meet the expected score (more negative gaps). Only few items got a positive gap average expected scores for the three universities, University Z got the highest average expected scores for tangibles dimension, while comparing the average perception scores, University X got the highest average perception score for the assurance dimension. Overall, the results show that there is a need for improvement (Badri et al., 2005). The highest gaps in the three universities were in the responsiveness dimension, while the smallest gaps were for tangibles dimension.

These results can be the input for any business excellence framework to enhance the quality. The framework can be applied so many times to get the ideal target (gap is zero). Malcolm Baldrige or

EFQM frameworks can be applied to Servqual gap scores to enhance IT performance in the three universities and reduce gaps.

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Innoframe: a project and portfolio management multilayer framework to support innovation-driven SMEs

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STRUCTURED ABSTRACT

Purpose – The purpose of this research was to discover what frameworks for project, portfolio, and innovation management there are and if necessary to propose a new framework useful for SMEs of the construction and building materials industry.

Design/methodology/approach – The methodology used in this research was the case study, in which the Canadian construction and building materials industry was selected. The research was based on literature review, interviews, group discussion and survey.

Findings – Although there are currently many frameworks available for the three management areas (project, portfolio and innovation), research has shown that a framework that helps companies to follow an approach that supports their business at these three levels is lacking.

Originality/value – Innoframe is a new framework for project, portfolio, and innovation management that incorporates a pipeline and two phases as well as a performance management matrix, that can be used for project and portfolio management, to support innovation-driven SMEs.

Keywords: Project management, Portfolio management, Innovation, Framework.

Paper type: Research paper

INTRODUTION

Currently, project, portfolio and innovation management are widely used terms to discuss companies' success and failure. Project management is the narrowest of the three. For a company to succeed, it must have a vision through defining its long-term goals and setting projects that meet it. Portfolio management is broader, looking at the interactions and combined importance of projects undertaken by an organization so that the development of these portfolios matches the goals and constraints of the company (Dutta, 2019). Portfolios can be made within a single firm or they can be alliance portfolios, or inter-organizational alliances which provide a wealth or capabilities and resources to be drawn from (Vasudeva, 2010). Firms that visualize their portfolios in the context of their entire industry and external environment, are more likely to develop high portfolios that increase the firm's value to any potential industry partners (Ozcan and Eisenhardt, 2009). Finally, innovation management is the broadest and used to foster productivity. Innovation facilitates success in SMEs and fosters sustainable competitive advantage if new innovations are capitalized on (Broersma, Van Gils and De Grip, 2016). A good strategy lies in the integration between projects within a certain portfolio through an innovation-support model. So this paper presents a multilayer framework to support innovation-driven SMEs in their project and portfolio management practices, developed during a PhD project based on the case of the industry of construction and building materials of Canada (Mishly, 2019), giving the answer to the following research question: How can an integration among project, portfolio and innovation management create a multidimensional framework to support SMEs for better end results on the three levels?

After this introduction, a literature review is presented introducing the basic concepts discussed and some frameworks available for project portfolio management and innovation management. The following section presents the main aspects of the research methodology adopted. Then the results of the data collection are presented followed by the framework development. The final section presents some conclusions and suggestions for future research.

LITERATURE REVIEW

Project management is the act of applying knowledge, skills, tools and various techniques to project activities to ensure that they meet project requirements (PMI, 2017). Portfolio management focuses on doing the right projects at the right time by selecting and managing projects as a portfolio of investments (Oltmann, 2008). It is used to organize the projects a company is looking to implement, to prioritize them, and to maintain them so that the group of projects undertaken aligns with the organizational strategy. Portfolios are important because they provide aggregate properties, such as increasing diversity, that affect performance, and because they drive network evolution through constant adjustments to satisfy overall strategy (Ozcan and Eisenhardt, 2009). The third integrated concept of interest is innovation management which is the management of technological or broad-scope innovations which can supplement project and portfolio management (McAdam *et al.*, 2007).

There are frameworks for project portfolio management: Portfolio management and enterprise management framework (Georgia Tech Strategic Consulting, 2018); Agile portfolio management framework (Portman, 2016); Project portfolio management framework (Aleksandrova-Boshnakova, 2018); PortfolioStep Portfolio Management Framework (TenStep Inc., 2007); Innovation portfolio management process (Williams, 2011); IT Portfolio Management Framework (PWC, 2018), among others (Mishly and Tereso, 2016; Mishly, 2019). And frameworks for innovation management: Channelvation innovation framework (Dancer, 2017); Business model innovation framework (Frankenberger *et al.*, 2013); Stage-gate innovation diamond framework (Shenhar and Dvir, 2007); Decision driven innovation framework (Decision Driven, 2008); Frost innovation framework (GasLabs, 2017); EFQM Innovation Lens (CenterCompet, 2020), among others (Mishly, 2019) (see Table 1 for comparative insights into existing frameworks). Although these frameworks are unable to combine key approaches to project, portfolio and innovation management being both structured enough to provide a useful process and flexible enough for any type of SME. Some are too vague, like general models, which are fine as guidance, but without expertise in the area will not be useful. Some are too specific, turning them too rigid, reducing its applicability. And there are missing pieces, not taking into consideration some key factors. So a gap has been revealed leading to further research (Mishly, 2019).

Table 1 – Comparative insights into existing frameworks.

Project Portfolio frameworks	**Innovation management frameworks**
Portfolio management and enterprise management framework (specific applicability) (cross-over with project management) (Georgia Tech Strategic Consulting, 2018)	Channelvation innovation framework (Broadly applicable) (Dancer, 2017)
Agile portfolio management framework (broadly applicable) (Portman, 2016)	Business model innovation (Broadly applicable) (Frankenberger *et al.*, 2013)
Project portfolio management framework (broadly applicable) (some cross-over with project management) (Aleksandrova-Boshnakova, 2018)	Stage-gate innovation diamond framework (specific applicability) (Shenhar and Dvir, 2007)
PortfolioStep Portfolio Management Framework (broadly applicable) (TenStep Inc., 2007)	Decision driven innovation framework (specific applicability) (Decision Driven, 2008)

Innovation portfolio management process (broadly applicable) (cross-over with innovation management) (Williams, 2011)	Frost innovation framework (broadly applicable) (GasLabs, 2017)
IT Portfolio Management Framework (specific applicability) (PWC, 2018)	EFQM Innovation Lens (broadly applicable) (CenterCompet, 2020)

RESEARCH METHODOLOGY

The methodology used in this research was case study were the case selected was the case of the industry of construction and building materials of Canada. The target group was made up of seven SMEs which work in this area, with a focus on suppliers (see the field and location of the companies selected in table 2).

Table 2 – Field and location of the companies selected.

Company	Field	Location
1	Metals fabrication and installation	North York, Ontario (Canada)
2	Construction and building materials preparation	Ottawa, Ontario (Canada)
3	Construction and renovation	North York, Ontario (Canada)
4	Construction	Toronto, Ontario, (Canada)
5	Construction and renovations	Mississauga, Ontario (Canada)
6	Paintings / Preparation and installation	Mississauga, Ontario (Canada)
7	Construction	Toronto, Ontario (Canada)

As the research is targeted towards project, portfolio and innovation management, the selected organizations were contacted, and interviews were arranged with a project manager in the company. It was important to ensure that the chosen companies had enough projects and at least one project manager in charge of these projects. A minimum of six projects per organization was a prerequisite to ensure that every company, and the project managers, had sufficient experience (see companies profile in table 3).

Table 3 – Companies profiles.

Company	Profile
1	A small-sized company with a team ranging between ten and twenty personnel working to offer the Canadian market top metal-related projects. Their projects encompass fabrication, designing, installation and other kinds of work.
2	A small-sized renovation and contracting company located in Ottawa and running projects in all of Ontario including greater Toronto area. A team of 10 people led by an experienced man work in two main domains, making some building materials and running renovation projects.

Company	Profile
3	A medium sized organization that is part of a widespread chain having around 5 branches in Canada. The engineering department is quite busy running several constructions, renovations and other projects. They have a special team of over 30 technical, manager and other personnel working in this area.
4	A medium-sized construction company that brings together twenty plus years of construction experience. A privately owned and operated company that prides itself on an unshakeable reputation in the industry as reliable, dependable and honest. It has multiple small, medium and big projects all over greater Toronto area.
5	A recognized leader in the industry. It provides general contracting, design build, construction management and preconstruction services to all sectors of the business world.
6	Construction and renovation company specializing in the painting line with strong capabilities to handle big and complexed projects within Ontario province. More than 6 years of services in this domain have enabled this company to enter joint venture projects with huge construction companies in the market.
7	A construction focus company with broad portfolio of projects and contracting modes including general contracting, design-build, bid-build, and public-private ventures.

Given the time constraint of the project, it was difficult to contact and interview a large number of companies and so it was crucial to choose sample organizations with care. A geographic limit on the location of the companies’ physical office(s) and their operations was set. Although companies who provide services throughout Canada or even internationally could be contacted, but they should have an office in Ontario (Canada). A clause was included to consider companies with offices located more specifically in the GTA (Greater Toronto Area), Ontario.

In order to identify an appropriate sample size, the target was first set, and its components classified. Once again, the research aimed to identify how to improve SMEs in the Canadian building materials industry by integrating innovative project portfolio management. Therefore, it was important to first understand the challenges that SMEs in this sector face. To get an in depth understanding of these challenges, it was important to get a rich amount of information during the research. Obtaining the depth of information necessary for this type of qualitative research requires a higher investment of time and cost, meaning that the sample size had to be smaller to ensure that the research was not overwhelming and was completed on time and on budget.

Qualitative sampling was chosen as it seemed the most appropriate method for improving the quality of management integration in SMEs. Recently, it has been recognized that basic quantitative indicators of business performance and measures of client satisfaction fail to generate sufficient insights into client needs or the effectiveness of client support (Sparrow, 1999). There is a need to get closer to the world of business owner-managers to identify how they see situations and how they might best be facilitated to develop their practices (Sparrow, 1999). We need to develop to a more sophisticated sampling process which will help in minimizing the risks facing those enterprises. While using qualitative analysis, there's an in-depth review and detailed observation for questions to understand the gap between different managements and the effect of adding innovation management to their frameworks, thus building a final comprehensive analysis. Through qualitative business research, a critical and reflexive view of the business world and its processes can be formed. It also helped to understand the acute risks accurately and structure them within a new framework.

After selecting the companies, the chosen methods to collect data were interviews, surveys/questionnaires, group discussions and observation. Table 4 presents some insights into the chosen methods.

Table 4 – Insights into the chosen methods.

Method	**Importance**
Interviews	Allowed researchers to ask in-depth questions to individuals without worry of anyone else influencing the response. Non-verbal cues also helped to further the information gleaned from the participants. High response rates to questions meaning a complete data-set was more likely to be achieved.
Surveys/Questionnaires	Questions can be targeted and structured so that only the pertinent information is gathered from the participants. Participants have time to think about the answers they give to researchers and often genuine feedback is common since identity is rarely necessary.
Group Discussions	Cultural and environmental insights on the workplace can be gained through viewing the interactions between the group of individuals. They are helpful for gathering information on complex issues through open discussion among the participants. Non-verbal cues can also help to increase the amount of knowledge gleaned from the interactions.
Observation	In-depth information could be collected through the viewing interactions as they would occur normally in a day-to-day setting. Easy to focus on the relevant parameters to the study. Behavioral and non-verbal cues add to the value of the study.

The interviews were done to a project manager or similar in each of the selected seven organizations. There were structured interviews with a set of 13 questions. These questions and a sample of the answers given will be presented in the next section.

In group discussion, the following topics where discussed:

1. The impact of the three concepts, project, portfolio and innovation management on the tasks of the audience;

2. The opinion of each member of the audience about the current frameworks being used nowadays;
3. The characteristics of an ideal useful framework, according to the opinions of each member of the audience.

This group discussion was made with three members of company 3, the ones that showed more interest in participating further.

A survey questionnaire was applied to several members of the selected companies by facilitators. This survey was conducted on 80 participants. The participants were managers and team members in the field of construction and building materials. Five statements were made and the participants could agree, be neutral or disagree. Results from the survey will be presented in the next section.

Finally, observation took place in an ongoing working situation. Over a period of some days the team member's actions, discussions, communications, and decisions that pertains to a certain phase of the project were observed in their working area. The purpose of this observation was to collect data about how team members of a business field deal with a real project in a real setting. Also, this observation allowed to know how the team members and managers interact together during the meeting. The observation provides useful information about the steps that occur in the planning phase and the execution phase in authentic situations.

RESULTS OF THE DATA COLLECTION

In this study, primary data collected inferred significant issues that are worth discussing related to the concepts of project management, portfolio management, and innovation management. The discussion covered three main areas:

1. The impact of project, portfolio and innovation management on the tasks of the participants;
2. The opinion of each participant about the current frameworks in use;
3. The characteristics of an ideal framework, according to the opinions of participants.

All the data collected during the interviews was transcribed and can be seen in Mishly (2019). Due to size restrictions, in this paper only the questions and a summary answer for each is presented below. The main focus was to summarize the practical needs of the interviewees which they didn't find in other models.

1. Question (Q): Taking into account the three main concepts that are the core of this research: project management, portfolio management and innovation management; what does each of them mean to you in terms of business processes?

Answer (A): Those three concepts are meant to organize and streamline the processes in any business. Innovation management is essential to the company's success, without innovation companies cannot compete in the market. Portfolio management is more treated on a scale higher than project management, it is more to help assess the priorities of the projects and what projects make more sense for us. Project management goes more into streamlining the processes of achieving something, what is step A, B and C and who is in charge of each one.

2. Q: How can you generally relate each of them to your company's objective, your tasks within the company, and your industry (construction and building materials) in general?

   A: The nature of the industry pushes us to offer the best and to be innovative as much as we can. Portfolio management has more to do with the company's mid and long-term objectives. The chosen portfolio has to be in line with the business objectives or else the portfolio will be rejected from the management. Project management practices used depend on the type of project.
3. Q: Do you see these three concepts as interrelated concepts that need to be handled together sometimes or as separate entities that should be treated each alone?

   A: Portfolio and project management have many things in common. And innovation should fall into both of them. In our company we emphasize the coherency among the personnel who are looking after each of these areas.
4. Q: From your point of view as a project manager in the construction and building materials industry, what makes each of these concepts important?

   A: Innovation management to increase competitive advantage; portfolio management to optimize resources; project management to ensure effective management for projects.
5. Q: Let us assume that the three concepts are put on one scale, how would you rank them in terms of importance for your job?

   A: From a project manager point of view I would rank project management in the first place, innovation management in the second place, and the last is portfolio management.
6. Q: What is your opinion on using business frameworks in general and would you recommend using it?

   A: Frameworks are considered important to businesses since they serve as defined guidelines to achieving certain process, goal, or situation.
7. Q: Does abiding to a framework facilitate or complicate the process in your opinion?

   A: It depends on the framework but a goof framework should facilitate, smoothen, and accelerate the approach of any operation.

8. Q: Do frameworks have more impact on organizing teams and raising their performances, or on the final outcomes and sales of the company?

   A: The team deals with the framework directly, so the impact should be direct. And if the performance of the team is impacted definitely, it will affect the final business outcomes.
9. Q: Do you currently use a specific framework with your team?

   A: We have built our own approach but are open to improvements.
10. Q: Does your management recommend using frameworks to enhance your operations and processes? Or they are only concerned about end results?

    A: If you mean by management the top management or the executive level, they don't involve too much into the tools and processes that we use.
11. Q: In your opinion, why do some companies avoid using frameworks in the context of project, portfolio and innovation management?

    A: Some are unidimensional and some are too complex.
12. Q: How does an ideal framework look like in terms of your tasks as a manager, your team's performance, and your company's business objectives?

    A: One roadmap that can help us manage our projects while ensuring innovation and meeting our portfolio strategy.
13. Q: Briefly and in one sentence if possible, in what sense would such a framework help you and your company?

    A: Performance perhaps. It helps in lifting our key performance indicators on all levels.

The data collected during the group discussion can be summarized in the following five points:

1. An ideal useful framework should integrate the three concepts, portfolio, innovation and project management;
2. It should allow communication and collaboration among different teams in the company;
3. An ideal framework is more like a roadmap that keeps every single step aligned with the portfolio guidelines, which were defined in the plan;
4. It should provide a clear approach, in order to enhance the ways of measuring success;
5. Finally, there should be some sort of universality in a sense that it can be used in different contexts.

As for the surveys, the results can be seen in table 5.

Table 5 – Survey responses.

Statement	Agree	Neutral	Disagree
In terms of the business process: project, portfolio, and innovation management are interrelated concepts.	81%	14%	5%
Using business frameworks is important for making the operations and processes more efficient.	94%	5%	1%
Business frameworks impact the performance of the teams who are using it more than impacting the final outcomes of the business.	79%	5%	%16
Many companies avoid using frameworks because they believe it consumes time and effort more than when avoiding it.	65%	9%	26%
A new framework that supports integration, flexibility, and universality would be a good option for companies who currently avoid using frameworks.	94%	2%	4%

The observation showed that the authoritarian style of management in certain companies decreases communication between the upper management and the working teams. This results in a more obedience style of the working team instead of an innovative style, and more time is wasted in trying to solve urgent problems due to reduced organization and the absence of a defined, clear and flexible framework.

The data collected allowed to identify the characteristics of an ideal framework, that can be summarized into 5 main points:

1. It should integrate the three concepts, portfolio, innovation and project management;
2. It should allow communication and collaboration among different teams in the company;
3. It should be setup like a roadmap that keeps every step aligned with the portfolio guidelines, which were defined in the plan;
4. It should provide a clear approach, in order to enhance the ways of measuring success;
5. And, there should be universality in the sense that it can be used in different contexts.

FRAMEWORK DEVELOPMENT

This section highlights the roadmap for designing the framework proposed, Innoframe, revealing the concepts and meanings behind the parts that will make up this framework. It has been taken into consideration that the framework shall be useful for companies with different sizes and in different industries. Yet it is important to mention that this framework was created to best fit small and medium sized businesses. It is also beneficial to reemphasize that this specific research and any similar studies are not only designed to solve a problem, but to shape, map out, and clarify the methods, approaches, models, and frameworks used, so that the whole industry can use it to solve similar problems.

Innoframe was developed with the purpose of guiding companies through three areas: project management, portfolio management and innovation management. The framework can be used as a tool that helps that these firms manage their projects in line with their portfolio strategy, while maintaining a high level of innovation.

The framework development process first took into account who the framework was being developed for, in this case SMEs in the construction and building materials industry. Then a pipeline, or an outline of the project path, was developed. Theoretical foundation of the framework was considered. This was especially important given the multidimensionality of the proposed framework. Value prerequisites were identified, and ideas on how the performance would be managed were discussed as well.

First, the foundation of the framework needed to be identified. Given the information gathered throughout the research, it was clear that the framework needed to be agile and adaptable. Innoframe however provides flexibility and teamwork due to the fact that it contains open statements that require intensive contribution of the teams. Innoframe was designed to allow for the alteration or modification of the statements without necessarily having to alter the scoring model, thus it was built considering the agile manifesto and to embrace the ever-changing business world. It was also designed to ensure that all stakeholders are engaged and in full support of the project given the overwhelming research supporting stakeholder engagement.

Creativity and innovation are also key facets of the Innoframe framework. This is due to the research supporting the importance of these elements to projects, project management, and frameworks. As well, conceptualization of a project is key. To satisfy this, Innoframe relies on a numerical scoring system so that the framework is more tangible than many frameworks used today. Of the two levels of project implementation, those being operational and strategic, the majority of frameworks are specific in the sense that they can only be used at one level or another – not both.

Now, the components of Innoframe shall be presented.

The first part of the framework is the pipeline. This can be seen below in figure 1. It shows several entrances to visualize the reality that project plan ideas come from several departments and get escalated to management for final discussion and approval. The plan is prepared by the assigned project manager, yet it needs to be reviewed and approved. And this explains why the pipeline has only one exit, meaning that the management will receive the suggested plans from several teams or departments, and they will have all to be reviewed and approved by top management before moving into the application phase. The main importance of using the pipeline is the concept of streamlining the projects through one defined route.

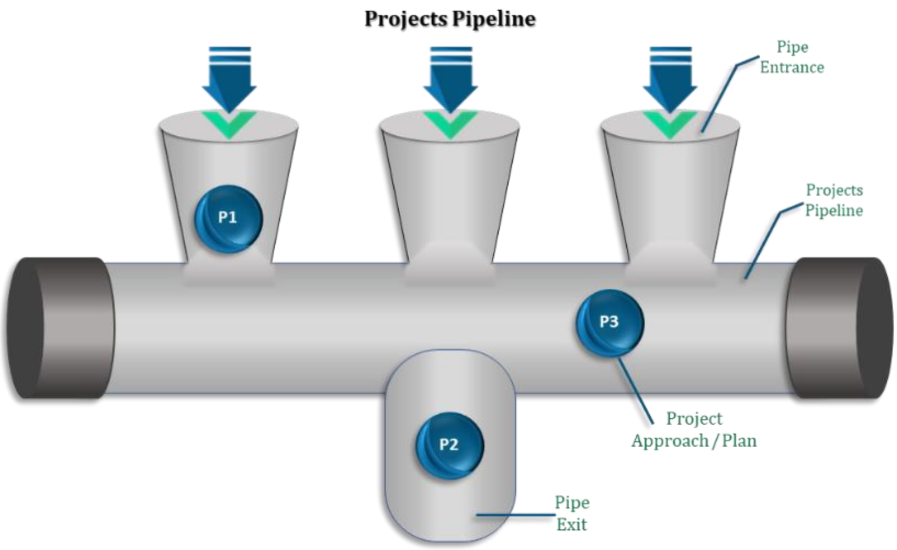

Figure 1 – Innoframe – The Pipeline.

Innoframe’s project pipeline contains two essential elements. The project entrance and project exit. The project entrance is the first point at which the firm interacts with the project. This may be the person that initiates the project, or the project manager that is assigned to the project. The pipeline exit, on the other hand, represents the beginning of another project phase. The exit symbolizes that the project has moved through its initial phase and that all the requisite departments and individuals have evaluated the plan. In order to efficiently balance Innoframe’s project pipeline, project managers will be required to thoroughly evaluate their resources to identify the firm’s capability to handle projects and, by extension, the pipeline’s capability. In doing so, they will also identify any limitations for the project which can be beneficial.

The first phase in Innoframe is the project management phase, seen below in figure 2. This is the main phase in the business framework. It uses a Likert Scale (5-point) or a numerical scoring scale, with the following interpretation: “SA: Strongly Agree” or 5, “A: Agree” or 4, “N: Neutral” or 3, “D: Disagree” or 2 and, “SD: Strongly Disagree” or 1.

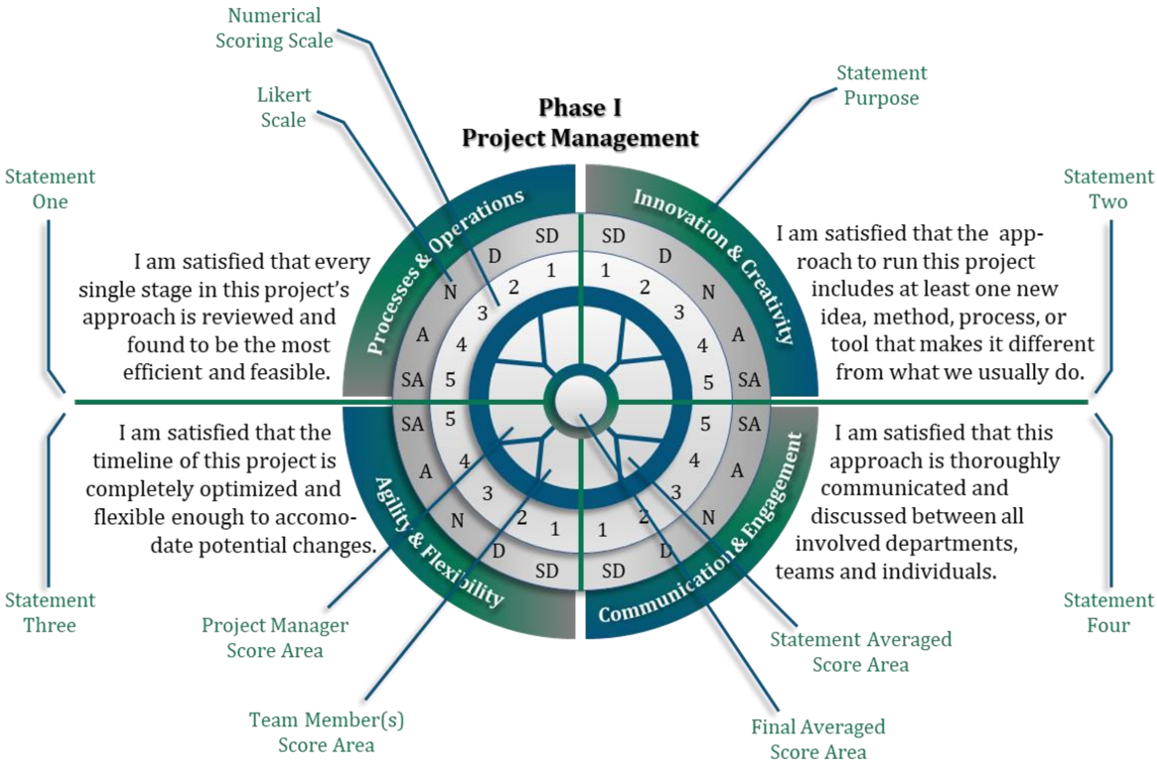

Figure 2 – Innoframe – Phase I.

Phase I works to ensure that four key concepts of project management are integrated and maintained. The four concepts are: Processes & Operations, Innovations & Creativity, Agility & Flexibility, and Communications & Engagement. Each of these serves a specific purpose that goes beyond integrating the project management concept into the project, to evaluating how well the strategy is integrated. The statements also serve to provoke discussions, centered on the concept, between the project manager and his team and within the team. This is important to ensure the entire team is on the same page with regards to what is required and the direction that the project is headed in. They also enable team members to have a voice throughout the project. Meetings between project managers and top management, as well as interdepartmental meetings are also important. These facilitate strategic alignment, and smoother transitions for projects when firms change direction.

Phase I has a number of conceptual statements that should be identified. A similarity in all the statements of Phase I is that they require engagement or communication from different levels.

- Statement one: I am satisfied that every single stage in this project's approach is reviewed and found to be the most efficient and feasible;
- Statement two: I am satisfied that the approach to run this project includes at least one new idea, method, process or tool that makes it different from what we usually do;

- Statement three: I am satisfied that the timeline of this project is completely optimized and flexible enough to accommodate potential changes;
- Statement four: I am satisfied that this approach is thoroughly communicated and discussed between all involved departments, teams and individuals.

The next phase in Innoframe is Portfolio management. This phase can be visualized below in figure 3. This phase will ensure that there is a high commitment level and cooperation between the project team and management. Portfolio management ensures that the management of the organization takes the necessary steps to ensure that projects are properly equipped and aligned to strategy which means facilitating the project team in every way possible. The four statements seen in figure 3 are meant to ensure that the project aligns with company strategy. By answering these four questions, the project manager continually keeps the bigger picture in mind and is able to adjust the project accordingly so that all four statements can be made with confidence.

- Statement five: I am satisfied that this approach is planned in line with project's portfolio strategy and helps in achieving its objectives;
- Statement six: I am satisfied that the project's approach has been reviewed by all stakeholders and it has their support and engagement;
- Statement seven: I am satisfied that this project ensures a well-rounded portfolio that meets all requirements and delivers a balanced risk-reward spectrum;
- Statement eight: I am satisfied that this project adds a new value to its portfolio in terms of nature, operations and end results.

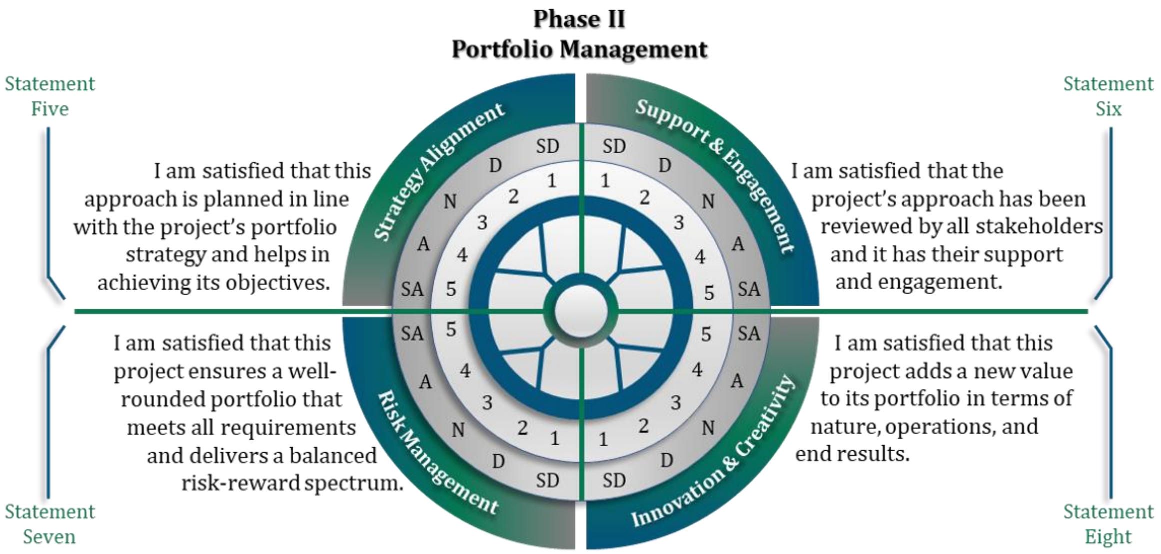

Figure 3 – Innoframe – Phase II.

The final portion of Innoframe is the matrix. This performance matrix is determined based on the final averaged scores for both phases. The results are plotted in a grid to establish how well the project performed in portfolio and project management metrics, as can be seen below in figure 4.

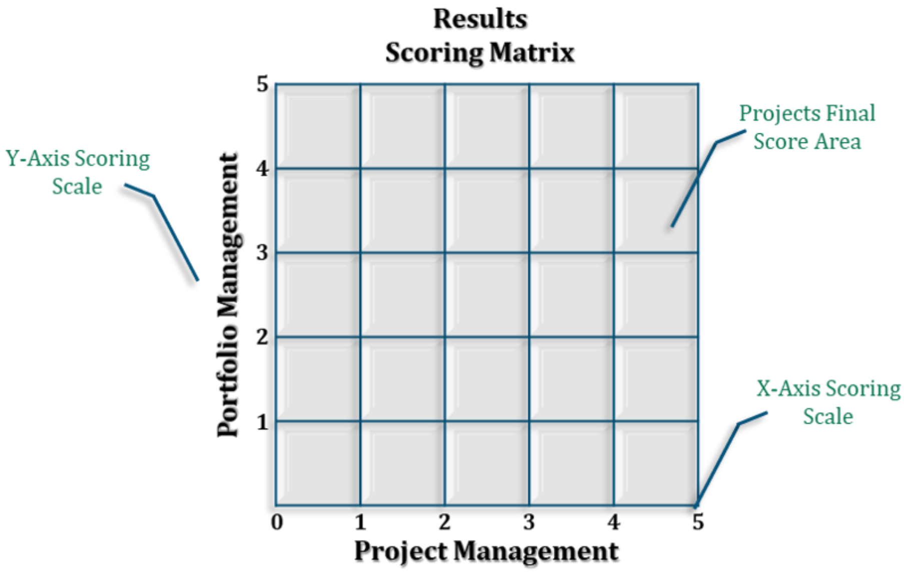

Figure 4 – Innoframe – The Matrix.

Performance management is important as it provides a check that can be used to identify what went right or wrong, where improvements are needed, and which aspects were unnecessary. Thus, Innoframe has included the matrix and scoring system as a performance management indicator. The scoring model consists of two scoring systems, the Likert Scale (5-point) and the numerical scoring scale. In addition to the scoring scales, both phases of Innoframe also consist of scoring areas for both the project manager and the team members to encompass the differing experiences of each group. In addition, all members relay their perceptions of how well the statements have been inculcated into the project, making it a more holistic evaluation. Following scoring from the project manager and team members, the scores are summed and averaged to find the final statement averaged score. Finally, each of the statements' average scores are summed and averaged to produce the final average score. This is placed in the final averaged score area. The final average score is important because it gives a quantitative picture of how the project has performed in terms of inculcating the statement for each phase. The results of each phase are then located on the matrix which provides the full picture on how the project performed during each phase.

CONCLUSIONS AND FUTURE RESEARCH

The research presented in this paper was develop to answer the following research question: How can an integration among project, portfolio and innovation management create a multidimensional framework to support SMEs for better end results on the three levels?

To arrive to the answer to this question, a case study of the Canadian construction and building materials industry was done. The methods used were literature review, interviews, group discussion and survey.

The relevant literature was examined, and although the fields of project, portfolio, and innovation management are growing in importance and recognition, there is still a lack in knowledge acquisition in academic literature. The primary research performed aimed to shed some light on this issue through firsthand experiences of project managers dealing with management challenges and framework implantation throughout their careers.

After data was collected and analyzed, a new framework called Innoframe was development. Innoframe is as a multidimensional framework that combines the main elements that are essential on three levels, project, portfolio and innovation management, and puts them together to give small and medium sized companies a new route for more efficiency and better end results. Innoframe provides a new approach based on the industry needs which none of the models studied provide at once.

The study itself and its outcome opens new paths for further studies and challenges further research to evaluate the usage, propose modifications and embed new enhancements into the framework. The nature of the outcome of this research is something that can be easily subjected to evaluation and assessments throughout the years. Because of this, the continuation of studies on this framework might be tempting to many academic students whether they are studying business or engineering majors. The framework proposes a theoretical and practical approach to companies, which is something that should be tested in the future in a research setting to test the effectiveness of the framework over the short, medium, and long run. As well, the framework can be tested for its effectiveness on a variety of projects to identify under what conditions and for what projects the framework is best suited.

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Development of Quality Dashboards: a case study of an electronic product

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ABSTRACT

Purpose – This work aims to study the management of products' and process' characteristics to ensure the products' quality, by leveraging the use of dashboards, that collect, analyse and display information about the quality of the production in near-real-time.

Methodology – The methodology used was based on the CRISP-DM reference model that comprises six stages: Business Understanding, Data Understanding, Data Preparation, Modelling, Evaluation and Deployment. The last two stages were not implemented.

Findings – The main findings of this work focus on the use of recent IT developments to build systems that assist the work of the quality team, with the implementation of a quality dashboard. It was also important to note that the use of dashboards with near-real-time data helps the decision making process of the stakeholders.

Practical implications – The resulting dashboards were considered very useful by the company, and the work developed served as pilot project on the creation of quality dashboards.

Originality – This work combines the fields of data analysis, quality and process monitorization techniques. It addresses the need to use data in a meaningful, easy and fast manner, as a way to provide stakeholders with the necessary insights about the quality of the production.

Keywords: Dashboards, Quality Control, Critical to Quality Characteristics, CRISP-DM.

Paper type: Case study

INTRODUCTION

The scope of this study is the management of products' and process' characteristics to ensure the products' quality. By leveraging the development at the information technology (IT) field, the focus is on the creation and implementation of quality dashboards, that collect, analyse and display information about the quality of the production in near-real-time.

With the developments in the field of IT, detailed data regarding products, processes, collaborators, clients, suppliers, and other company's assets can be stored and accessed. However, the raw data available at the servers is not sufficient for the stakeholders to have an overview of the quality of the products and processes. In order to support them, data needs to be cleaned, analysed and distributed in such a way that it provides useful information.

Therefore, the main goals of the study are:

- To analyse and define the requirements and information needed by the different stakeholders of the company to make better decisions in a smaller timespan.
- To study a specific case and apply the adequate methodology to extract information from the analysed data and display it to the different stakeholders, through the creation of dashboards.

This study combines the areas of product quality management and IT data development. It contributes to the improvement of quality professionals' work by applying new technologies supporting the Quality 4.0 concepts.

In the next section a theoretical background is presented, focused on the topics of Quality Control, Quality 4.0 and a Data Mining method, CRISP-DM. Following, the methodology used in this work is explained. Afterwards the case study is described by addressing the product and process, the critical characteristics, the data analysis and preparations, and, finally, the modelling of the dashboards. The final section presents the main conclusions, as well as some indications regarding future developments and the more relevant contributions of this work.

THEORETICAL BACKGROUND

Quality Control

Dunn (2020) states that "good quality products (low variability) actually boost your profits by lowering costs. You have lower costs when you do not have to scrap off-specification product, or have to rework bad product. You have increased long-term sales with more loyal customers and improved brand reputation as a reliable and consistent supplier". Montgomery (2019) also refers that "quality is inversely proportional to variability" and believes that the quality of a product increases if the variability of the product characteristics decreases and therefore that "quality improvement is the reduction of variability in processes and products" (Montgomery, 2019).

Before looking for ways to reduce variability, it is important to distinguish between its two main types: (i) variability due to natural causes that are related to uncontrollable aspects that affect the processes, even the well designed and maintained and (ii) variability due to special causes that can be associated with machine settings, operator mistakes and material condition, among others. A process under statistical control is a process only influenced by natural causes, while an out of control process is also influenced by special causes of variation (Montgomery, 2019).

The use of Statistical Process Control (SPC) allows the identification of special causes of variation and aims to eliminate them, thus reducing the variability of the process to improve its stability and capability.

One of the main tools used in SPC is control charts that have three fundamental uses: (i) reduction of process variability; (ii) estimation of product or process parameters; and (iii) monitoring of such process.

The Shewhart control chart, developed in the 1920s, is a tool that graphically represents a statistic related to a quality characteristic and compares it to defined control limits (figure 1). The values presented in blue, represent the evolution of the statistic (average, for example) over time, calculated based on samples retrieved from the production. The control limits (lower control limit – LCL and upper control limit – UCL) are defined based on the natural variability expected for the characteristic and calculated using statistical concepts. If a point is outside the control limits, it is an indication that the process is out of control and that a special cause occurred on the process. This cause needs to be studied and eliminated (Montgomery, 2019).

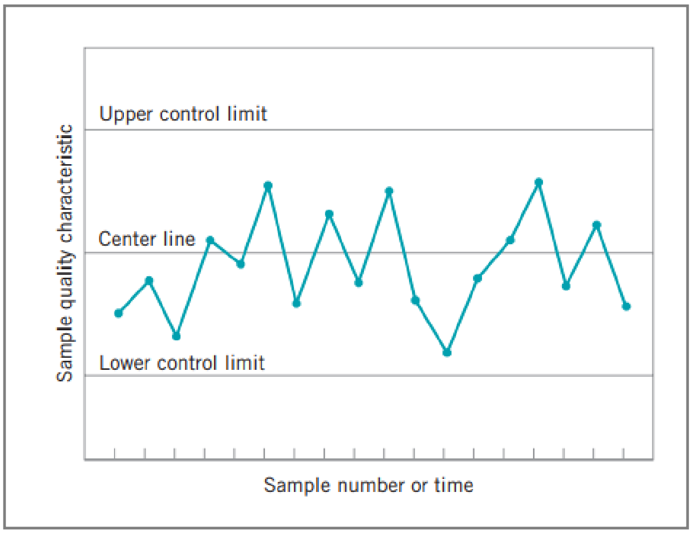

Figure 1 – Control chart (Montgomery, 2019)

To implement control charts, a methodology consisting of two phases should be conducted. The first phase aims to estimate the population parameters and to determine the control limits. During this phase, the historical process data is analysed, considering its central tendency and variability. The points considered out of control are then identified and their causes studied and eliminated, improving the process under study. For this improved process, new control limits should be defined (Montgomery, 2019) and, finally, the process parameters are calculated.

The second phase focuses on monitoring the process by using new data in real-time and it is assumed that all of the special causes present in the process were detected and eliminated on the previous phase. The control limits should be periodically reviewed, especially if some change occurs, but must not be constantly recalculated considering the new data (Montgomery, 2019).

There are several types of control charts. In this work, the individual values-moving range (I-MR) control chart are going to be applied. These two charts are used together (figure 2), the first for controlling the central tendency of the process, based on the individual values, and the second for controlling the variability of the process using the moving range (the difference between the values of each point and the previous one).

The control limits and the central lines of the I-MR charts are calculated based on the following expressions:

MR chart (see the bottom chart of figure 2)

$$\mathrm{UCL} = \mathrm{D}_4 \cdot \overline{\mathrm{MR}}$$

$$\mathrm{CL} = \overline{\mathrm{MR}}$$

$$\mathrm{LCL} = \mathrm{D}_3 \cdot \overline{\mathrm{MR}}$$

I-MR chart (see the top chart of figure 2)

$$\mathrm{UCL} = \bar{\mathrm{x}} + 3 \cdot \frac{\overline{\mathrm{MR}}}{\mathrm{d}_2}$$

$$\mathrm{CL} = \bar{\mathrm{x}}$$

$$\mathrm{LCL} = \bar{\mathrm{x}} - 3 \cdot \frac{\overline{\mathrm{MR}}}{\mathrm{d}_2}$$

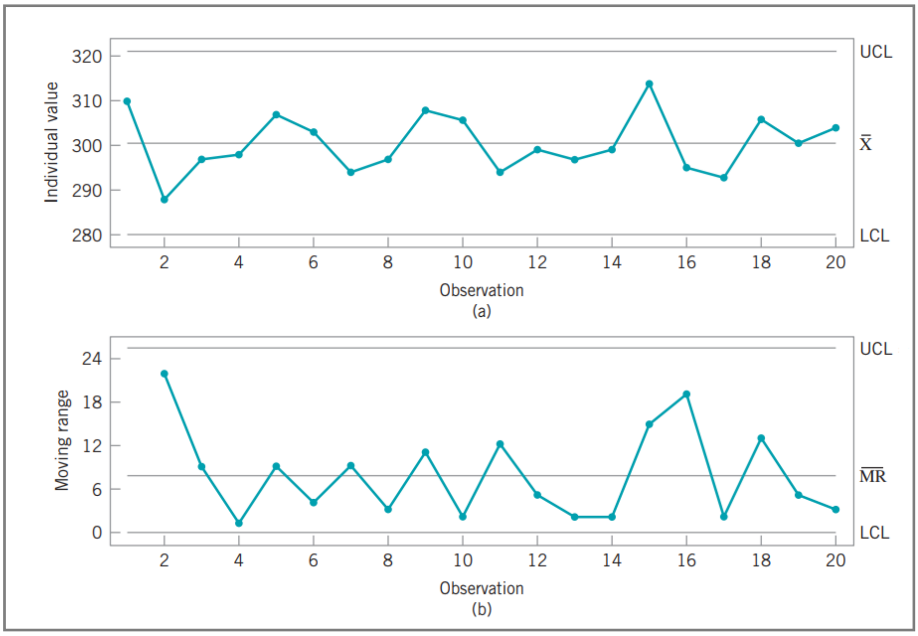

Figure 2 – I-MR control chart (Montgomery, 2019)

The interpretation of the I-MR charts starts by observing if the MR one is under control. Montgomery (2019) states that one should "never attempt to interpret the chart when the [MR] chart indicates an out of control condition". As such, any detected deviations from the under control state should be studied and its causes should be identified and eliminated.

After that, the individual value chart should be analysed. These analyses should focus not only on out of control points, but also if some cyclic pattern, a trend or a shift in the process level is present (Montgomery, 2019).

After the process is stable and its parameters have been estimated, it is desirable to calculate its capability. In fact, it is very important that the process being monitored (second phase of SPC) has a good capacity to produce parts/products within the specification limits.

Process capability analysis consists of "analysing [the process] variability relative to product requirements or specifications" (Montgomery, 2019). The specifications are the limits defined by the customer and should not be confused with the control limits. If the product is outside the specification limits (upper specification limit – USL and lower specification limit – LSL) the customer will not accept it and it will be considered a waste.

Two main indicators are used to represent the capability of the process:

$$C_p = \frac{USL - LSL}{6 \cdot \sigma}$$

$$C_{pk} = \min\left(C_{pu} = \frac{USL - \mu}{3\sigma}; C_{pl} = \frac{\mu - LSL}{3\sigma}\right)$$

C_p is the ratio between the allowed variation and the real variation and does not consider the location of the values relative to the specification's target. C_{pk} ratio makes the same evaluation taking into consideration the centre of the process. It is commonly established "that C_p measures potential capability in the process, whereas C_{pk} measures actual capability" (Montgomery, 2019).

As Dunn (2020) mentions it is important, in order to achieve a final product with a high level of quality, that systems present low levels of variability both regarding process parameters and product characteristics. Rather than waiting until the end of the process, it is crucial to monitor in real-time the critical intermediate steps of the process.

Quality 4.0

As already mentioned SPC provides tools to perform this task but it should be noticed that there have been technological developments useful for implementing SPC solutions as well as other monitoring methods.

In this context the concept of Quality 4.0 has emerged and is defined as the application of Industry 4.0 technologies into the quality field (Sisodia and Forero, 2020). "Industry 4.0 can be perceived as a natural transformation of the industrial production systems triggered by the digitalization trend" (Rojko, 2017). It is about "the users of that technology, and the processes they use to maximize value" (LSN Research, 2017).

These developments are mostly presented from the technology perspective and implemented by IT teams. However, the Quality 4.0 framework presents them as organizational issues and, within this setting, quality professionals need to reposition themselves as the owners of these changes. As process management experts, they should be the ones defining how to use the data and why (ASQ, 2018; Sisodia and Forero, 2020).

Zonnenshain and Kenett (2020) discuss several opportunities in the quality field to leverage these new technologies, such as "quality as a data-driven discipline, modelling and simulation for evidence based quality engineering, prognostics for quality, integrated quality management (…)" and more.

The concept of Quality 4.0 is presented in this work to support the implementation of the proposed dashboard as a way to provide the quality team with systems that distribute and analyse data regarding the quality of the production.

With the massive amount of data available today and the need to access the data, it is important to develop projects of knowledge discovery and data mining (Maimon and Rokach, 2010), as a way of facilitating data-driven decision-making and actions.

Data mining can be described as "the process of discovering correlations, patterns, trends or relationships by searching through a large amount of data stored in repositories, corporate databases, and data warehouses" (Rohanizadeha and Moghadama, 2009).

The application of data mining techniques in quality control activities provides the stakeholders with meaningful data about the characteristics of products and processes. Kano and Nakagawa (2008) state that "To achieve product quality improvement, we need to predict product quality from operating conditions, to derive better operating conditions that can improve the product quality, and to detect faults or malfunctions for preventing undesirable operation.".

Next, CRISP-DM, the data mining methodology used in this work, will be described.

Data mining: CRISP-DM

CRoss-Industry Standard Process for Data Mining, CRISP-DM, is a data mining process developed in 1996 by a consortium of industries with the aim of building an "industry-, tool- and application-neutral" methodology (Chapman et al., 2000). The model represents the life cycle of a data mining project and consists of six phases. The sequence of the steps is not rigid, and it is common to go back to a previous stage when more insights and understanding are gained. Figure 3 shows the six steps and the most common dependencies between them, represented by the arrows.

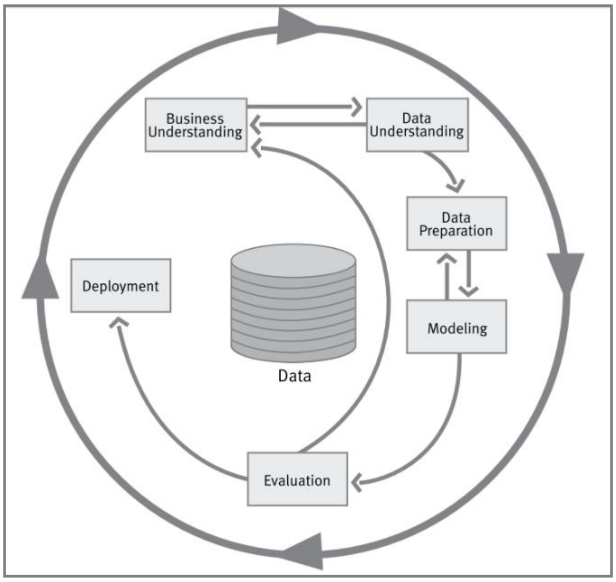

Figure 3 – CRISP-DM Reference Model (Chapman et al., 2000)

The first step is about getting to know the project. It is at this stage that the business requirements and the data mining goals are defined, the situation at hand is assessed and the project planned.

With more knowledge about the business, the next phase deals with understanding the data. Thus, the data is collected, described, explored and its quality is verified. As more knowledge about the context is obtained in this step, it may be necessary to go back to the previous one and upgrade the business understanding.

During the data preparation step, the tasks related to extracting-transforming-loading (ETL) are performed to build the final dataset. The "tasks include table, record, and attribute selection, as well as transformation and cleaning of data for modelling tools" (Chapman et al., 2000).

At the next step, different modelling techniques are applied and tested in order to solve the data mining problem. Some of these models may require adjusting the data set and a need to go back to the previous step.

When the model built reaches a satisfactory quality, the evaluation step begins. At this stage, it is important to assess the performance of the model from a data point of view, but also from a business perspective. The goals and objectives defined in the first step should be reviewed.

At the deployment stage, the defined model needs to be deployed in a way that integrates the decision-making processes of the company, for example creating a dashboard on a web page, together with a monitoring and maintenance plan of the model created. It is during this step that a review of the project is performed and a final report written.

METHODOLOGY

Several activities regarding identification, acquisition, handling, analysis, visualisation and display of data were conducted in order to build the dashboards with the relevant information for their users.

With this goal, a methodology based on the CRISP-DM reference model was applied.

Business Understanding

The first step of the model is to gain a deep understanding of the case at hand. In order to do so, and after the identification of the team involved and the motivation for the dashboard, information about the product and the production process was gathered. All the support documents to the project, like failure mode and effect analysis (FMEA), control plans (CP), value stream mapping (VSM), customer support requirements (CSR), among others, were collected and analysed. Also, a more hands-on approach to explore the environment was achieved through observation of the production steps and by interacting with the production teams.

In this step, the identification of the critical to quality (CTQ) characteristics was done together with the quality engineer. The CTQ characteristics are the base to define what are the goals of the dashboard and its functional requirements.

Therefore, during this phase, the following outcomes were attained:

- Product description (should include the main functions);
- Production process mapping;
- Team identification;
- CTQ characteristics identification and inspection method;
- Goals for the dashboard.

Data understanding

With the goals for the dashboard defined and the information requirements identified, the second step is to focus on the data. The first part was to identify, for the required information, the necessary data and to compare it with the data that was already being collected and stored. A data strategy plan was defined in collaboration with the IT responsible. This plan consisted of the data flow mapping, and the definition of the format and structure in which the data was going to be accessed.

Besides this, data analyses were done in order to gain sensibility to the data and to its quality.

The outcomes were:

- Identification of the data;
- Data analysis.

Data preparation

The data preparation phase consists of the integration of the data into the model. For this study, the tool for modelling the data was MS Power BI. This tool has the capability to gather different sources on the same platform, to create a relational model and to perform ETL tasks.

The following outcomes were obtained:

- Data model;
- ETL tasks on the MS Power BI file.

Modelling

After having the data imported to MS Power BI, at the modelling phase the visualizations of the data were created. In this phase, visualization principles should be applied, together with statistical techniques and process control tools.

It is crucial to keep in mind who are the stakeholders and how they will interact with the dashboard and use the information.

For this phase, the outcomes are:

- Identification and selection of data visualization and statistical analysis techniques;
- Creation of the pages with data visualization in MS Power BI.

Evaluation

The dashboard was ready to be evaluated but, due to time constraints, it was not possible. At this stage the objective was to present the dashboard to the quality engineer and the main users in order to obtain some feedback regarding possible necessary adjustments.

Afterwards, a trial period with the users would be required in which the usage of the dashboard would be tested, so as to conclude its final version.

Deployment

The deployment of the dashboard did not take place but it is expected that it will be deployed in the near future in collaboration with the IT team. An also important output would be some lessons learned in the process, and that could be of value for further projects.

Following all the phases a report is written, in order to document the main outcomes of each step.

CASE STUDY

In this section, the application of CRISP-DM methodology to a particular electronic product is explained. It starts with an introduction to the product and its production process as well as its CTQ characteristics. After that, an exploratory data analysis and the data preparation method are presented. Finally, the dashboard pages are briefly described and two examples of its visualization are shown.

Product and Process

The product that was analysed is an electronic wireless equipment that serves as a communication portal between fire detectors and control panels. This product belongs is part of a fire detecting network (see figure 4).

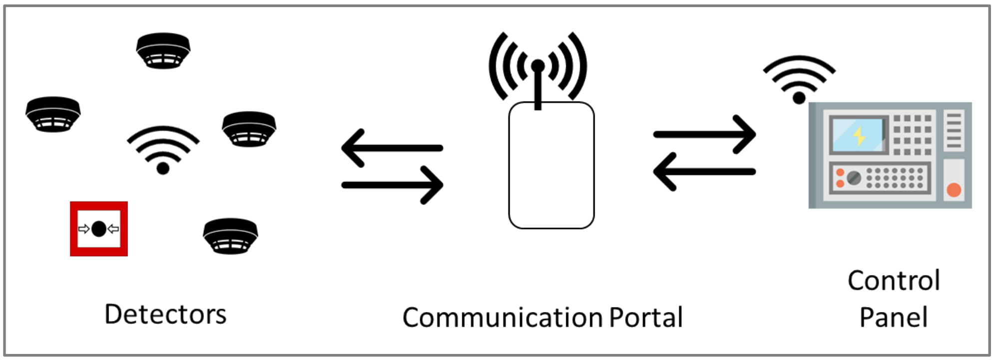

Figure 4 – Fire detection system

The product consists of the following main parts: the radio module, the antenna, the housing, and the Printed Circuit Board (PCB). The production process, presented in figure 5, consists of the production of PCB, using surface mount technology (SMT) and through-hole technology (THT) technologies, followed by the application of coating protection on the PCB and by the milling process. At the final assembly station (FAS), the PCB is submitted to a functional test, then the antenna's and the audio jack's pins are manually soldered to it and assembled on the housing. Then a final test is performed, where several functionalities are tested including the signal of the Radio Frequency module (RF module). If the product passes the test, it continues to the last FAS activity, which is the packaging. There are also additional inspections, an x-ray test to evaluate the soldering quality and a customer acceptance test (CAT).

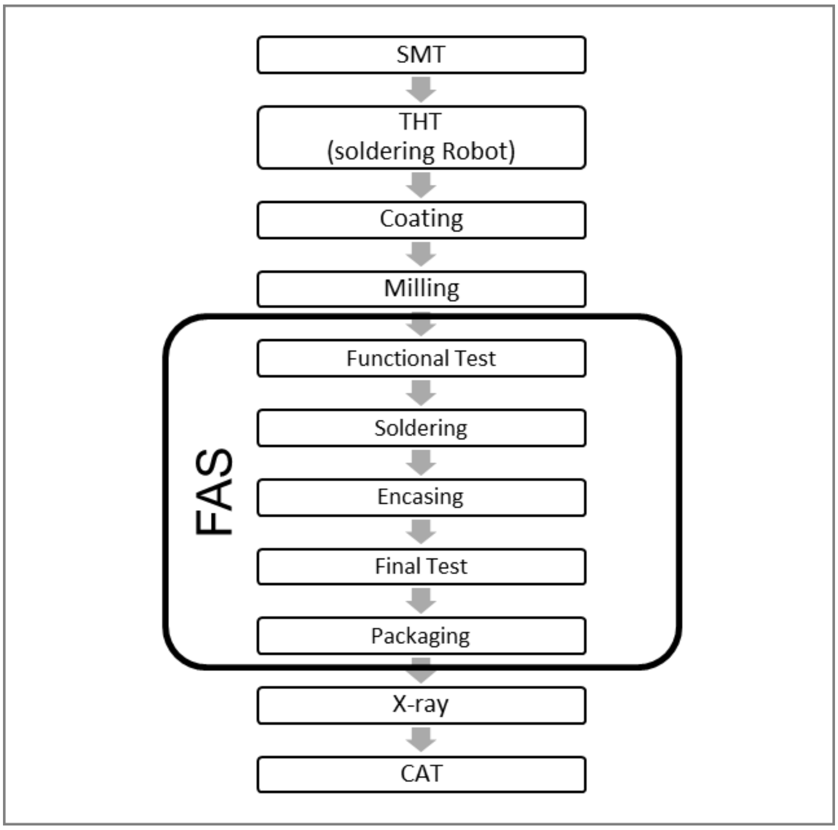

Figure 5 – Production process

Critical to Quality Characteristics

After thoroughly understanding the product and its process it was necessary to involve different stakeholders in order to identify the CTQ characteristics and to define the information to be included in the dashboards.

With this in mind, people from the development team, the industrialization team and the quality department, met to discuss the project at hand.

The strategical goals identified were: overview of the CTQ, evaluation of the production state, analysis of the rejection and failure modes and a single product view.

Then, the user goals for the team were described. Based on those goals, the functions of the product and the knowledge regarding the production process, the following characteristics were identified as critical to quality (CTQ):

-RF signal strength, as the main function of the device, tested at the end-of-line test (EOL);

-Filling rate of the soldering pins that are inspected trough an x-ray test.

Exploratory Data Analysis

An exploratory data analysis was performed in order to better understand the process. Data related to three months of production, which corresponded to 174 units, was gathered.

The analysis starts with a brief view of the production rate, followed by a more in-depth study of the identified CTQ characteristics, namely the soldering performance and the signal strength.

<u>Production Output</u>

The first step was to analyse the manufacturing rate so the output per week is presented in figure 6, in which the weeks without production were not considered. There is some instability of the production output due to the fact that the production plan depends on the forecasted demand, which can change substantially.

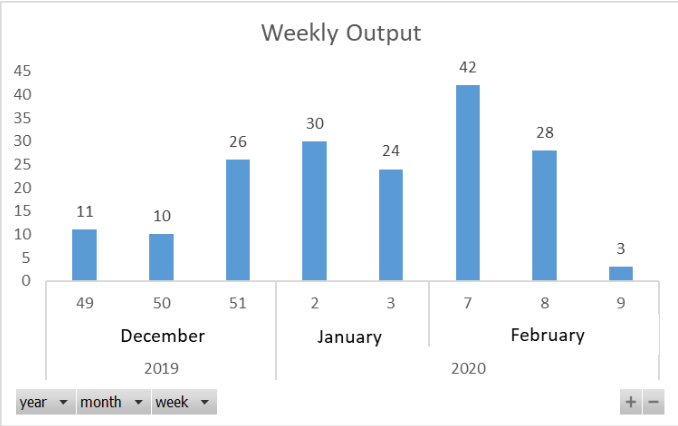

Figure 6 – Production weekly output

All the products go through the EOL test and need to pass once to be considered ready for use. Nevertheless, some problems related to the test or some extra reparations can lead to the same product being tested more than once, therefore, the analysis considers the units tested and the tests done.

During the period under analysis 12 of the 174 units failed the EOL test (6,9% of the products failed at least once). However it should be noticed that a total of 204 tests were done and 20 of those failed (9,8% of the tests failed).

<u>Pin's Filling Rate</u>

The pin filling rate is a critical characteristic that must comply with safety norms. The product has five pins that are filled by a manually soldering process. It is later evaluated by a visual x-ray inspection (figure 7).

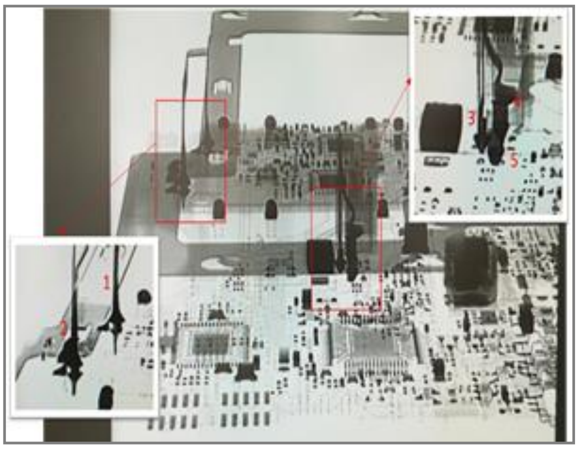

Figure 7 – X-ray inspection

The inspector registers the percentage of filling rate at each pin. Later each pin is categorized into four classes: A. < 75%; B. 75%- 100%; C. 100%; D. >100%.

The ideal is to have all the pins in class C, however if the pin is in class B is still accepted. If the pin is in class A it is underfilled and there is no connection and if the pin is in class D, the pin is overfilled and can cause a short circuit, and in those situations the product needs to be rectified.

Only one product at pin four was classified as class D and the rest at class C. Therefore, no extra action or analysis was taken since, at the moment, the collaborator performing this task has extensive training and experience. Nonetheless, this characteristic will continue to be 100% monitored.

Signal Strength

The product main function is to communicate with the control panel and the fire detectors, which is done via radio frequency signals that are transmitted (transmitted signal from device to tester – TS) and received (received signal from tester to device – RS).

During the EOL test the strength of the signals received by each product and by the tester are recorded. The specification limits for both signals levels are between -82 dB and -60 dB.

From the 204 tests performed only 192 were recorded since the data of some fail tests were not registered. The plot of both signals, TS and RS, gives an overview of the behaviour of the signals (figure 8Figure). It should be noted that the data recorded was rounded to the unit, so it appears to correspond to discrete variables.

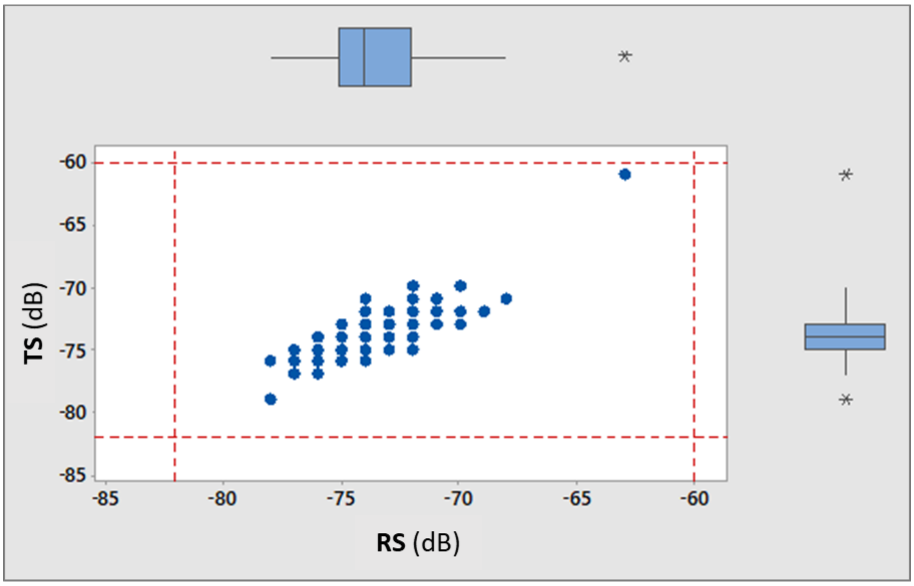

Figure 8 – Transmitted signal versus Received signal plot

Table 1 presents the data statistics from the signals and it can be observed that the values are highly concentred between -75 dB and -73 dB for TS and -75 dB and -72 dB for RS, representing 50% of the values (from Quartile 1 to Quartile 3).

Table 1 – Descriptive statistics of data from TS and RS strength

	TS (dB)	**RS** (dB)
N	192	192
min	-79	-78
Q1	-75	-75
Median	-74	-74
Q3	-73	-72
Max	-61	-63
Mean	-73,73	-73,71
StDev	1,87	1,96

Analysing the scatter plot and the two individual boxplots, shown in figure 8, it is possible to identify an outlier. This outlier was removed from the data points and no other outliers were identified after removing this point. In table 2, the updated values are presented.

Table 2 – Descriptive statistics of data from TS and RS strength (without outlier)

	TS	**RS**
N	191	191
min	-79	-78
Q1	-75	-75
Median	-74	-74
Q3	-73	-72
Max	-70	-68
Mean	-73,80	-73,76
StDev	1,63	1,80

The next step of the study was to analyse the behaviour of the signal over time. In addition to simply verifying the time series correspondent to the signals, control charts for individual values and moving ranges (I-MR) were implemented in order to monitor the stability of the process, corresponding to the first implementation phase of statistical process control. Figure 9 presents both I-MR charts for TS strength and figure 10 shows those charts but for RS strengh. As in the individual value control chart each sample consists of one value, the same chart, without considering the control limits, also represents the time series of the values measured. In figures 9 and 10, it can be seen the change of the signals strength along the time, the determined control limits of the referred charts and the identification of the out of control points.

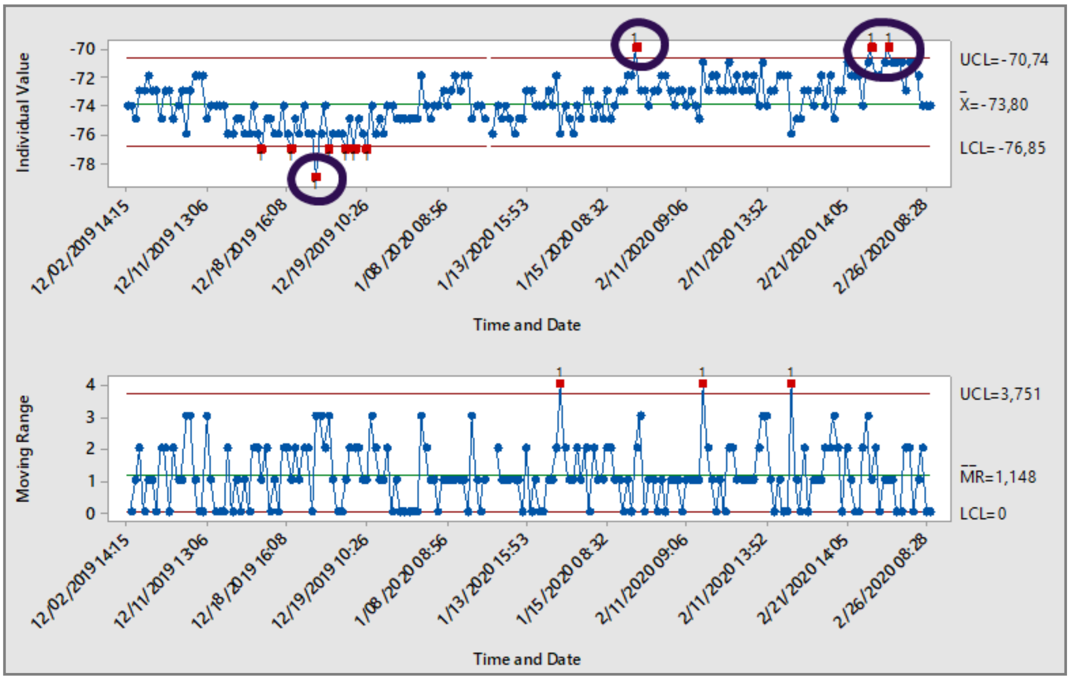

Figure 9 – I-MR control charts for TS strength

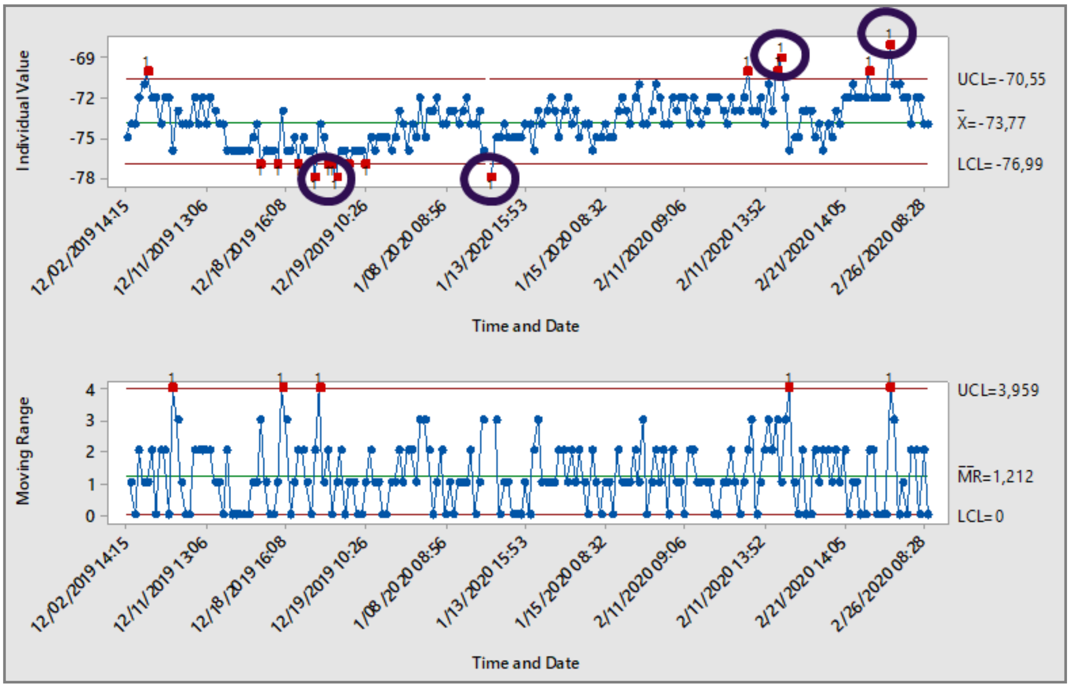

Figure 10 – I-MR control charts for RS strength

Due to the data discretization, the control limits were approximated to the unit, as presented in table 3.

Table 3 – Individual values control limits

	TS	RS
UCL	-70,74 =-71	-70,55 = -70
LCL	-76,85 = -77	-76,99 = -77

For both sets of signals, the moving range chart upper control limit is defined as 4, therefore no point is considered out of control. In the individual values charts, several points are identified as out of control and marked in figures 9 and 10: 4 for TS and 5 for RS. It should be noticed that some of the points marked in red were not considered as being out of control because of the way the control limits were defined (see table 3).

All the units and tests that correspond to these points were discussed with the quality engineer in charge of the product in order to investigate possible assignable causes, and no clear reason for the deviations was found. Since in all the cases the signals were between the specification limits, it was decided to pay attention to the future evolution of the signals, but not to take any action considering the past points.

Nevertheless, an analysis where the points out of control were removed and the control limits recalculated was done. The result was that the control limits for both transmitted and received signals were -71 dB and -77 dB. In figures 11 and 12 the updated I-MR charts are presented and, once more, the points in red were not considered out of control because of the strategy used to determine the control limits.

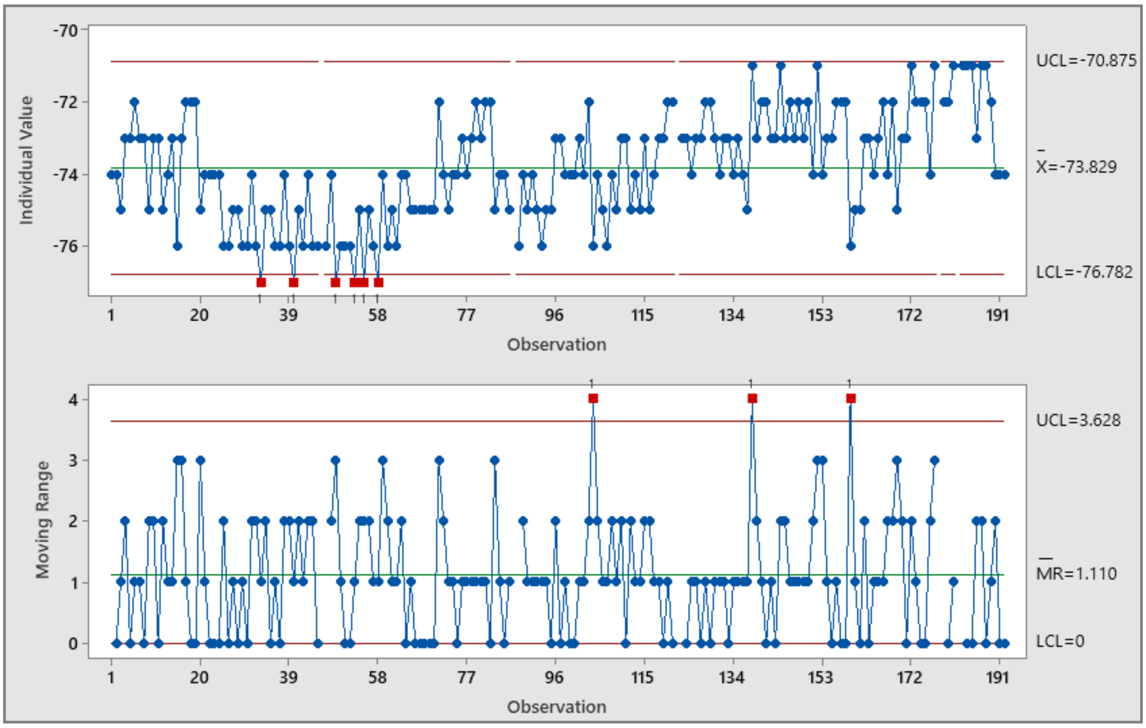

Figure 11 – I-MR control charts without points out of control for TS strength

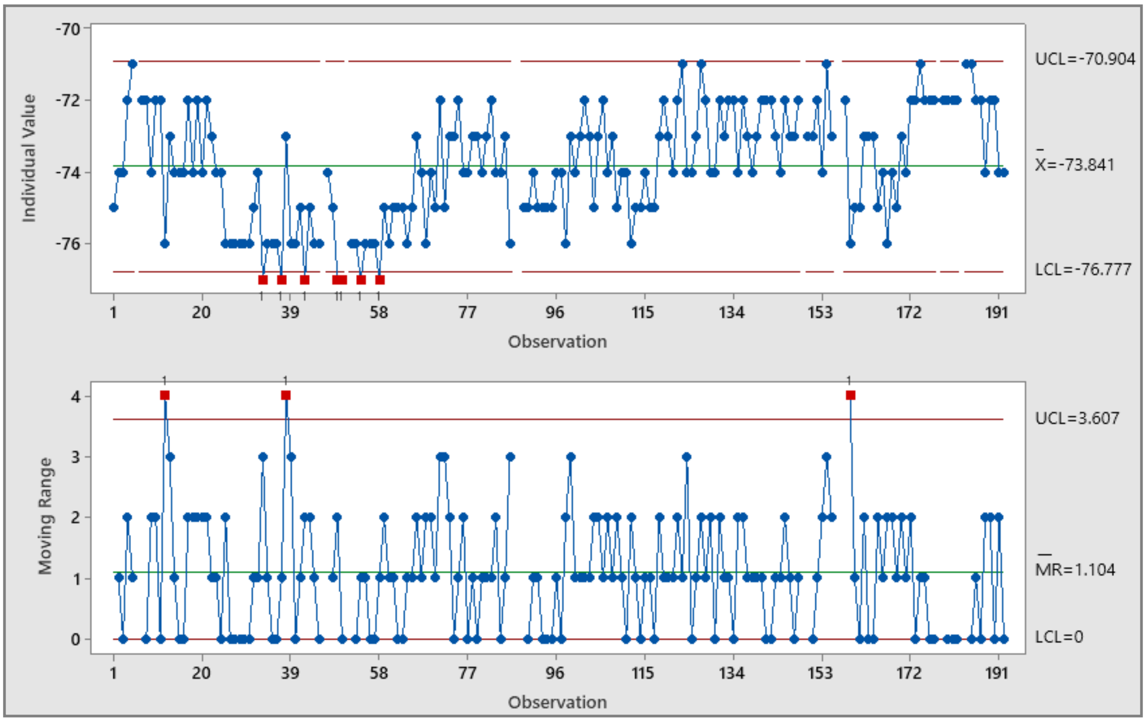

Figure 12 – I-MR control charts without points out of control for RS strength

After analysing the stability of the process over time, a capability analysis was done. First, tests to evaluate the normality of the data were performed. It can be concluded that the distribution of both transmitted and received signals strength can be considered approximately normal, so the indices C_p and C_{pk} can be used to measure the capability of the process.

By observing figures 13 and 14, it can be concluded that the processes are capable to perform between the specification limits, showing high capability indexes ($C_p > 2$ and $C_{pk} > 1{,}5$).

Considering that the C_p values are higher than two, it can be concluded that the process has very good potential capabilities. The C_{pk} values indicate a deviation from the centre of the process (-71 dB) and point to high real capabilities. It is visible on the graphs (figures 13 and 14) some tendency to have signals centred between -73 dB and -74 dB.

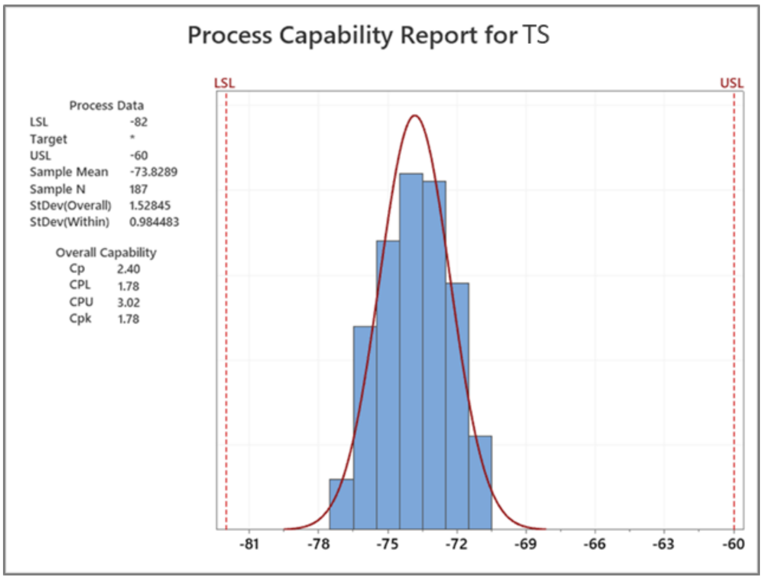

Figure 13 – Capability Analysis corresponding to TS

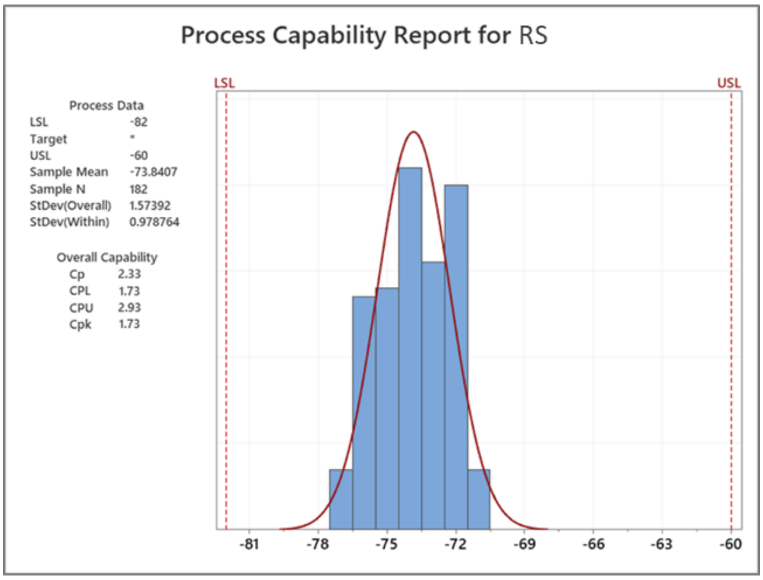

Figure 14 – Capability Analysis corresponding to RS

This exploratory data analysis allowed the stakeholders to have a better knowledge about the process. Additionally the data analyst acquired more sensibility and context about the data he/she is working with.

Data Preparation

Based on the goals and the different tests done to the product the data needed was collected from the following sources: (i) the EOL test, that provides the result pass-fail of the production and the RF signals strength, (ii) the X-ray inspection, and (iii) the CAT inspection

To access the production database and the results of the EOL test, an executable file was created to extract the needed data to CSV files stored in a network folder. As for or the X-ray and CAT inspection, the data was already stored in Excel files that were easily accessed because they were stored in network folders.

From those files it was possible to extract the necessary data, through the use of MS Power BI functionalities. MS Power BI also has a feature that allows defining the data structure of the dashboard.

The data schema was defined by applying multidimensional data modelling. From the three main activities, three fact tables were defined. Three dimension tables were also created namely, one related to the product, a common dimension to all of them; another associated with the step fails of the EOL test, and one for storing some comments regarding the X-ray data source. An extra table was created to store the control and specification limits.

Modelling

Based on the previous analyses and with the data needed prepared, five pages were created to display the information about the product: Overview, X-ray: Soldering performance, RF Signal Performance, Final Test Failure Analysis, Single Unit Overview.

As an example, two of those pages are shown in figures 15 and 16, specifically the page related to the RF Signal Performance and the one that shows the Single Unit Overview.

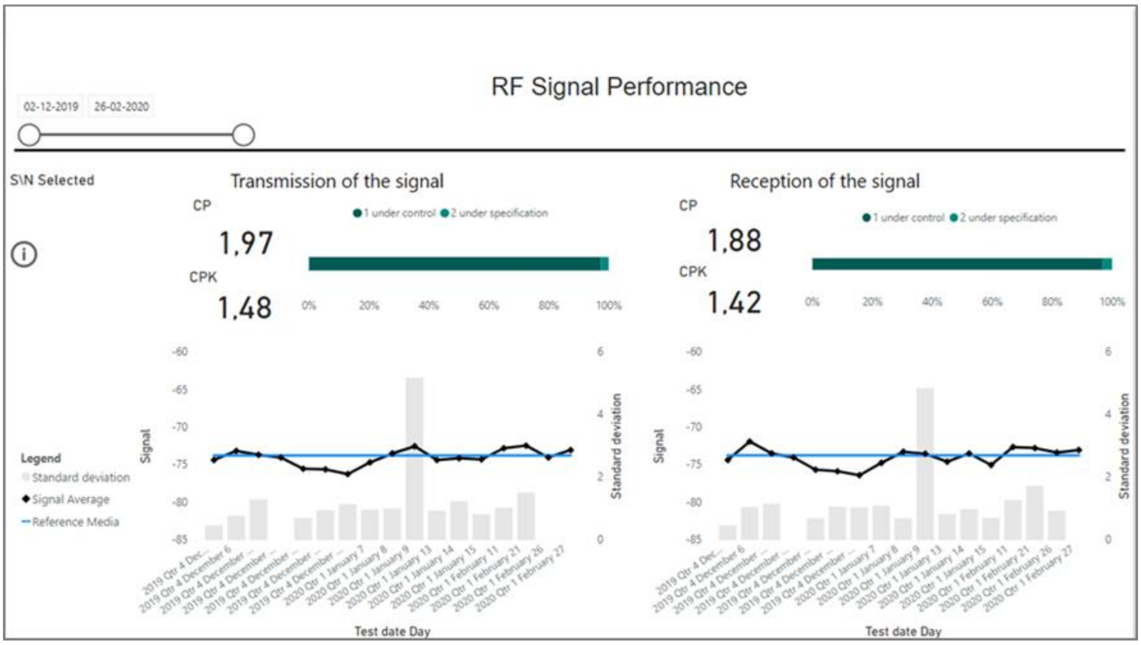

Figure 15 – Dashboard for RF Signal Performance

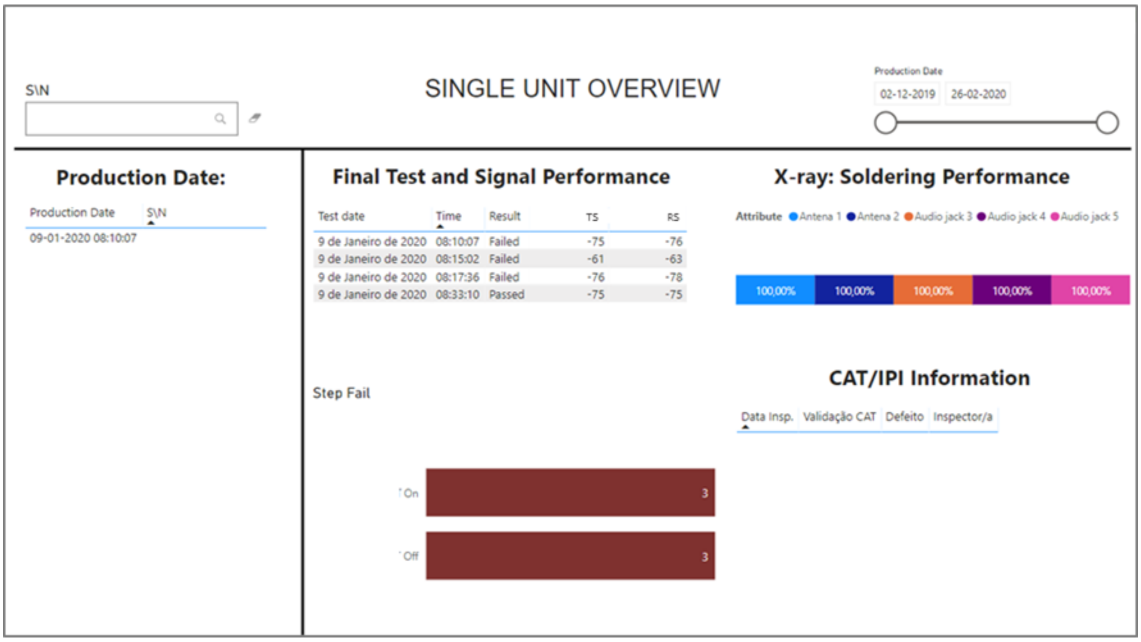

Figure 16 – Dashboard for Single Unit Overview

During the process of creating the dashboards, the principles presented by Knaflic (2015) - know the context, choose the right chart, think like a designer, design dashboards not reports - were taking into account since the objective of data visualization is facilitating its communication (Kirk, 2012).

The visualization is an interface between the data and its users, supporting them in identifying process improvements or potential causes of problems, by allowing them to detect patterns, deviations and outliers in the data (Celonis, 2020). With that in mind, the aim of the dashboards that were built was not to give a direction, but to support the decision-making process of their users.

CONCLUSIONS

The work combined the fields of data mining and analysis, quality and process monitorization techniques. The issue faced was that the needed data was not available for use in a meaningful, easy and fast way to give to the stakeholders the necessary insights about the quality of the production.

Several analyses were done in order to get more knowledge about the problem and the situation, and to analyse and define the information needed to help the decision-making process of different stakeholders. In this paper a case study was also reported where, through the application of the CRISP-DM method, it was possible to analyse a specific product and to develop quality dashboards containing the visualization of the relevant information.

During this work some insights regarding the dashboard development process arose. The experience highlighted the importance of, what may be considered the "backstage" of the dashboard, the preparation and study of the data, and how the mistakes at that level can later lead to other problems.

Another challenge was to manage the data and the analysis without being its direct user. Only after the Exploratory Data Analysis that the information that should be extracted from the data started to become more clearly understood.

As next step, it is crucial to present the dashboard to the stakeholders and start a pilot period and evaluation of its usage. After concluding this evaluation and implementing some adjustments, the dashboard should be deployed but it is important to keep evaluating and to consider upgrading, if necessary, the dashboard, by adding other features.

The main contributions of this work focus on leveraging from the recent IT developments to build systems that support the work of the quality team, with the implementation of a quality dashboard. The creation of dashboards with near-real-time data enables the stakeholders to use it in their decision-making process. Therefore, the results of this work allow stakeholders to make better and faster decisions and contribute to the development of a data-driven mindset in the company.

ACKNOWLEDGEMENTS

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Project Risk Management in an Automotive Company

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STRUCTURED ABSTRACT

Purpose - The main purpose of this research project was to analyse the project risk management practices in an automotive company, in order to recommend appropriate improvements.

Design/methodology/approach - The research methodology chosen to conduct the study was case study, since the research was carried out in a multinational company in the automotive industry, and data was collected through observation, document analysis and a questionnaire.

Findings – Although the company has defined how to approach project risk management, it was found out that the reality experienced does not reflect what is proposed by the major references. The proposal for an approach to risk management, process by process, was well received and appreciated by the project team.

Research limitations/implications - Due to the size of company, and also in some cases due to confidentiality reasons, it was not possible to obtain all the necessary data for a more accurate analysis. Additionally, due to the work routine, communication with colleagues was rarely immediate or fluid. It is also important to highlight the fact that project risk management is not an established practice within the organization.

Originality/value – Risk management practices as other project management practices are context dependent and should be adapted to the situation. Other companies working with a similar context can benefit from this study and adopt similar procedures to improve their risk management practices.

Keywords: Case Study, Project Management, Project Risk Management, Risk Management Processes.

Paper type: Research paper

INTRODUTION

Since we live in a competitive world and are forced to face the growing evolution of the market, organizations need to be increasingly flexible and have a strong capacity to adapt to change. The current organizational environment requires organizations to focus on a global perspective, ambitious awareness and innovation. To gain competitive advantage in this global economy, it is paramount to embrace different challenges with new approaches, combining the interaction between projects and focusing on long-term benefits (Blichfeldt & Eskerod, 2008). With a correct application of project management techniques, problems of effectiveness and efficiency will be solved, giving companies bases for delivering consistent commercial value and, therefore, establishing strategic competencies within the organization (PMI, 2017).

Project management is a progressively consistent reality in the organizational environment. Therefore, there is a growing need to manage projects in a well-organized and systematic way, so they contribute positively to companies. In this way, project management has achieved weight and relevance, becoming a strong organizational asset to complex management challenges (Zhai, Xin, & Cheng, 2009). Thus, with the progressive interest in project management, the focus has also expanded to multiple projects, programs, portfolios and other applications in organizational environments (PMI, 2017).

In summary, according to PMI's vision, project management can be defined as an organized and interrelated group of processes, with the purpose of achieving previously outlined objectives, through the combination of the use of tools and techniques to plan, perform, monitor and control work activities.

In order to remain competitive, due to the constant changes in technology and markets, companies need to use practices and tools to plan and control their projects. Since projects are becoming more complex and deal with a higher level of risk, it is essential to choose the best practices and tools to be applied in different types of projects in order to comply with their objectives and increase their probability of success (Ribeiro, 2018). In this sense, project risk management turns into an essential activity factor to contribute to project success. To be more effective, risk management must become part of the culture, within the organization. This should be incorporated into the organization's philosophy, practices and business processes, rather than being seen or practiced as a separate activity. When this is achieved, everyone in the organization is involved in project risk management (ANZS, 2004). A strategic approach to manage risks in projects also recognizes the need to introduce advanced risk management practices in all areas of the decision-making process (Wieczorek-Kosmala, 2014). Thus, in order for decision making to be as informed and effective as possible, it is essential that there is a very well organized and methodical approach in order to reduce the likelihood of project failure.

The course of the development and implementation of a project is followed by unique and temporary characteristics, being a complex process and always associated with some level of risk and uncertainty. In this sense, risk management has been developed as a fundamental part of project management. As it is one of the most pertinent areas of knowledge among good project management practices, there is a significant number of authors who have published standards and guidelines on how to manage the risk in a project (Fernandes, Ward, & Araújo, 2013).

To the concept of "risk" is often attributed as negative connotation, a view shared by older publications, which consider risk as the cause of failure, therefore, a barrier to success (Miles & Wilson, 1998; Padayachee, 2002). Although the inclination for this perspective to be more intuitive, there are other interpretations regarding this term. By consulting the Project Management Body of Knowledge (PMBOK) and the Management of Risk: Guidance for Practitioners (M_o_R), risk can not only affect negatively the purposes of a project, but also influence it positively (AXELOS Global Best Practice, 2014; PMI, 2017). Both ISO 31000: 2018 and NP ISO 31000: 2012 identify these two sides (negative and positive) of the risks. Other relevant references, such as the Individual Competence Baseline (ICB4) and the Managing Successful Projects with PRINCE2, practice the separation between “threat” and “opportunity”, where the first refers to the negative effects and the second to the positive effects of the occurrence of certain events that influence the project's objectives (IPMA, 2015; OGC, 2009).

Risks are inevitable when the topic is “projects”, since they are facilitators of changes and changes introduce uncertainty, hence many risks. The risk management practice must always be systematic and not punctual, throughout the project life cycle. The aim is to proactively identify, assess and control the risks that may affect the delivery of project results (OGC, 2009).

According to PRINCE2 and M_o_R, risk is an uncertain event that, when it occurs, contributes to the success or failure of a project, by influencing the achievement of its objectives. It consists of a combination of the probability that the negative or positive event will occur, and the magnitude of the impact on the objectives. Consequently, the term risk management refers to the systematic application of procedures to the tasks of identifying and assessing risks and then planning and implementing plans to respond to those risks, providing an appropriate environment for decision making (AXELOS Global Best Practice, 2014; OGC, 2009).

Project risk management includes the processes of plan risk management, identify risks, perform qualitative and quantitative risk analysis, plan and implement risk responses, and monitor risks. The objectives of project risk management are to increase the probability and/or impact of positive risks and, of course, to decrease the probability and/or impact of negative risks, in order to optimize the possibility of the project being successful (PMI, 2017).

Risk management aims to enable professionals not only to understand and efficiently deal with threats, but also opportunities. As it is a continuous process throughout the life cycle of a project, it must always go through the risk identification and characterization phase, as well as assessment, response planning and implementation, and control. A project manager is responsible for keeping the project team engaged in the risk management process, involving all stakeholders and encouraging them to remain alert to new threats and opportunities (IPMA, 2015).

RESEARCH METODOLOGHY

In order to answer the research question "How to improve project risk management practices in an automotive company?" all research work was conducted with a very close contact with the organization, since the main researcher was inserted in the company's environment.

The strategy underlying the research methodology in this project was case study and the techniques used to collect data were observation, document analysis and a questionnaire. The case study methodology allows an in-depth understanding of the current situation, giving the opportunity to propose new practices. According to Yin (2014), the chosen research methodology becomes relevant when the main objective is to explain some present circumstance, for example, in the case of clarifying “how” or “why” some contemporary social phenomenon occurs. It is a suitable methodology to use when dealing with an investigation of the situation in its real context, and it can even be used as a complement to other types of investigation. In addition, the case study reveals a very useful way to explore an existing theory, enabling the development of in-depth and detailed knowledge about the risk management practices in the company.

PROJECT RISK MANAGEMENT

Within the scope of this study, it is essential to understand how risks are managed in the organization’s projects and how the risk management process fits into the project management practices.

The present investigation was developed under the scope of two projects, the Ford C-HuD (Ford Combiner Head-up Display) and the BMW C-HuD (BMW Combiner Head-up Display). A head-up display is a vehicle’s extra feature located in front of the steering wheel in the driver's front field of view. Depending on the equipment, it is responsible for projecting important information to the user, such as traffic signs, current speed, navigation directions, speed limit warnings, and other notifications, so that the driver can keep his eyes on the road (BMW, 2020; Ford, 2020).

In order to characterize the reality experienced regarding to risk management within these two projects - Ford and BMW C-HuD -, a small questionnaire was carried out and distributed to the most relevant project team members. The main objective of this action was to understand the general perspective perceived by the teams concerning the risk management practices, addressing the underlying processes and other relevant issues, and assessing the current level of risk management maturity.

The observation and daily interpersonal contact, as well as the document analysis, which happened during the development of this study, made possible the awareness that not all risk management processes are carried out regularly. Thus, one of the main objectives of the questionnaire was to confirm or refute this understanding.

The data collected by the questionnaire confirms the deductions previously exposed. Figure 1 presents the risk management processes suggested by PMI (2017), with the respective percentage of team members who confirm their realization during the course of projects.

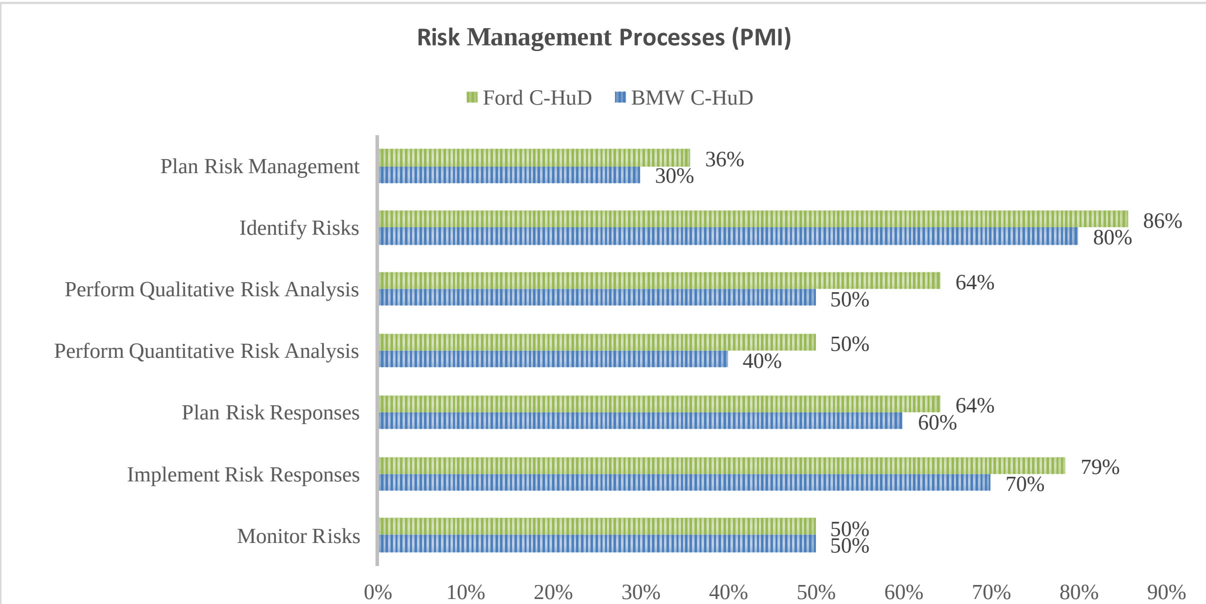

Figure 1 – Perception of execution of risk management processes in the projects

Once questioned about the risk management activities the team feels are being conducted in these two projects, the vast majority agree that risk management planning is not carried out efficiently. It appears that plan risk management is considered a secondary activity, making risk management a reactive process and not a continuous one. It becomes evident the need to develop a risk management plan duly substantiated and detailed so that, when included in the project management plan and, therefore, presented to the project team, its contribution is normalized and effective.

The identification of risks is conducted on a regular basis, however in a non-formal way. Most of the risks are identified verbally in regular project meetings and later described in presentation format for later discussion with the project team and the customers. Initially, a Risk Register was created and filled sporadically throughout the life cycle of the projects, however it was eventually abandoned. This is the risk management process most practiced in the project, according to the data collected, although not always carried out at the beginning of the projects.

Regarding qualitative risk analysis, in general, the definitions of risks associated with the probability of the risks occurring and the severity of their impacts are presented simultaneously with the risks identified.

The quantitative risk analysis process, as expected, is rarely carried out. This reality is understood if one considers the dimension of the organization, due to a difficulty in accessing certain information, such as costs and data related to the quantitative analysis of the identified risks impacting on the objectives of the projects. In addition, this process is also not always applicable to the types of risks identified.

In the planning of risk responses, it seems that the responses are defined in the moment, in most cases with little planning or consideration, due to the few amount of time available to plan and analyze in detail the responses to the risks identified.

At the same time, the implementation of responses also appears reactively, neglecting planning. However, it turns out to be one of the most performed processes.

Finally, risk monitoring is the risk management that must be seen as an activity transversal to the project, of continuous monitoring, and not momentary.

The project teams define the current risk management practices as something that needs improvement, as it shows in Figure 2 (Hillson, 1997; Hopkinson, 2017). It’s considered to influence decision making in the sense that promotes the project performance, however there is no structured, well-defined and generic approach, which does not allow to take advantage of all the benefits that an effectively implemented risk management approach has to offer.

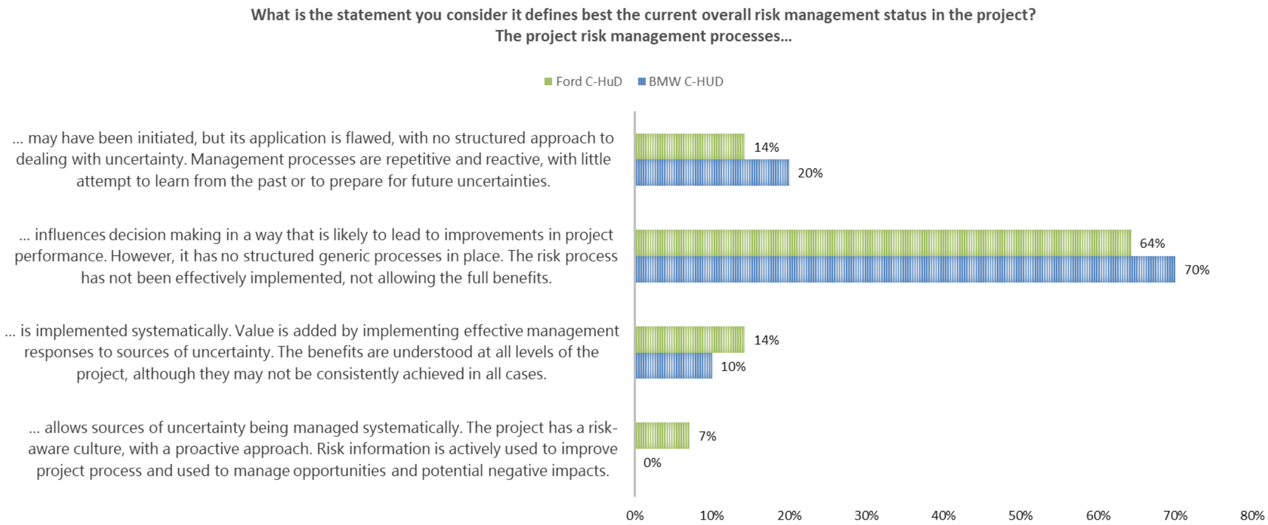

Figure 2 - Risk management characterization in Ford and BMW C-HuD projects

Adapted from Hillson and Hopkinson (Hillson, 1997; Hopkinson, 2017)

By the analysis of the questionnaire responses, there also seems to be a tendency to consider that certain risk management processes are performed when in reality that is not what it is observed directly in the investigation field. Although the organization has a recommended and accessible project risk management process, in the specific case of the projects under study, the process is not followed, at least in its entirety.

Therefore, there is a clear need to promote what the main references and standards outline and consider as good project risk management practices.

PROPOSED APPROACH TO PROJECT RISK MANAGEMENT PROCESS

The organization’s projects, as they present such a wide range of different people and backgrounds, face numerous adversities and uncertainties, that, if not managed efficiently, can lead to the downfall of the projects. Thus, there is a need for a well-defined risk management process, with notable maturity, so that the emerging risks do not affect the achievement of the project's objectives, which are often representative in terms of the organization's capital. With this in mind, the improvement of existing risk management practices becomes relevant, which involves the improvement of the underlying processes that favor the risk management practice.

The PMBOK Guide® is currently recognized as one of the best references regarding the knowledge underlying the project manager profession, which includes the traditional good practices and also some innovative ones in this area. There is consensus on its usefulness and value, since its application to real projects can increase the probability of success. Despite using a generic structure, this guide is also flexible to change the number of phases depending on the complexity of the project (PMI, 2017).

Thus, based on the recommendations of the PMBOK Guide®, a proposal for an approach to manage risk was defined for the Ford and BMW C-HuD projects, which can always be improved. The proposal comprises the seven processes suggested by the PMBOK Guide® and it will be presented next.

Plan risk management

Before risks are properly identified, it is necessary to plan how they will be managed. Here it is important to develop and implement, in a consistent way, a risk management model framed with national and international standards of the industry in which the project is inserted, and with the policies followed by the organization. This model should have as its main objective to ensure that threats and opportunities are managed in a systematic way throughout the life cycle of the project.

The risk management plan should contain the description on how risk management activities will be performed and structured, the specific tools and general approaches that will be used to managing risk on the projects and the roles and responsibilities that will support all the processes. In addition to all of this, it is also necessary to define when and how often the project risk management processes will be conducted throughout the project life cycle. The funds for activities related to project risk management must also be clearly defined, as well contingencies and management reserves (PMI, 2017).

This risk management plan must also be documented in the project files and accessible to all stakeholders. Once defined, it must also be summarized into a short version by the project manager, to be presented to the whole team, possibly in one of the regular meetings of the project. In this plan, as well as in the presentation, the objectives and benefits of the risk management approach must be clearly emphasized, in order to motivate the team.

Identify risks

The identification of threats and opportunities is an activity of great challenge because it is a significant part of a continuous process and for which it is essential to get people involved, given that the sources of risk are identified throughout the life cycle of the project. For this process, the use of a risk register is proposed (Figure 3), which must be intuitive and user friendly, and integrate the risks identified with all the remaining risk management processes, except the risk management planning.

The identification of risks should always be adapted to the activities and methodologies already followed in the scope of the two projects. As communication is mainly based on online platforms, it is recommended to collect current risks through meetings with the project team via video conference calls, since the team is not all in the same location. As a support, it can be used the master time schedule of each project - time plan with all project activities - as a guide for dialogue, in order to help provide a direction to follow while identifying risks. Weekly, during regular project team meetings, an internal assessment should always be conducted to see if new risks have emerged.

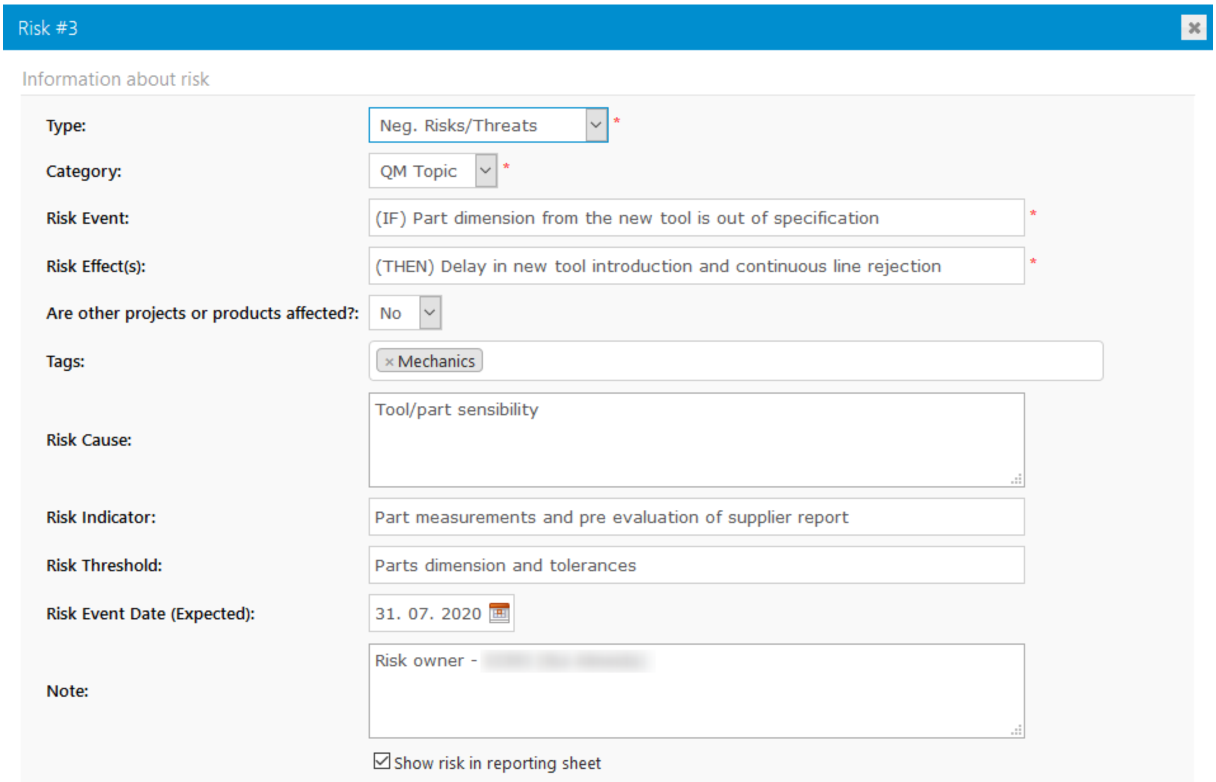

Figure 3 - SuperOPL Risk Management Tool: new risk example (Bosch, 2020h)

Qualitative risk analysis

Once threats and opportunities are identified, it is essential to assess their likelihood of occurrence and future consequences. The insertion of a new risk in the risk register allows the qualitative assessment of risks not only in the present, but also after the response action measures have been implemented (Figure 4).

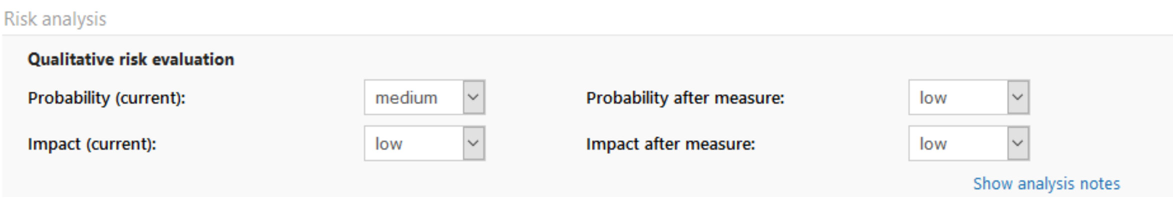

Figure 4 - SuperOPL Risk Management Tool: risk analysis example (Bosch, 2020h)

As a support, and in order to standardize the entire process, the same auxiliary assessment tables should be used, one for the probability of the risk occurring (Table 1), and two for the severity of its impact, separating between negative risk (Table 2) and positive risk (Table 3).

Table 1 – Risk probability assessment (AXELOS Global Best Practice, 2014)

Probability	Criteria	Likelihood
Very High	> 75%	Almost certainly will occur.
High	51 – 75%	More likely to occur than not.
Medium	26 – 50%	Fairly likely to occur.
Low	6 – 25%	Unlikely to occur.
Very Low	0 – 5%	Extremely unlikely or virtually impossible.

Table 2 – Negative risk impact assessment. Adapted from Bosch (2019d)

Severity of Impact	Deadline	Specification / Quality	Costs	Time
Very High	- Postponement of important delivery dates (e.g. testing, release samples). - Postponement of other milestones. - May cause SOP* to be postponed.	- Clear deviation from the specification, not acceptable for (RB**) customer. - Very Severe Flaw: flaw that may have a detrimental safety effect and/or violates statutory regulations.	500 K EUR increase in costs	6 months increase in time
High	- Postponement of important delivery dates (e.g. testing, release samples). - Negative effects on SOP* currently not expected.	- Clear deviation from the specification and not acceptable for (RB**) customer. - Severe Flaw: operational capability of the vehicle strongly reduced, immediate visit to car workshop mandatory.	250 K EUR – 500 K EUR increase in costs	3 – 6 months increase in time
Medium	- Postponement of few important delivery dates (e.g. samples) and/or milestones. - Acceptable for the customer.	- Clear deviation from the specification but most probably acceptable for (RB**) customer (under certain conditions). - Average Flaw Severity: minor annoying impact for the customer who will most likely experience a minor adverse effect only.	100 K EUR - 250 K EUR increase in costs	2 – 3 months increase in time
Low	RB**-internal postponement of date only.	- Slight deviation from the specification, hardly perceived by the (end) customer, acceptable for (RB**) customer. - The Flaw is of Minor Importance: minor annoying impact for the customer who will most likely experience a minor adverse effect only.	50 K EUR- 100 K EUR increase in costs	1 - 2 months increase in time
Very Low	RB**-small internal postponement of date only.	- Slight deviation from the specification, hardly perceived by the (end) customer, acceptable for (RB**) customer. - It is unlikely that the flaw could have any perceivable effect on the vehicle behavior.	< 50 K EUR increase in costs	< 1 month increase in time

*SOP = Start of production
**RB = Robert Bosch

Table 3 - Positive risk impact assessment. Adapted from Bosch (2017, 2019d)

Severity of Impact	Scope	Specification / Quality	Costs	Time
Very High	Scope extension desired by (RB**) customer.	- Clear deviation from the specification. - Quality increase desired by (RB**) customer.	500 K EUR decrease in costs	6 months decrease in time
High	Many scope areas affected.	- Clear deviation from the specification. - Only challenging applications are affected.	250 K EUR – 500 K EUR decrease in costs	3 – 6 months decrease in time
Medium	Few scope areas affected.	- Clear deviation from the specification. - Only a few applications are affected.	100 K EUR - 250 K EUR decrease in costs	2 – 3 months decrease in time
Low	No noticeable scope extension.	- Slight deviation from the specification. - Hardly perceived by the (end) customer. - No noticeable quality increase.	50 K EUR- 100 K EUR decrease in costs	1 - 2 months decrease in time
Very Low	Additional project scope is of no use.	- Slight deviation from the specification. - Hardly perceived by the (end) customer. - Additional quality increase is of no benefit.	< 50 K EUR decrease in costs	< 1 month decrease in time

**RB = Robert Bosch

After the risk probability and impact assessment, the probability-impact matrix is generated, as shown in Figure 5:

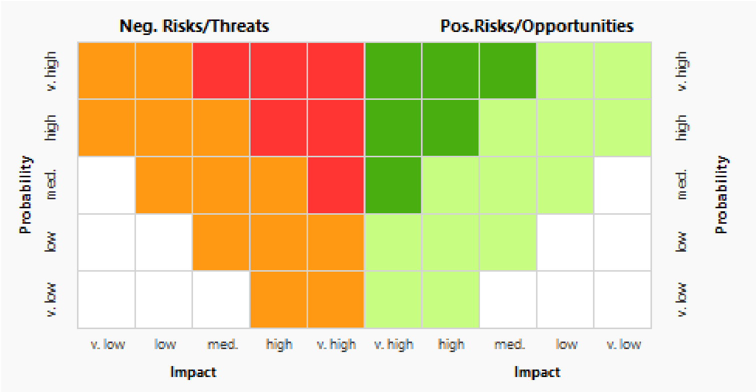

Figure 5 – Probability-impact matrix: example (Bosch, 2020h)

Quantitative risk analysis

Quantitative risk analysis is the process considered least doable since, in most cases, it is either not applicable to the type of risk identified or, due to the size of the company, requires information that is difficult to obtain. To support this process, if performed, it should be taken advantage of techniques such as data/document analysis.

Nevertheless, the insertion of a new risk in the risk register allows the evaluation of the Expected Monetary Value (EMV), if all fields are completed. Figure 6 shows a template example for quantitative assessment of risks in the risk register.

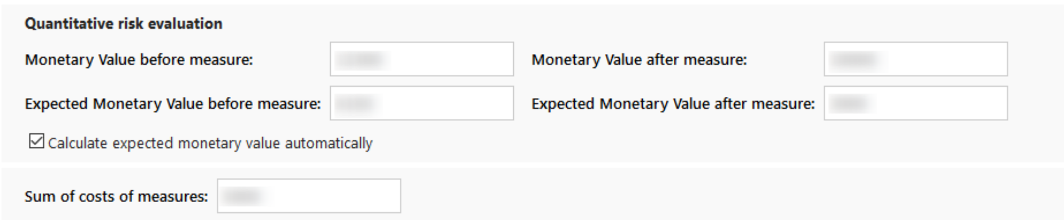

Figure 6 - SuperOPL Risk Management Tool: risk analysis example (Bosch, 2020h)

Plan risk responses

Once threats and opportunities have been assessed and conclusions withdrawn, it is important to consider the need for action to manage risks. It is up to the project manager to organize response planning meetings, and once these are implemented, the probability and impact assessments should be re-evaluated.

Risk responses must be designed to minimize threats and increase opportunities accordingly to project objectives. Strategies to respond to threats include avoid, mitigate, transfer and accept. In the case of opportunities, it is possible to exploit, enhance, share and accept. These responses are for moments before risks arise.

In addition, the project team can also rely on contingency response strategies, used only when certain events or conditions occur, that is, they are responses previously planned to the (negative) risks and implemented after these occur. In the case of opportunities, this type of response is called "augmentation", implemented after the opportunities materialize.

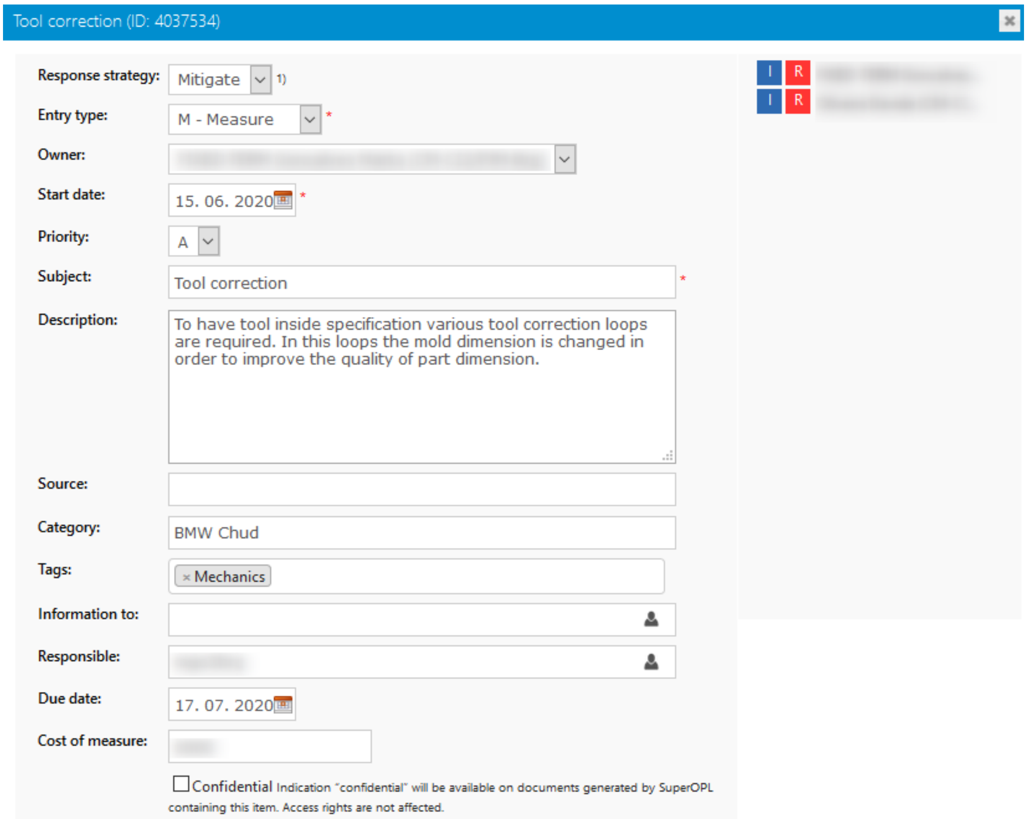

Figura 7 - SuperOPL Risk Management Tool: response measure example (Bosch, 2020h)

Implement risk responses

Once the various possible responses have been evaluated and the most appropriate ones have been selected, it is also necessary to implement them. As a support, regular meetings should be held to put into practice the response provided at the right moment and aligned with the project team.

Monitor risks

As previously mentioned, project risk management is not a one-time process, but an ongoing one throughout the project life cycle. Threats and opportunities should be monitored in parallel with the other risk processes, as responses chosen and implemented will need to be reassessed regularly.

At the first project meeting each month, the current status of all measures implemented for each respective identified risk should be updated. The status of the most critical risks and the updating of the risk list should also be a regular item on the agenda. New risks, if any, must be considered on the list of risks, assessed and resolved or mitigated by installing appropriate measures.

Summary

Table 4 summarizes and compares what was already being done/suggested and what the researcher proposes.

Table 4 – Project risk management summary table

Risk management processes (PMI)	What the company does or suggests	Reality experienced in the Ford and BMW C-HuD projects	What the researcher proposes
Plan risk management	Full definition of how and when risk management activities will be carried out on the project - should be documented in the project management plan. Participating team definition and methods to be used in the identification, assessment, reaction and control of risks.	Absent.	Plan carefully how the risk will be managed to ensure that threats and opportunities are systematically managed throughout the project life cycle. The objectives and benefits of the risk management approach must be clearly emphasized, in order to motivate the team. The risk management plan should also be documented in the project files, accessible to all stakeholders. A more short version should be created to be present in a project team meeting.
Identify risks	Collection of risks and documentation of their characteristics through a risk register (in SuperOPL or Bosch Risk Register).	Presentations (PowerPoint format) to present the risk list to the project team and customer. Bosch Risk Register initiated in the project beginning but then it was out of date.	Collection of risks in the risk list (in SuperOPL), using the master time schedule of all project activities as a support. Weekly assessment to check for new risks at project meetings.
Perform qualitative risk analysis	Determination of the priority of the identified risks (using the SuperOPL or Bosch Risk Register). Risk Indicator (RI) = Probability (P) x Impact (I). Scale for assessing the probability of the risk occurring. Assessment of the severity of the impact of the risk. Probability-impact matrix (Butterfly Diagram).	Presentations (PowerPoint format) to present the risks analysis to the project team and customer. Bosch Risk Register initiated in the project beginning, with risk analysis, but then it was out of date.	Risk analysis presented simultaneously with the identified risks (in SuperOPL). Table for assessing the probability of the risk occurring. Risk impact severity assessment tables. Probability-impact matrix.
Perform quantitative risk analysis	Costs can be determined for all identified risks or only for those that represent the greatest criticality. It serves as a basis for numerical assessing of risks (mostly impact costs) and their effects on the project objectives. Tools: EMV, tornado diagram (sensitivity analysis), and escalation scenarios in the case of interrelated risks.	Mostly non-existing.	If possible / applicable considering the most critical identified risks.
Plan risk responses	Measures should be evaluated in terms of cost-benefit of implementation and effectiveness. Planning considering response strategies for threats and opportunities.	Little planning and thoughtfulness.	Planning considering response strategies for threats and opportunities. If applicable, update the list of project open points (in SuperOPL) and the master time schedule of all project activities.

Implement risk responses	The previously agreed risk response plan must be properly implemented and executed. The main purpose of this process is to prevent no actions to be taken after opportunities and threats have been identified, evaluated and documented, and response measures have been defined.	Implementation of the responses appears in a reactive way, neglecting the planning.	Assess alternative means and methods for the implementation of the response plan. Regular internal meetings should be taken for alignment and introduction of the response plan.
Monitor risks	Risk monitoring and controlling should be seen as a continuous improvement process. The risks already identified, and the possible appearance of new ones should be reviewed regularly. There must also be close monitoring of previously agreed response plans implementation and an assessment of the effectiveness of this process.	Momentary, not taken as a continuous process.	Process that must be transversal to the project and continuous. At the 1st project meeting of each month, the status of registered risks and defined response measures should be analyzed.

CONCLUSIONS

During the course of the research project, the understandings and good practices associated with project risk management were studied, from a theoretical perspective, in order to apply to a case study and understand how risk management in certain projects could be improved. Based on the written literary review, as well as the direct observation of the case study, recommendations were suggested on how to conduct the processes underlying project risk management.

Risk management is an important concept recognized by the company's employees, however it seems not to be established in a consolidated and mature manner, perhaps due to a poor definition of priorities associated with the intense pace of work experienced, which often translates into a shortage of available time.

This research work provides the basis for a future implementation of the good practices recommended. Nevertheless, this restructuring represents different challenges, both in terms of processes and in the stakeholders' mindset. The developed project, because it addresses such a controversial and relevant topic in a project management context, also opens doors for several future investigations and opportunities for new studies, in order to complement the contributions achieved.

Thus, there is a clear need to raise project risk management to a higher level in terms of maturity. To this end, it is pertinent to make a contribution to existing knowledge in these matters, in order to document lived experiences and lessons learned, in order to be able to take advantage of the information shared.

PMI (2017), the organization used as the main reference for project management, presents risk management as a set of seven processes, namely: (1) plan risk management; (2) identify risks; (3) perform qualitative risk analysis; (4) perform quantitative risk analysis; (5) plan risk responses; (6) implement risk responses; and lastly, (7) monitor risks. The questionnaire carried out, as well as interpersonal contact, direct observation and document analysis to which the researcher was exposed, provided evidence that these processes are not always accomplished efficiently. This study made it possible to verify that risk management lacks maturity and a structured approach to deal with uncertainty.

It became pertinent to define the content of the next step: the definition of a proposal for an approach to risk management, process by process, which could be improved after evaluating the results of its possible implementation.

Bearing in mind the results of this research, there is a clear need for training sessions on how to manage risks within projects. This study can and should serve as a basis for implementing risk management at a global level in the company, in a standardized and uniform way, with the possibility of being customized to the project itself if appropriate. In addition, the project team's reactions and behaviors to the changes made must also be analyzed.

In the future, the company should define priorities clearly, always considering top management and the long-term vision for the company's objectives and mission. Promoting greater motivation and enthusiasm for risk management is crucial, and this mindset is only fixed in the heart of the company if it is encouraged by its leaders. Basically, all efforts should be encouraged to promote a risk management culture, making aware of all the advantages that come from this process, which will end up benefiting the organization and, therefore, the employees themselves.

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Continuous Improvement Programs and Industry 4.0: Descriptive Bibliometric Analysis

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ABSTRACT

Purpose - Continuous improvement and Industry 4.0 are not exclusive concepts. However, there is a lack of literature related to the links between improvement programs and digital technologies. This article aims to map both the field production and impact on the combination of continuous improvement programs and Industry 4.0 technologies.

Design/methodology/approach – The descriptive bibliometric analysis was the most suitable method to achieve the paper's aim. The sample was obtained from the Web of Science scientific index. The data processing procedure used the "Bibliometrix" package, running in the RStudio integrated development environment.

Findings – Despite there are no top productivity authors in the field, scientific production has increased in recent years. Most of the influential journals are from the "computer sciences", "industrial engineering", and "business, management, and accounting" domains. Continuous improvement programs most often associated with Industry 4.0 technologies are lean manufacturing, six sigma, and recently lean six sigma. The most current technologies, according to the authors' keywords, are Machine learning, the internet of things, and big data.

Research limitations/implications – The descriptive bibliometric analysis allows analyzing the articles' metadata that imposes a limitation. The content analysis is missing. The next step is to go deeply on bibliometric analysis applying multivariate methods and developing a content analysis.

Originality/value – There is a literature gap in studying the links of continuous improvement programs and industry 4.0 technologies.

Keywords: Continuous Improvement, Industry 4.0, Quality Management, Bibliometrics.

Paper type: Literature review

INTRODUCTION

Over the last decades, the continuous improvement philosophy evolved into several programs such as total quality management (TQM), total productive management (TPM), lean manufacturing, six sigma, and the hybridization lean six sigma. Nowadays, continuous improvement is a sustained improvement culture that aims at eliminating waste in all systems and processes of an organization (Bhuiyan and Bhagel, 2005).

Due to the competitiveness growth in the global industrial, the manufacturing digitization evolution has led to the concept of Industry 4.0 emergence, known as the fourth industrial revolution. The idea represents a new phase for the industry, offering significant technological advances that allow real-time connectivity among all participants in the value chain, making them more productive and agile (Schumacher et al., 2016). The connection between new technologies for collecting, transmitting, managing, and analyzing data in real-time provides decentralization of production processes and decision-making. This connectivity changes the existing manufacturing systems to open, digital, automated, intelligent manufacturing platforms (Kamble et al., 2019). Therefore, the primary aim of intelligent production systems is machine synchronization and self-optimization in the production line of the entire process.

Continuous improvement programs and Industry 4.0 are not unique concepts (Kolberg and Zuhlke, 2015). Continuous improvement programs use manufacturing process information to achieve their goals (Devlin et al., 2012). For the program development to be efficient, the information must be available in the entire company and the supply chain. New data management technologies have the potential to help programs. Intelligent production systems can autonomously diagnose the performance and propose continuous improvement projects to success (Alavian et al., 2020). As an example, lean automation arises from a combination of lean manufacturing practices and Industry 4.0 technologies (Kolberg and Zuhlke, 2015). Although not characterized as a new continuous improvement program, decentralized structures support lean automation that targets small modules with a low level of complexity.

The role played by the Industry 4.0 technologies in continuous improvement programs is still little explored in the literature, and the resulting impact is unclear. Thus, the potential of Industry 4.0 technologies on boosting improvement programs is a relevant research field to be further explored (Arcidiacono and Pieroni, 2018). The following research question guides the investigation on how the literature has been addressing this link: What is the current description of the domain on continuous improvement programs and Industry 4.0 technologies?

Therefore, this article aims to map the field production and impact using descriptive bibliometric analysis. The article is structured as follows: the next section summarizes the theoretical background on continuous improvement and industry 4.0. The research design and data analysis are then presented. The results are presented and followed by a conclusion section.

THEORETICAL BACKGROUND

Continuous Improvement

Over the last few decades, several continuous improvement programs have been developing to reduce waste, simplify the production line, and achieve incremental improvement: TQM; TPM; lean manufacturing, six sigma, and the six sigma lean hybrid method. All these programs originate in the manufacturing sector and lead to superior quality by continuous minor changes that provide a disciplined structure for carrying out the improvement activities (Chesanow, 1997).

The ideas of W. Edwards Deming, Joseph Juran, Phillip Crosby, and Kaoru Ishikawa are the foundations of the TQM movement, whose roots in four interconnected assumptions: quality, people, organizations, and leadership. As predicted by Hackman and Wageman (1995), the TQM is one of several programs in the tradition of work enrichment and goal management that gave way to other current management models. Continuous improvement is an essential element of the TQM movement and it is a critical criterion in all management systems, certificates, and related awards (Sanchez-Ruiz et al., 2019).

In 1971, a Toyota Motor Company supplier, Nippon Denso Co. Ltd., introduced the Total Productive Maintenance. The approach is based on the concepts and methods of productive maintenance. It brought innovation to maintenance management, optimizing equipment effectiveness, eliminating breakdowns, and promoting autonomous maintenance by operators through daily activities (Ahuja and Khamba, 2008).

Another approach is lean manufacturing that has become widely disseminated and focuses on eliminating waste, reducing, or minimizing the variability of suppliers, customers, product design, and internal processes to achieve organizational efficiency (Bhuiyan and Bhagel, 2005; Shah and Ward, 2007). The roots of lean manufacturing are closely related to the Toyota Production System (TPS), created by Taiichi Ohno during the 1940s in Japan. The TPS aim is to reduce the total cycle time and process lead time, using different tools and techniques such as 5S, value stream mapping, and cause-and-effect analysis (Jevanesan et al., 2019; Satolo et al., 2020).

Six sigma is a data-driven approach closely related to quality movement and aims to stabilize and improve the process and sustain long-term improvements (Antony et al. 2018; Jevanesan et al., 2019). In 1986, the improvement program gained popularity in the USA, measuring process quality using statistical processes to control (Bhuiyan and Bhagel, 2005). The program has helped many companies to improve their results by designing and monitoring daily business activities to minimize waste and resources and increase customer satisfaction (Harry and Schroeder, 2000).

As an integrated method, lean six sigma includes the speed of lean and the robustness of six sigma through a disciplined and systematic approach to problem-solving (Antony et al., 2018). The complementary relationship between lean manufacturing and six sigma is widely accepted today, and more companies are establishing hybrid programs, especially as lean six sigma showed proven capability at leading companies such as GE and Toyota (Salah et al., 2010).

Industry 4.0

Industries are increasingly adhering to technological advances in cybernetics, integration of computing resources, IT infrastructures, and new data acquisition and management technologies (Reis and Kenett, 2018). These new process monitoring and control technologies allow meeting current consumers' requirements (Yao and Ge, 2018). This achievement is likely because of the combination of resources, machinery, and information, creating an intelligent manufacturing system named Industry 4.0. (Ji et al., 2016). The German federal government released the term in 2011 in a presentation at the Hannover Messe. It is a comprehensive concept that refers to the digital manufacturing system resulted from the successful integration of production processes, information technologies, and specific techniques (Kamble et al., 2019). However, there are several names for the same concept in different countries as the United States, Canada, France, and others (Liao et al., 2018). For Davis et al. (2012), Industry 4.0 is also a platform designed for technological integration. From a macroscopic view of the company and the supply chain, it creates a new paradigm in process improvement, providing higher returns on future investments.

The network communication and fast connectivity are the foundations of Industry 4.0 technologies, which allow the usage of a large and diverse amount of data (big data) to support the management in an innovative approach (Kagermann et al., 2013). Although unlimited computing power is available at a little cost through cloud computing (Iansiti and Lakhani, 2014), in that environment, information quality is of central importance (Reis and Kenett, 2018). The communicative integration of the productive system elements is possible using the wireless internet (called the internet of things or IoT) synchronized with data processing (Kagermann et al., 2013). Historically, the internet of things refers primarily to objects labeled with RFID that used wireless internet to communicate (Gao and

Bai, 2014). Today, IoT is a widely disseminated technology platform on the rise suitable to increase productivity, efficiency, and profitability simultaneously with predictive analytics and data analytics (Kamble et al., 2019).

Industry 4.0 technologies have the potential to help in achieving specific performance improvements as cost reduction, better product quality, more excellent responsiveness, superior flexibility, and collaboration with environmental sustainability and employee safety (Chiarini et al., 2020). Research on Industry 4.0 technologies is growing, driven by steady innovations in manufacturing systems (Kipper et al., 2019).

RESEARCH DESIGN

The most appropriate research method to explore a field regarding scientific production and impact is the bibliometric analysis. The focus is to identify the principal authors, journals, and publications, authors' affiliation, and authors' keywords. The bibliometric analysis follows the steps: (1) definition of the study: definition of the aim, choice of the database and definition of the filters applied to delimit the sample; (2) data collection and treatment: selection, capture and treatment of data after applying the filters defined in the previous step; (3) data analysis: use of software for bibliometric and statistical analysis; and (4) interpretation: interpretation and dissemination of results (Zupic and Cater, 2015).

The reference linkage by DOI made the Web of Science scientific index preferable because it facilitates the data processing procedure. The following search string was applied to the title, abstract, and keywords fields:

(TS=(("industr* 4.0" OR "digital ubiqui*" OR "smart manufactur*" OR "big data" OR "machine lear*" OR "augmented real*" OR "internet of*" OR "cyber phys*" OR "cloud comp*" OR "virtual fact*" OR "digital tw*" OR "3D prin*" OR "additive man*" OR "blockchain*" OR "human machine inter*" OR "radio freq*" OR "machine to machine") AND ("kaizen" OR "contin* improv*" OR "contin* quality improv*" OR "total prod* maint*" OR "TPM" OR "total quality manag*" OR "TQM" OR "lean manuf*" OR "lean aut*" OR "lean prod*" OR "lean manag*" OR "six sigma" OR "lean six sigma" OR "DMAIC")) AND LANGUAGE: (English) AND DOCUMENT TYPE: (Article OR Early Access OR Review).

The search string was formulated iteratively based on terms related to all Industry 4.0 technologies and the continuous improvement programs addressed in the previous section. The sample registers were processed using the "Bibliometrix" package, version 3.0.0 (Aria and Cuccurullo, 2017), running in the RStudio integrated development environment, version 1.2.5042, and graphs created using both Excel spreadsheets and the R package "ggplot2", version 3.2.0 (Wickham, 2016).

RESULTS

Data collection happened on 30/07/2020. The sample size is 382 documents (350 articles and 32 reviews, according to WoS), published in 261 journals. Figure 1 illustrates the scientific production and impact (citations) in the field from 1993 to 2020. The annual scientific production has been rapidly increasing since 2015. Higher production occurs in 2019 (87), and 2020 and Early Access (90). The scientific production curve shape shows that the field has been gaining relevance since 2015. Regarding the impact (orange line), several peaks of impact occurred, namely in 2000 (0.8), 2004 (6.69), 2014 (7.33), and 2015 (8.5). Naturally, the curve has declined in recent years.

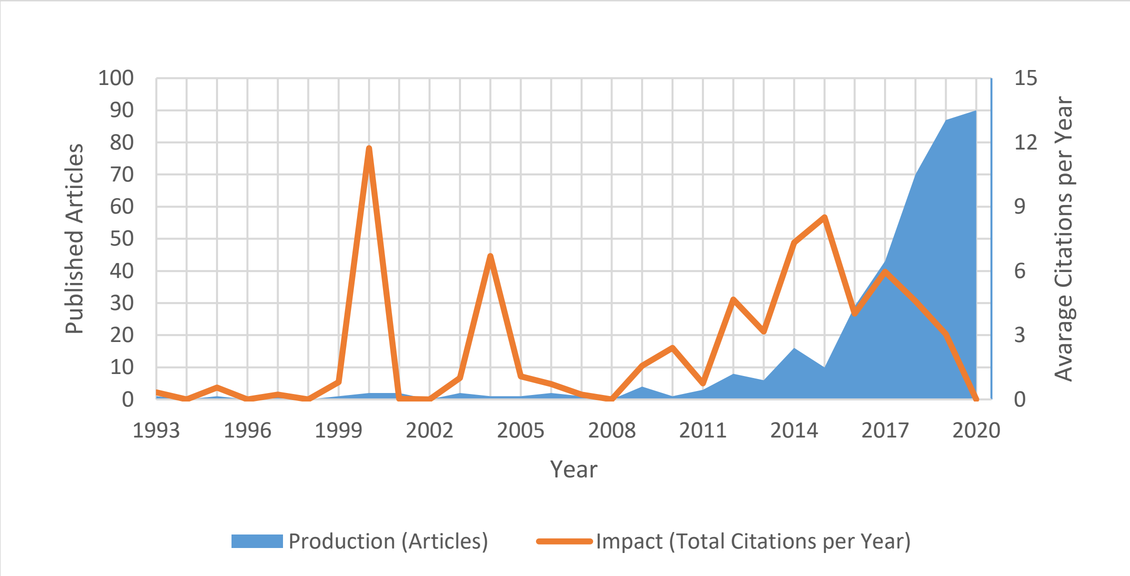

Figure 1 – Annual scientific production and impact on average citations per year.

Table 1 illustrates the most productive authors in the domain regarding scientific production and papers' global impact (total citations). Most of the sample authors have published a maximum of three articles. Most of the productive authors published two years ago. Joseph C. Chen, who focuses on lean manufacturing and RFID, is an exception. Angappa Gunasekaran emphasizes the lean six sigma and big data integration. Martin Molina combines lean manufacturing with deep learning techniques, and Guilherme Luz Tortorella, the most productive authors, approaches lean manufacturing in the broader context of Industry 4.0.

Table 1 – Most relevant authors' scientific production and impact.

Author	First Publication Year	Production	Total Citations
Joseph C. Chen	2011	4	75
Angappa Gunasekaran	2018	4	52
Martin Molina	2018	4	4
Guilherme L. Tortorella	2018	6	99

Table 2 presents the most locally cited documents, i.e., those citations received from the sample documents. Sanders et al. (2016), the most locally and globally cited article, analyze the incompletely perceived link between Industry 4.0 and lean manufacturing, focusing on how to overcome barriers of lean implementation through Industry 4.0 technologies. Kolberg et al. (2017) present the ongoing work towards an interface for digitizing lean production methods using cyber-physical systems. A demonstrator realizing the Kanban method was used to prove the interface feasibility. Tortorella and Fettermann (2017) investigate the relationship between lean production practices and Industry 4.0 technologies in Brazilian manufacturing companies. The findings suggest a positive association between lean practices and Industry 4.0 technologies and show the concurrent implementation leads to excellent performance improvements. Buer et al. (2018) identify the significant research streams concerning the link between Industry 4.0 and lean manufacturing and propose a research agenda for future studies.

Among the nine articles with the highest total number of local citations, eight are from the 2016-2019 period. The evidence reinforces the previous results (Figure 1) regarding field emergence. Although those papers were published recently, their impact is remarkable. Moreover, only G. L. Tortorella and J. C. Chen, top impact authors (Table 1), are among the authors of most relevant articles.

Table 2 – Most cited articles (within the sample).

Reference	Year	Local Citations	Global Citations	% Local/Total
SANDERS A, 2016, J IND ENG MANAG	2016	23	110	21%
KOLBERG D, 2017, INT J PROD RES	2017	21	52	40%
TORTORELLA GL, 2018, INT J PROD RES	2018	21	76	28%
BUER SV, 2018, INT J PROD RES	2018	21	62	34%
YIN Y, 2018, INT J PROD RES	2018	9	70	13%
MA J, 2017, SENSORS-BASEL	2017	6	10	60%
SONY M, 2018, PROD MANUF RES	2018	6	23	26%
CHEN JC, 2014, INT J ADV MANUF TECH	2014	5	10	50%
ROSSINI M, 2019, INT J ADV MANUF TECH	2019	5	11	45%

Table 3 offers the sample leading journals based on the number of articles, the total number of citations, and the h index of published articles. Most outlets have published articles in this decade, except for the Expert System with Applications. The International Journal of Production Research dominance is outstanding (24 articles) regarding both published articles and impact (citation and h index).

Table 3 – Top field journals.

Source	Articles	First Publication Year	Total Citations	h index
INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	24	2000	494	125
SENSORS	9	2010	16	153
IEEE ACCESS	8	2018	7	86
SUSTAINABILITY	7	2017	20	68
INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY	6	2014	84	112
JOURNAL OF CLEANER PRODUCTION	6	2018	62	173
RAPID PROTOTYPING JOURNAL	6	2014	37	78
TOTAL QUALITY MANAGEMENT & BUSINESS EXCELLENCE	6	2019	19	76
EXPERT SYSTEMS WITH APPLICATIONS	5	1993	130	184
JOURNAL OF MANUFACTURING TECHNOLOGY MANAGEMENT	5	2018	44	65

Figure 2 complements the previous table, offering a dynamic perspective of outlets. The abbreviations in square brackets identify the journal's scope: General Engineering [E]; biological sciences [BS]; mechanical engineering [ME]; computer sciences [CS]; industrial engineering [IE]; electrical engineering [EE]; business, management and accounting [BMA]; social sciences [SS]; and environmental sciences [ES].

The result shows that, although the concept of Industry 4.0 is new, several articles have been associating digital technologies with continuous improvement programs since 1993. Chaturvedi (1993) proposes the use of machine learning to address the problem of the flexible manufacturing system. The advantage of the proposed system is that it provides a manufacturing manager with a flexible and goal-seeking control mechanism that allows for continuous improvement in decision outcomes.

The Expert Syst. Appl. and Int. J. Prod. Res. are pioneers in the field. Figure 2 reinforces the Int. J. Prod. Res. dominance in recent years. The Int. J. Adv. Manuf. Technol. has been publishing steadily since 2014, followed by many others. The outlets with a focus on environmental science and computer science have gained notoriety since 2017.

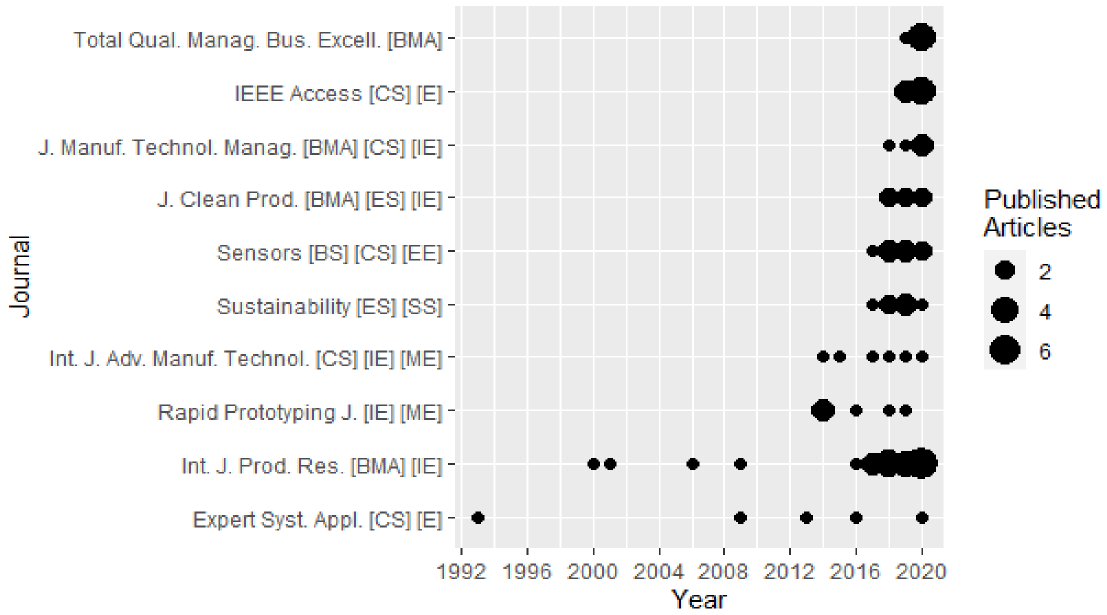

Figure 2 – Journals dynamics.

The authors' keywords are central articles' metadata to unveil the issues which authors approach in the domain. Hence, the author's keywords were divided into two classes: continuous improvement keywords and Industry 4.0 keywords. Figure 3 presents the most frequent continuous improvement keywords. Lean manufacturing dominance is evident, including related concepts as lean production, lean management, and lean automation. Lean is followed by terms related to six sigma like "DMAIC" and "design for six sigma". TQM and TPM are much less frequent. "Lean six sigma" is the most recent keyword to gain notoriety.

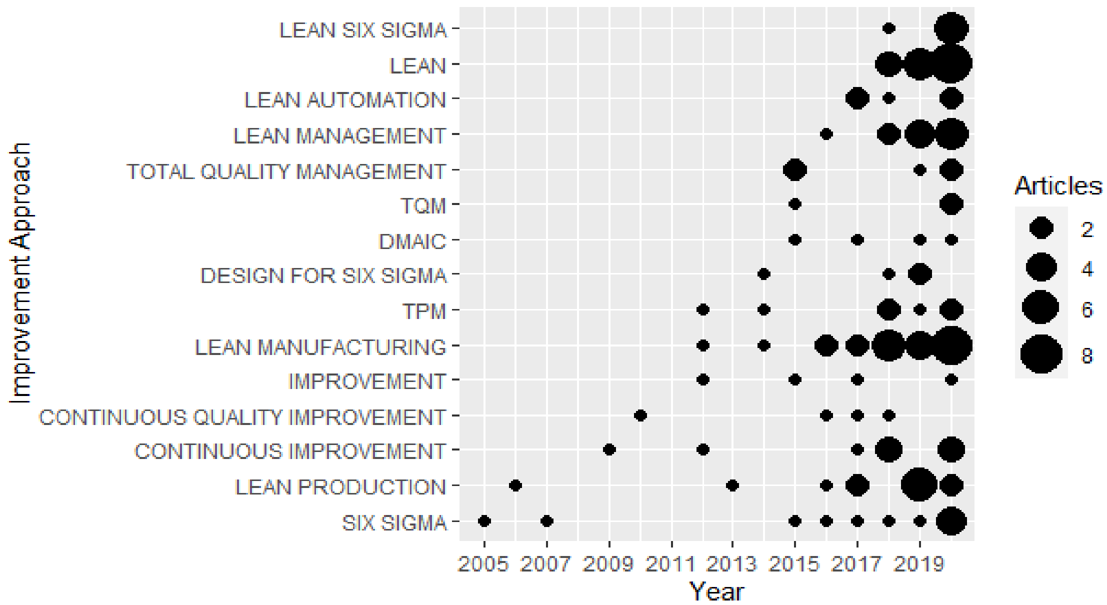

Figure 3 – Keywords dynamics (continuous improvement).

Figure 4 poses the most common Industry 4.0 keywords. Machine Learning, RFID, and Virtual Reality are the oldest technologies to be addressed. Machine Learning has gained renewed importance in the last few years, likely because of computer processing power improvement. Industry 4.0 technologies also have been cited continuously since 2014, alongside cloud computing, big data, and the internet of things. The internet of things, big data, and machine learning are the most common keywords associated with Industry 4.0 in the sample.

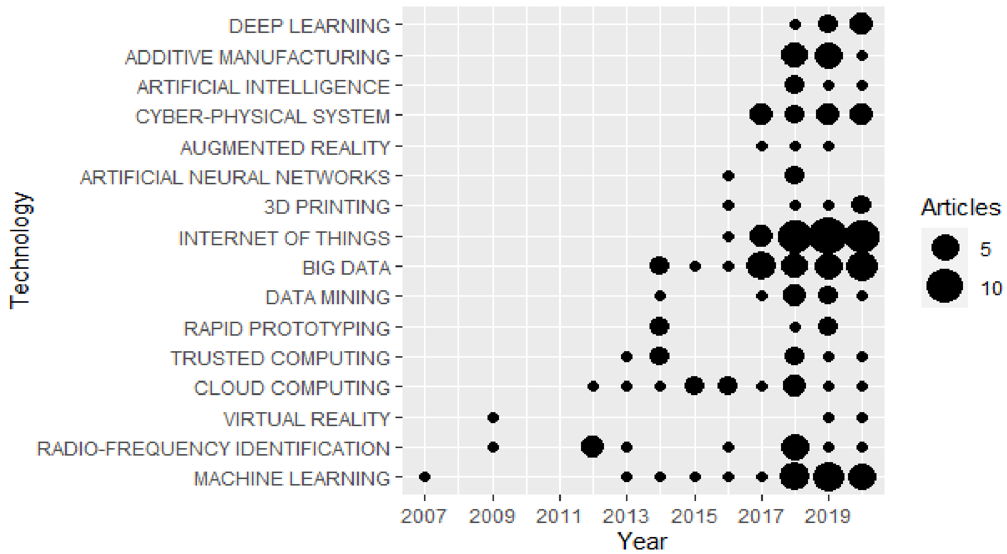

Figure 4 – Keywords dynamics (Industry 4.0 technologies).

Figure 5 presents the geographical distribution of scientific production based on authors' nationality (full counting). The most productive countries are the USA (290) and China (157). UK (81), Germany (79), Italy (69), and India (53) also show a high number of publications and collaboration in the sample. The USA also has the highest impact on total citations (1661), followed by China (909).

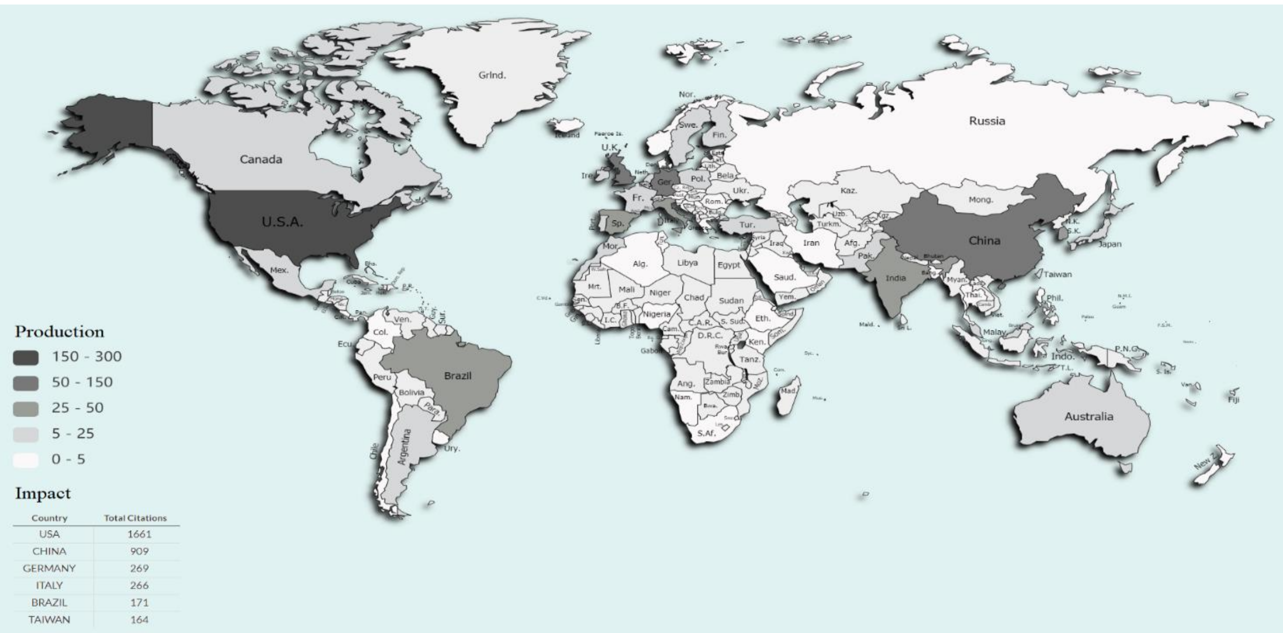

Figure 5 – Country scientific production.

Finally, Table 4 shows the most productive universities, considering the authors' affiliations (full counting). Universidade Federal de Santa Catarina (11 articles, Brazil) is the most productive affiliation, followed by Purdue University (10 articles, USA) and Universidad Politécnica de Madrid (9 articles). Further, four US universities – Purdue University, Carnegie Mellon University, University of Connecticut, and the University of Michigan - concentrate the scientific production.

Table 4 – Most productive universities.

Affiliation	Production	Country
Univ. Fed. Santa Catarina	11	Brazil
Purdue Univ.	10	USA
Univ. Politecn. Madrid	9	Spain
Carnegie Mellon Univ.	7	USA
Jinan Univ.	7	China
Univ. Oxford	7	UK
Univ. Connecticut	6	USA
Univ. Hong Kong	6	Hong Kong
Univ. Michigan	6	USA

CONCLUSIONS

This paper unfolds details on the links between continuous improvement programs and Industry 4.0 technologies applying bibliometric analysis methods. The field's scientific production has been rapidly increasing since 2015. The scientific production curve shape shows that the theme has been gaining relevance (Figure 1). There are still very few authors of higher productivity in the field (Table 1). The most relevant authors combine lean manufacturing to RFID and IoT and six sigma to big data analytics. A significant impact within the sample comes from a distinct set of authors whose papers range from 2016 to 2019 (Figure 1, Table 2). Most of the influential journals publish papers on computer sciences, industrial engineering, environmental sciences, and business, management, and accounting (Table 3). The USA and China are the most productive and caused more impact (Figure 5 and Table 4).

The link between Industry 4.0 technologies with both lean manufacturing and six sigma is remarkable. (Figure 3). More recently, another link raised between Industry 4.0 technologies and lean six sigma. Regarding the technologies, IoT, big data, and machine learning show a higher frequency of occurrence (Figure 4).

The next step is to go deeply on bibliometric analysis applying multivariate methods and developing a content analysis. That will provide better insights for understanding the interplay between different continuous improvement programs and the Industry 4.0 technologies.

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Technology and Quality Management: a review of concepts and opportunities in the Digital Transformation

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ABSTRACT

Purpose - The Digital Transformation brings change to organizations, their processes, and their production systems. Nevertheless, most efforts observed in its context tend to be technology-driven, and it is often argued that Quality Management is inadequately integrated into the discussion.

Design/methodology/approach – Surveying the literature, this work reviews, list, and organizes the different technological concepts and integration opportunities that have been explored in the scope of Quality Management in the Digital Transformation.

Findings – Findings include the expanded capacity of quality tools and methods for managerial purposes; the reinforced importance of Data Quality; the increased automation and augment resources for Quality control; and the increased process optimization and integration of systems and between organizational areas.

Originality/value - It is demonstrated that although scattered in the literature, there are already a number of works exploring the impacts of technology in the management of Quality in the scope of the Digital Transformation. Three main areas for integration arise: (a) Digital Quality Management (application of industry 4.0 technologies to Quality Management itself, its tools, methods, and systems), (b) the management of the Quality of digital products and services, and (c) the management of the Quality of digital product development and production processes.

Keywords: Quality Management, Digital Transformation, Industry 4.0

Paper type: Literature review

INTRODUCTION

Industry 4.0 and the Digital Transformation have been studied predominantly from a technological point of view (Liao et al., 2017; Schroeder, et al. 2019; Vial, 2019). As a result, advancements are mostly observed from a technological point of view (Kan, 2002; Firesmith, 2005). Nevertheless, technology is often argued not be the most important driver of the Digital Transformation (Kane et al., 2015), being only part of the complex puzzle that must be solved for organizations to remain competitive in a digital world (Vial, 2019).

It is in the perspective that we argue for the importance of discussing the implications for Quality brought by Digital technologies. It has been claimed that, in the scope of the Digital Transformation, there has been limited innovation in the field of Quality (Lee, Kao, and Yang, 2014; Shubin and Zhi, 2018). The truth, however, is that there has been an active discussion in this scientific and professional field – one that has often revolved around the branding of "Quality 4.0" (Schönreiter, 2016; Jacob, 2017; Krubasik, et al., 2019). It has taken two forms: one, led by Quality experts, has been focused on how to advance the field in the face of the new technological and organizational opportunities brought by the Digital Transformation. The other, led mainly by technologists, has been driven by effort to guarantee technical performance of new technologies and systems. These different approaches have a deep impact on the general perceptions of Quality Management moving forward. In this sense, it is important to gain an overview of each one, and understand how to better integrate them.

The approach promoted by Quality experts and researchers has focused on concepts, strategies, methods, and tools of Quality in this transition. Examples include the issue of Quality Assurance in manufacturing processes (Illés, Tamás, Dobos, and Skapinyecz, 2017) or the revision of performance improvement initiatives under the concept of Organizational Excellence (Carvalho, Sampaio, Rebentisch and Saraiva, 2019). Some authors have looked at the opportunities and challenges for Quality in different organizational areas, including strategic alignment (McAdam, Miller, and McSorley, 2019), supply chain integration (Zhang, Guo, Huo, Zhao, and Huang, 2019) or the combined monitoring process and product information (Xiao, Jiang, and Luo, 2019). Others have focused on the fit between existing Quality tools and methods and the new industrial paradigm (Bossert, 2018; Vandenbrande, 2019).

In parallel, several works have been presented from a more technology-oriented point of view. Works sharing this perspective highlight the potential that the use of new industrial technologies has for the improvement of quality and performance in an organization (Stojanovic, Dinic, Stojanovic, and Stojadinovic, 2016; Oliff and Liu, 2017; Radziwill, 2018).

These two perspectives have been poorly integrated, impairing the understanding of the role and impact that the technological development has for Quality Management in the Digital Transformation. It has been argued that it is hard to find studies on the role of related technologies and their impact on Quality Management (Gunasekaran, Subramanian, and Ngai, 2019). Furthermore, the literature shows that most organizations do not yet have a specified a Quality-based strategies or models to address this transition (Bauer, Bas, Durakbasa, Kräuter, and Ugur–Tuncer, 2019; Völker, Friesenhahn, and Seefeld, 2019).

Consequently, a generalist approach is increasingly observed in Quality issues in the Digital Transformation, and topics that have been discussed in Quality-specific forums do not transition to practical deployment (Bossert, 2018). Likewise, efforts and budgets to fund Quality Management Systems are being diverged for new production technologies (Johnson, 2019). While critiques to generalist perspectives on Quality Management are not new in the field, this increased focus on technology brings the problem back into the spotlight. In a transition that is mostly technology-driven, the lack of such perspective means that technologists rather than quality-experts are making the decisions on Quality Management.

It must be admitted that this technology-driven advancement of Quality does have its benefits, and that it creates expectations also within the Quality community. Závadská and Závadský (2018) surveyed Industry 4.0 expectations next to Quality managers, and identified prospects of significant growth in the use of technology to improve Quality control and management. Furthermore, these technologies have been proved to help improve the performance of an organization (Stojanovic, Dinic, Stojanovic, and Stojadinovic, 2016; Oliff and Liu, 2017), and can themselves be branded as “Quality 4.0 Tools” (Radziwill, 2018). However, they are not guided by a Quality-driven perspective, and offer limited creativity in terms of Quality itself (Lee, Kao, and Yang, 2014; Shubin and Zhi, 2018).

This becomes critical also as we look at the today’s increasingly digital and data-driven products. Products are moving from a single ‘physical’ reality to one that includes also a ‘digital’ dimension, where the online and offline states are interrelated, interdependent, and complementary (De Beer, 2016). In the face of such reality, manufacturing processes are increasingly becoming more digitalized (Parkhurst, Morris, Tahy, & Mossberger, 2015). As a result, and it is important to understand what quality issues might affect the growing range of digital products and their (also increasingly digital) production processes.

RESEARCH OBJECTIVES AND METHODOLOGY

Research on the impact of Digital Transformation technologies on Quality is still somewhat limited and, above all, poorly connected. In order to counter this reality, this paper reviews, lists, and integrates different concepts and examples existing in the literature. It is made with a double aim of (1) understanding the contributions of new technologies to Quality Management, and (2) understanding how to manage the Quality of products and processes deeply changed by Digital Transformation technologies. The outcome of this review is not meant to be an in-depth exploration of the individual relations between different technologies and their impact on Quality, or vice-versa. Instead, its goal is to identify some of the different technologies that offer a potential for integration with Quality, based on already demonstrated and published applications.

In order to conclude this review, works from both academic and professional authors were considered. The initial screening for sources targeted scientific works with high impact and citation rates, using databases such as Scopus and Web of Science. While these guaranteed sources of quality and relevance to the field, they also left outside the scope of this research a series of works – which, either for their origin, means of publication, or newness were not featured in these databases, but could provide different perspectives and valuable inputs to the review of the literature. Accordingly, in a second phase particular efforts were made to include recent works with new research trends and yet limited impact, and non-scholar perspectives. One of the databases/search engines added – the one with the most impact in the search for literature – was Google Scholar.

Ultimately, sources of this review included books, journal articles and proceedings within the research fields of quality engineering and management, operations management, industrial engineering and engineering management, computer science, information sciences, and organizational sciences (business and management). The selection was made with basis on the critical analysis of their quality and fit against the identified gaps, or promotion of relevant perspectives.

LITERATURE REVIEW

Literature on the Digital Transformation often shows a generalist approach to Quality Management, with limited integration and innovation in the field (Lee, Kao, and Yang, 2014; Shubin and Zhi, 2018; Bossert, 2018). In this review, we tried to cover the existing works that may help counter this view. In order to do so, this work lists not only the reported benefits of the relationship between technology and Quality Management, but offers also an integrated perspective on how this relationship can be further explored to improve the performance of organizations. It aims to emphasize the practical applicability of new technologies in pursuit of better Quality.

Analyzing the literature, it was found that three main areas arise. They are (a) Digital Quality Management (i.e. application of industry 4.0 to Quality Management itself, its tools, methods, and systems, as well as the impact on people), (b) the management of the Quality of digital products and services, and (c) the management of the Quality of digital product development and production processes. These were used to structure the literature review.

Digital Quality Management

Digital Quality Management is understood here as the application of digital technologies to Quality Management, with impact in its tools, methods, and systems – both at a technical and human levels. Related works are centered in circumstances that these Quality Management face in an increasingly connected and data-driven industrial setting. With increasingly integrated and connected systems, the assessment and control of isolated processes becomes outmoded. Vandenbrande (2019) argues on the need for a new perspective for Statistical Process Control (SPC)**,** arguing that technology itself is replacing process control. In this sense, the author suggests that SPC can have renewed impact if used as a managerial tool, shifting its attention from the control of isolated processes to a perspective of system and organizational management. A similar perspective is found in regards to Six Sigma methodologies. Bossert (2018) argues that the use of six sigma methods has to be directed to the creation of data strategies for our organizations with respect to Quality, process improvement and analysis. However, there is yet a poor integration of Six Sigma with **Big Data**, and to improve this reality, it is imperative that fundamental gaps are understood and addressed (Antony, Sony, Dempsey, Brennan, Farrington, and Cudney, 2019). Six Sigma must support the use of Big Data, connect with new technologies, and be expanded with the use of predictive analytics and multivariate analysis (Bossert, 2018). On example of such integration is provided by Graafmans, Türetken, Poppelaars, and Fahland (2020). The authors explore the usage of **Process Mining** techniques in Six Sigma-based process improvement initiatives, showing the benefits that using process mining offers for collecting data on their business processes through their event logs. As a result, a standard operating procedure is proposed to increase the efficiency and effectiveness of process improving efforts in their organizations. Process Mining allows the collection of data from different processes, based on their event logs (van der Aalst, Weijters, and Maruster, 2004). Its application results in the improved description of processes, products and organizational systems (Kirchmer, M., Laengle, S., and Masias, 2013), and may be used for improving quality, auditing, compliance adherence and risk management (van Aalst, van Hee, van Werf, and Verdonk, 2010; Caron, Vanthienen, and Baesens, 2013). Furthermore, it allows to automatically discover process models from raw event data, do conformance checking, and perform bottleneck analysis (van der Aalst, 2016). Accordingly, process mining brings digitalization and **Data Science** into Quality Management Systems. It reinforces the process-centric vision of an organization, providing important inputs to the integrated Management Systems and allowing to better promote process improvement and ensure compliance and standardization. In the same lines, the way data is collected and treated is critical for the creation of such value.

The use of these data-driven technologies thus needs to be combined with quality tools and methods, expanding their capacity as managerial instruments in the digital era.

As for the human side of Quality Management, Gunasekaran, Subramanian, and Ngai (2019) propose a research pathway for exploring its alignment with technology. Different scenarios are presented in accordance to different levels of engagement. Deeper individual engagement and newer technology is referred as micro level engagement, and focuses on specific issues such as security, risks, compliance management, alignment of Quality Management Systems, and the use of new technologies. Macro level engagement is more about continuous improvement issues addressed by both human aspects and technological revolution (Gunasekaran, Subramanian, and Ngai, 2019). However, the authors still identify a clear research gap in understanding how human aspects affect the integration between Quality Management and technology aspects. This aligns with an overall trend in Industry. Rauch Linder, and Dallasega (2020) used an anthropocentric perspective to look at the business environment before and during the transition towards Industry 4.0. The authors highlight the central role that a human-centered approach has in both paradigms, but identify different perspectives before and during this transition. Before, the environment was shaped by a change from technology-oriented production design towards a human-centered design. However, the authors claim that during the transition there has been a technology-driven transformation of physical and cognitive systems – leaving the human side often forgotten.

Quality of digital products and services

The Digital Transformation accelerated the advent of digital products, and with them, bought new perspectives for the management of Quality. One example relates the use of **Internet of Things (IoT)** in these products. IoT devices are linked in a network, and capable of interacting both with each other and with a centralized system (Lee and Kyoochun, 2015). As such, not only they provide new features for end users, but they also create an opportunity for constant monitoring, fault detection, and diagnosis of these products (Yen, Zhang, Bastani, and Zhang, 2017). IoT systems support higher levels of Quality Assurance by integrating and validating the different parts and components of a system - its devices and sensors, gateways, and apps (Tuncer, Davutoğlu, Durakbasa, 2019). Additionally, after sale, they provide organizations with improved access to real time data, and expanded use information sharing Karkouch, Mousannif, Al Moatassime, and Noel, 2016).

With new products and services being able to collect, generate, or make use of **Big Data**, integration is facilitated. Nevertheless, when making use of large volumes of data, it is important to understand that the quality of the information collected is critical. Gathering large volumes of data does not create value – that happens only when the collected data leads to organizational gains (G. Watson, 2014). Similarly, it does not ensure the correct use of such data. That occurs only when the collected data is treated and used in such a way that it creates feasible strategies with clear organizational gains (H. Watson, 2014).

Data Quality thus becomes a critical component of Quality Management in the Digital Transformation. With new products increasing connected and interacting with large volumes of data, integration is facilitated by the creation of information loops, which allow new functionalities based on the collaboration between systems (Colombo, Karnouskos, Kaynak, Shi, and Yin, 2017). They promote an integration between the digital with the "real" dimensions of a product. However, it is important to understand that the ideas of digitization, connectivity and analytics go beyond the simple use of platforms and technological tools (Leischnig, Ivens, Wölfl, and Hein, 2019), and should focus in adapting to them to enhance productivity and value generation for the customers (Skapinyecz, Illés, and Bányai, 2018; Lele, 2019). In the scope of data-driven and digital products, the use of **Machine Leaning** (ML) and Artificial Intelligence (AI) also brings promising potential. ML and AI may be used to combine quality control and reliability analysis in order to support predictive maintenance (He, Gu, Chen, and Han, 2017) and to reduce the number of customer complaints (Lou and Huang, 2003). Nevertheless, important questions are still being raised concerning safety in Machine Learning (Amodei et al., 2016; Varshney and Alemzadeh, 2017), a topic that will have strong impact in the Quality of these products, processes and systems. The same is true for bias towards certain groups or populations (Holstein et al., 2019; Mehrabi, et al., 2019).

Furthermore, ML can be used for the improvement of Quality along the design and development phases of new products, as well as for its production processes (see next section). Acooridngly, ML is set to become part of the design tools and to help improve product quality, but also production efficiency (Long, Lin, Cai, and Nong, 2020).

With improved connectivity, access to greater volumes of data, and the use of machine learning and artificial intelligence, maintenance and after-sales assistance go live, allowing level of "supercare" – one with a greater focus on continuously improving the service provided to the customer, that predicts and prevents errors before they occur, and that reduces the frustration of breakdowns and complaints. However, and with the closer integration of the digital with the “real” dimensions of a product, Data Quality and security become critical components for the management of Quality.

Quality of digital product development and production processes

The Digital Transformation and the increased use of Smart Manufacturing technologies offers a good fit for further integration between Systems Engineering and Quality. Systems Engineering and Management deals with the development of highly complex products and projects (Oehmen, Thuesen, Parraguez, and Geraldi, 2015), promoting the integration between different organizational areas (de Weck, 2018). Such integration is seen as critical for the mapping and assessment of this new industrial paradigm as a whole (Brusa, 2018; Wortmann, Combemale, Barais, 2017).

Amongst possible applications is the use of **Digital Twins**. Digital Twins allow the digital representation and modeling of smart systems. They help organizations create an experimental, virtual reality that can be used not only for engineering challenges but to address different aspects of the organization (Schluse, Priggemeyer, Atorf, and Rossmann, 2018). Digital Twins offer a simulation-based, interdisciplinary systems approach, enabling the consistent use of simulations to assess varying scenarios throughout the lifecycle (Schluse et al., 2018). Integrated with smart manufacturing technologies, Digital Twins lay the foundation or innovative products and Quality traceability (Tao, Qi, Wang, and Nee, 2019).

Taking advantage of the growing integration possibilities offered by **Cyber-physical systems (CPS)** also offers opportunities. By creating interconnected systems, these CPS allow different technologies to be structured and managed in a collaborative way. Through their use, information is closely monitored and synchronized between the physical factory floor and the cyber computational space, allowing for enhanced equipment efficiency, reliability and quality (Lee, Bagheri, Kao, 2014). Similarly, **Closed-loop Manufacturing (CLM)** also allows quality related data, gathered during manufacturing in the production machine, to be shared in a closed loop with different systems along the product lifecycle (Danjou, Le Duigou, and Eynard, 2017). This allows immediate information sharing with product development activities, leading, for example, to the update of CAD drawings and simulations, reducing process variability and the risk of non-conformities from (Saif and Yusof, 2019).

The quality of processes may also be improved through the use of increased automation – such as **Robotic Process Automation (RPA)**. RPA allows the elimination of operational risk and brings companies the opportunity to better manage their resources, attaining savings in time and cost (Jovanović, Đurić, and Šibalija, 2018). RPA will deliver higher quality by standardizing operations and processes, and reduces human errors by diminishing or eliminating the possibility of a process being done the wrong way or by an operator without proper knowledge (Mendling, et al., 2018; Jovanović, Đurić, and Šibalija, 2018).

Another area that gains interest from a systems perspective is that people increasingly collaborate with robots and intelligent assistant systems (Gorecky, Schmitt, Loskyll, and Zühlke, 2014; Kadir, Broberg, Souza da Conceição, 2018). Technologies supporting such systems include **collaborative robots (COBOTs)**, **Augmented Reality (AR)**, and **Smart Human Interfaces (SHI)**, and a number of smart technologies such as screens, 3D glasses, or exoskeletons. Such systems, rather than replacing humans, collaborate and augment human capabilities. As such, they too allow companies to achieve standardization, attain superior performance, and avoid human errors (Djuric, Urbanic, and Rickli, 2016; Frank, Dalenogare and Ayala, 2019; Chiarini and Manesh, 2020).

In the same scope, the relationship between **Additive Manufacturing** (AM) and Quality Management deserves attention for the process advancements it brings. By promoting an alliance between information and digital technologies and advanced production technologies, Additive Manufacturing creates truly new manufacturing realities. AM goes beyond the features and usability of products, and includes benefits such as faster design, development, and prototyping (Hamzeh, Zhong, Xu, Kajati, and Zolotova, 2018; Tortorella and Fettermann, 2018; Frank, Dalenogare, and Ayala, 2019), superior level of customization, and a closer relationship with customers (Schmidt et al., 2015). AM offers an opportunity for both superior Quality and reduced process costs, as it reduces the investment in tooling, cuts the time between design and production and - by allowing the final design to be approved by the customer - reduces the costs of resigned or rework (Preuveneers & Ilie-Zudor, 2017). This reality leads to a future empowerment and amplified voice of the customer, creating a personalized and individualized experience of collaboration and co-creation (Zairi, 2020).

In short, the Digital Transformation offers increased automation and augmented resources for Quality control. The same gods for optimization and integration between processes, systems, and organizational areas. Furthermore, it helps bring the customer into the design and development process, enhancing the customers experience and improving the potential for satisfaction.

CONCLUSIONS

This review departs from the understanding that there is limited research and alignment between the technological aspects of the Digital Transformation and Quality Management. In the face of this reality, this article surveys the literature for different practical examples of how Quality Management may both impact and be impacted by the use of new technologies. In doing so, it creates a better understanding of the relationship between Quality Management and the technologies supporting the Digital Transformation.

First, it is demonstrated that although scattered in the literature, there are already a number of works exploring the impacts of technology in the management of Quality in the scope of the Digital Transformation. Furthermore, this work resulted in the sorting and integration of the reviewed works into three areas:

(a) Digital Quality Management, considering the application of digital technologies to Quality Management itself, its tools, methods, and systems, and its human side;

(b) Implications for the management of Quality in digital products and services, often data-driven and marked by increased connectivity;

(c) Implications for the management of the Quality in increasingly digital product design, development, and production processes.

Table 1 summarizes these findings.

Table 1 - Summary of the literature review on the implications of technology for Quality within the Digital Transformation (DT)

Area	Description	Technology integration	Findings
Digital Quality Management	Quality tools, methods, and systems; human side in Quality Management	• Big data • Process Mining • Data Science	(1) New data-driven technologies may be used together with quality tools and methods, expanding their capacity as managerial instruments. (2) Studies on impact of technology in the human side of Quality Management (QM) are limited, curbing its understanding.
Quality in digital products and services	The management of Quality in digital products and services	• Internet of Things • Big Data • Machine Learning	(3) Maintenance and after sales services go live, allowing level of "supercare". (4) With the integration of the digital with the "real" aspects of a product, Data Quality and security become critical components of QM in the DT.
Quality of digital product development and production processes	The management of the Quality in increasingly digital processes	• Digital Twins • Closed-loop Manufacturing • Robotic Process Automation • Collaborative Robots • Augmented Reality • Smart Human Interfaces • Additive Manufacturing	(5) DT offers increased automation and augmented resources for quality control. (6) DT allows for increased optimization and integration between processes, systems, and organizational areas. Furthermore, it helps bring the customer into the development process.

In this review, it is demonstrated that there are clear benefits brought by these technologies for the management of Quality in an organization. Expanded integration and connection are amongst such benefits. Several new technologies support and promote integration and connectivity across an organization, allowing different functional units and systems to better work together. This improves information sharing, quality assurance, and efficiency, while reducing risks and uncertainty, and driving down costs. Nevertheless, it is clear that an anthropocentric perspective and a combined Quality strategy are the main limitations of this relationship.

Limitations and future work

There are some limitations to this work that must be reported, especially as they may also configure future research opportunities. This review focused on technologies that offer the most potential for integration with Quality Management, based on already demonstrated and discussed applications. It looks essentially at new technologies for process and systems integration, data management, and integration with existing Quality tools, techniques, and systems.

What it does not consider is the relationship between Quality and Risk Management under this disruptive scenario, especially for (1) Quality processes that primarily deal with uncertainty and probabilistic phenomena, and (2) the further integration of processes and tasks along the lifecycle of a product. Risk Management can serve as a bridge of efficiency in the development of digital products and digital production capabilities. This relationship may significantly improve the quality during the early production runs by better leveraging testing and sensor data for understanding production-related quality risks: feeding-back information from production to development areas (to avoid production risks during design), as well as feeding-forward information from R&D to production (to better prepare for unavoidable production challenges). Risk Management is especially relevant for radically new products, as there is significantly more uncertainty, and Quality Management extends to earlier phases of the development and business case.

Another limitation relates to the depth to which each technology or its resulting opportunities for Quality Management have been presented in this review. The objective of this work is to identify, list, and organize some of the different technological opportunities for Quality Management in the Digital Transformation. Due to size limitations and narrative constraints, we could only highlight a few aspects of what each technology brings to Quality Management. Accordingly, a more profound review and better understanding of the relationship between each technological opportunity and Quality Management offers a clear opportunity for future research.

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Preliminary Model for IoT-Related ISO 10000 Integrative Augmentation

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ABSTRACT

Purpose: To present an initial model for augmenting an ISO 10001 customer satisfaction code system with ISO/IEC 27701, in planning, designing, and implementing a healthcare professional's hand hygiene privacy code (HPHHPC). The HPHHPC addresses the privacy of the data collected through an Internet of Things (IoT)-facilitated hand hygiene monitoring system (HHMS). It also supports the "*business relationship management*" component of an ISO 20000-1 service management system.

Design/methodology/approach: A literature review identified the concerns of healthcare professionals regarding HHMSs with automatic data collection. Elements of an HPHHPC that deals with one of these concerns were developed. The requirements of ISO/IEC 27701: 2019 for privacy information management were mapped to the activities related to the planning, design and implementation of the HPHHPC in order to identify the requirements capable of augmenting it.

Findings: An ISO/IEC 27701 privacy subsystem can augment an ISO 10001 code system related to the use of the personally-identifiable information collected through an automated HHMS.

Practical implications: The ISO 10001 privacy-related code may be applied to potentially increase the satisfaction of healthcare professionals with an IoT-based service. The results may be useful for healthcare organizations that intend to implement or have implemented IoT technology.

Originality/value: To our knowledge, this paper is the first to present an integrated use of ISO/IEC 20000-1:2018, ISO 10001:2018 and ISO/IEC 27701:2019.

Keywords: Integrated management systems, customer satisfaction, healthcare, Internet of Things.

Paper Type: Research paper.

INTRODUCTION

The healthcare sector is one of the leading adopters of the IoT technology (Laplante, 2018). This technology is used, for example, to track assets and to gather patient data (Laplante et al., 2018). "*Hand hygiene monitoring*" (e.g., Boscart et al., 2010; Ellingson et al., 2011; Boyce et al., 2019) is another important application of IoT in the healthcare context (Boyce et al., 2019; Iversen et al., 2020). Previous studies explored the acceptability of these systems (Boscart et al., 2008; Levchenko et al., 2011; Ellingson et al., 2011). Before accepting such systems, healthcare professionals want to have precise information about the type of data to be collected, who will have access to this data (Boscart et al., 2008), and what will be its use (Boscart et al., 2008; Ellingson et al., 2011). A healthcare professional's hand hygiene privacy code (HPHHPC) following the ISO 10001: 2018 standard, while augmented with ISO/IEC 27701:2019 that deals with these concerns, could be used to increase healthcare professional's confidence in an "*automated Hand Hygiene Monitoring*" (Iversen et al., 2020) System (HHMS).

Previous related articles explored the integration of an ISO 10001 system for a code dealing with how nurses introduce themselves to patients with subsystems based on other customer satisfaction standards from the ISO 10000 series (Khan and Karapetrovic, 2013 and 2015; Khan, 2016; Khan et al. 2018). However, to our knowledge, no research has investigated the integration of an ISO 10001 system with subsystems based on standards outside the ISO 10000 series in the healthcare context.

This paper presents the construction of an initial model for augmenting the planning, designing, development and implementation components of an ISO 10001 system with the privacy controls component of ISO/IEC 27701:2019, for an HPHHPC that addresses the privacy of the data collected through an automated HHMS. The proposed model also shows how the ISO 10001 system can, in turn, augment the "*business relationship management*" component of an ISO/IEC 20000-1 service management system. The verification of this model will be covered in the next phase of this study.

LITERATURE REVIEW

Augmenting standards, such as ISO 10001, ISO 10002 and ISO 10004, focus on a specific component of a management system (MS) and can be used to improve the overall performance of that MS (Karapetrovic, 2005). Augmenting standards can be implemented to create an independent MS or subsystems of an overarching MS (Karapetrovic, 2012). Integrative augmentation refers to the "*sequential or parallel incorporation of augmenting standards into the organization*" (Karapetrovic, 2007). Integrative augmentation can occur both horizontally, e.g., when the overarching system for a customer satisfaction code based on ISO 10001 is augmented by an ISO 10002 complaints-handling (sub)system, and vertically, e.g., when an ISO 10001 (sub)system is integrated within an ISO 9001 MS (Karapetrovic, 2007).

Integrative augmentation – related research for the healthcare context includes examples based on the different combinations of the ISO 10000 standards:

- ISO 10001 - ISO 10002 (Khan and Karapetrovic, 2013 and 2015);
- ISO 10002 - ISO 10004 (Khan and Karapetrovic, 2014);
- ISO 10002 - ISO 10003 (Fernandez-Ruiz et al., 2017);
- ISO 10004 – ISO 10001 (Fernandez-Ruiz et al., 2017);
- ISO 10001 - ISO 10002 - ISO 10004 (Khan, 2016; Khan et al., 2018).

On the other hand, Vargas-Villarroel (2015) proposed an electronic integrative augmentation model for the implementation of an ISO 10008 Business to Consumer Electronic Commerce Transaction system, augmented with ISO 10001, ISO 10002, ISO 10004 and ISO/IEC 27001 subsystems in a higher education environment.

With respect to the Internet of Things (IoT), the ISO/IEC 20924:2018 standard defines it as the *"infrastructure of interconnected entities, people, systems and information resources together with services which processes and reacts to information from the physical world and virtual world"*. Laplante et al. (2018) identified three use cases of IoT technology applications in the healthcare domain: *"tracking humans"*, *"tracking things"*, and "*tracking humans and things*". IoT applications for tracking humans include applications for collecting patient data (e.g., see Montgomery et al., 2004; Shnayder et al., 2005; Zhou et al., 2007) and for tracking human-physical location (e.g., see Marco et al., 2008; Chang et al., 2008; Yan et al., 2008).

Automated HHMSs are an example of an application for tracking the location of humans in the healthcare context (e.g., see Sahud et al., 2012; Sharma et al., 2012; Boyce et al., 2019; Iversen et al., 2020). These systems are designed to detect when a healthcare professional enters an individual patient environment, to detect when hand hygiene is performed and to remind the healthcare professional to perform hand hygiene if needed (Ferenc, 2012). The recorded "*hand hygiene compliance*" is shared with administrative staff who can review it and provide feedback to healthcare professionals (Ferenc, 2012). Healthcare professionals using an automated HHMS reported not being concerned about *"being monitored or watched"* (Boscart et al., 2008; Levchenko et al., 2011). However, they expressed concerns about the *"availability and confidentiality of the data collected"* (Boscart et al., 2008) and its *"potential punitive use"* (Ellingson et al., 2011).

RESEARCH METHODOLOGY

This paper is part of a broader research study on customer satisfaction standards and IoT in the healthcare context. The work related to the integrative augmentation and customer satisfaction codes includes two stages. The first stage, covered in this paper, encompasses the construction of a preliminary model focused on integrative augmentation. The second stage will include the verification of the model in a hospital unit in Canada.

The methodology used for the construction of the preliminary model had five steps:

1. A literature review was conducted to determine the concerns of healthcare professionals regarding automated HHMSs and resulted in finding concerns related to data privacy.
2. An automated HHMS developed by the Toronto Rehabilitation Institute (Boscart et al., 2010; Levchenko et al., 2011, 2012, 2013 and 2014) was selected for the IoT-based service example to construct the model, due to its similarity with the system to be used for the verification stage. A description of the objectives, processes and resources required for the provision and utilization of this service was developed in the form of a flowchart following ISO/IEC 20000-1:2018.
3. ISO and IEC standards dealing with customer satisfaction and information / communication Technology, respectively, were reviewed to select relevant guidelines to deal with privacy-related concerns. An ISO 10001 code was identified as useful. The objective of this code was established, and the promise and examples of performance indicators were prepared. The ISO/IEC 27701 standard was also recognized as relevant. It was reviewed to find requirements capable of augmenting the activities involved in the planning, design, development and implementation of the ISO 10001 privacy-related code.
4. Selected ISO/ IEC 27701:2019 requirements were integrated into the ISO 10001:2018 privacy-related system.
5. The ISO 10001 requirements, already integrated with the ones from ISO/IEC 27701 in step 4, were mapped and incorporated into the process flowchart developed in step 2.

RESULTS

An Overall Framework for an IoT-related integrative augmentation

This paper presents a preliminary model with three layers for the integration of a service management system with a code and a privacy subsystem. The first layer is an ISO 20000-1 Service Management

System (SMS). The term *"service"* is used in the sense of the definition provided in ISO/IEC 20000-1: 2018. Thus, the HHMS, combined with other service components (ISO/IEC 20000-1: 2018, clause 3.2.18), such as information, documentation and supporting services, is, in this case, the *"service"*. As stated in ISO/IEC 20000-1 (clause 3.2.15), the service is the *"means of delivering value for the customer* [e.g., healthcare professionals, infection prevention and control personnel and quality management (QM) staff] *by facilitating outcomes the customer wants to achieve* [e.g., monitoring hand hygiene compliance accurately and securely]*"*. The hospital implementing the HHMS is, in this case, the *"service provider"* (ISO/IEC 20000-1, clause 3.2.24), as it manages and delivers the service.

The second layer is an ISO 10001 subsystem that supports the "*business relationship management*" component of the ISO 20000-1 SMS (ISO/IEC 20000-1, clause 8.3.2). The objectives of this component include "*managing customer relationships* [e.g., between the hospital and the healthcare professionals being monitored by the HHMS] *and maintaining customer satisfaction* [e.g., healthcare professional satisfaction with the HHMS]." The ISO 10001 subsystem augments the *"business relationship management"* component through the design and implementation of an HPHHPC that may help the hospital maintain healthcare professional satisfaction with the HHMS.

Finally, the third layer includes an ISO/IEC 27701 privacy management subsystem that supports the planning, design, development and implementation components of the ISO 10001 subsystem. This augmentation is performed by facilitating the preparation and implementation of the internal and external communication plan (ISO 10001, clause 6.7, 7), the determination of the resources needed (ISO 10001, clause 6.8) and the implementation of these resources (ISO 10001, clause 7).

For the proposed preliminary model, the data collected through the HHMS and the actors involved in its processing are described using certain terms from ISO/IEC 27701 and ISO/IEC 29100. In the context of the ISO/IEC 27701 privacy management subsystem, personally identifiable information (PII) refers to "*any information that can be used to identify the PII principal to whom such information relates, or is or might be directly or indirectly linked to a PII principal*" (ISO/IEC 29100, clause 2.9). Data identifying healthcare professionals, data about the exact time when a healthcare professional enters and leaves protected areas and data about individual hand hygiene compliance are examples of PII in this case. Healthcare professionals being tracked by the HHMS are the "*PII principals"*, as they provide their PII for processing (ISO/IEC 29100, clause 4.2.1). The hospital is the "*PII controller"*, as it "*determine[s] the purpose of processing hand hygiene data and how this processing will take place*" (ISO/IEC 29100, clause 4.2.2). Infection prevention and control personnel and QM staff are the "*PII processors*", since they *"carry out the processing of [hand hygiene data] on behalf of a PII controller, acts on behalf of, or in accordance with the instructions of the PII controller,* *observe the stipulated privacy requirements and implement the corresponding privacy controls"* (ISO/IEC 29100, clause 4.2.1)

The third layer of the proposed model also includes two subsystems based on ISO 10004 and ISO 10002. The ISO 10004 subsystem facilitates the evaluation of the HPHHPC and the satisfaction with it. The ISO 10002 subsystem augments the collection of unsolicited feedback about the HPHHPC.

An Expanded Model for an IoT-related Integrative Augmentation

Figure 1 depicts an ISO 20000-1 / ISO 10001 / ISO 27701+ISO 10002+ISO 10004 augmentation using the overall framework presented in the previous section. This top-level model is independent of the IoT application. The outside layer (Layer 1) corresponds to a Service Management System (SMS) based on ISO/IEC 20000-1. This SMS involves *"a set of capabilities and processes to direct and control the [hospital's] activities and resources for the planning, design, transition, delivery and improvement of [the HHMS and the other service components that constitute the IoT-based service] to deliver value"* (ISO/IEC 20000-1, clause 3.2.22).

Layer 2 corresponds to an ISO 10001 subsystem used to support the *"business relationship management"* subsystem. For brevity, only the activities related to integrative augmentation were included here.

Layer 3 includes activities related to the planning, designing and implementation of the HPHHPC that are augmented by other standards. Some activities are supported by the ISO/IEC 27701 standard that deals with the privacy aspects of the HPHHPC. For example, clause 7.3.2 of ISO/IEC 27701 can be used to support the determination of the information to be included in the external communication plan (ISO 10001, clause 6.7). Additional details related to the ISO 10001 - ISO/IEC 27701 part of the integrative augmentation are included in Table 2. Other activities in Layer 3 are supported by the ISO 10002 and ISO 10004 standards. For example, ISO 10004 can be used to evaluate the HPHHPC performance by conducting a survey to determine the percentage of healthcare professionals confident about the adequate use of their PII collected through the HHMS. In this example, the ISO 10004 subsystem is applied to assess the code performance and not only the satisfaction with the code as in previous studies (Khan, 2016; Khan et al., 2018).

As shown in Figure 1, in the case of the augmentation with the ISO/IEC 27701 standard, activities are supported using only some of its clauses. For example, the implementation of the external communication plan for the HPHHPC (ISO 10001, clause 7) is supported by clauses 7.2.4 and 7.3.3 of ISO/IEC 27701. This kind of use is similar to the one presented in Fernandez-Ruiz et al. (2017) and Vargas-Villarroel (2015), where only certain components of ISO 10003 were used to augment an

ISO 10002 system and selected clauses of ISO/IEC 27001 were applied to support an ISO 10008 B2C ECT system, respectively. Other clauses of the ISO/IEC 27701 standard are not applicable for the augmentation of the HPHHPC. For example, clauses 5.3 and 5.5 are not applicable as they relate the whole privacy management system and not the specific privacy issues dealt with the HPHHPC.

On the other hand, ISO 10002 and ISO 10004 augmented activities are fostered by the whole respective standard, as the establishment of a feedback-handling subsystem and a subsystem for monitoring and measuring satisfaction is relevant for the maintenance and improvement of the HPHHPC. For example, the entire ISO 10004 standard can facilitate the evaluation of healthcare professionals' satisfaction with the HPHHPC.

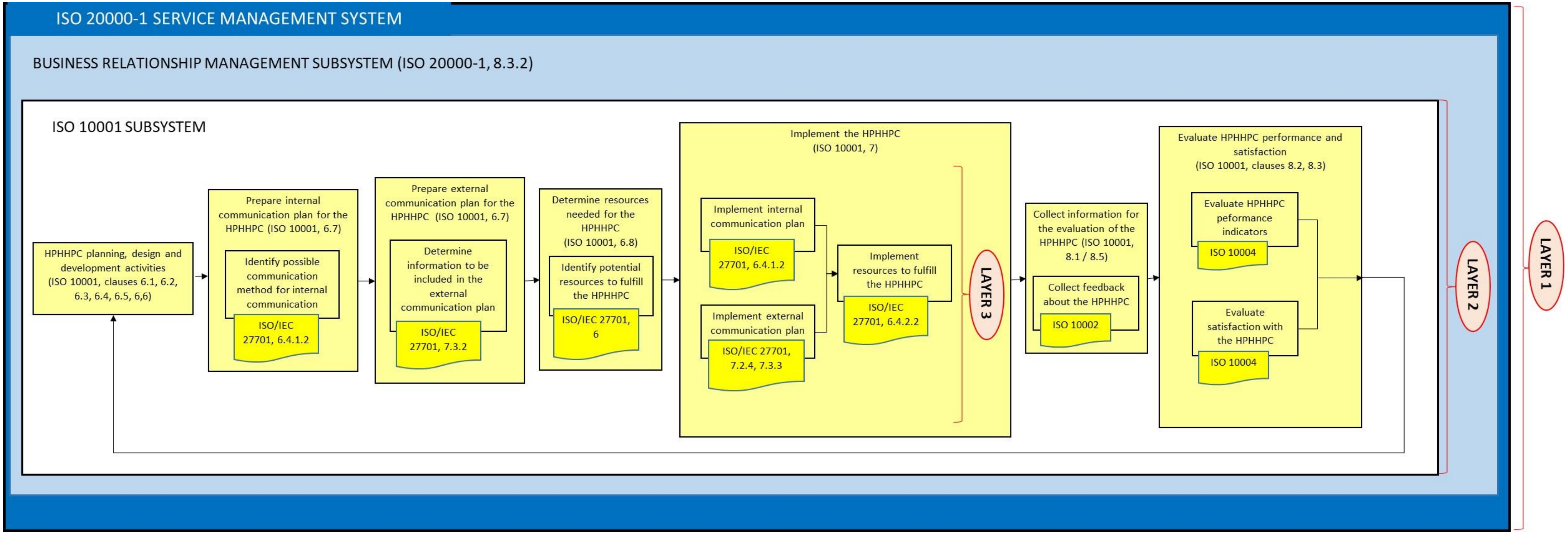

Figure 1 – Expanded Model for IoT-related Integrative Augmentation

Augmentation of the HPHHPC system with an ISO/IEC 27701 privacy subsystem

This section presents five of the seven components of the ISO 10001 HPHHPC system (layer 2 in Figure 1) and describes how the ISO/IEC 27701 privacy subsystem (layer 3 in Figure 1) augments the related code. The other two components, namely HPHHPC procedures (ISO 10001, 6.6) and the resources needed for the HPHHPC (ISO 10001, 6.8), will be included in the next stage of this study, as empirical data will allow for their effective development.

The HPHHPC objective (Table 1, column 1) is in line with previous studies regarding automated HHMSs, which showed that healthcare professionals want to have precise information about the intended use of the data collected through these systems before embracing them (Boscart et al., 2008; Ellingson et al., 2011). These professionals also emphasize the importance of *"clear and concise policies and procedures"* (Boscart et al., 2008) and *"a clear communication strategy"* (Ellingson et al., 2011) for addressing their concerns related to how information collected through HHMS will be used and who will have access to that information (Boscart et al., 2008; Ellingson et al., 2011). Following this objective, the proposed promise is related to the use of the data collected through the HHMS by the PII processors (Column 2). An example of a performance indicator that could be measured using a survey and supported by clause 7.3.3.2 of ISO 10004: 2018 is shown in Column 3. Finally, actions with respect to the communication plans are illustrated in Columns 4 and 5.

Table 1 – HPHHPC System Components

HPHHPC Objective (ISO 10001, 6.1)	**Promise (ISO 10001, 6.4)**	**Performance Indicator (ISO 10001, 6.5)**	**Internal Communication Plan (ISO 10001, 6.7)**	**External Communication Plan (ISO 10001, 6.7)**
Enhance healthcare professionals' confidence in the hospital's adequate use of their HHMS-collected PII.	"PII collected from healthcare professionals through the HHMS will only be used by the hospital for the purposes stated on the consent form and communicated to the healthcare professional".	Percentage of healthcare professionals confident about the adequate use of their PII collected through the HHMS.	Informs Infection Prevention and Control personnel and QM staff about the HPHHPC and their responsibilities for the privacy of the data collected through the HHMS.	Informs healthcare professionals about the HPHHPC.

After having developed the components of the HPHHPC system, a tabular approach was used to map the guidelines of ISO/IEC 27701:2019 against the ones from ISO 10001:2018 for a potential establishment of the HPHHPC. Table 2 shows the results of this mapping process. The first and second columns illustrate the designators of applicable ISO/IEC 27701 and ISO 10001 sub-clauses, sections and sub-sections in italics, respectively, followed by examples of the corresponding activities within the hospital context in the third column.

Table 2 – ISO/IEC 27701 augmenting an ISO 10001 privacy-related code

ISO/IEC 27701:2019	ISO 10001:2018	Examples
6.4.1.2	*6.7* *Annex I.2*	• As part of the preparation of the internal communication plan, the hospital (PII controller) could include the promise in the *"contractual agreements"* (ISO/IEC 27701, clause 6.4.1.2) to be signed by infection prevention and control personnel and QM staff (PII processors). • The *"contractual agreements"* (ISO/IEC 27701, clause 6.4.1.2) should also state the *"responsibilities of the PII processors for the privacy of [HH data collected through the HHMS]"* (ISO/IEC 27701, clause 6.4.1.2).
7.3.2	*6.7* *Annex I.3*	As part of the preparation of the external communication plan, the hospital should "*determine and document the information to be provided to PII principals* [i.e., healthcare professionals] *regarding the processing of their PII and the timing of such a provision*" (ISO/IEC 27701, clause 7.3.2), e.g., information about the purpose of the processing of data collected through the HHMS.
6	*6.8*	• The guidance on information privacy controls can be helpful for the hospital to identify the resources needed (such as procedures and training) to fulfill the HPHHPC. • These privacy controls might be used as resources for the fulfillment of code promises concerning the privacy of IoT-collected data.
6.4.1.2	*7.a*	The hospital could implement the internal communication plan by having infection prevention and control personnel and QM staff sign their contractual agreements, which include the HPHHPC and their responsibilities for the privacy of the IoT-collected data.
7.2.4 *7.3.3*	*7.a*	• The hospital could implement the external communication plan by informing healthcare professionals about the HPHHPC using the consent form. • The promise could be included in the consent form that is signed by healthcare professionals when they agree to be monitored by the HHMS.
6.4.2.2	*7.a*	• Infection prevention and control personnel and QM staff (PII processors) should receive awareness education and training in organizational policies and procedures related to the privacy of data collected through the HHMS following clause 6.4.2.2 of ISO/IEC 27701.

Figure 2 shows the activities involved in the provision and utilization of the HHMS and in the use of the data collected through the HHMS. The section of the flowchart related to the utilization of the HHMS is based on information found in the literature (Levchenko et al., 2011, 2012 and 2013). The requirements of the ISO 10001 standard, and the applicable requirements of the ISO/IEC 27701 standard for the augmentation of ISO 10001 (presented in Table 2), were also incorporated into the Figure 2 flowchart.

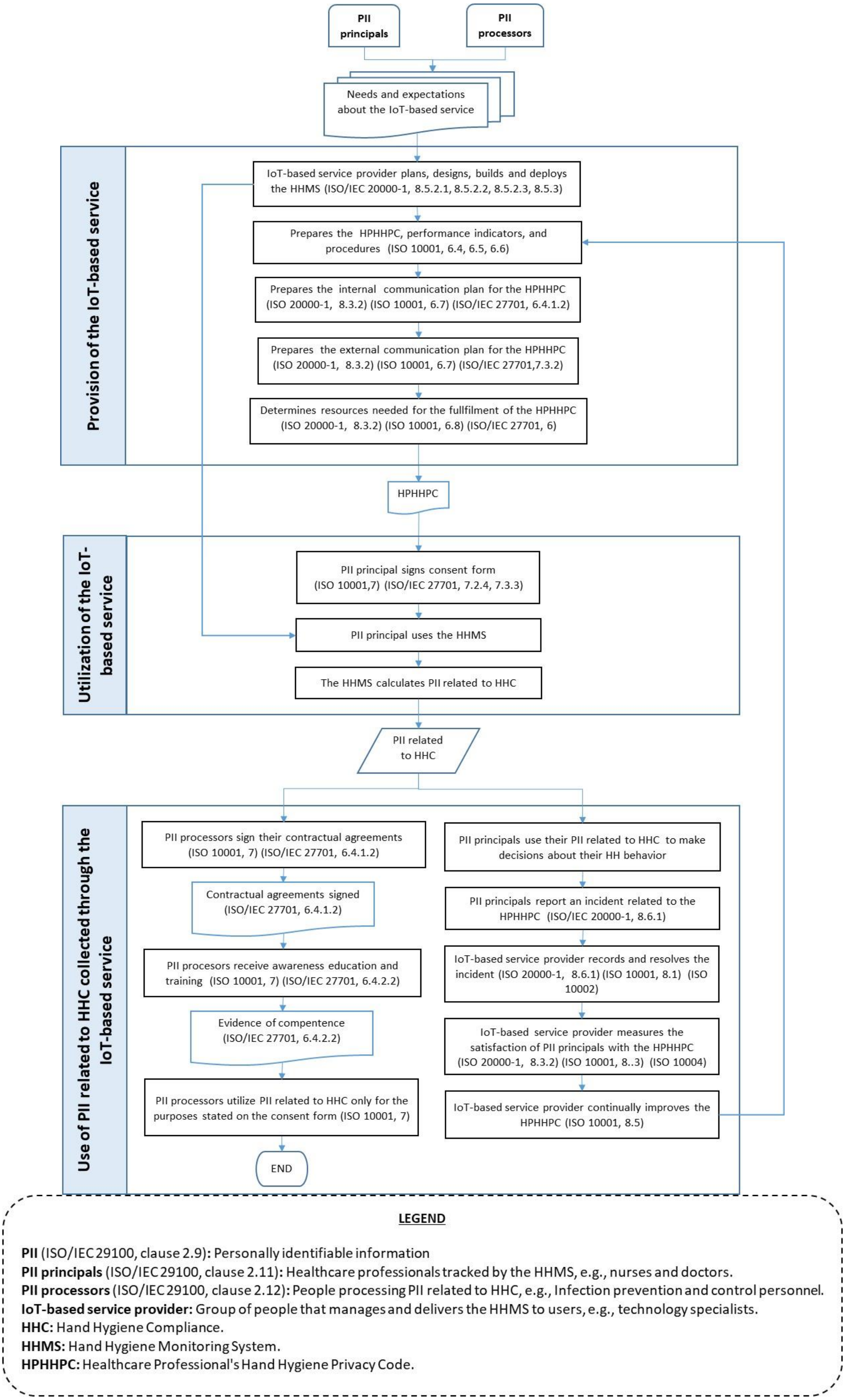

Figure 2 – Augmentation of ISO 10001 with ISO/IEC 27701 for an HHMS

CONCLUSIONS

A model with three layers for an IoT-related integrative augmentation was presented. The first layer is an ISO 20000-1 SMS. The second layer is its ISO 10001 subsystem that supports the "*business relationship management*" component of the SMS. The third layer is an ISO/IEC 27701 privacy management subsystem that augments the ISO 10001 code system.

An automated HHMS system developed by the Toronto Rehabilitation Institute (Boscart et al., 2010; Levchenko et al., 2011, 2012, 2013 and 2014) was used as the IoT-based service example to explore the potential implementation of the proposed model. An ISO 10001 HPHHPC that deals with privacy-related concerns of healthcare professionals regarding the HHMS (Boscart et al., 2008; Ellingson et al., 2011) was presented. Examples of the integration between ISO 10001 and ISO/IEC 27701 for planning, designing and implementing the HPHHPC were detailed.

Previous research has explored the integration of a customer satisfaction code based on ISO 10001 with other standards of the ISO 10000 series in the healthcare context (e.g., Khan and Karapetrovic, 2013 and 2015; Khan, 2016; Khan et al. 2018). However, to our knowledge, this paper is the first to illustrate the use of the ISO 10001 standard to develop a satisfaction code for internal customers in the healthcare context.

The proposed model and the examples presented regarding the integration between ISO 10001 and ISO/IEC 27701 for planning, designing and implementing an HPHHPC may benefit healthcare organizations that intend to implement or have implemented an IoT-based HHMS. The establishment of an HPHHPC may increase the healthcare professional's confidence in the system and therefore increase its acceptability.

This paper shows the construction of a preliminary model for IoT-related integrative augmentation of standardized management systems. It will be further developed in the next stage of the study. For instance, two components of the HPHHPC system and four elements of the HPHHPC itself will be designed, and other standards (e.g., ISO/IEC 29184: 2020) may be added. Since no empirical data was used in the development of the proposed model, in the next stage, interviews will be conducted with healthcare professionals of a hospital unit in Canada implementing an HHMS for its verification.

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Can employees be delighted?

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ABSTRACT

Purpose: This paper proposes employee delight as a concept not yet considered in the study of remarkable experiences at work, which is different from other concepts that, until now, have been the focus of research. Thus, the study presents two main goals: (I) to adapt the concept of delight to the context of organisational behaviour; and (II) to propose a model on the antecedents and consequences of employee delight, building on the Cognitive Appraisal Theory (CAT) and the Affective Events Theory (AET).

Design/methodology/approach: This is a theoretical paper. The theoretical background is based on the customer delight literature, the cognitive appraisal theory and the affective events theory.

Findings: The paper extends the concept of delight, initially developed in the field of consumer behaviour, to the field of organisational behaviour; and presents a new employee delight conceptual model that includes the affective events and cognitive evaluations that may precede it, as well as its potential impact on employee behaviour.

Research limitations and implications: Despite its contributions, the present research also presents some limitations that can be understood as a new opportunity for further research. The main limitation remains in the fact that this paper is a theoretical proposal that will require empirical validation.

Originality/Value: the conceptualisation of employee delight and the analyses of its antecedents it's the main value of the present research.

Keywords: employee delight, employee satisfaction, cognitive affect theory.

Paper type: Conceptual paper

INTRODUCTION

Weiss & Cropanzano (1996) emphasise the importance of recognising emotion in the workplace. Objects and events have an impact on employee's emotions, and employees' emotions have, in turn, an impact on workplace attitudes and behaviours (Ashton-James & Ashkanasy 2005). However, as Ashkansky and Dorris (2017) highlight, there has been a pervasive tendency for research scholars to categorise discrete emotions into positive and negative dimensions. The problem with this is that positive and negative emotions are in theory often treated in the same way, when the focus should be on what is driving each of the processes and the different outcomes resulting from that particular discrete emotion. For instance, anger and fear are both negative discrete emotions, but they play out in different ways. The same can be said for positive emotions, which have been less studied than negative ones but have been getting increasing attention from scholars (Diener, Thapa & Tay, 2020).

One positive emotion that has received scant attention in the organisational behaviour literature is employee delight. Delight has been studied intensely in the consumer behaviour literature, but just a few papers have proposed its relevance when applied to employees. In this sense, customer delight involves going beyond satisfaction to delivering what can be best described as a pleasurable experience for the client (Torres and Kline, 2006). Thus, the present paper takes customer delight's literature as a reference to develop the employee delight construct for the following reasons: (I) Customer satisfaction, have been successfully transposed to the organisational behaviour field (Lings & Greenle, 2009); (II) following the emotional contagion theory (Barnes et al., 2015), employees' and customers' emotions influence each other; and, (III) some management approaches consider employees as the internal customers of the organisation (Kim et al., 2015).

This study presents two main goals. First, to adapt the concept of delight to the context of organisational behaviour. And, second, to propose a model on the antecedents and consequences of employee delight, building on the Cognitive Appraisal Theory (CAT) and the Affective Events Theory (AET).

The present paper is organised as follows. Section one will describe the most important approaches to customer behaviour and customer delight. The second section will introduce the theories implemented to develop THE conceptual model to defining employee delight: the affective events theory and the cognitive appraisal theory. Finally, the last section will extract the main conclusions, limitations and further lines of enquiry of the research.

CONCEPTUALISING DELIGHT: A THEORETICAL BACKGROUND

Customer delight has been mostly studied in marketing and positive psychology, and has been theorised following three approaches: affective, attitudinal or motivational (Torres and Ronzoni, 2018). These three conceptual approaches have been grouped into two different categories (Escobar et al., 2019): affective and cognitive. The first one, the affective approach, understands delight as a result of experienced emotions and surprise, while the cognitive approach defines delight as a result of fulfilling human needs and as extreme customer satisfaction. Based on the research developed by Escobar et al. (2019), Figure 1 summarises the most relevant aspects of each approach. This paper will follow the same categorisation to study employee delight.

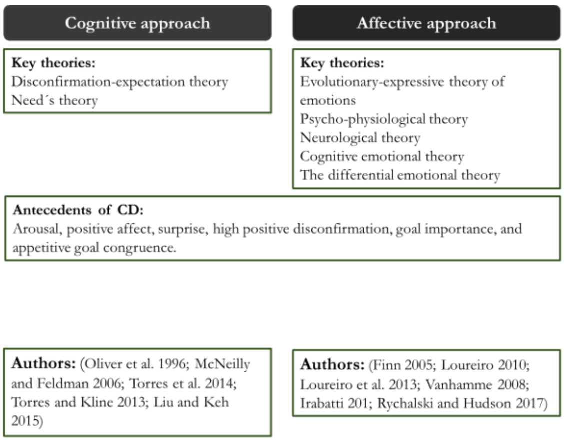

Figure 1: Summary of theories and contribution in customer delight constructs

By adopting an approach similar to the customer delight field, employee delight has been conceptualised as an affective response to what happens in the work environment and a cognitive representation of the meaning of work events for the employee (Frijda and Mesquita, 1994, p.51). It is a concept which is related to joy, arousal and having fun at work (Kim et al., 2015). According to this approach, providing employees with unexpected fascination might create emotional benefits, job satisfaction, lowered turnover intentions and higher employee commitment to customer services. Hence, based on the previous and taking into consideration the proposal of Torres et al. (2020), employee delight may be defined as experiences that engage employees at an emotional level, exceed their expectations and fulfil their needs.

EMPLOYEE DELIGHT: A CONCEPTUAL MODEL

The few existing publications on employee delight tend to define it as a purely emotional response that includes surprise. As an example, Kim and colleagues (2015) defined employee delight as “an emotion that is a mixture of great joy and high arousal” and related the concept with having fun in the workplace. According to these authors, employee delight arises when people are joyfully surprised in reaction to the disconfirmation of an expected situation. They assert that by “wowing” people and providing them with unexpected fascination, delight may create further emotional benefits.

This emotional approach to employee delight is consistent with affective events theory (AET) (Weiss & Cropanzano, 1996), which holds that discreet work events determine the emotions that arise in the workplace. These events generate specific emotional reactions that are hypothesised to influence behaviour and attitudes (Ashkanasy, 2003). AET also proposes that stable work environment features, such as job scope, predispose the occurrence of certain types of affect-producing events. Nevertheless, some studies have demonstrated that different people may evaluate differently the same category of events, generating different discrete emotions (Basch & Fisher, 1998) and therefore different behaviours. These differences can be explained by cognitive appraisal theory (CAT) (Lazarus, 1991). This theory assumes that the perception of an event (not the event itself) results in both positive and negative emotions. In other words, the cognitive assessment of an event determines the emotions that the individual will develop. Thus, different perceptions can generate different emotional reactions and behaviours. In summary, some events at work tend to be affectively assessed, and the specific resultant emotion of such assessment depends on individual cognition along several dimensions.

According to CAT, specific dimensions or components interact with each other to provoke different emotions (Roseman, 1996). First, emotion is either positive or negative depending on the appraisal that the person makes of the situation in accordance with their own goals. The relevance of personal goals in the cognitive assessment connects with the view of delight as a result of need fulfilment. The pioneering research by Rai and Sinha (2002), is an exemplar of delight as need fulfilment since they understood job delight as the result of exceeding high expectations that employees try to achieve through their work.

Furthermore, emotions also have a certain degree of intensity that can be predicted by evaluating the dimensions of goal relevance and goal realisation (Scherer & Ceschi, 1997). Goal relevance is understood as the appraisal of the importance, interest and value of the result for a person's needs or objectives. The appraisal of the goal relevance affects the intensity of the emotion because it is associated with the event’s desirability and results. On the other hand, goal realisation refers to the degree, quantity or range of the result obtained. Thus, in the case of a congruent goal (positive emotion), goal relevance and goal realisation will define the degree of the positive emotion and will help to identify the result of the discretionary positive emotion.

Other dimensions, such as agency (Roseman, 1996), entail the evaluation of whether the employee themself, their work colleagues or particular circumstances, are responsible for the outcome of a specific situation. Nevertheless, it is difficult to determine whether agency has a positive or negative relationship to employee delight as there is no research available on this particular topic. The research reports on job satisfaction are not conclusive, either, since they have shown both negative, non-significant and positive relation between internal locus of control and job satisfaction (see, for example, Muhonen & Torkelson, 2004).

Lastly, the dimension of novelty enables the evaluation of the extent to which an experience departs from a person's expectations. It is interpreted as the suddenness or unexpectedness of an experience and is frequently associated with delight (Scherer, 1993).

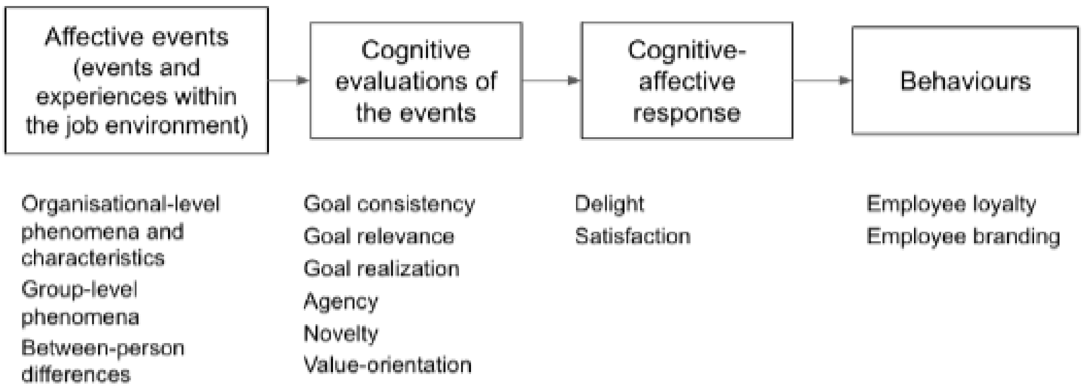

Figure 2: Conceptual model of employee delight

CONCLUSION

This paper has proposed a conceptual model of employee delight, tracing a parallel with the concept of customer delight from the consumer behaviour literature. Using AET and CAT, employee delight has been explained as a cognitive-affective response to affective events that take place within the job environment. Affective events in the workplace may be judged along the dimensions of goal consistency, goal relevance, goal realization, novelty and value-orientation to elicit the delight response, which in turn causes the employee to behave in one way or another, particularly regarding their performance, loyalty and involvement in employee branding.

An empirical test of this proposal would distinguish employee satisfaction from employee delight through their antecedents and their impact on employee behaviour. In particular, specific affective events should be selected as context or antecedents of affective responses, and adequate measures for the dimensions of cognitive evaluation should be developed.

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Organizational Learning, Change and Total Quality Management: Investigating the Link

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ABSTRACT

Purpose – The paper aim is to investigate the interrelationships between TQM, Organizational Learning and Change.

Design/methodology/approach – Using an extensive literature review the authors argue that quality has a 'learning" footprint and change is an integral part in all quality standards/programs/awards or initiatives.

Findings – Over the years' scholars and practitioners, either praised or heavily criticized the overall philosophy and practices of TQM. The truth is that quality is the heart of all organizations functions and customer satisfaction is the ultimate goal of all organizations (private or public, small or multinational) worldwide. Furthermore, managing change become a major challenge for CEO's due to increased uncertainty and lack of organizational resilience.

Practical implications – The key to bring quality into everyday processes, increase awareness and create readiness for change as well as fully utilize the organization's human resources is to create a Learning Organization

Keywords: Total Quality Management, Organizational Learning, Change, Literature Review

Paper type: Literature Review

INTRODUCTION

Reality can be harsh for organizations today. Globalization, and the rapidly expanding diffusion of new technology requires use of knowledge. Markets are changing and international competition is intensifying. Customers are becoming more demanding in terms of quality, flexibility and speed of service. The transition to knowledge-based organizations, has brought new sources of competitive advantage such as innovation, flexibility and responsiveness Dess&Picken (2000). Businesses need to become learning organizations, that is to say, capable of creating, acquiring and transmitting knowledge and modifying their behavior in order to reflect new knowledge and opinions. Learning organizations avoid stagnation by constant self-evaluation and experimentation. People at all levels, and not just executives, must be involved in exploring the environment for critical information, proposing changes to strategies and programs, working with others to continually improve working methods, processes and techniques. evaluation.

According to Grant, et.al (1994), a significant part of the knowledge lies in the 'social constructed reality' that was created and disseminated by quality theorists and practitioners. This accumulated knowledge over the years and the evolution of quality improvement in the modern western business world has developed into an everyday objective reality. Total Quality Management (TQM) and Organizational Learning (OL) complement each other, as their strategies aim in the long run to gain competitive advantage and improve overall organizational performance. The success of both can be measured by the degree of employee involvement at all levels of the organization, the encouragement and full utilization of their skills and abilities, and the support and empowerment of learning practices within the organization. Gloet (2002), views OL as an extension of an organization's TQM practices.

Furthermore, OL is to accept, embrace and seek for change (McGill, et.al, 1992). Only through learning can an organization face the disproportional change in the real business world (Chan,1994). Thus, organizational learning can be seen a tool for introducing change in an organization (Zetie,2002). A significant number of papers stress that changing requires a focus on the creation of a learning organization (Senge,1990; Senge, et.al,1994; DiBella&Nevis,1998; Roth&Kleiner,2000).

RESEARCH METHODOLOGY

The aim of this exploratory study is to identify and analyze literature that have been published globally in order to investigate the interrelationship between TQM, Organizational Learning and Change. The main objective was to trace and analyze articles that were exceptional and were either rhetoric or empirical in nature. According to Snyder (2019), “by integrating findings and perspectives from many empirical findings, a literature review can address research questions with a power that no single study has”. The authors tried to avoid bias and strived to present reliable, evidence-based description of the actual literature review. Furthermore, the author’s approach to this review was to “carefully identify and synthesize relevant literature in order to evaluate a specific research domain and build a conceptual model for a better understanding of the research issue (Palmatier et all,2008). Conducting a literature review includes identification of keywords and search terms, selection of studies, data processing and classification and data synthesis (Tranfield et al., 2003). The papers that have been analyzed were published from 1991 until today under the following keywords: TQM, OL and Organizational Change. It seems that these 30 years were very crucial not only for papers that investigated the TQM-OL relationship but whole concept of changing based on the new paradigm (as TQM is referred to). All relevant databases (Emerald, Scopus, Springer Link, Elsevier, Taylor & Francis, Wiley, etc.) to the subjects under study were included a semi systematic literature review approach. Overview research area and track development over time. Typically, this type of literature review is conducted to evaluate the state of knowledge on a particular topic. It can be used, for example, to create research agendas, identify gaps in research, or simply discuss a particular matter (Snyder,2019; Tranfield et al., 2003)).

LITERATURE REVIEW

Total Quality Management (TQM) and Organizational Learning (OL)

Total Quality Management is a system of values, principles, standards and modes of action, a management philosophy based on total commitment to continuous improvement of products and processes, which is delivered through the participation of all members of the organization, in order to satisfy perfectly current and future customers’ needs (Martinez-Lorente et.al.,1998: Dean and Bowen,1994; Prajogo & Sohal,2006). According to Vouzas & Psychogios (2007) TQM is associated with a move towards a better societal values, an innovative way of improving performance and a management paradigm. Fisher&Harricks (1993) states that TQM emphasizes the importance of understanding changes, conducting measurements, satisfying customers and ensuring workers’ participation in all organization’s levels, aiming at continuous improvement. Some of the main principles of TQM are: commitment of leadership, notion of internal and external customer, consumer’s satisfaction, continuous training and continuous improvement (Hill &Wilkinson, 1995; Hellsten &Klefsjo,2000)

Organizational Learning (OL) is the acquisition of new knowledge, behavior, skills and values and includes the composition of different kinds of information. Miller (1996) defines organizational learning as the acquisition of knowledge from individuals and teams, who are willing to apply this knowledge in their work for decision making and for influencing others, so that the mission of their organization is completed. Organizational learning is characteristic of an adaptable organization, that is of an organization capable of sensing the changes through internal or external signs and adjust accordingly.

Literature on Organizational Learning was initially based on theories of organizational behavior, focusing on forwarding information and making decisions in order for an organization to obtain the appropriate management techniques for adjusting to the changes of the environment (Cyert and March, 1963; Easterby-Smith, 1997; Gherardi, 1999). Senge (1990) was the first to introduce the term "learning organization" (LO). Ever since, a lot of research has been done into how a learning organization is created and how it leads to organizational learning, concluding that both learning organization and organizational learning constitute a dynamic model of organizational development (Argyris and Schon,1996; Nevis et al., 1995; Pedler and Aspinwall, 1998; Senge et al.,1999).

Many attempts have been marked in the bibliography to segregate the terms "organizational learning" and "learning organization" (Marsick and Watkins, 1994; Argyris and Schon, 1996; Griego et al., 2000; Yang et al., 2004; Kontoghiorghes et al., 2005). According to Easterby-Smith (1997), literature on organizational learning derived mostly from academic research, while literature on the learning organization was based on practice. Lastly, as Mardquardt (1996) notes, learning organizations focus on "what", meaning the characteristics, principles and systems that an organization produces and learns as a whole, while organizational learning, on the other hand, is referred on "how", meaning the capabilities and the processes of knowledge creation.

Furthermore, learning is a key-element for developing and sustaining a competitive advantage (Armstrong and Foley, 2003; Nonaka, 1994; Senge, 1990). Organizational Learning represents a dynamic synergy between individuals, actions, symbols and processes within an organization (Schwandt and Marquardt, 2000). Considering the definitions of OL as mentioned above, the literature predicates the creation of proper circumstances, as a way to enhance both individual and organizational creativity, through managing people and focusing on their values, attitudes and beliefs: "building a learning organization requires fundamental changes in the way individuals think and act" (Kofman and Senge, 1993). Hall and Parker (1993) stress that the structure of a learning organization must enhance the flexibility of human resources management. Attempts include change of organizational culture, with the support and commitment of managers and the activation of empowerment between workers. Furthermore, the leadership, vision and management of resources, appear to be constituent parts in the creation of organizational learning.

Given the fact that Total Quality Management involves continuous improvement, which means that an organization learns to do things better and better, and training programs in order to achieve its goals, it emerges that there is a link between Total Quality Management and Organizational Learning. There are various approaches in literature concerning this linkage. Deming first, one of quality gurus, talked about the system of “profound knowledge” of an organization, consisting of four parts: appreciation of a system, knowledge of variation, theory of knowledge and knowledge of psychology. Learning is involved in every procedure of an organization entertained by the philosophy of total quality management. Also, the PDCA (Plan – Do – Check - Act) cycle of Deming could form a learning cycle, leading to continuous improvement, as it presents many similarities with Kolb’s (1984) learning cycle EERC (Experiment – Experience – Reflect – Conceptualize), which is a fundamental way for individuals to learn (Zetie,2002).

According to Nonaka (1994), knowledge creation takes place through socialization, externalization, combination and internalization. Many practices of total quality management support the above procedures (Linderman, et.al 2004). Brown & Duguid (1991) in their theory for the learning organization mention “communities of practice”, which are parallel to “quality circles”, a practice of total quality management (Zetie,2002). They are teams of employees, with a common base of expertise, who are called either to face a common organizational procedure, or to solve different types of problems (Gray,2001). Communities of practice as well as quality circles, through the exchange of ideas and experiences between their members, enhance learning, and through collection, elaboration and adoption of the optimum solutions, improve quality.

Other practices of total quality management, as certification of quality through a standard, are efforts of implementing rules aiming at continuous improvement and learning. Marcus & Naveh (2005), in their research on the impact of the implementation of ISO 9000, conclude that a new rule (in other words, a standard) facilitates, integrates and guides other aspects of the management system of an organization, reinforcing the organizational understanding, change and learning. The organization’s quality manual is the repository of organizational learning (Zetie,2002). Also, the EFQM Excellence Model emphasizes on learning through the diffusion of feedback of the organization’s results into the enablers. According to Martin-Castilla & Rodriguez-Ruiz (2008) “enablers are a set of criteria that offer a relevant approach for the achievement of excellence in organizational results” (Martin-Castilla & Rodriguez-Ruiz,2008). Furthermore, TQM rhetoric calls for a cultural shift emphasizing self-control, autonomy having a significant effect in the way people are managed. Management and utilization of people is at the core of the EFQM Excellence Model and it seems that organizations implementing the model are striving to focus on specific HR related practices in order to improve individual and team performance, and create a climate of innovation and learning. This of course requires that organizations should give to the HRM function a direct and substantial role in total quality efforts, by establishing a culture that supports an innovation and learning, designing and implementing plans for employee empowerment and development or applying TQM principles, practices and techniques within the HR function (Vouzas,2007)

It seems that a relationship between the "soft" and the "hard" aspects of quality and OL exist according to a study in Indonesia (Sisnuhadi, 2014). The author found that "significant impact of soft factors on organizational learning suggests that the managers could implement the soft factors, such as leadership, customer focus, involvement of people, continuous improvement, mutually beneficial supplier relationship to improve organizational learning processes which in turn increase the companies' competitiveness".

Additionally, many tools of total quality management – Quality Control tools, like check sheets, Pareto analysis, flow charts, cause-effect diagrams and brainstorming, contribute to problem solving within teams or not, diffusion of knowledge and quality improvement, involving the creation of organizational learning (Johannsen,2000). According to Ishikawa, the prominent quality Guru, data are the base of quality control, enlighten decision making and action, and constitute the stimulus which provide the "building blocks", the "thinker toys" for our creativity. Knowledge management is the procedure through which data are transformed into important and useful information (Waddell & Stewart,2008), and Quality Control tools support this procedure (Johannsen,2000).

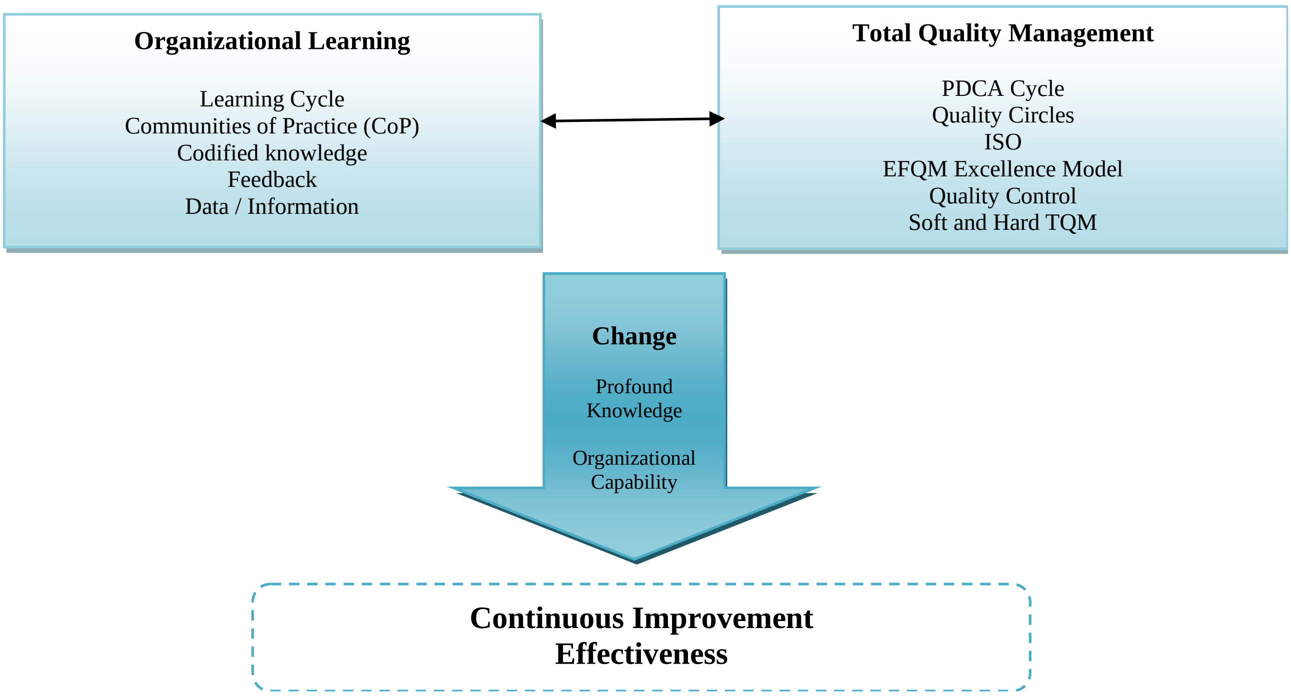

Figure 1: TQM, Organizational Learning and Change Framework.

Many more researchers underline the importance of implementing principles of Total Quality Management with the support of organizational culture for the enhancement of Organizational Learning Sohal & Morrison,1995; Baldwin,et.al,1997; Pool,2000). According to Linderman et al.,2004), TQM becomes the source for creating knowledge and achieving a competitive advantage, while knowledge itself, as an important resource of an organization (Knowledge-based View of the firm), is the competitive advantage which improves the organization's performance. Furthermore, many authors state that that there is a strong relationship between TQM, Organizational Learning, and Innovation Performance (Hung, et.al,2011; Yusr, et.al. 2013; Kafetzopoulos,et.al,2020).As a conclusion the synergy between total quality management and the learning organization, should be seen as a dynamic way of facing difficult problems and achieving organizational change and competitive advantage (Figure 1).

Organizational Learning, Change and Effectiveness

At a time when quality, technology and variety have become widely available at a relatively low cost, the only sustainable competitive advantage that an organization can create is its ability to learn faster than its competitors and be ahead of changes in the business unsteady environment (Yusr, et.al, 2013; Zetie, 2002). According to Drucker (1992), we are now entering the society of knowledge, where only knowledge and knowledge workers will be the basic financial resource. Knowledge consists the heart of the production, it is the new form of labor (DeGeus,1988; Drucker,1992). And it is the quality of our knowledge, as individuals, as organizations and as communities, which will define our overall development (Chan,1994).

According to Chan (1994) total learning includes two types of learning: "maintenance learning", that is the possession of fixed perceptions, methods and rules for facing known and recurrent situations, and "innovative learning". The first type of learning is designed to preserve the present system (Drucker,1992) and consists a type of "programmed-knowledge" (Zuboff,1988). On the other hand, "innovative learning" could bring change, renewal, reconstruction and correction of problems of individuals and organizations. It includes both provision, where people of the organization make plans considering the tendencies in the environment, and participation, where the organization through collaborations, dialogue and open communications checks and evaluates its operational rules and values towards the others. The second type of learning is actually the field of "questioning insight" (Zuboff,1988) and consists a critical factor for organizations to meet the requirements of a rapidly changing environment.

Only through learning can an organization face the disproportional change in the real business world (Gloet,2002). Thus, organizational learning can be seen a tool for introducing change in an organization (McGill, et.all,1992). Many efforts to change focus on the creation of a learning organization (Senge,1990; Senge et.al, 1994; Lessem, 1991). As mentioned earlier, learning can come up in the form of error correction or in the re-examination of the thought that led to a mistake in the first place (Revans,1982). According to Dogson (1993), individuals are primary entities of learning in an organization, and it is them who create organizational forms that enhance learning and organizational "transformation". Therefore, change is embedded in the learning procedures of an organization, involving all human resources, and it happens there, where job execution requires from individuals to adopt new attitudes and skills, focusing on innovation and development of their capacities (Bokeno,2008).

With the adoption of clear goals and mission, with the commitment of leadership and empowerment, with experimentation, reward, team work and problem resolution, and with effective knowledge transfer, organizations enhance their learning ability and engage themselves in a constant process of change (Goh,2003; Gorelick,et.al,2004). And this ability of continuous learning, and consequently of continuous change, consist an imperative need for organizations who desire to acquire a competitive advantage (DeGeus,1988).

Achieving a competitive advantage requires from organizations to learn fast and effectively from successes and failures (Goh & Richards,1997). According to Belasen (2000), organizations are open, adaptable systems, which operate in a way that inputs of data both from the external or the internal environment, are modified to outputs of products or services. The result reflects the value that the organization adds transforming inputs into outputs. The organization adjusts, through feedback exploitation and modulation of processes and finally, improves its effectiveness. From all the above it is obvious that OL is a mean to achieve sustainability and improve effectiveness. The key is to utilize the organization's talent by engagement and commitment in all functions and all levels inside the organization (Akhavan & Jafari, 2006).

Škerlavaj et.al (2007) in a study in Slovenia investigated the concept of organizational learning culture (OLC) and its link to organizational performance. Organizational learning culture was defined as "a set of norms and values about the functioning of an organization". The authors find a strong relationship between OLC and financial and non-financial performance. Another study in ex-Soviet republic of Estonia found that successful implementations of change and organizational learning were positively correlated with both individual active-ness and collaboration with a clear distinction between manufacturing and service sector as far as levels of individual active-ness and collaboration. The authors argue that "encouraging learning and individual initiative as the key to translating strategy into action successfully" (Alas &Sharifi, 2002).

Total Quality Management could become the vehicle to effective diffusion of knowledge and evolvement of firms into learning organizations (Sohal & Morrison,1995). Organizational learning, in its turn, is the corner stone of total quality management and contributes radically to the creation of a quality culture, that focuses on the satisfaction of both internal and external customers (McAdam et.al1998), R., Leitch, C., and Harrison, R. (1998). Furthermore, Ford & Evans (2001) states that the Malcolm Baldrige Award model in the US, "encourages organizational learning, particularly learning of the double-loop variety, that results in the adjustment of the processes used by the firm to develop and implement strategic change". Change can be

CONCLUSIONS AND FURTHER RESEARCH

It is clear that through the "alliance" of Total Quality Management and Organizational Learning, the organization's ability to adapt to the demands of the modern environment is improved, a culture of change is developed, and ultimately leads to the achievement of competitive advantage and improved efficiency. By adopting clear goals and mission, leadership commitment and empowerment, experimentation, reward, teamwork and problem solving, and effective knowledge transfer, organizations enhance learning ability and engage in a continuous process of change (Goh,2003; Gorelick,et.al,2004).

The authors are aligned with Dogson (1993) stating that individuals are the primary learning entities in organizations, and they are the individuals who create the organizational forms that facilitate learning and organizational 'transformation'. Change, therefore, is embedded in an organization's learning processes, encompassing all its human resources, and occurs where performing work tasks requires individuals to acquire new behaviors and skills, focusing on innovation and developing their capabilities. In that notion TQM provides the "platform" and the framework for integrating OL into the organization by changing its structure, strategy and policies towards a "learning-oriented" philosophy.

From the above analysis it is clear that the TQM-OL-Change relationship is very dynamic and complex and worth examining discussing. It is also obvious that a more thorough literature review based on a Systematic Literature Review (SLR) methodology will shed light and provide the basis for the development of a conceptual framework. This paper is part of a larger scale research which is aimed to empirically evaluate the above relationship in selected organizations in Greece.

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A Framework to Support Quality Data Mart Solutions: an approach developed based on practical cases

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STRUCTURED ABSTRACT

Purpose – Today, due to the large amount of data available in companies, solutions for extracting information and knowledge to support decision-making processes are needed. To address this issue, data mart implementation with proper dashboard can represent good solutions. However, due to the complexity involved in this kind of projects and its multidisciplinary nature, appropriate methodologies for conducting data mart development are needed. The present study aims to propose a framework to guide the process of development of quality data marts in a Portuguese electronics company.

Methodology – The methodology used to conduct this study combined the principles of two well-known approaches – DMAIC and BPM. The first was useful in addressing and understanding the problem, while the second was used to guide the process. Two practical cases were used, the first as an experimental scenario and the second one as a testing scenario.

Findings – The main result of this study is a ready to use framework to guide industrialization teams in development of quality data marts to help users in their decision-making processes.

Originality/value – As there are no standard procedures available for companies to implement quality data mart solutions, the proposed framework, which is easy to apply, can be a valuable tool

when a company wants to industrialize a new product. It can also be valuable for researchers working at the interface of the Quality and Information Systems areas.

Keywords: Quality, Data Mart, DMAIC, BPM lifecycle, BPMN 2.0

Paper type: Case Study

INTRODUCTION

With the developments in the field of Information Technologies (IT), detailed data regarding products, processes, collaborators, clients, suppliers, and other company's stakeholders are easy to get and to store. Nevertheless, if the data is not appropriately processed, it is not possible to obtain the necessary information to support decision making at the various levels in the organizational context. Therefore, more and more, companies look for ways to take advantage of this reality and to have data-driven decisions and actions.

With the massive amount of data available today and the simplicity to access it, such important projects of knowledge discovery can be supported (Maimon and Rokach, 2010). Searching through a large amount of data stored in repositories, corporate databases, and data warehouses, is usually a difficult task when appropriate solutions are not considered. Concerning this issue, data mart implementation can be suitable solutions that can be applied in diverse industrial fields, like quality control, process optimization, human factors, job shop scheduling, material handling, maintenance, reliability of production systems (Soroush Rohanizadeh & Moghadam, 2009).

The raw data available at the servers is not sufficient for the stakeholders to have an overview of products and processes. In order to support them, business intelligence tools like dashboards, data marts and data analytics can be used to extract the information from the available data. Moreover, data needs to be cleaned, analysed and distributed in such a way that it provides useful information.

Given the large amount of data that organizations usually collect and the need to convert that data into information, having appropriate methodologies for guiding the development of business intelligence solutions can help companies handle with this issue.

Usually, companies do not have a clear way on how to execute and create quality data marts. Neither the steps, nor who is responsible for executing them or when should each one be performed are defined. This situation leads to difficulties related to the ambiguity on the way of working.

The aim of this study is thus, to propose a framework to support the process of development of quality data marts. The process' conceptualization was based on two real cases at the industrialization phase, from a Portuguese plant operating in the electronics industry.

This paper is structured in five sections. In the current section, the relevance and the aim of the paper are highlighted. Next, a brief discussion of some relevant concepts based on literature review, emphasizing the topics of Data Mart, BPM lifecycle and DMAIC process is introduced. Then, the methodology used to conduct the study is described, combining the BPM lifecycle and DMAIC approaches and using two cases in order to develop and to test the framework. In the results section, a framework to guide the process of quality data marts development is presented. Lastly, in the conclusions section, final remarks, including some limitations of the study, and suggestions for further research are described.

THEORETICAL BACKGROUND

This chapter highlights the fundamental concepts to understand the domain of the problem under study and the approaches adopted to solve it. Thus, a brief reference to the data marts will be made, since this represents the main frame on which the solution will be developed. Next, for a better understanding of the approach adopted to solve the problem, BPM lifecycle and DMAIC process will also be addressed.

Data Mart

A data warehouse is described as "a subject-oriented, integrated, time-variant, non-volatile collection of data in support of management's decision-making process" (Inmon, 2002, p. 54). It contains data from a large number of diverse sources at the company or even external sources. With the purpose of supporting decision-making processes, the data warehouses differ from the organization operation systems that aim to support the daily business processes. This difference has a big impact on which data is stored and how it is stored. The concept of a data mart is generally described as a subset of a data warehouse. While the data warehouse stores data from diverse subjects of the entire organization the data mart keeps data about a single topic, for example, sales or quality (Jensen, Pedersen, & Thomsen, 2010, p. 32).

Hamoud et al. (2020) present a data mart built with the focus to improve decision making about human resources. Another model is presented by Hamoud, Hussien, et al. (2020), with the aim to improve service quality by analyzing complaints data. Data marts are also designed with the aim to support further analysis, as the data mart developed by Park et al. (2020), which stores data needed to apply programming constraints to support scheduling activities.

Data marts are built as "systems for decision support, to obtain conclusions based on the analyzed pattern of data to the decision maker(s) of the organization" (Jayashree and Priya, 2020).

BPM Lifecycle

A business process is defined by Dumas, Marcello, Mendling, & Reijers (2018, p. 6) "as a collection of inter-related events, activities and decision points that involve a number of actors and objects, and that collectively lead to an outcome that is of value to at least one customer." Several authors affirm that organizations' survival depends on the good understanding of their business processes (Ouali, Mhiri and Bouzguenda, 2016).

Business Process Management (BPM) is a broad field that focuses on improving the performance of business processes with the aim of enhancing the organizational operational performance, increasing productivity and reducing costs. It applies knowledge from different areas, such as information technology and management (Chinosi and Trombetta, 2012; Aalst, 2013; Dumas *et al.*, 2018; Geiger *et al.*, 2018).

Dumas et al. (2018, p. 28) clarify that "BPM is a body of principles, methods and tools to discover, analyse, redesign, implement and monitor business processes". The BPM lifecycle supports organizations to better manage their processes and consists of the six phases presented in Figure 1.

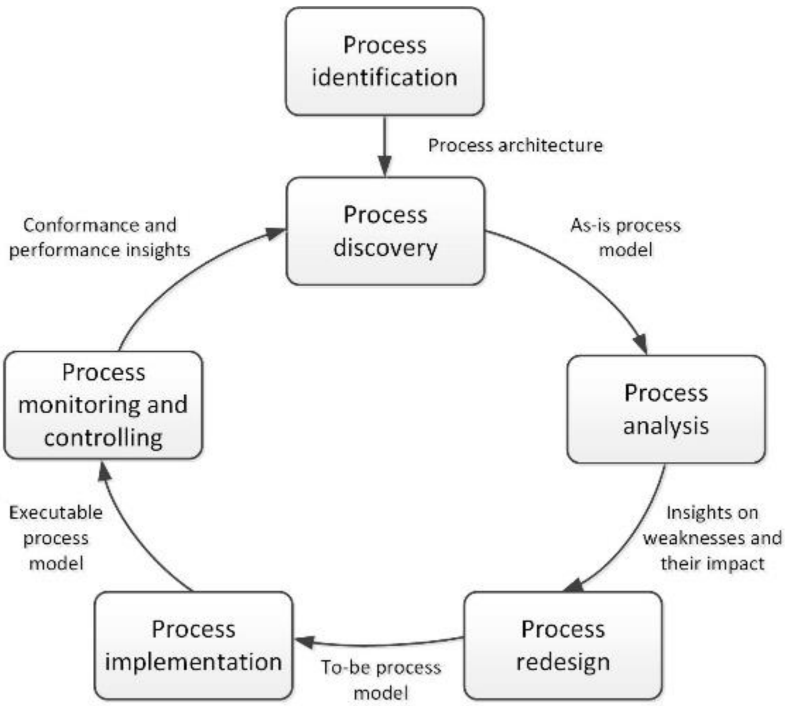

Figure 1 - BPM lifecycle (Dumas *et al.*, 2018)

BPM lifecycle starts by identifying the processes to be studied. It is important to define the problem to be solved and to identify the processes involved before starting to analyse them. Besides that, the scope and the relations with other processes need to be defined. The performance indicators should be identified to give quantitative information of the state of the problem and the process. Occasionally, this step is part of the analysis phase since the data is more relevant at that moment. The second phase is the process discovery, where a deeper understanding of how the work is done is acquired. As an outcome, one or more As-is models of the process are done. It is in this phase that process modelling techniques are applied. In the third phase, process analysis is done with the goal of assessing possible issues and opportunities to improve it. The next phase focuses on "[identifying] and [analysing] potential remedies for these issues" (Dumas et al., 2018, p. 20). It results in a redesigned process to be implemented in the next phase. The implementation phase consists of making the necessary changes to reach the To-be process.

These changes address mostly two complementary areas: (i) organizational change management, that deals with adapting established working methods and (ii) process automation, that requires an investment on the organization's IT level (Dumas et al., 2018, p. 23). After the implementation phase, the process needs to be continuously monitored in order to ensure its performance. Finally, the monitoring and controlling phase, a restart of the lifecycle and a new discovery, analysis and redesign of the process are performed, as shown in Figure 1.

To support the representation of As-is and To-be processes, the Business Process Model and Notation (BPMN 2.0), developed by Object Management Group, is usually applied. (Object Management Group, 2011).

DMAIC process

The DMAIC process is used as a roadmap for projects with that aim at improving a process and consist of five phases: Define, Measure, Analyse, Improve and Control (Council for Six Sigma Certification, 2018). The American Society for Quality defines it as "a data-driven quality strategy for improving processes" (ASQ, 2020). Although it is mostly associated with six sigma projects, the DMAIC method is a very flexible and general problem-solving procedure and can be applied in different contexts (Montgomery, 2019).

Even though it is mostly presented as a linear process, DMAIC has an interactive problem-solving approach allowing to get back to earlier steps, which brings to this method a generalized and powerful framework to think about problems (Smith and Phadke, 2005).

Each phase has its focus and a set of recommended tools to be applied. Two of the characteristics of this solving problem method are the application of statistical tools and the purpose to bring data to the decisions and validation of ideas. "The DMAIC framework utilizes control charts, design of experiments, process capability analysis, measurement systems capability studies, and many other basic statistical tools" (Montgomery, 2019, p. 29).

The DMAIC process starts by defining the problem to be addressed. First, a framework for the project is done by defining the goals, the resources needed, the team involved, the process and the environment where the problem occurs. To map the process, tools such as Value Stream Mapping (VSM) and SIPOC (suppliers-inputs-process-outputs-customers) analysis are applied. To understand the customer's expectation towards the project, tools as the Voice Of the Customer (VOC) are used. All this information should be used to create a project chart, a one page document that summarizes the project plan and main objectives.

The Measure phase aims to assess the current performance of the process. Therefore, Critical To Quality (CTQ) characteristics of the process are identified and measured. Output and quality performances are also measured by conducting Pareto analysis and capability studies, to understand, for example, defect frequencies. The initial situation is described and a baseline performance is specified providing an understanding of the initial situation.

During the Analyse phase, the focus is on identifying influencing factors of the CTQ and the root causes of their behaviour. For the root cause analysis, Failure Mode and Effect Analysis (FMEA) and hypothesis testing are some of the tools that can be applied.

During the Improve phase, the root causes identified are addressed. Adjustments are designed and implemented in order to improve the process's performance. In this phase, the ideas to improve the process are validated. Payoff effort matrix, Design Of Experiments (DOE) and kaizen events are applied during this phase.

At the last step, the outcome is controlled and revised. Quality control plans are constructed to support the monitorization of the improvements made. Statistical Process Control, visual control with 5Ss, and mistake-proofing tools are applied.

RESEARCH METODOLOGHY

This study consisted in the development and validation of a framework to implement data marts that support quality functions (quality data marts), based on two practical cases.

Figure 2 illustrates the methodology used, where the phases of DMAIC and BPM can be visualized, as well as the cases where the last one was used. It is important to note that during this study two practical cases were developed - Case 1 and Case 2 - and each one played a different role in the project. Case 1 was used to discover the process and to understand how the quality data mart should be performed, being used as a valuable input to develop the proposed framework. Case 2 was used to validate and to refine the framework. Note that Case 2 refers to a more complex product, requiring a more complex manufacturing process.

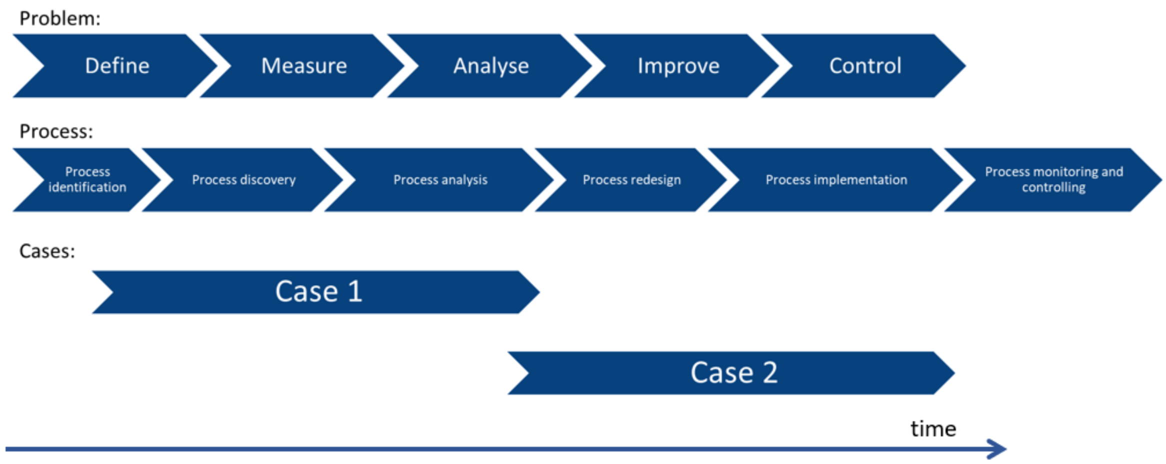

Figure 2 - Methodology Timeline

Although the DMAIC method is mostly known for its usage on lean six sigma projects that aims to reduce the variance of a process, this method can also be applied to a big variety of structure and semi-structured problems. In their study, De Mast & Lokkerbol (2012, p. 10) conclude that “DMAIC is suitable for rather extensive problem-solving tasks, requiring all of the components of problem definition, diagnosis and the design of remedies”. Therefore, the DMAIC was chosen to be the problem-solving method.

Integrated with the DMAIC process, the BPM lifecycle was applied in order to develop the quality data marts’ framework. The activities performed in each phase are described next.

The first phase aims to define the problem at hand. Before addressing the problem, itself, an initial onboarding period took place, with training sessions about the work dynamics at the company. After that, the project opportunity was further presented, which also corresponded to the process identification step. The goals and scope of the project were defined. The methodology to follow during the project was then studied and the plan of activities, its milestones and timeline were designed.

At the second phase, the aim was to assess the current situation by defining and measuring key points of the problem. Therefore, during this phase, a characterization of the current conditions was done, together with the definition of the baseline state and the desired state. It was also during this phase that the process discovery phase happened together with the beginning of the first case.

Afterwards, at the analysis phase, several points of the problem related to IT, the quality and the execution perspective were analysed. The aim of these analyses was to obtain a better understanding of the problem and its causes in order to solve it.

At the improvement phase, the ideas and solutions to the problems identified earlier were implemented. It was during this phase that the process redesign and implementation were performed, simultaneously with the beginning of Case 2.

In the last phase, the impact of the improvement actions should be evaluated, the use of dashboards should be assessed, and a revision and conclusion of the project should be done.

RESULTS: PROPOSED FRAMEWORK

As the main result of this project, a framework to create a quality data mart was proposed, based on the study performed and experience acquired while implementing two practical cases, Case 1 and Case 2. This framework was divided into four main steps: project definition, data provision, dashboard design and deployment, each representing a project milestone, as can be seen in Figure .

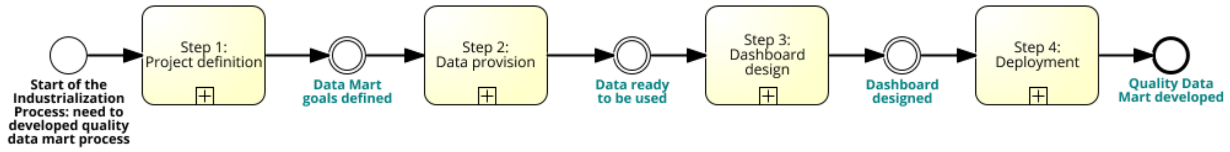

Figure 3 - Quality data mart framework steps

In the following sections, each step is going to be described in detail, using BPMN 2.0. As can be seen in the representation of Figure 4, there are three actors actively involved in this process, represented by lanes - the quality engineer, the data mart responsible and the test engineer - so as to illustrate their responsibilities through the development of the quality data marts. It is important to note that the detail chosen had in consideration the aim of the representation, that is to illustrate the activities needed to develop the quality data mart. In the descriptions below, more context is presented.

The process starts with the need to develop the quality data mart that comes from the industrialization of a new product. Step 1, shown in Figure , is about the definition of the project.

The responsible for developing the data mart should obtain knowledge about the product, by reading the available documents, by direct observation and by interacting with the collaborators involved in the production. Here the quality engineer has the role to support the data mart responsible to obtain the necessary insights about the product and its production. With all the insights gathered, the goals for the project, as the timeline and team involved are defined. Then the sailboat diagram is built, by defining the strategical, the user goals and the system requirements. The sailboat diagram serves as a graphic way to represent the different goals and uses cases. Not only supports to structure the goals but also to define what are the functionalities needed for the dashboard in order to fulfil the goals. It also serves as a communication tool for showing the purpose of the dashboard, presenting not only the high-level goals but also to present the functionalities and the data needed by IT engineers, when building the data strategy plan (Cockburn, 1999).

This main step is finished by having the goals and the sailboat diagram defined and approved by the quality engineer.

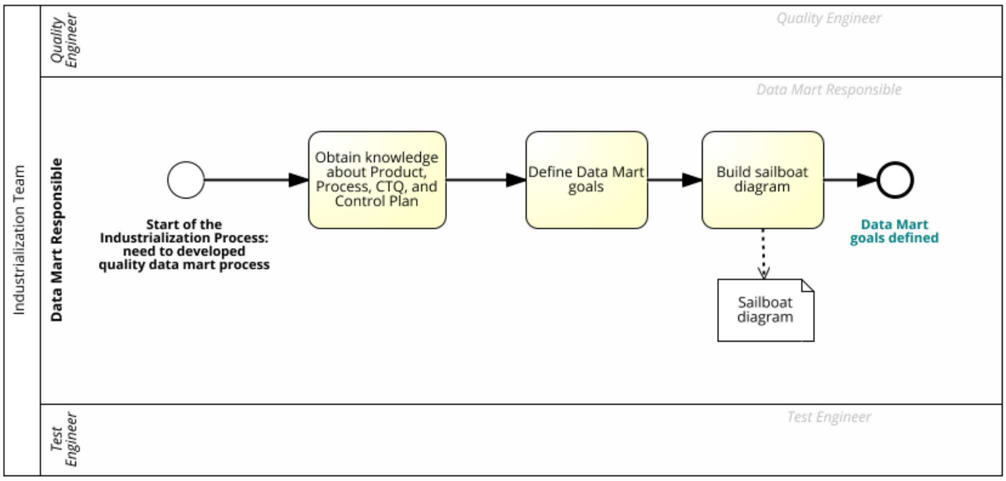

Figure 4 - Step 1: Project definition

Step 2, shown in Figure , describes the stages followed to provide the data necessary for the dash board creation. After the measurement equipment and tests equipment are ready to use and the data is stored, the data mart's responsible has the conditions to explore the data available. An evaluation of the data collected should be done to ensure its quality and if it is sufficient for the analyses needed, followed by an exploratory data analysis, giving data mart's responsible more sensibility and understanding of the data. Simultaneously, the data strategy plan should be developed by defining data access and flow from the production to the software to be used in implementing the data mart (e.g. Microsoft Power BI). Following, the plan has to be implemented in order to have access to the data and to define its structure. After these two activities, the extract-transform-load (ETL) tasks can be performed, ending the second step with the data prepared, connected and modelled, ready to be used in the data mart.

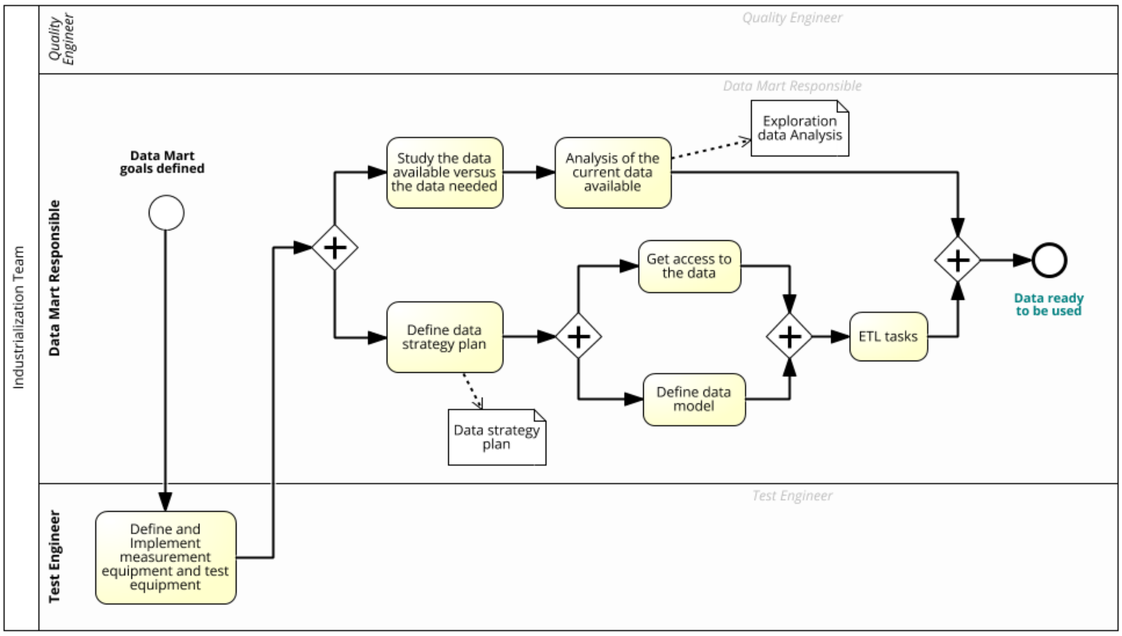

Figure 5 - Step 2: Data provision

In Step 3, represented in Figure 6, the design of the data mart is performed. It starts with the definition of the number of required pages, based on the needs and goals defined at the sailboat diagram during the first step. Then, each page visuals are created. This stage consists of selecting the right graphs, measures and indicators which are made in the software tool being used in implementing the data mart, followed by the definition and integration of the filters for the page. Once all the pages are created, the responsible for the data mart needs to consider the user experience and the application of design and visualization principles. The first draft is presented to the quality engineer for feedback and when all the needed feedback loops are concluded and both the quality engineer and the data mart responsible are satisfied, the third step is concluded.

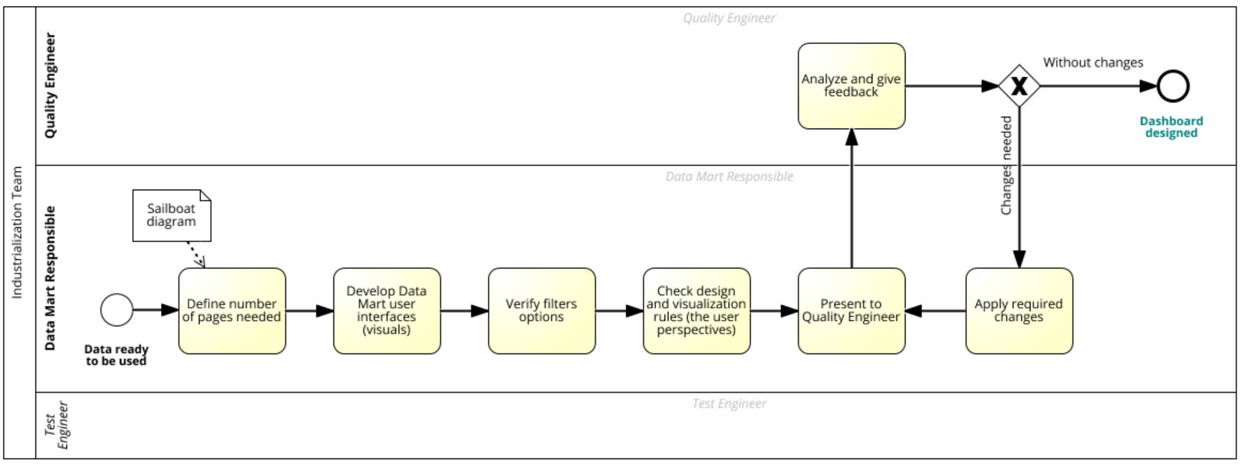

Figure 6 - Step 3: Dashboard design

Step 4, that is represented in Figure 7, focus on deploying the dashboard to the team. It consists of presenting the dashboard, gather feedback and evaluate its usage and overall experience, making the necessary adjustments before publishing it. At this step, the documentation of the project should be finalized, concluding the project.

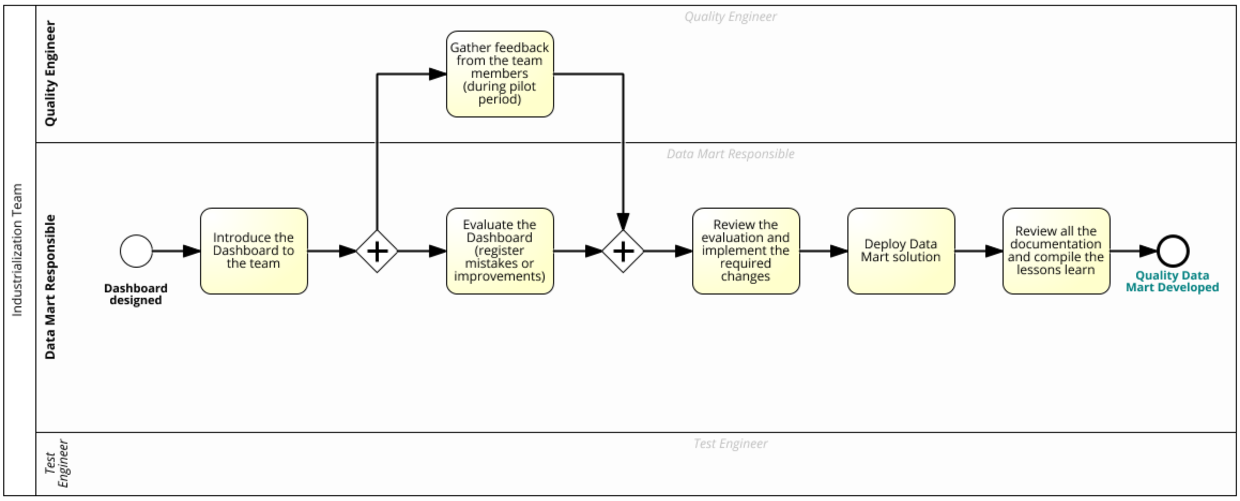

Figure 7 - Step 4: Deployment

During the execution of the quality data marts, its main developments should be documented. Therefore, it is suggested that an executive summary is elaborated along the process, where all the documents and progress are recorded.

Although the framework steps were presented one by one, it should be noticed that the use of the framework implies the steps integration and interconnection and thus they cannot be performed separately.

CONCLUSIONS

The framework proposed to develop the quality data mart consists of four main steps. The first step focusses on defining the project, by getting to know the product under analysis and defining the goals. The second step focusses on the data, by conducting an exploratory data analysis and performing ETL tasks. With the data ready to be used, the dashboard interface is designed in the third step. The last step consists of collecting feedback from the team and deploying the quality data mart. This framework should be executed during the industrialization period of the product.

To develop the quality data mart framework, Case 1 was used as an experiment and source of information, while Case 2 was used to validate the proposed framework.

One limitation faced during the study was that, due to time constrains, Case 2 could not be finished. Thus, as future work it is suggested to finish developing the Case 2 data mart and to refine and validate the framework developed.

Another limitation is that it was not possible to evaluate the impact of the proposed framework, since the causes of an easier execution of Case 2 can be associated with the experience gained from the quality data mart responsible and/or having a framework to follow. To address this issue, it is recommended the framework to be applied by a collaborator that does not have experience developing this type of quality data marts making possible to evaluate its effectiveness.

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Operational Excellence Using Heuristics: Exploratory Study

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ABSTRACT

Purpose*:* Decision-making under complexities and uncertainty environment leads to the use of heuristics. Heuristics is a form of decision-making that occurs when problems become more complicated. There are different forms of decision-making: heuristics, satisficing, maximization, muddling through, and improvisation. In this research paper, the context of heuristics and its effect on making decisions are being discussed. A closer look into literature review on heuristics and satisficing has led to study how and in which conditions they are applied in organizations. Moreover, the impact of operational excellence models like Malcolm Baldrige and European Foundation for Quality Management (EFQM) on decision-making is also demonstrated.

Design/methodology/approach: A case study from Dubai Police is analyzed and discussed in order to integrate the operational excellence into decision-making. A number of 250 questionnaires were distributed on different Dubai Police departments and 175 questionnaires were obtained.

Findings: It is concluded that decisions taken by managers for operational excellence are positively correlated to the organizations' excellence. Furthermore, the decision-making can be also influenced if applied in dark triad, the case of emergency, or in case of ignorance.

Research limitations/implications: Applying heuristics tool can result in some biases. Hence, certain tactics can be used to mitigate the biases resulted from heuristics.

Originality/value: This research paper demonstrates the case study of Dubai Police to examine the positive effect of organization's excellence on decisions taken by managers for improving performance and ensuring continuous improvement meeting its strategic plans.

Keywords: Heuristics, Operational Excellence, Malcolm Baldrige, EFQM.

INTRODUCTION

Due to the high uncertainty and complicated conditions we face on daily basis, decision-making in organizations has become a challenging job. The literature review have discussed several studies on project management and suggested different decision-making tools. These tools can be used such as heuristics, satificing, maximizing, muddling through and improvisation. Heuristics, also called rules of thumb (Tversky and Kahneman, 1974), is a practical method to solve problems to reach the desired goals regardless whether it is irrational, illogical, or imperfect (Tversky and Kahneman, 1974), (McCray et al., 2002). Heuristics can appear in these forms: representativeness, availability, adjusting and anchoring (Tversky and Kahneman, 1974). Satisficing is taking the first logical decision to solve a complex problem with no prior preparation and with minimal time (McCray et al., 2002). Maximization is getting the best solution among the alternatives after time being taken to study the alternatives (McCray et al., 2002). For example, choosing the highest quality products with least cost after taking time for this study. Muddling through is the process of comparing the next state to the previous one (Eriksson and Kadefors, 2017). Decision makers in muddling through take an option, study the consequences, and move on if the results are logical. If not, they move backward again to the previous state and another option is chosen and so on. The last form of decision-making is improvisation. If bodies of knowledge failed to give a suitable view for decision makers, then improvisation is used. Improvisation is going away from a plan proposed by the manager previously to start another one that suits the situation (Schwartz et al., 2011). Applying heuristics to decision making may result in certain biases that need to be mitigated by some tactics. Hence, decisions taken in black triad and in ignorance situations and in emergency cases are discussed.

BACKGROUND

Heuristics is a number of decisions that people make to solve their complexities. When there are complexities and uncertainties, more probabilities exist and taking decisions becomes a more complicated task. Therefore, heuristics considered as one of the possible solutions. It has several forms; one of them can be “satisficing”, which is adopting the first logical decision in a complex situation depending on different factors. Other types of heuristics may be representativeness, availability, adjustment and anchoring (Eriksson and Kadefors, 2017). Satisficing can be affected be one’s personal experience and lack of other choices. There are advantages and disadvantages of using heuristics. Some of the advantages may be giving reasonable solutions in a reduced time. On the other hand, the existence of some biases and serious errors that appear due to fast and unplanned decisions can be the disadvantages of heuristics.

In this research paper, the business excellence models such as Malcolm Baldrige and European Foundation for Quality Management (EFQM) are used to enhance performance and ensure continuous improvement. Dubai Police case study is real example of integrating operational excellence into decision-making (Al-Dhaafri et al., 2016).

Decision-making is a vital strategy in our lives and in any organization. As a result, this study is important in solving complex problems in projects, facilitating every day's life, adding strategic values to project management and other disciplines. This research paper also highlights the effect of these heuristics in the case of dark triad, ignorance and emergencies (D'Souza and Franco de Lima, 2015), (Komazec et al., 2014).

LITERATURE REVIEW

A decision is an action towards a certain situation. It consists of three parts: choice, expectations and consequences (Goodrich et al., 1998). Decisions also can be conscious, sub-conscious, and non-conscious (Goodrich et al., 1998). Three types of decision-making were introduced: normative, descriptive and prescriptive (Jain et al., 2013). Normative decision-making gives managers decisions they should follow. Descriptive decisions making describes how managers are deciding. On the other hand, prescriptive decision-making is a comparison between what decisions that should be followed and what is actually decided (Schwartz et al., 2011). There are certain factors affecting decisions like project role, age and experience of managers as well as cultural intelligence (Payan, 2020).

Decision-Making Concepts

Due to the various mentioned factors, organizations face troubles with the increasing complexities and uncertainties. Under these complexities, decision-making became a difficult task. Tversky and Kahneman introduced decision-making concepts like heuristics (or rules of thumb) [9]. Heuristics' role is to simplify complex tasks to help managers predict probabilities in order to give simple judgments (Payan, 2020). Heuristics are represented of three forms: representativeness, availability, adjusting and anchoring.

Representativeness is a form of heuristics where a small sample is considered to represent a larger sample. For example, engineers are known for their interest in mathematics, however, there may come an engineer that disproves this stereotype (Eriksson and Kadefors, 2017). Factors that lead to representativeness heuristics can be insensitivity to prior probability of outcomes, which means if there is no proof, prior probabilities are used. However, if there is a proof, then prior probabilities are ignored (McCray et al., 2002). Moreover, misconceptions of chance refers to a small sample that is studied and its findings are generalized to larger samples' findings. The illusion of validity and misconceptions of regression are also other factors that lead to representativeness heuristics (Schwartz et al., 2011).

Availability is the probability of event whose occurrences directly comes to the mind (Schwartz et al., 2011). For example, if a question is asked about the most severe killing disease, people whose answer is cancer are most probably those who had prior experience with people that died from cancer. Factors leading to availability can be (Payan, 2020): Biases due to retrieved instances, biases due to the effectiveness of a search set and biases of what can be imagined (Payan, 2020).

Adjustment and Anchoring are building a final decision or estimating in relevance or starting from another initial estimate (Schwartz et al., 2011). Different initial values may lead to different final estimates.

Satisficing is taking the first reasonable and satisfactory decision (good enough with no need to be optimal) to solve a problem without taking time to prepare and plan (Payan, 2020). Robust satisficing is a type of satisficing that deals with normative decision-making (Schwartz et al., 2011). The second project manager of the Sweden transport used satisficing heuristic as a deliberate strategy for implementing rail tunnel (Schwartz et al., 2011). This project examines the role of rules of thumb (or heuristics) to design routines in large infrastructure projects (Payan, 2020). Satisficing heuristic was vital for decisions related to organizing projects. In this project, satisficing showed low validity. Results from the study can be simple and the shared heuristics can be named as catchphrases or mantras. As a result, they developed new practices, raised awareness and tested in a new area (Goodrich et al., 1998).

Goodrich, Sterling and Frost designed satisficing controls to aid managers in no linear dynamic situations with lack of information limited time, and limited rationality (Goodrich et al., 1998).

Maximization is choosing the best decision after planning and taking time for studying. Sometimes, it is not efficient because time maybe spent and the decision turns out as not being the best.

Jain, Bearden and Filipowicz made a study to compare the performance of maximizers and satisficing (Jain, 2013). Their study was to predict the outcome of 2010 Fifa World Cup (Jain, 2013). Because of this study, they concluded that maximizers were less calibrated than satisfiers. Satisfiers gained advantage over maximizers since their predictions contained less noise (time and effort spent to get the best option). Time taken by maximizers turned out to be less productive (Jain, 2013).

Improvisation comes to do the task when bodies of knowledge fail to solve complex problems. It is affected by time limit and pressure. Managers go away from planned agreement into a spontaneous response to a certain situation. Improvisation consists of intuition, creativity, and bricolage (things created from diversity) (Payan, 2020).

Muddling Through is selecting options similar to the initial one. If difficulties disappear, the path is continues, else a different option is chosen (Payan, 2020).

Decision-Making in Project Life Cycle

Heuristics can be applied in the forecast phase, execution, and after the project is completed. The project life cycle consists of initiation, planning, execution, control and closeout. Initiation and planning phases and execution and control phases are combined together when studying the effect of heuristics (McCray, 2002). Information systems projects were examples of applying these heuristics in projects life cycle (Erikson and Kadefors, 2017).

Heuristics and biases during initiation examples can include inappropriate comparisons of previous experiences, misinterpretation of data, anchoring, failure to consider alternatives, and narrow beliefs as doctrine. The latest is when someone sticks to his belief based on a previous experience regardless of its applicability in the current situation. Impact of these heuristics during this phase will be over or under estimation of cost, time and work requirements (Erikson and Kadefors, 2017), (Schwartz et al., 2011)

Heuristics and biases during execution and control examples can be over confidence, bounded rationality, preference for details and gamble's fallacy. It refers to wrong beliefs caused by repetitive negative events. Biases in this phase can result in ill-fated projects, irrational reasoning for unpredicted outcomes (Payan, 2020).

Heuristics and biases during closeout effect are minimal, yet problems may appear in the future (Payan, 2020). The hindsight bias is the concept in which the result of projects is predicted before the beginning of the project. This creates over confidence in one's ability (Tversky and Kahneman, 1974), (Erikson and Kadefors, 2017).

These forms of decision-making help managers lead to some drawbacks like biases. Project manager should know an efficient way to mitigate negative impact or biases resulted from heuristics before a project fails. This can be done by specifying objectives and methods clearly and planning an oversight. Moreover, sharing project manager process with team members and preparing more than one applicable backup plan to the project or process will help to handle the biases. In addition, building an oversight team within the organization that plans the projects and prepares backup and emergency plans is another tactic that manager can apply (Komazec et al., 2014), (Goodrich et al., 1998)

Business Excellence Models

Organizations need to assess and evaluate its performance regularly to ensure quality and continuous improvement. Decision makers adopt some business excellence frameworks such as Malcolm Baldrige (Rao Tummala and Tang, 1996), (Rahayu et al., 2019), Dubai Business Excellence Model 4G [17] and European Framework for Quality Management (EFQM) (Hıdıroğlu, 2019), (Rao Tummala and Tang, 1996).

Malcolm Baldrige business excellence depends on seven criteria: leadership, strategic planning, customer and market focus, management analysis, management of knowledge, human resources focus, process management, and business results (Arezki and Elhissi, 2018), (Rahayu et al., 2019). Malcolm Baldrige framework is applied to different industries and in different countries worldwide. First few years from 1987 to1992, Malcolm was widely applied in the manufacturing industry (Miller and Parast, 2018). Moreover, it is applied in education (Rahayu et al., 2019), and healthcare (Edi Wahyudi and Yuliantry Permanasari, 2018), (Goldstein and Schweikhart, 2002).

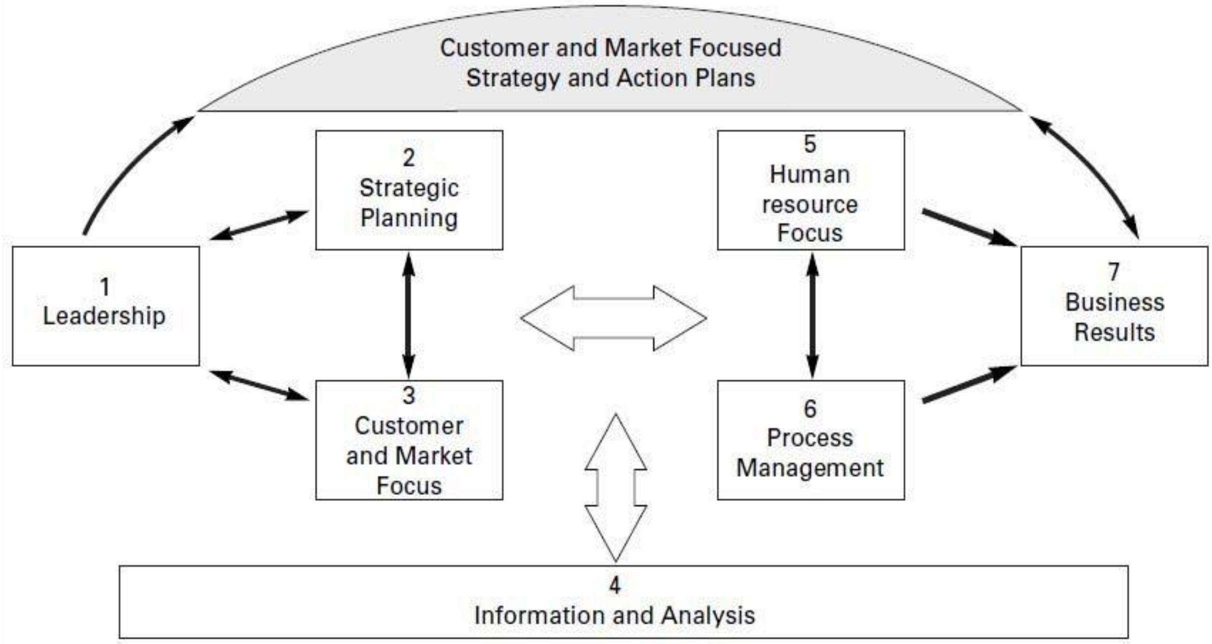

Figure 1: Malcolm Baldrige Framework (Arezki and Elhissi, 2018).

The above figure shows Malcolm Baldrige framework with its criteria. Malcolm Baldrige framework uses methods of ADLI in the process criteria of the Malcolm framework. ADLI stands for Approach, Deployment, Learning, and Integration. This framework was used due to its comprehensive approach and its effectiveness. The outcome criteria deal with results and the used methods are LeCTI, which stands for Level trend, comparison and integration (Rahayu et al., 2019), (Goldstein and Schweikhart, 2002).

The other business excellence model that can be used is the European Framework Quality Management (EFQM). It is a business excellence model to meet the sustainability of the stakeholders of an organization. EFQM self-assessment can be applied in different sectors such as education information technology (Jaeger and Matyas, 2016).

EFQM framework is made up of the following main principles: Result orientation, customer orientation, leadership and consistency of objectives, management by processes and facts, the development and involvement of people, the development of partnerships and the social responsibility of the organizations (Jaeger and Matyas, 2016), (Suárez et al., 2017).

To implement these principles, we need three phases: Initiation phase, realization phase and maturity phase (Suárez et al., 2017). EFQM has nine criteria divided into two categories, which are enablers and results. Enablers' criteria are responsible for key activities management. On the other hand, results criteria are responsible for the way the results of an organization are achieved. These criteria include Leadership, Strategy, people, alliances, resources, processes, products, and services (Suárez et al., 2017).

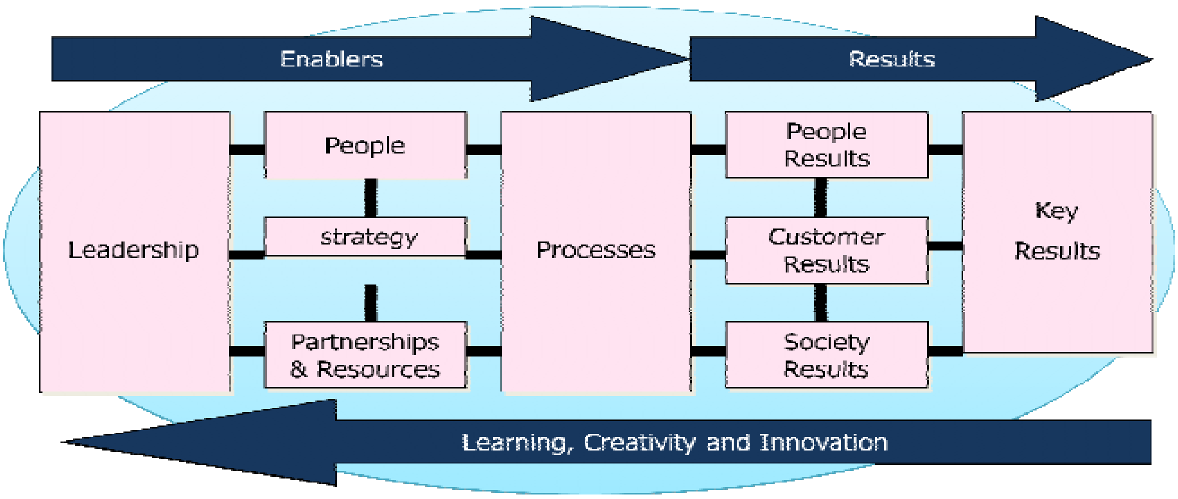

Figure 2: Old EFQM Framework (Suárez et al., 2017).

Figure 2 shows the EFQM framework and its criteria, which are grouped into enablers and results.

The latest version of EFQM (Nenadál, 2020) is represented by Figure 3. It has three main dimensions with seven criteria. The dimensions are direction (why to implement the new framework), execution (how to implement), and results (what is obtained as an outcome) (Nenadál, 2020).

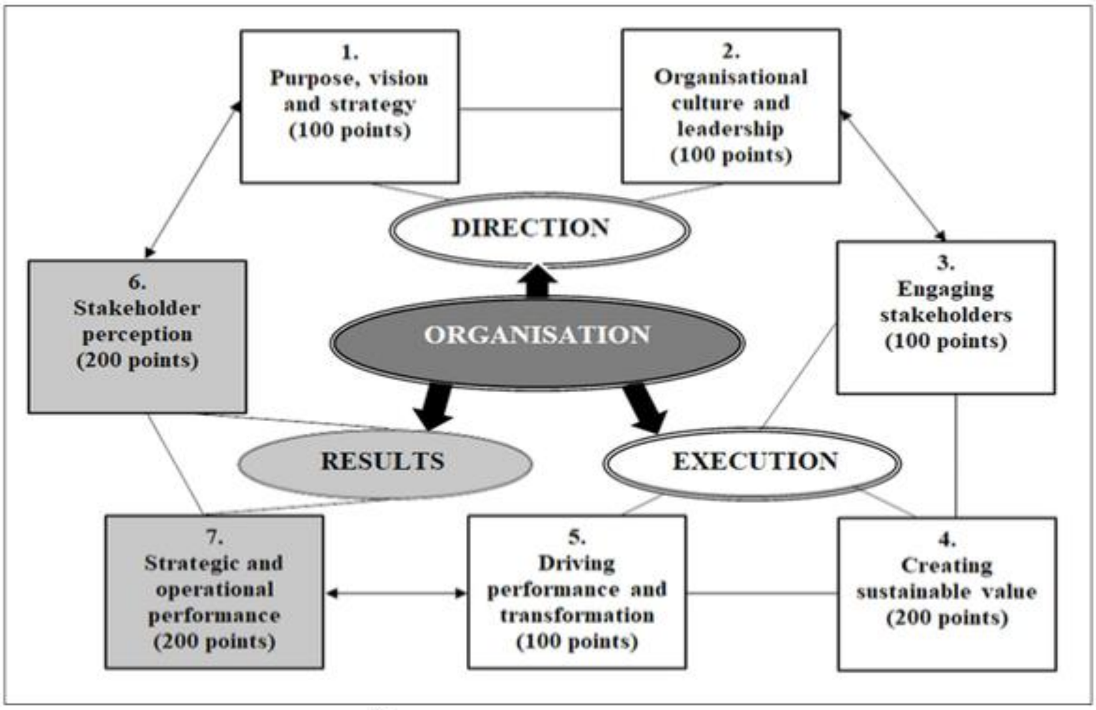

Figure3: New EFQM Framework (Nenadál, 2020).

The framework consists of seven criteria: purpose, vision and strategy, organizational culture and leadership, engaging stakeholders, creating sustainable value, driving performance and transformation, stakeholder perception, strategic and operational performance (Nenadál, 2020).

There are advantages of the new EFQM model implementations. It maintains sustainability, cause and effect relationships are more obvious and accepted by managers and academics and results regarding stakeholders perceptions are concentrated on criterion six, rather than scattered on three different result criteria (Nenadál, 2020).

Another form of business excellence framework is the 4G framework that is adopted and implemented by the Dubai Police as business excellence framework in its operations. This framework is made up of three main pillars: achieving vision, innovation and enablers. Each pillar consists of a number of criteria. The first pillar (60%), which is achieving vision has four main criteria. They are Dubai plan 2021, main functions, seven star services and smart government (Al-Dhaafri et al, 2016)

The innovation pillar (20%) consists of two main criteria. They are future shaping and innovation management. The third pillar is the enablers (20%) with three main criteria. They are human capital, assets and resources, and governance (Al-Dhaafri et al, 2016).

Each criterion of each pillar has capabilities and ways of planning and implementation. In addition, each criterion has ways for assessments of the implementation and follows up using certain performance indicators and perception measures of contributors (Al-Dhaafri et al, 2016).

Critical Analysis & Dubai Police Case Study

The previous authors didn't focus on cultural, economical, political, and sociological aspects of the society. Managers should have a broader look on all factors affecting the society, which in return will affect their decisions. Managers should be aware of all surrounding conditions inside and outside the organization. Managers' experience in a certain discipline along with their wide knowledge of the surrounding is rarely mentioned in literature, despite their importance in leading the organizations.

Decision makers should be wise, intelligent, and brave against risks and with a wide knowledge and experience. The literature review didn't put much importance on the traits and psychology of the managers while taking their decisions. Moreover, decision makers see problems and find solutions from their own perceptions. They see the reality that they want to see but not the actual reality. Therefore, emotional intelligence and perceptions are also important factors that differentiate between outstanding and adequate leaders.

Since we don't live in a perfect world, sometimes decision makers in an organization don't have the needed ethical requirements. At that time, the organization enters the "dark triad" phase of leadership. The organizations' benefit is no longer that aim of the decision makers. They don't think of any of the previous decision making tools discussed before. Their decisions come from their own benefit regardless of the overall loss (D'Souza and Franco, 2015).

Ignorance is also considered as one factor affecting heuristics. It is the lack of knowledge. Black swans are the unknowable unknown unknowns (Payan, 2020). Managers can't give decisions on unknowable unknown unknowns.

Another concern that should be taken into consideration is managers' decision making in the cases of emergencies (social, economical, political or even within the organization itself). An emotional intelligent manager should be able to take the appropriate decision within urgent conditions where there is high level of complexities and uncertainties, like the existence of the current pandemic COVID19. Managers should be able to take the risk and get an appropriate and strict solution in a very small interval of time. Komazec et al suggested a software modeling system for decision-making in emergencies (Komazec et al., 2014).

Several studies were done in complex and ambiguous environment (Saleh and Watson, 2017). In this paper, the authors suggested some excellence frameworks for such ambiguous situations such that BEVUCA, which stands for Volatile, Uncertain, Complex and Ambiguous. It deals with literature review gaps of quality and risk management. Risk management gaps with validity and uncertainty criteria were solved by success factors such as agility and understanding respectively. Risk management with complexity and ambiguity criteria was solved by clarity and vision success factors respectively (McCray et al., 2002), (Saleh and Watson, 2017).

A case study of a governmental organization from UAE using a successful Dubai Business Excellence Model is analyzed in this section. Dubai Police is a government entity founded in 1956. They give importance not only to customer satisfaction, but also to customer happiness. In Dubai Police, the Dubai-4G and the EFQM have been used along with Trade method for benchmarking to offer an outstanding service (Al-Dhaafri et al., 2016), (Ghufli, 2012).

Dubai Police, under the leadership of Commander in Chief His Excellency Major General Abdullah Khalifa Al Merri, created new form of excellence inside UAE and abroad (Ghufli, 2012).

Dubai Police started implementing EFQM since 2005 and became a leader in quality in the region, where they offered training to assessors and Six Sigma professionals.

Dubai Police exceeded their role of ensuring safety to meet the expectations of the customers in their strategic planning. They have developed institutional performance criteria in the application of strategic planning, simplifying procedures and managing the human and financial resources more proficiently. They provide service to multi-cultural population following the “Smart Secure Together” motto. This motto represents technology, openness and tolerance that are the corner stone of UAE identity (Al-Dhaafri et al., 2016).

Dubai is classified as the second safest country. Furthermore, Dubai won the EQFM Global Excellence Award 2018 Prize in sustaining outstanding results (Ghufli,2012).

Another case study on Dubai police was done to examine the effect of organizational excellence on performance excellence (Al-Dhaafri et al., 2016). This study had the hypothesis that “organizational excellence has a positive and significant effect on organizational performance”.

To validate the hypothesis 250 questionnaires distributed on different Dubai Police departments. Around 175 questionnaires were returned and fully completed (Al-Dhaafri et al., 2016). Figure 4 is the used framework in the research study. This figure shows the organizational excellence as an independent variable and the organizational performance as a dependent variable (Al-Dhaafri et al., 2016). Organization excellence has several attributes such as commitment, customer, and innovation. While organization performance is measured through OPF, OPC, OPI, OPL attributes (Al-Dhaafri et al., 2016). OPC refers to organizational performance customer, OPF to organizational performance financial, OPC to organizational performance customer, OPI to organizational performance innovation, and OPL refers organizational performance learning and growth. (Al-Dhaafri et al., 2016)

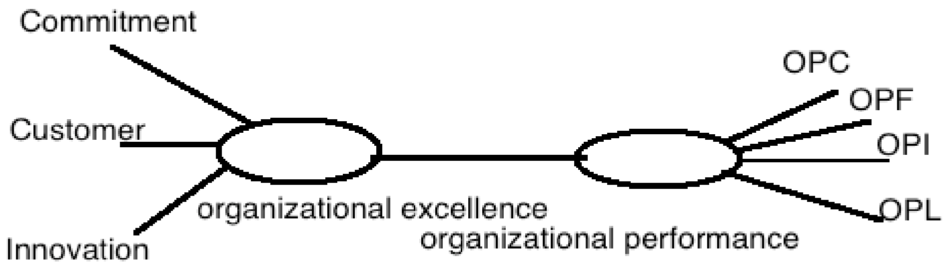

Figure 4 : Research Framework (Al-Dhaafri et al., 2016).

After collecting data, Partial Least Squares (PLS) data analysis was used. The measurement of the outer and inner model is applied to validate the results. To measure the outer model, content validity, convergent validity, and the discriminant validity were used (Al-Dhaafri et al., 2016). The table below shows the discriminant validity table. It is shown that the values on diagonal are larger than any other value in rows or columns (Al-Dhaafri et al., 2016).

Construct	Commitment	Customer	Innovation	OPC	OPF	OPI	OPL
Commitment	**0.839**						
Customer	0.720	**0.937**					
Innovation	0.795	0.696	**0.901**				
OPC	0.606	0.715	0.552	**0.808**			
OPF	0.626	0.464	0.532	0.491	**0.791**		
OPI	0.592	0.500	0.690	0.491	0.489	**0.791**	
OPL	0.618	0.610	0.662	0.704	0.528	0.655	**0.801**

Figure 5: Discriminant Validity Table (Al-Dhaafri et al., 2016).

Now consider the inner structural model for validating results. The results showed that organizational excellence has a positive and significant effect on organizational performance ($\beta = 0.825$, $t = 35.248$, $p < 0.001$) (Al-Dhaafri et al., 2016):

Table1: Inner Structural Model for Validating (Al-Dhaafri et al., 2016).

No	Hypothesis	Path Coefficient	Standard Error	TValue	PValue	Decision
1	Excellence Performance	0.825	0.023	35.248	0.000	Supported

The results showed that organizational excellence has a positive and significant effect on organizational performance ($\beta = 0.825$, $t = 35.248$, $p < 0.001$) (Al-Dhaafri et al., 2016).

It is concluded from this study that decision makers, managers, and organizations leaders should take into consideration performance excellence within their strategies and practices (Al-Dhaafri et al., 2016). Therefore, operational excellence has vital role in shaping any organization’s top management decisions.

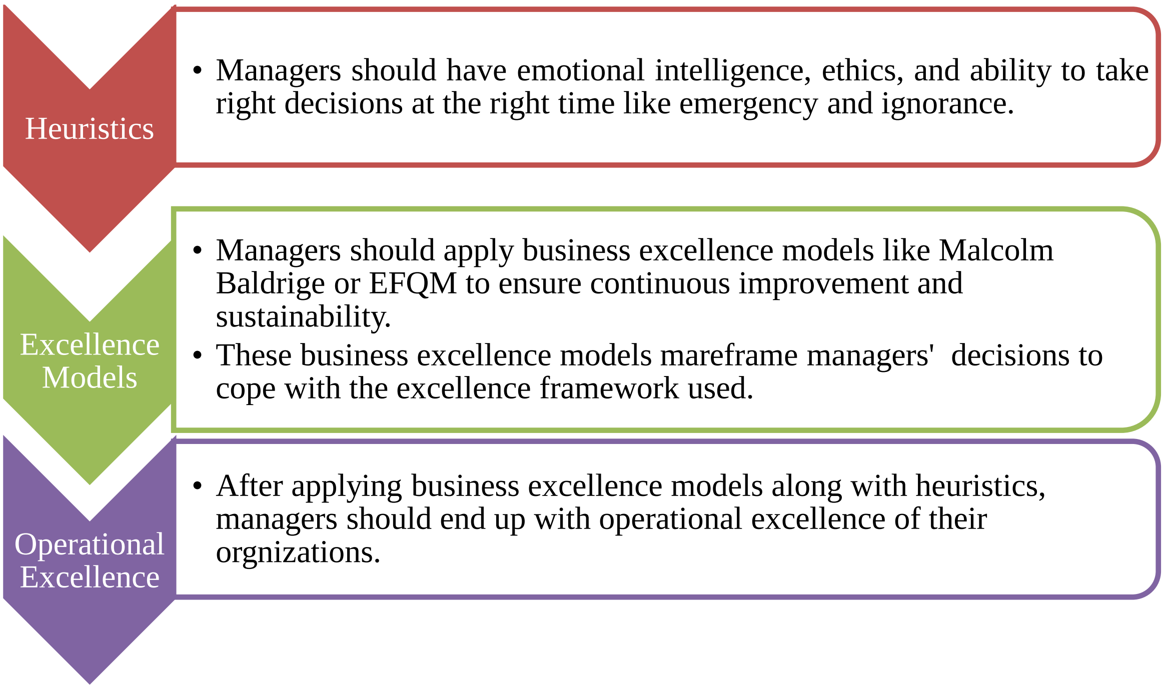

Figure 6: Study Roadmap for Managers on Decision-Making

RESEARCH QUESTIONS AND FUTURE WORK

More research studies can be done from the previous suggested limitations in the literature review of heuristics and other forms of decision-making. The following research questions and solutions are suggested.

Table1: Research Questions and Solutions.

Research Questions	Solutions
How can black triad affect the managers' use of heuristics in the UAE?	The human resources department should put strict qualifications to choose the appropriate manager for each unit in the organization with the suitable experience and knowledge of the technical, social, economical, and political aspects surrounding the organization.
What are the effects of ignorance and black swans on heuristics and decision-making in the UAE?	Managers should be chosen to have high level of ethics, wisdom, knowledge, and long run vision to help the organization to reach its goals efficiently and in less time and fewer resources.
What are the effects of managers' perceptions on decision-making and heuristics in the UAE?	Organizations owners should take direct and appropriate actions towards all managers with dark triad traits; because projects and organizations may face inevitable failures and losses.
What are procedures followed in case of emergencies and high risk situations?	Organizations should have an emergency planning group that will help managers decide in case of emergencies. In addition, there are software models to help managers in decision making in the case of high-risk situations [6].
How business excellence models support organizations decision makers in UAE?	Apply business excellence models to enhance performance and quality.

Future studies' suggestions may include impact of every concept of heuristics on the same project and comparing results. Comparing heuristics in different countries and sectors is another future research. Future research can study the effectiveness and efficiency of decision-making tools in case of emergencies. Another future research can include the conditions in which maximizers may do better or worse than satisfiers. Future researchers may include the effect of business excellence models like Malcolm Baldrige or EFQM on decision makers in UAE firms. Future studies can include the application of some business excellence models to reduce limitations caused by heuristics in UAE organizations.

CONCLUSION

Currently, organizations face complexities and uncertainties. Decision making among these situations is a difficult task for managers. Different decision-making concepts were introduced like heuristics with its three forms, in addition to satisficing, improvisation, maximization and muddling through.

An emotional intelligent manager should be able to choose the appropriate method depending on the overall situation. Heuristics and biases in project's life cycle were identified. They are heuristics and biases during initiation and planning, heuristics and biases during execution and control, and heuristics and biases during closeout. These heuristics solved the complexity and uncertainty problems and led to the existence of biases in projects. Some tactics were used to mitigate this negative side effect of heuristics.

It is also validated that the sectors getting the lowest scores from the first time applying Malcolm Baldrige framework are the most expected sectors to increase their quality and scores if Malcolm Baldrige is further applied. Furthermore, it is found that the healthcare sector is the most influenced by Malcolm Baldrige framework recently (Edi Wahyudi and Yuliantry Permanasari,2018), (Golstein and Schweikhart, 2002)

Dubai Police case study (Al-Dhaafri et al., 2016) showed the positive impact of organization excellence on organization performance.

There are several factors that might affect the use of heuristics and other decision-making tools like perceptions, dark triad traits, emotional intelligence, emergencies, ignorance, and business excellence frameworks. Future research can study the effect of these factors on heuristics and decision-making.

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The role and significance of ISO 9004 standard

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STRUCTURED ABSTRACT

Purpose – The aim of the paper is to determine the role and significance of ISO 9004 standard as a component of the ISO 9000 family. The study utilizes the retrospective perspective i.e., the analysis covers not only the current but also all previous revisions of the standard.

Design/methodology/approach – The paper is based on the results of a literature review, an analysis of ISO standards content and lastly on a research questionnaire carried out among 73 researchers dealing with quality management.

Findings – The carried out research shows that the identity of ISO 9004 is not shaped. The role the document plays within the ISO 9000 family is not precisely defined and has undergone changes during successive revisions. The significance of the standard's content is evaluated as average or low. Therefore the ISO 9004 standard does not seem to play a significant role in practice in spite of having big potential.

Originality/value – Compared to the previous studies concerning ISO 9004, the research made does not focus on utilizing the standard in companies but on determining the nature and significance of the document from the perspective of quality management researchers.

Keywords: ISO 9004, ISO 9000 series of standards, self-assessment

Paper type: Research paper

INTRODUCTION

ISO 9000 is a family of international standards that aims to support organizations' quality efforts, regardless of their sector and size. ISO 9000 series of standards generally indicates a whole family of international standards that are published and revised by the ISO Technical Committee 176, the institutional scope of which is quality management and quality assurance (Riillo, 2013). It is common to address only three most notable standards of the family i.e. ISO 9000, ISO 9001 and ISO 9004 (Panneerselvam and Sivasankaran, 2011). Each of the documents has a different profile: ISO 9000 covers the basic concepts and language; ISO 9001 includes requirements for a system of quality management; and ISO 9004 focusing on how to make an organization/quality management system more efficient and effective (Murmura and Bravi, 2017). From the practical point of view, especially important are ISO 9001 and ISO 9004 because they describe the ways of managing organizations. Although the scientific literature offers a wide choice of publications presenting research results on ISO 9001 (e.g. Sampaio et al., 2009), few studies have been conducted on ISO 9004. There are even opinions that there is a lack of publications about the standard (Boys et al., 2004) and (Kafel and Sikora, 2014).

This paper is meant to make the research gap smaller. It tends to determine the nature of ISO 9004 standard by answering two research questions:

RQ1: What is the role of ISO 9004 within the ISO 9000 series of standards?

RQ2: What is the evaluation of the content significance included in ISO 9004?

THEORETICAL FRAMEWORK

The review of the scientific literature shows that the researchers tend to see ISO 9004 as a tool enabling improvement of ISO 9001 quality management system (see table 1).

Table 1- Characteristic of ISO 9004 standard.

Author	Description
Y. T. Hwang, D. Y. Kim, M. K. Jeong	ISO 9004 gives guidance on a wider range of objectives of a quality management system than does ISO 9001, particularly for the continual improvement of an organization's overall performance and efficiency, as well as its effectiveness. ISO 9004 is recommended as a guide for organizations whose top management wishes to move beyond the requirements of ISO 9001, in pursuit of continual improvement of performance.
H. D Seghezzi	With an installed ISO 9001 quality system as starting point the ISO 9004 offers an excellent model for intensification. Without conflicts in contents ISO 9004 contains the requirements of ISO 9001 and adds recommendations to gain impressive improvements.

K. A. Boys A. E. Wilcock	Firms that wish to advance their quality management system beyond ISO 9001 minimum requirements can make use of the ISO 9004 standard
W. Stimson	ISO 9004 can best support the requirements of ISO 9001 strategically and tactically.
A. Jarvis P. C. Palmes	Implementation of ISO 9001 quality management system will define foundational quality while ISO 9004 encourages organizations to go beyond the fundamental QMS requirements to be able to address all the challenges today's business environment faces.

The authors seem to unanimously claim that the organizations which introduce ISO 9001 quality management system can gain all possible benefits only in a situation when they simultaneously employ ISO 9004 standard (Beattie and Sohal, 1999), (Bendell, 2000) and (Hwang et al., 2012). Sometimes – however much less often - other uses of ISO 9004 are pointed out. For example, the fact that the organizations may utilize the document to enhance their quality management system towards business excellence (Boys et al., 2004), to strengthen their principles of quality management and implement TQM (Zouhir and Bouaouine, 2018) or to maintain uninterrupted functioning of an organization (Zapłata, 2011).

Despite positive opinions on opportunities ISO 9004 gives, the document is paradoxically not widely known or used. Wilcock et al. (2006) even proved that in ISO 9001 registered companies, ISO 9004 is not well known (only 46, 1% of registered companies indicated awareness of this document). Similar conclusions result from the studies carried out by Salimova and Makolov (2016) and Murmura and Bravi (2017).

The vast majority of publications on ISO 9004 concern the self-assessment tool. ISO 9004 recommends that top management should consider establishing and implementing self-assessment. The self-assessment is a careful evaluation, usually performed by the organization's own management, which results in an opinion or judgment of the organization's effectiveness and efficiency and the maturity of the quality management system (Hwang et al., 2012). However the evaluation of the usefulness of the tool is ambiguous. Vanalle et. al (2016) claimed that the self-assessment tool is capable of precisely and adequately measuring the maturity level of the appraised management system. The method also enables the identification of best practices for the study organization, which can be employed by the administration to develop action plans to improve their management system. While Kafel et al. (2013) proved that organizations using self-assessment tool have reservations about the tool. Managers saw it as an ineffective tool for improving the organization's management system. In the opinion of the surveyed managers, methods and tools (such as 5S) in which implementation procedures are clear and obvious are much easier and more effective in management system development than the ISO 9004 self- -assessment model. On the other hand, Wolniak (2011) claimed that the self-assessment tool presented in ISO 10014 *Quality management - Guidelines for realizing financial and economic benefits* is more useful than the tool described in ISO 9004.

THE EVOLUTION OF ISO 9004

ISO first published its ISO 9004 standard in 1987. The document entitled *Quality management and quality system elements — Guidelines* consisted of an introduction and 20 chapters. Chapters 4 to 20 presented the guidelines for designing and maintaining a quality management system. Up to now, the ISO 9004 standard has been revised four times.

The first revision took place between 1993 -1994. It was quite unusual as the ISO 9004 standard was divided into four parts i.e.

1) ISO 9004-1:1994 *Quality management and quality system elements* — Part 1: *Guidelines;*
2) ISO 9004-2:1994 *Quality management and quality system elements* — Part 2: *Guidelines for services;*
3) ISO 9004-3:1993 *Quality management and quality system elements* — Part 3: *Guidelines for processed materials;*
4) ISO 9004-4:1993 *Quality management and quality system elements* — Part 4: *Guidelines for quality improvement.*

Each of those parts represented a separate document while ISO 9004-1:1994 was a direct continuation – on the basis of content - of ISO 9004:1987. The remaining parts i.e. 2, 3 and 4 had no previous equivalents.

In 2000 a further revision to ISO standards of 9000 series was performed. The ISO 9004:2000 *Quality management systems — Guidelines for performance improvements* standard was published (this time as one unified document). It consisted of an introduction, eight chapters and two annexes. The first of them provided guidelines for self-assessment of an organization in the area of the effectiveness and efficiency of the organization and the maturity of the quality management system. The second annex included guidelines concerning the process of continual improvement.

In 2009 a subsequent revision of the standard, ISO 9004:2009 *Managing for the sustained success of an organization — a quality management approach*, was published. It consisted of an introduction, nine chapters and three annexes. The first annex provided guidelines for self-assessment. The second one was devoted to presenting and synthetic description of 8 quality management principles. The third one discussed relations between ISO 9004:2009 and ISO 9001:2008 standards.

The current revision of the standard i.e., ISO 9004:2018 *Quality management — Quality of an organization — Guidance to achieve sustained succe*ss was published in 2018. Its content includes: (1) foreword and introduction, (3) eleven chapters describing guidelines for organizations and (4) an annex presenting the self-assessment tool.

Table 2 provides the titles of individual revisions of ISO 9004.

Table 2- Succeeding revisions of ISO 9004.

Year of publication	**Title**
1987	Quality management and quality system elements — Guidelines
1993-1994	- Quality management and quality system elements — Part 1: Guidelines - Quality management and quality system elements — Part 2: Guidelines for services - Quality management and quality system elements — Part 3: Guidelines for processed materials - Quality management and quality system elements — Part 4: Guidelines for quality improvement
2000	Quality management systems — Guidelines for performance improvements
2009	Managing for the sustained success of an organization — A quality management approach
2018	Quality management — Quality of an organization — Guidance to achieve sustained success

Source: (ISO 9004:1987), (ISO 9004:1993 – Part3), (ISO 9004:1993 – Part4), (ISO 9004:1994 – Part1), (ISO 9004:1993 – Part2), (ISO 9004:2000), (ISO 9004:2009), (ISO 9004:2018).

RESEARCH METODOLOGHY

The research aimed to evaluate the significance of the content included in ISO 9004. The research was performed in two stages.

The first stage was to identify the components included in ISO 9004. The term *components* means distinguishable, homogenous in content parts of the analyzed document. In order to identify the components, an overview of all revisions of the standard was performed.

The second stage was to evaluate the significance of separate components by scientific workers dealing with quality management. A specially prepared research questionnaire was assigned to people who between January 2015 and July 2018 published a research paper concerning ISO 9000 series in one of the following journals: „International Journal of Quality & Reliability", „Total Quality Management and Business Excellence Management", „TQM Journal", „Problemy jakości" (Polish scientific journal concerning quality management) or were the authors of Polish-language reviewed monograph on quality management, which included issues concerning ISO 9000 series standards. 218 people complying with the criterion were identified and sent a request to fill in the questionnaire. The answers were received from 73 people, including 45 Poles and 28 from other countries (i.e. from

Malaysia, Portugal, Sweden, Italy, Spain, India, Serbia, UK, Brazil, China, Finland, Greece, Lithuania, Germany, Slovenia and USA). The sample group (73 experts) was dominated by researchers 40 years old or older (87%), employed at universities (92%), and having dealt with quality management for ten years or longer (92%). Apart from their scientific activities, they had also, in the previous three years, delivered lectures to students (92%) and carried out professional training sessions on quality management (66%) and practical activities i.e. performing audits, implementing quality management systems, etc. (62%). The respondents evaluated the validity of claims concerning ISO 9004 included in the research survey. They used a 5-grade scale in the process.

The internal consistency reliability indicator (Cronbach alpha) for the study was 0.815 so the reliability coefficient of the study variables exceeded the minimum acceptable level of 0.7.

RESULTS

Identification of the components of ISO 9004 standard

Basing on the carried out analysis of the content of ISO 9004, eight components of the standard were identified. They are presented in table 3.

Table 3 – Components of ISO 9004 standard.

No.	Year of publication	1993	1996	2001	2009	2018
1	Guidelines explaining the requirements for a quality management system	x	x	x	x	x
2	Guidelines related to additional (i.e. not included among requirements for the system of quality management) activities/solutions connected with quality management	x	x	x	x	x
3	Guidelines concerning quality management in relation to chosen forms of activity (e.g. related to services)	-	x	-	-	-
4	Guidelines concerning improvement of an organization including the description of chosen techniques and tools such as e.g. Pareto chart	-	x	-	-	-
5	Self-assessment tool	-	-	x	x	x
6	Definitions	-	x	-	x	-
7	Quality management principles	-	-	-	x	-
8	Description of the relation between chosen standards	-	-	-	x	-

Source: Own study.

It is noticeable that the first five components listed in table 2 are included exclusively in ISO 9004. The remaining three (i.e., definitions, quality management principles, description of the relation between chosen standards) are or have also been included in other ISO standards of 9000 series (i.e. in ISO 9000 and/or ISO 9001).

Evaluation of the significance of ISO 9004 components

The research questionnaire included eight statements concerning previously identified components of ISO 9004. They were formulated in the following way: *I find <name of the component> a significant part of ISO 9000 series of standards and it should be included in the standards*. The respondents' task was to decide to what extent they agreed with the given statements by selecting one of the choices on the following: 1 – not at all, 2 – rather not, 3 - neither yes nor not, 4 - rather yes, 5 – totally agree.

The average evaluations of the significance of every analyzed component with the values of standard deviation are presented in table 4.

Table 4 – The evaluation of the significance of ISO 9004 components.

No.	Component	Average	Standard deviation
1	Guidelines explaining the requirements for a quality management system	4.33	0.99
2	Guidelines related to additional (i.e. not included among requirements for the system of quality management) activities/solutions connected with quality management	3.89	1.03
3	Guidelines concerning quality management in relation to chosen forms of activity (e.g. related to services)	3.89	1.03
4	Guidelines concerning improvement of an organization including the description of chosen techniques and tools such as e.g. Pareto chart	3.99	0.96
5	Self-assessment tool	4.12	1.05
6	Definitions	4.55	0.75
7	Quality management principles	4.59	0.57
8	Description of the relation between chosen standards	3.78	1.28

Source: Own study.

DISCUSSION

RQ1: What is the role of ISO 9004 within the ISO 9000 series of standards?

The carried out research may result in an opinion that the role of ISO 9004 within 9000 series is not clearly defined. The conclusion is supported by following evidence:

1. Every ISO standard suggests using a certain document. The scope of the current revision of ISO 9004 was defined in the following way: "this document gives guidelines for enhancing an organization's ability to achieve sustained success. (...) This document is applicable to any organization, regardless of its size, type and activity" (ISO 9004:2018). A similar function of ISO 9004 been defined in the previous revisions of the document, e.g., in 2009 revision, it can be found

the following statement: „This International Standard provides guidance to organizations to support the achievement of sustained success by a quality management approach. It is applicable to any organization, regardless of size, type and activity (ISO 9004:2009)". However, the researchers dealing with quality management tend to claim that ISO 9004 is dedicated to organizations that have implemented ISO 9001 quality management system (see table 1).

2. While browsing through the successive revisions of ISO 9004 it is noticeable that the document is strongly characterized by (in comparison with e.g. ISO 9000 and ISO 9001) variability in both: the title and the included components. The titles of the standard (depending on the revision) stress some keywords such as: „quality management", quality management system", „improvement", „sustained success", „quality management" and „quality of an organization" (see table 2). While the content of specific revisions of ISO 9004 identifies 8 different subject components, with only two appearing in all revisions of the document (see table 3).

3. The overall aim of the ISO 9004 standard, which is improvement of an organization/quality management system can be achieved in many ways i.e., by providing (a) guidelines explaining the requirements for an ISO 9001 quality management system, (b) guidelines related to additional, i.e., not included among requirements for the system of quality management activities/solutions connected with quality management, (c) guidelines concerning quality management in relation to chosen forms of activity (e.g., related to services), (d) guidelines concerning improvement of an organization, such as principles of quality improvement and methodology for quality improvement or (e) methods and techniques, such as self-assessment tool and Pareto chart. ISO 9004 standard has utilized all those approaches. However, the authors of the standard are not consistent about it. Some of the approaches have been taken into account, others have been employed consistently but the level of focusing in all revisions is different (it is noticeable that (a) approach was dominant in older revisions while the newer ones were characterized by increased significance of (b) approach).

RQ2: What is the evaluation of the content significance included in ISO 9004?

The carried out evaluation of the significance of the ISO 9004 components, allowed categorizing the components. To serve this purpose, the following way of interpretation of the average component significance was arbitrarily adopted:

(4.5, 5] – acceptance with a high level of recognition,

(4, 4.5] – acceptance and with average level of recognition,

(3.5, 4] – acceptance with a low level of recognition, (3, 3.5] – acceptance with a very low level of recognition,

[1, 3] – lack of acceptance,

On this basis, it can be claimed that all ISO 9004 components are accepted by experts dealing with quality management.

Table 5 – Categorization of ISO 9004 components.

No.	Component	Average	Categorization
1	Quality management principles	4.59	Acceptance with a high level of recognition
2	Definitions	4.55	
3	Guidelines explaining the requirements for a quality management system	4.33	Acceptance with an average level of recognition
4	Self-assessment tool	4.12	
5	Guidelines concerning improvement of an organization including the description of chosen techniques and tools such as e.g. Pareto chart	3.99	Acceptance with a low level of recognition
6	Guidelines related to additional (i.e. not included among requirements for the system of quality management) activities/solutions connected with quality management	3.89	
7	Guidelines concerning quality management in relation to chosen forms of activity (e.g. related to services)	3.89	
8	Description of the relation between chosen standards	3.78	

Source: Own study.

It must be given the attention that the level of acceptance of separate components is diverse.

1. The highest graded was the usefulness of two components i.e., „quality management principles” and “definitions”. However, none of them is included in the current revision of ISO 9004. Furthermore, they cannot be called the core elements of the standard, because they are included in ISO 9000 mainly.

2. The next two components were evaluated as having average significance. They are: “guidelines explaining the requirements for a quality management system” and “self-assessment tool”. Relatively high position of “guidelines explaining the requirements for a quality management system” supports the previously formulated findings, which say that the researchers claim ISO 9004 to be a tool meant to improve ISO 9001 quality management system. Moreover, such evaluation may indicate that the primary purpose of the standard should be the interpretation of the requirements for an ISO 9001 quality management system.

3. The last, biggest group consists of four components. Although the experts accept them, their significance was evaluated as low. It is worth to mention “guidelines related to additional activities/solutions connected with quality management”. The significance of the component was

clearly evaluated lower than „guidelines explaining the requirements for a quality management system". It is an important observation as the newest revisions of the standard have been mostly oriented towards developing "guidelines related to additional activities/solutions connected with quality management" instead of „guidelines explaining the requirements for a quality management system".

Concluding, it may be claimed that the nature of ISO 9004 is not clearly shaped. Facing so many ambiguities and problems, it is justified to fully agree with Wilcock et al. (2006), who claimed that ISO 9004 has a great potential but needs a complete overhaul.

CONCLUSIONS

This paper presents the results of the research on the nature of ISO 9004 standard. It has been demonstrated that the role of the document within 9000 series is not precisely defined and undergoes changes in successive revisions (as a result, the character of the standard seems unstable). Furthermore, the content included in ISO 9004 is evaluated as average or low. The above consideration – according to the author - may point out the key reasons that ISO 9004, in spite of having great capabilities, does not play a major role in companies.

The practical implication of the received findings, most of all, comes down to indicating the need and directions for reflecting and redesigning ISO 9004 to make the document entirely useful for organizations and thus employed more often.

There are two main limitations of the study. Both of them relates to the sample. The first one is that the sample group covered only 73 respondents, 45 from the same country. The second limitation is taking into account only researchers in the questionnaire. Therefore, further research is suggested to increase the sample group, including practitioners (i.e., managers, consultants and auditors).

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Enabling Strategic Foresight in Organizations through Quality Management and Organizational Excellence Concepts: A Case Study in Saudi Arabia

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STRUCTURED ABSTRACT

Purpose - In this era of accelerated change and big uncertainties, disruption is emerging in all aspects of our modern lives. In this context, foresight as strategic tool to face these social and economic challenges in organizations comes into prominence. Foresight has been widely used by organizations as a strategy to support leaders and decision makers in situations that involve long lead times and uncertainties. This study, which falls within a national research project, aims to investigate and to assess the readiness level of Saudi organizations to adopt and practice foresight methods in their strategies to achieve the strategic goals set in the National Vision 2030. Within this paper, we will discuss the relationship between foresight capability and quality management and organization excellence approaches. Essentially, we will attempt to answer the fundamental research question: "*To what extent quality management and organizational excellence approaches and models lead to enabling and building future foresight capability of modern organizations*?"

Design/methodology/approach - A survey questionnaire was developed based on literature review, and administered online to leadership of Saudi organizations national wide. Statistical analysis performed.

Findings - The analysis showed that quality management and organization excellence frameworks implementation in Saudi organizations would be an enabler for successful foresight implementation. This led to pronounce that in order to achieve their strategic objectives in line with the national vision 2030, Saudi organizations should implement quality management systems such as ISO 9001:2015 and the national quality award (KAQA).

Originality/value - The paper opens a discussion between quality professionals and foresight experts on the potential link between quality management principals and foresight capability in modern organizations operating in an accelerated change environment and disruption.

Keywords: Quality Management, Organizational Excellence, Foresight, Industry 4.0, Saudi Vision 2030

Paper type: Research paper

INTRODUCTION

We are living in an era of accelerated change, where disruptive technologies and immerging uncertainties are affecting personal lives, business environment, and national and international policies. In these situations, foresight research and methods implementation at the organizational and national levels come into prominence to foresight future scenarios and anticipate targeted horizons. Foresight has been defined as a "systematic, future-oriented, analytical and interactive process that partly contributes to shared visions concerning long-term developments within science, technology, business and society and partly facilitates the alignment of relevant stakeholder groupings around desirable developments through relevant strategies, decisions and actions" (Andersen and Rasmussen, 2014). Foresight activities support decision making in situations and areas that involve long lead times, such as long-term labor market planning, education and training for future skills development and anticipation. At the strategic level, foresight projects have been traditionally used as a policy tool for priority setting in identifying key strategies to be implemented, key areas of national priorities to be achieved and how to make investments in an efficient and effective manner towards the achievements of organizational or national goals (Vinnari and Tapio, 2013).

A substantial increase of interest in foresight studies around the world has been registered during the last three decades. The biggest number of studies came from countries like Japan, United States, United Kingdom, Finland, Denmark, France, Germany and Russia, which have large and longer foresight programs national wide (Bakhshi et al., 2017 ; Rohrbeck and Kum, 2018; Rhisiart et al., 2017; Rhisiart, 2018 and Gokhberg and Sokolov, 2017). Limited foresight studies were reported from developed countries like Brazil, Columbia and Iran. Only, very limited studies were published in Arab countries like the MENA region, mainly in the Kingdom of Saudi Arabia and the UAE (Algshami, 2017; Al-Shahri, 2018; Al-Homaid, 2020; Aichouni et al., 2020).

Saudi organizations in both public and private sectors are operating within a national momentum driven by the 2030 Saudi vision. The strategic goals set to achieve the vision are three folds: (a)

Diversification of the economic sectors and efficient localization of industries (such as military, mining, renewable energy, and logistics services), (b) Vibrant Society (through cultural transformations) and (c) Building an ambitious nation. To achieve these strategic goals, the government launched 13 vision realization programs (VRPs) together with national strategies for industry and quality. The realization of the vision requires economic and social transformations associated with the fourth industrial revolution (Industry 4.0) technological drivers. In this national context, it is of particular importance to foresight the skills, competencies and the jobs landscape required by the kingdom to achieve its strategic goals.

The present study falls within a national research project, with the aim to assess and measure the readiness level of Saudi organizations to adopt and practice foresight methods in their strategies to achieve the strategic goals set in the National Vision 2030. Within this paper, we will discuss the relationship between foresight capability and quality management and organization excellence models. Essentially, it attempts to answer the fundamental research question: “To what extent quality management and organizational excellence approaches and models lead to enabling and building future foresight capability of modern organizations?” It is expected that the result of the project would support Saudi leaders and decision-makers for priority-settings and identifying key strategies and investments in human capital development through education, training, research and innovation in areas related to future scenarios driven by the Saudi Vision 2030 and requirements of Industry 4.0 revolution.

QUALITY MANAGEMENT AND ORGANIZATIONAL EXCELLENCE SYSTEMS AS ENABLERS TO FORESIGHT CAPABILITY IN ORGANIZATIONS

For the last decades, quality management systems and organizational excellence models such as the Malcolm Baldrige National Quality Award (MBNQA) and the European Foundation for Quality Management (EFQM) have been used by organizations worldwide to achieve and sustain excellent performance through a systematic and holistic approach to managing the various aspects of the organization. Excellence can be used proactively as a modern management method for building the future and sustaining governments and organization performance. Through a set of fundamental principles and guiding criteria, excellence helps organizations and governments to preserve the interest of the society, and to build a happy future for communities and providing them with the conditions to thrive, prosper and enjoy high quality of life standards (Zairi, 2019).

The new organizational excellence approach stimulates governments to build their plans and goals continuously without stopping at the point of achievement or satisfaction of successful implementation to ensure the economic, social and environmental long-term sustainability. Government entities should implement excellence models to develop their future anticipation capabilities through using future foresight tools to identify continues future trends and global directions. This helps the government entity be able to predict, analyze and respond to the global and future changes to create its future readiness through continuous redefinition of existing business models supported by new and advanced technology driven by digital disruption of Industry 4.0. Excellence has been used to help organizations realize ambitious visions and strategic objectives. Vision Realization through foresight projects is an essential criterion that excellence models address (Zairi, 2019). Readiness and preparedness for the future can be considered as a powerful predictor for becoming an outperformer in the business, for attaining superior profitability and for gaining superior excellence (Rohrbeck and Kum, 2018).

Foresight has been used as a powerful tool to help organizations operate more effectively in today's environment of rapid, highly complex, often unpredictable changes in technology, social and economics. Organizations readiness to foresight can be measured using foresight maturity models such as the Grim`s Foresight Maturity Model (GFMM, 2009). This model which has been widely used in the open literature is a set of best practices that ensure that the organization develops a robust, useful, and comprehensive approach to take charge of the change and anticipate desirable future scenarios. The model divides foresight activities into six fundamental disciplines as shown in table (1) where each discipline can be assessed within five levels of maturity (ad-hoc, aware, capable, mature, world class).

Table 1. Fundamental Components of the Foresight Maturity Model (Grim, 2009)

Fundamental Concept	**Measure in the Foresight Activity or project**
Leadership	Clear ownership and active leadership to implement and institutionalize foresight capability
Framing	Establishing the boundaries and scope of the endeavor
Scanning	Collection of appropriate and relevant information in a format and timeframe that support useful retrieval
Forecasting	Description of long-term outcomes that contrast with the present to enable better decision-making
Visioning	Creation of a preferred future that imaginatively captures values and ideals
Planning	Ensuring that the plans, people, skills, and processes support the organizational vision

Saudi organizations either in public or in private implement quality management systems (ISO 9001:2015) and organizational excellence model (King Abdul-Aziz Quality Award - KAQA) to achieve performance excellence in line with their strategic goals and objectives. This is mainly driven by the momentum of the 2030 Saudi vision and the government`s official approval of the national strategy for quality early 2019. In the present study, we were interested to investigate whether the implementation of such quality systems and organizational excellence model would give an indication of the organization`s readiness and capability to adopt foresight for future opportunities and targeted horizons as prescribed by the vision 2030. For that purpose, the researchers used Figure 1 to make a mapping between the fundamental concepts of quality management adopted by QMS, ISO 9001:2015, the organizational excellence concepts and the foresight concepts as defined by Grim Maturity Model.

Quality Management	**Organizational Excellence**	**Foresight**
1. Customer focus	1. Adding Value for Customers	1. Leadership
2. Leadership	2. Creating a Sustainable Future	2. Framing
3. Engagement of people	3. Developing Organizational Capability (for change)	3. Scanning
4. Process approach	4. Harnessing Creativity & Innovation	4. Forecasting
5. Continuous improvement	5. Leading with Vision, Inspiration & Integrity	5. Visioning
6. Evidence-based decision making	6. Managing with Agility (to respond effectively to opportunities and threats)	6. Planning
7. Relationship management	7. Succeeding through the Talent of People	
	8. Sustaining Outstanding Results	

Figure 1 - Mapping between Quality Management, Organizational Excellence and the Foresight Capability Principals (Grim Foresight Maturity Model, 2009)

RESEARCH METHODOLOGY

The present work was initially dedicated to measure the readiness level of Saudi organizations towards the implementation of foresight as a strategy to achieve the goals of the national Saudi vision 2030. The perceptions of both management and operational employees towards this issue were measured through a survey administered online to Saudi organizations. The main objective of the study was to report on the views and experiences of leadership management and staff members regarding foresight implementation as means to achieve the objectives of the 2030 Saudi vision. The survey consisted of several parts:

- Part 1 – Demographic characteristics (respondents' characteristics: position in the organization, educational level, age, gender, professional experience) and (organization characteristics: organization`s size, business sector, regional location in the kingdom, adoption of foresight manager, quality manager at the organization, ISO certification status of the organization, national quality award participation, and the development of a strategic plan in line with the 2030 vision).

- Part 2 – Saudi Organizations readiness to implement foresight.
- Part 3 – Degree of knowledge and implementation of foresight methods.
- Part 4 – Barriers to foresight implementation in Saudi organizations.
- Part 5 – Additional information and personal comments from respondents.

The survey questionnaire was distributed to major Saudi organizations from government and the private sectors during March 2020 online, through the network of students and graduates of the Master program in quality engineering and management, who were from leadership of Saudi organizations from different regions of the kingdom. Of about 300 questionnaires sent, 221 questionnaires were received, which means a response rate of 73.67 %. More details about the research survey instrument and the research methodology can be found in Al-Homaid 2020, a&b).

In this paper, we will discuss only the results related to the research question related to foresight capability and quality management and organizational excellence models implementation.

RESULTS AND DISCUSSION

1. Analysis of the validity of the results

In exploratory survey investigations, validity and internal is measured by calculating Cronbach's alpha coefficient. A value of Cronbach's alpha greater than 0.7 indicates homogeneity and consistency of the survey element and validity of its results. In the present study, the Cronbach coefficients of the survey elements are shown in Table 1, where it can be seen that high values were obtained, indicating the reliability of the survey and the validity of the results.

Table 1. Cronbach`s Alpha values for the survey elements

Part	Survey elements	Number of Questions	Number of Responses	Cronbach`s Alpha
2	Readiness to implement Foresight	11	221	0.921
3.1	Foresight Methods Knowledge	19	221	0.954
3.1	Foresight Methods Implementation	19	93	0.969
4	Barriers to Foresight Implementation	10	221	0.881

2. Participants Characteristics

Table 2 summarizes the respondents profile characteristics. A careful examination of this Table shows that respondents to the questionnaire are about 47.51 % from top management (9.05 % CEOs, 16.29 % Middle management and 22.17 % managers) and 14.93 % from academic sector. It can be seen that a percentage of 62.44 of respondents were from leadership and academic. 67.6 % are PhD and MSc holders with 41.6 % are more than 40 years old and with extensive professional experience, since 79.2 % of the respondents have more than 5 years' experience in the organization. These statistics give a confidence about the study since the respondents turn out to be closely related to the decision making process, with relevant professional experience in the business sector. These factors are important in foresight projects which usually require some knowledge and expertise in the business filed (Vinnari and Tapio, 2013; Andersen and Rasmussen, 2014, and Rohrbeck and Kum, 2018).

Figures 2 and 3 show the characteristics of the sampled organizations. The organizations were ranked as either large organizations (43.89 %) or small and medium organizations (56.11 %). The government organizations represent 54.75 % of the participant and the private represent 18.55 %. The business activities were distributed between education and training with 26.24 %, Military with 9.95 %, industrial sector with 7.69 %, services with 7.27 %, and healthcare with 10.86 %. The study was carried out national wide, where all the 13 administrative regions participated. The big majority of participants (88.69 %) came from the main cities of the kingdom (Riyadh, Makkah, Madinah, Dammam, Gassim and Hail) where most of businesses and government departments operate.

Table 2. Demographic Characteristics of the Survey Respondents

Respondents Characteristics	Frequency	%age Frequency
Position		
Top Management (CEO, or Business Owner)	20	9.05
Middle Management (HR, Quality Manager, etc.)	36	16.29
Executive Management (Supervisors)	49	22.17
Academician or Researcher	33	14.93
Employee	28	12.67
Other	55	24.89
Education		
PhD	42	19.00
MSc	62	28.05
BSc	99	44.80
Diploma	14	6.33
High School	4	1.81
Age		
21-30 years	36	16.29
31-40 years	82	37.10
41-50 years	66	29.86

Over 50 years	37	16.74
Gender		
Male	160	72.40
Female	61	27.60
Professional Experience		
Less than 1 year	8	3.62
From 1 to 5 years	38	17.19
From 6 to 10 years	34	15.38
From 11 to 20 years	61	27.60
More than 20 years	80	36.20

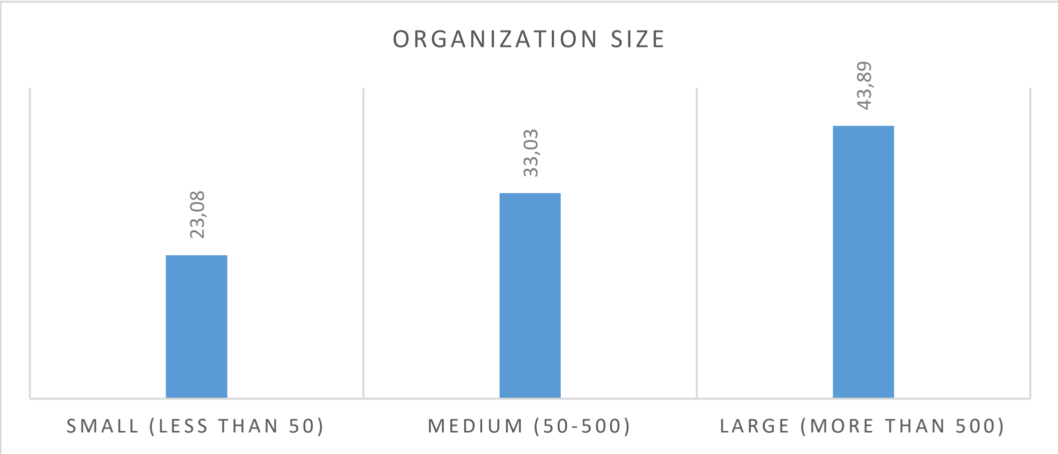

Figure 2 - Respondents` Distribution by Organization Size

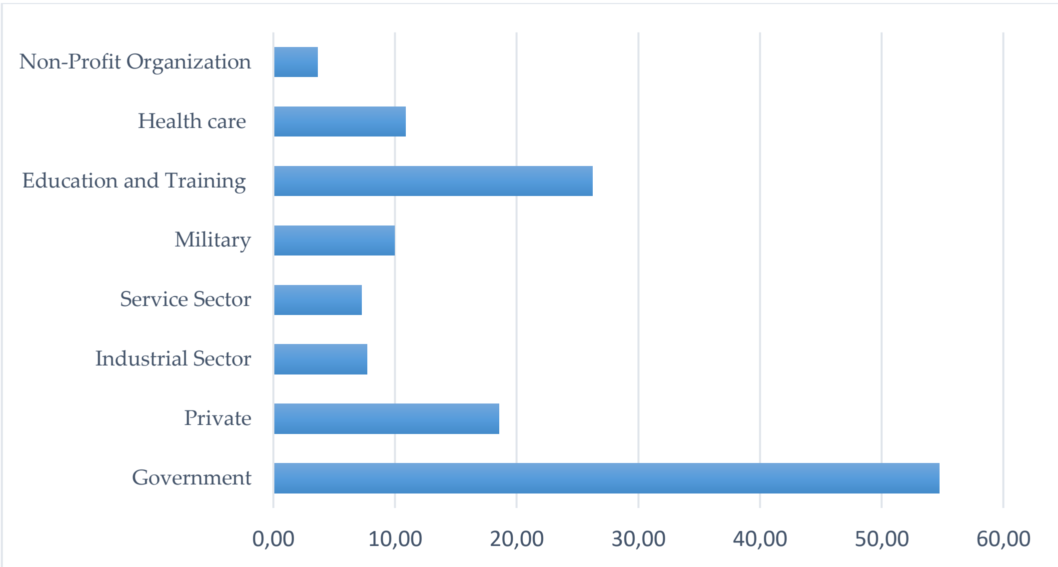

Figure 3 - Respondents` by Organization Business Sector

4.3. Foresight, Quality Management and Organizational Excellence Principals Relationship

As mentioned earlier, Saudi organizations either public or private implement quality management systems (ISO 9001:2015) and the national organizational excellence model (King Abdul-Aziz Quality Award - KAQA) to achieve performance excellence in line with the strategic goals of the national 2030 vision. It has to be mentioned here that a strong momentum towards quality management has been created within the frame work of the vision and the subsequent government`s official approval of the national strategy for quality (NQS) early 2019. In this paper, we are mainly interested to investigate whether the implementation of such quality systems and organizational excellence model would correlate with the organization`s readiness to adopt foresight for future opportunities and targeted horizons.

Table 3 and Figure 4, which summarizes the results that measure these aspects, show that while 84.16 % of the organizations have a quality manager, 53.85 % of them have undergone the process of ISO certification to their management systems (QMS, EMS, etc.), and only 20.36 % of them implemented the national quality award criteria in their businesses. A relatively high percentage of 78.28 of the surveyed organizations have a strategic plan in line with the 2030 Saudi vision. These statistics give an indication of the level of readiness towards the adoption and implementation of quality management systems and organizational excellence models, which constitute an organizational enablers and catalysts for foresight implementation, from the author's point of view.

The percentages of organizations that had established a position of foresight in their organizational chart was 37.10 % and those who performed foresight projects previously were 24.89 %. These percentages would give a clear indication of a relatively high level of readiness of Saudi organizations towards adopting foresight as a strategy to achieve their goals. This is believed to be associated with the high level of implementation of quality management and organizational excellence approaches.

Table 3. Frequency distributions related to Quality Management Systems and Foresight

Quality or Foresight Concept	**Survey Construct**	**Yes**		**Not sure**		**No**	
		Count	**Fr (%)**	**Count**	**Fr (%)**	**Count**	**Fr (%)**
Planning and Visioning (Foresight)	The organization has a strategic plan in line with the 2030 Saudi Vision	173	78.28	26	11.76	22	9.95
Foresight Awareness	Do you support the decision to establish foresight departments or centers in Saudi organizations?	194	87.78	20	9.05	7	3.17
Foresight Department	The organization has a department or a person responsible for foresight	82	37.10	63	28.51	76	34.39
Foresight Practice	Did your organization performed a foresight study previously?	55	24.89	89	40.27	77	34.84
Quality Department	The organization has a department or a person responsible for quality	186	84.16	13	5.88	22	9.95
Quality Management Systems	The organization has a certified management system (ISO 9001, 14001, 26000)	119	53.85	43	19.46	59	26.70
Organizational Excellence	The organization participated previously in National King Abdul-Aziz Quality award	45	20.36	91	41.18	85	38.46

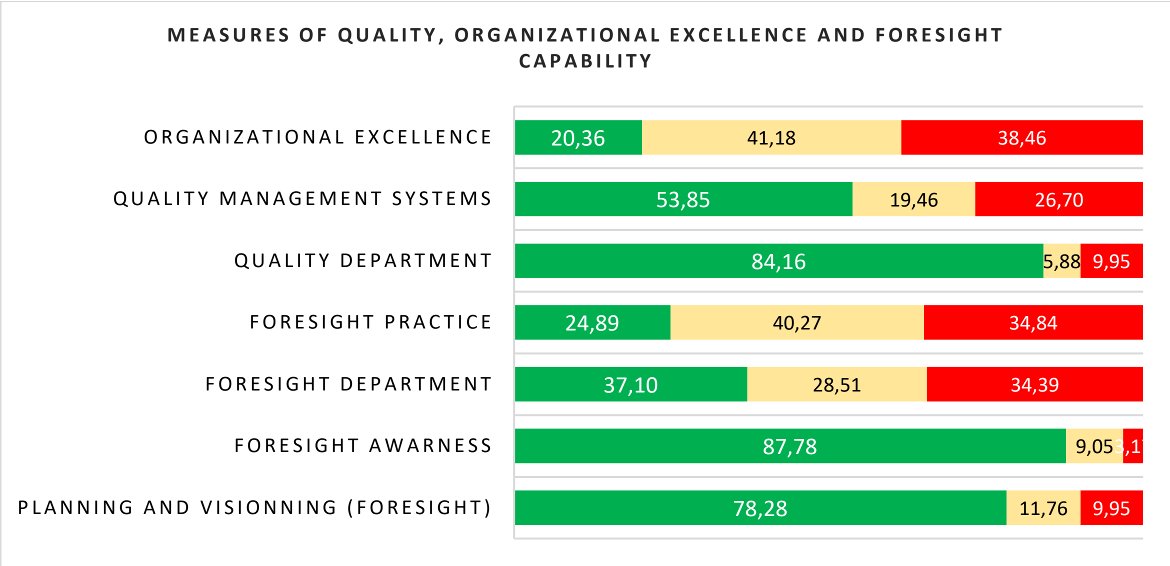

Figure 4 - Measures of Quality Management, Organizational Excellence and Foresight Capability in Saudi Organizations

In order to determine if there is an association between the organizations characteristics (size, business activity, and King Abdul-Aziz Quality Award implementation) and the existence of foresight department in the organization Tabulated statistics and Chi-Square tests were used. The statistics in Table (4) show that organizations, which have already established a foresight department, are equally distributed with the size of the organization. No indication that a specific organization type (size) have invested more in foresight though the national momentum driven by the Saudi 2030 vision. From the survey data, the Pearson chi-square statistic is 0.267 (with a p-value of 0.992) and the likelihood chi-square statistic is 0.267 (which also gives a p-value of 0.992 > 0.05). So, with an alpha significance level of 0.05, we can conclude that there is no significant association between the two variable (Organization Size, Foresight department). Similarly, no significant association between Organization business activity and foresight department, was found with the Pearson chi-square statistic is 22.655 (with a p-value of 0.066) and the likelihood chi-square statistic is 23.136 (which also gives a p-value of 0.058 > 0.05).

Table 4. Tabulated Statistics: Organization Size vs Foresight Department

Organization Size		**Foresight Department**			
		Yes	**No**	**Not sure**	**All**
Large Organization	Count	36	31	29	96
	Fr(%)	35.62	32.58	27.80	43.44
Medium Organization	Count	27	26	20	73
	Fr(%)	27.09	24.77	21.14	33.03
Small Organization	Count	19	18	15	52
	Fr(%)	19.29	17.65	15.06	23.53
All Organizations	Count	82	75	64	221
	Fr(%)	37.10	33.93	28.96	

The statistics in Table (5) show the organizations, which have already established a foresight department with the implementation of the national excellence model (King Abdul-Aziz quality award, KAQA). The Chi-square test performed for the association between the two variables, with a Pearson chi-square statistic of 46.655 (with a p-value of 0.000) and the likelihood chi-square statistic 47.362 (which also gives a p-value of 0.000<0.05). So, with an alpha significance level of 0.05, we can conclude that there is a significant association between the two variables (the implementation of the KAQA model and foresight activity in the organization). This would lead us to conclude that quality management and organization excellence frameworks implementation in Saudi organizations would be an enabler for successful foresight implementation. This would lead us to pronounce that in order to achieve their strategic objectives in line with the national vision 2030, Saudi organizations to implement quality management systems such as ISO 9001:2015 and the national quality award (KAQA).

Table 5. Tabulated Statistics: KAQA Implementation vs Foresight Department

KAQA Implementation		**Foresight Department**			
		Yes	**No**	**Not sure**	**All**
Yes	Count	22	12	11	45
	Fr(%)	16.70	15.27	13.03	
No	Count	25	49	10	84
	Fr(%)	31.17	28.51	24.33	
Not sure	Count	35	14	43	92
	Fr(%)	34.14	31.22	26.64	
ALL	Count	82	75	64	221
	Fr(%)	37.10	33.93	28.96	

CONCLUSIONS

Through measurement of the readiness level of Saudi organizations to adopt foresight activity as a strategic tool to anticipate future changes dictated by the 2030 national vision and Industry 4.0 drivers, this paper discusses the relationship between foresight and quality management and organizational excellence approaches.

The paper shows that the role of quality management and business excellence is pivotal to the building of Saudi organizations` competitive advantage based on foresight as one of its core competences. The statistical analysis of the surveyed organizations shows that the degree of Saudi organizations readiness to adopt foresight in their strategies is rather high and it is at an international standard. The analysis shows clearly that quality management and organization excellence frameworks implementation in Saudi organizations would be an enabler for successful foresight implementation.

This would lead us to pronounce that in order to achieve their strategic objectives in line with the national vision 2030, Saudi organizations to implement quality management systems such as ISO 9001:2015 and the national quality award (KAQA).

It is the author's belief that further discussion between experts would be required to explore the important relationship between quality management, organizational excellence, and foresight approaches for a better future world.

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Optimization model for waiting list management and service continuous improvement

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ABSTRACT

Purpose - This study aims to assess the number of hours*doctor required per day in each week, in a time horizon of 52 weeks, so that it is possible to gradually and controllably reduce the waiting list and the response time for the triage process that precedes the scheduling of an hospital appointment of orthopaedics speciality. A national decree law requires a response time equal or less than 5 days for the triage process, but currently, in the hospital under study, with a waiting list of 1244 users, the response time is, on average, 66 days for the speciality of orthopaedics.

Design / methodology / approach - With a team of orthopaedists (constituted with the objective of improving access to orthopaedics speciality appointments), the current status of the waiting list was analysed and possibilities for improvement were discussed. Based on the professional's expertise, several parameters were defined as the more relevant to manage the waiting list for the triage process, allowing the development of an optimization model which aims to minimize the number of hours*doctor per day per week required to achieve the defined objectives.

Findings - The model is able to define an optimal number of hours*doctor per day per week meeting all the process constraints. Thus, it is required 1400 hours*doctor to reduce and maintain the waiting list between the boundaries defined as acceptable, as well as reduce the waiting time to 9 days. The model is also capable of orienting the professionals to search alternative optimal solutions that for specific contexts may better fill the hospital needs.

Originality / value - This study presents a tool that can support waiting lists management across any service provided by health organizations. The model ease of use allows for fast parameterization and results achievement in continuous improvement meetings.

Keywords: Operational Research, Hospitals, Continuous Improvement, Optimization Model.

Paper type: Case Study

INTRODUCTION

One of the biggest challenges that hospitals face today relates to the performance of their functions given the large number of users appealing for their services. This is a challenge due to the limited human and financial resources available in hospitals. This problem is reflected by the long waiting lists existing in the different services provided by the hospital units, common in several modern health systems, with regard to public health services (Johannessen and Alexandersen, 2018). If, on the one hand, waiting lists provide for the uninterrupted use of the expensive resources of health services, justifying the installed capacity, on the other hand the dimensions they reach go far beyond the numbers necessary for this purpose (Worthington, 1987).

The orthopaedics appointments are the gateway to the orthopaedic surgery services, which, largely driven by the aging of the population, presents a growing demand trend (Jarman et al., 2020), being in this case one of the specialities with largest number of users on hold. In the specific case of this study, which focuses on the MGRT (Maximum Guaranteed Response Time) of the triage process for scheduling appointments for the orthopaedics speciality, of a public hospital in Portugal, the waiting list for the triage process had (by the date of the study) 1244 users with an average waiting time of 90 days. It is expected that the hospital perform the triage process for appointment request in a MGRT of 5 days (Ministério da Saúde, 2013). Beyond a slow response regarding the patient's point of view, the hospital is incurring financial penalties by the Central Administration of the Portuguese Health System for non-compliance of this times.

Thus, taking the example of supply chain management mentioned by Priyan (2017), in other areas of hospital operations management the people responsible for decision-making are doctors who, despite their excellent clinical capacity, do not have knowledge in the area of operations management. That way, taking into account the contributions and the potential of applying operational research to the efficiency and effectiveness of healthcare services (Carter et al., 2012), this work aims to develop and analyse an optimization model that can be applied as a means of support and guidance to the management of the triage waiting list, in order to respond to the hospital and patients' needs. Recognizing the importance of matching capacity to demand (Eriksson et al., 2011; Siciliani et al., 2014), the model should be able to define an optimal number of hours*doctor per day per week meeting all the process constraints.

To achieve this goal, the case study methodology is adequate. Thus, a case in a public hospital is characterized and analysed to create a solution that can reduce the waiting list. Operational research is not a new approach in the healthcare systems, many researchers and managers in the health services adopt operational research concepts and methodologies used in other business areas (Priyan, 2017).

This study also had the contribution and participation of a team of orthopaedists, constituted in order to improve the service level and consequently its response effectiveness. It is important to recognize the importance of the involvement of health professionals in this process as their contribution was fundamental in the definition of problem parameters and goals.

CHARACTERIZATION OF THE WAITING LIST FOR TRIAGE PROCESS

This study was developed as part of a project for continuous improvement of the external appointments service of the orthopaedics speciality of the hospital. The study regards the access to the first appointment of orthopaedics speciality and aims the reduction of the waiting list and consequently the waiting time.

Patients may access to the hospital (to a speciality appointment) in three different ways: as an outpatient, as an emergency patient, and as a hospitalized patient. This study focuses on the outpatients who came from the primary healthcare services, by the request performed by general clinical doctors (also known as "family doctors" in Portugal). The focus on this type of access to the hospital is justified since it is on this type of access that the hospital is monitored by regulatory health authorities and through which the hospital is subject to financial penalties for non-compliance with the regulated MGRT, shown in Table 1.

Table 1 - MGRT (Ministério da Saúde, 2013)

MGRT (Days)		
Triage	5	
First Appointment	Very urgent requests	30
	Urgent requests	60
	Normal requests	120

At the date of this study, the number of requests waiting for a first orthopaedic appointment was 4835 with an average waiting time of 210 days. These requests have to be subjected to a triage process and, from the 4835 patients, there was 1244 patients without triage process, with an average waiting time of 66 days and maximum of 543 days. According to the information analysed, only very urgent requests had met the MGRT for the first appointment.

The triage process aims to establish a priority level so that the requests may be ranked according to its urgency. However, in the triage process it is also possible to accept or discard the appointment request. If the request is accepted, then a priority is assigned. If the request is discarded, then it may be completely discarded being then removed from the system (and waiting list). However, the request may be temporarily discarded, being returned to family doctor to review the clinical process of the patient (for example, due to lack of clinical information or due to lack of exams). In the returned requests, the patient remains in the system and the waiting time increases continuously until a response is obtained from the family doctor. The time elapsed between returning the request and receiving the updated request is a time in which the hospital has absolutely no control and compromises its indicators, namely the MGRT for the triage process.

This project has as an essential principle which is the involvement of doctors in the improvement process. So, with the improvement team, consisting of orthopaedic doctors, were presented and discussed the main conclusions of an exhaustive analysis of information collected from the Hospital, referring to the records of the speciality.

According to the orthopaedics doctors, many of the patients who are observed in the appointments were sent to the hospital without a previous study of the disease, namely without being prescribed any exams. It was also identified that several patients do not presented pathologies justifying an appointment in the hospital. All these factors are contributing for the increasing of the waiting list and for the unnecessary use of highly specialised resources as the orthopaedics doctors.

Situations like these would be easily avoidable through the triage process, by discarding or returning the requests. However, the orthopaedic doctors recognize that it is unacceptable to discard a request that is waiting for so long for the triage process (maximum 543 days), and after the triage process will wait for the first appointment. Return a request will only delay the patient process. So, the conclusion is that if the triage time is high it is unacceptable to discard requests. If the triage time is very short, then the hospital may discard non-justified requests.

In this way, relying in the expertise of the team, a waiting time of two weeks for triage was defined as an acceptable period for the discarding of a request. Being so, one of the main objectives outlined by the team was to increase the number of triages to reduce the response time. With the definition of this objective, it was intended to achieve the response time that allows the rejection of requests within the time considered acceptable, becoming also more flexible in identifying the urgent requests.

Thus, since the orthopaedic doctors admit that no triage time is defined in their schedules (the triage process was performed by good will in the emergency room in periods of low service demand), it became essential to assess the number of hours necessary for the objective to be achieved, and also to include those hours in the doctors schedule. In this sense, an optimization model was developed in order to provide a solid support base for decision making, regarding the management of the waiting list for triage process, with the aim of assessing the needed capacity, translated into hours*doctor per day, for the triage process.

OPTIMISATION MODEL TO DEFINE THE REQUIRED DOCTOR CAPACITY

This section shows the modelling of the problem, which aims to achieve the optimal solution for the minimum number of hours*doctor required per day, on a weekly basis, for one year, to control the waiting list of the triage process.

Although apparently simple, the problem definition is more complex than it looks like at a first glance. There are several constraints related to the triage process that makes the problem hard to solve empirically. The problem is constrained by the existing number of requests in the waiting list, by the requests that arrive to the hospital daily (demand), by the processing time to perform a triage (and the efficiency of the resources), by the number of days that the speciality operates, by the number and distribution of the triage hours by resources and their schedules, and by the waiting list behaviour to achieve the required MGRT.

In order to achieve the intended objective, it is necessary to establish the constraints that the solution to this problem must meet. Thus, regarding the control of patients in the waiting list, two constraints were considered. One of the constraints considers a progressive reduction of the waiting list (maximum number of patients in the list), and the other constraint considers a minimum number of patients in the list. This pair of constraints aims to define the limit values of the waiting list in order to achieve the desired response times and also to distribute, in a more uniform way, the workload between the several weeks of analysis.

Another important constraint to be taken into account is the number of hours*doctor per day that doctors can dedicate to the triage process. As there is a capacity limit (in terms of hours dedicated to the triage process, either by limited number of orthopaedists, or the time they have to dedicate to other tasks) it was established a maximum number of hours*doctor per day. As well, a minimum limit to the number of hours*doctor per day was establish for the triage process. This minimum limit is necessary because since the defined number of hours*doctor per day can only be changed on a week basis (meaning that during a week the number of hours*doctors per day is always the same), this restriction prevents the model from defining weeks without triage process (hours*doctor per day = 0), which is mandatory because a week without triage may mean that urgent cases are not analysed.

Finally, in order to avoid a disparity in week schedules, a pair of restrictions were also established that aim to contribute for smoothing the doctors' schedules, thus imposing a limit on the variation of hours*doctor per day allocated to the triage process between two consecutive weeks.

Being an optimization problem in the area of operational research, it is necessary to define the mathematical notation of the parameters, decision variables, objective function and constraints of the problem. This mathematical notation allows an adequate conceptual modelling of the problem.

Parameters:

LI (initial waiting list): represents the current waiting list when the model is executed.

$\mathbf{LP_i}$ (expected waiting list): represents the expected (forecasted) waiting list for week i.

$\mathbf{FMAX_i}$ (desired maximum waiting list): represents the desired maximum waiting list for week i.

$\mathbf{FMIN_i}$ (minimum waiting list): represents the minimum waiting list for week i.

D (planned days): represents the number of days planned for the service to operate.

P (demand): represents the average number of daily requests that enter the hospital.

TC (cycle time): represents the standard time for the execution of the triage process.

E (efficiency): represents the level of efficiency in the triage process, that is, it quantifies the percentage of time that is actually dedicated to the triage process and, consequently, the percentage of time that is wasted with voluntary or involuntary stops.

T (time factor): Represents the time factor that converts the number of planned days into weeks.

Decision variables:

The model intends to establish the minimum number of hours*doctor per day for every 52 weeks of the study, as follows in expression (1):

$$x_i = \text{number of hours} * \text{doctor per day in the week i} \quad (1)$$

$$x_i \geq 0 \wedge x_i = \text{integer}, \forall\, i \in \{1, 52\}$$

Objective function

The purpose of the model is to minimize the total number of hours*doctor per day, per week, for the triage process, according to equation (2).

$$Z = \text{Min} \sum_{i=1}^{52} x_i \quad (2)$$

Constraints

- Expressions (3) and (5) indicate the maximum number of patients on the waiting list for the triage process in the week **i** ($FMAX_i$):

For $i = 1$:

$$\left(\frac{E \times 60 \times D \times T}{TC}\right) x_i \geq FMAX_i - LI - P \times D \times T \quad (3)$$

For $i > 1$:

$$\left(\frac{E \times 60 \times D \times T}{TC}\right) x_i \geq FMAX_i - LP_{i-1} - P \times D \times T \quad (4)$$

- Minimum number of patients in the triage waiting list in the week **i** (**$FMIN_i$**,) are presented according to expressions (5) and (6) :

For $i = 1$:

$$\left(\frac{E \times 60 \times D \times T}{TC}\right) x_i \leq FMIN_i - LI - P \times D \times T \quad (5)$$

For $i > 1$:

$$\left(\frac{E \times 60 \times D \times T}{TC}\right) x_i \leq FMIN_i - LP_{i-1} - P \times D \times T \quad (6)$$

- Expression (7) shows the maximum number of hours*doctor per day in the week **i** (**$HMAX_i$**):

$$x_i \leq HMAX_i \quad (7)$$

- The minimum number of hours*doctor per day for week **i** (**$HMIN_i$**) is indicated by the expression (8)

$$x_i \geq HMIN_i \quad (8)$$

- The maximum variation in the number of hours * doctor per day between two consecutive weeks (**V_i**) is limited according to expressions (9) and (10):

$$x_i - x_{i+1} \leq V_i \quad (9)$$

$$x_{i+1} - x_i \leq V_i \quad (10)$$

The described model was applied to the specific case of the waiting list for triage process of the orthopaedics speciality, and the results obtained are presented and discussed in the following section.

RESULTS

All the information needed to parameterise and solve the problem was compiled into a spreadsheet in the Microsoft Office Excel software. The optimiser engine used was the OpenSolver tool.

The parameterization of the model was done according to the values presented in Table 2:

Table 219 – Parameters of the problem.

Parameters	
LI	1244 (patients)
$FMAX_i$	Represented in Figure 1
$FMIN_i$	300 (patients)
D	244 (days)
P	42 (patients)
TC	6 (minutes)
E	80%
T	0,02
HMAXi (hours)	8
HMINi (hours)	4
Vi (hours)	2

The data presented in Table 2192, with regard to LI, refers to the current state of the triage process waiting list when the model was executed. The TC was determined according to the expertise of the team of specialists. The D corresponds to days scheduled for the year in study. The value of P corresponds to the daily average demand of the previous year. As for the value of the efficiency, that was determined taking into account the voluntary and involuntary stops, since the doctors perform different functions in different services at the hospital. The parameter T corresponds to a conversion constant to convert the number of days into weeks. With regard to $FMAX_i$, because it represents a desired value for the waiting list, it is presented together with the model solution. The $FMIN_i$ represents the minimum number of patients in the waiting list.

The values of the parameters were defined according to the information obtained from the hospital and from the inherent characteristics of the triage process. All parameters characterize as accurate as possible the real state of the hospital and orthopaedics speciality.

According to the information parameterised, the model presented an Optimal Solution (OS) that meet all the constraints of the problem. Figure 1 shows the solution of the problem, as well as the values of the constraints FMAXi and FMINi imposed.

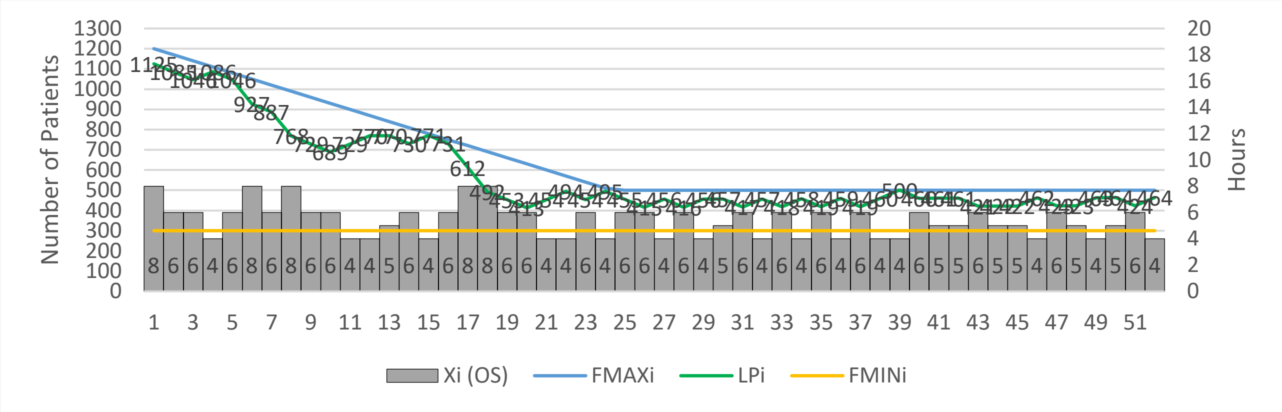

Figure 1 - Optimal solution of the problem (x_i – right *y* axis).

The results represent the optimal solution for the problem with respect to each of the 52 decision variables established in order to minimize Z. As can be seen, the maximum number of triage processes per day ($FMAX_i$) was defined as decreasing by an amount of 30, from one week to the other, until week 24. This behaviour will create a steady reduction of the triage processes requests in the waiting list as shown by the LP_i curve. It was also defined that the number of patients could be between 500 and 300. Such event occurs after week 25.

Thus, according to the objective function, the minimum number of hours*doctor required to meet all constraints is 1400 hours*doctor. From week 1 to 24, the maximum is 8 hours*doctor and the minimum is 4 hours*doctor, which may be diluted by the team members. After week 25, the minimum is still 4 hours*doctor, but the maximum does not exceed 6 hours*doctor.

It is important to notice that the expected (forecasted) behaviour for the waiting list complies with $FMAX_i$ and $FMIN_i$ constraints by varying between the constraint's lines (in the graph). The variation is more accentuated in the first 25 weeks and tends to stabilise after that. This may be explained as the variation of the limits of the waiting list become more constrained after week 25 which allows less variation to the forecasted waiting list.

Since the very beginning, the development of the optimisation model was designed to constitute an agile tool for use in the continuous improvement meetings of the project team. The ease of use allows the team to use it during the plan phase of each continuous improvement cycle. One of the capabilities of the tool is to allow the team to search an alternative optimal solution in a guided manner. These capabilities also allow the team to understand the effects of changing the number of hours*doctor per day, per week, in the length and MGRT of the waiting lists. These capabilities are especially important so the team can reallocate the number of hours*doctor to best fit the doctors' schedules. Therefore, to ensure the compliance with all the constraints, a colour scheme was applied to the model in a way that any violation of any constraint is identified. As said before, this allows for searching alternative optimal solutions and also search for solutions that (although may not be optimal in terms of minimum hours*doctor per day) may better adjust the number of hours*doctor according to the service context. This approach transforms the model into a useful and didactic tool for the continuous improvement team, that will allow testing alternative scenarios to verify which is the best alternative solution.

So, by applying the described method, an Alternative Optimal Solution (AOS), shown in Figure 2, was found. The values of the decision variables were entered manually, in order to establish a higher number of hours in the first weeks, to guarantee faster effects in the reduction of the waiting list and reach the stability of the waiting list sooner. This approach also allows for a better balance in terms of doctors' schedules considering the needed hours for the triage process. It is important to state that similar results could be automatically obtained by changing the parameters of $FMAX_i$, requiring a faster decrease in the waiting list.

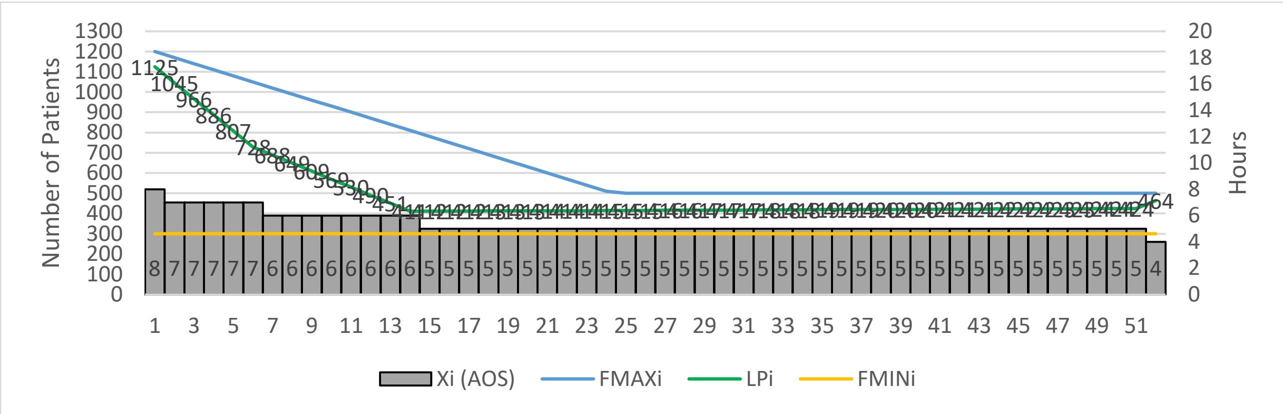

Figure 2 - Alternative Optimal Solution of the problem.

Analysing the results, the most significant changes are visible in LPi that stabilizes after 14 weeks, 4 weeks less than in the previous solution, which would be expected as this solution uses more hours*doctor in the same time horizon (OS = 405; AOS = 444). This forcing in the first weeks is only possible if the doctors' schedules can accommodate such number of hours. Being an optimal solution, the value of the objective function remained the same, 1400 hours*doctor for a period of 52 weeks.

As it is possible to verify, 5 hours*doctor per day nearly meets the current demand. This means that depending on the desired aggressiveness to decrease the waiting lists the number of hours*doctor per day may vary, then stabilizing around 5 hours*doctor per day.

The possibility of subcontracting or proposing overtime hours to doctors in the service has been considered by the hospital administration, although this only make sense if the needed hours cannot be accommodated in the doctors' schedules.

A comparison between the Optimal Solution and the Alternative Optimal Solution was developed in order to understand the effects of the solutions presented regarding the MGRT. Figure 3 shows the MGRT for triage at the end of each week, for each of the solutions.

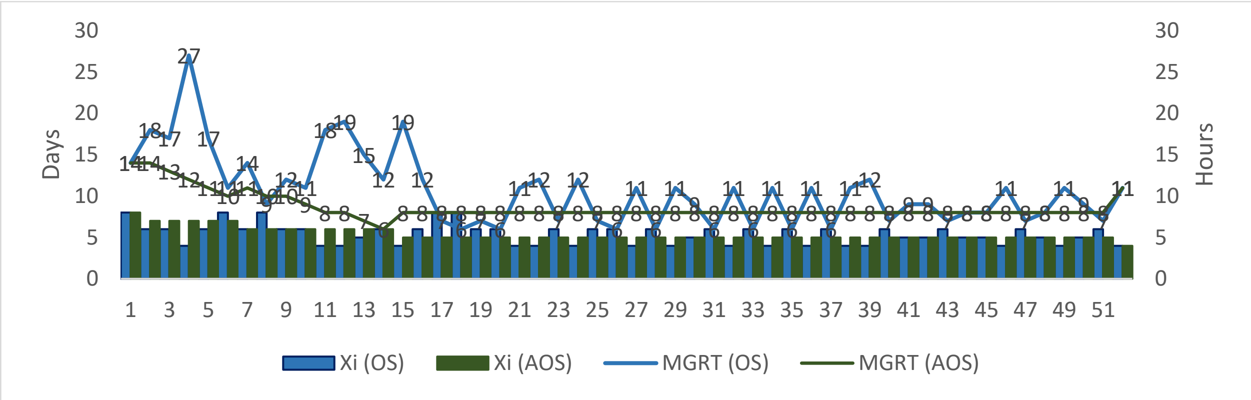

Figure 3 - MGRT for triage process.

Regarding the presented results, it is important to note that the values represent the system state at the end of each week, which means that the MGRT represents the expected value if the capacity of current week was maintained in the following week.

As an example, in the first week of the study both OS and AOS defined 8 hours*doctor per day. With this number of hours, the MGRT at the end of the week is 14 days for both solutions. In the second week the OS defined 6 hours*doctor per day and the AOS defined 7 hours*doctor per day. This difference also promoted a difference in the MGRT: the AOS maintained a MGRT of 14 days and the OS presented a MGRT of 18 days (increase of 4 days).

Throughout all the 52 weeks period, it is possible to observe that there is a higher variation of the MGRT in the OS than in the AOS. This was an expected behaviour as the main goal when defining the AOS was to minimize the variation of hours*doctor per day between weeks.

In both solutions, after the waiting list reach the stable stage, the MGRT values were steadily maintained below the two weeks period indicated as acceptable by the team. In global terms the average MGRT for the OS is 11 days and for the AOS 9 days, which also corroborates the specified two weeks period.

CONCLUSIONS

The model presented an optimal solution to the problem, revealing the minimum number of hours*doctor per day required, meeting all the constraints of the problem. Considering all the constraints and their parameterization, the minimum number of hours*doctor for the time horizon of 52 weeks is 1440. The MGRT obtained is dependent on the hours*doctor per day, per week. In global terms the average MGRT for the OS is 11 days and for the AOS is 9 days, which meet the requirements of being less than two weeks.

More than defining the number of hours needed, this project built a sense of awareness on the dimension of the problem which also reinforced the need of a team for continuous improvement. The work carried out with the continuous improvement team will allow a better perception of the information analysed, as well as a better adaptation to the reality of the speciality under study.

The developed optimization model presents itself as a tool to support decision making regarding the management of the waiting list for the triage process, however it can be extrapolated to deal with other services waiting lists. The model was also designed to be a useful and didactic tool for the continuous improvement team, that will allow testing alternative scenarios to verify which is the best alternative solution. In a continuous improvement cycle the model may be easily updated to start a new cycle in the plan phase.

Allied to the model and the definition of the needed hours to decrease the waiting list for the triage process, the team of orthopaedic doctors has been strongly committed to attain an overall improvement of the service. Such commitment is, in fact, the most important input for continuous problem solving.

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