UNIVERSITY
INSTITUTE
OF LISBON

Redesigning the picking process followed in the advanced warehouses at Hospital CUF Tejo

Catarina Albarran Rosmaninho

Master in management of services and technology

Supervisors:

Prof. Teresa Grilo, Assistant Professor
Iscte Business School,
Department of Marketing, Operations and General Management

Prof. Abel Camelo, Invited Professor
Iscte Business School,
Department of Marketing, Operations and General Management

October 2023

Redesigning the picking process followed in the advanced warehouses at Hospital CUF Tejo

Catarina Albarran Rosmaninho

Master in Management of Services and Technology

Supervisors:

Prof. Teresa Grilo, Assistant Professor
Iscte Business School,
Department of Marketing, Operations and General Management

Prof. Abel Camelo, Invited Professor
Iscte Business School,
Department of Marketing, Operations and General Management

October 2023

Acknowledgements

First and foremost, I express my sincere gratitude to my father and mother for creating an environment conducive to the development of my academic journey, as well as for inspiring me to achieve the best version of myself.

To my sister, I am thankful for her continuous support throughout the entire process, closely following the development of this project.

To Pedro, for his unwavering support, unwavering belief in my abilities, and for motivating me to never give up on my goals.

To my two academic mentors, Professor Teresa Grilo and Professor Abel Camelo, I extend my appreciation for their tireless encouragement to produce the best possible work, demonstrating precision and readiness in all our meetings and discussions. Without their guidance, this project would not have been realized.

To the CUF team, especially to the coordinator of the logistics department at Hospital CUF Tejo, Ana Ramos, I extend my gratitude for providing the necessary conditions for the completion of this project, displaying consistent availability and support.

To the entire clinical and logistics team, who welcomed me with kindness and were always ready to offer assistance, I offer my deepest thanks. Without their collaboration, the realization of this project would not have been possible.

Finally, to my friends, colleagues, I thank you for making this journey more enjoyable and interesting throughout these years.

Resumo

Atualmente, o termo "eficiência" é amplamente discutido e valorizado e o setor da saúde não é exceção. Dito isto, o interesse público e privado está focado em assegurar os melhores cuidados de saúde através da utilização eficiente de recursos, de maneira a minimizar os seus custos.

O presente estudo teve lugar nos armazéns avançados do Hospital CUF Tejo em Lisboa, Portugal, com o desafio de redesenhar o *processo de picking* executado pelas auxiliares de ação médica nos armazéns avançados do Hospital, com o objetivo de melhorar a sua eficiência e eficácia.

Considerando o objetivo referido, a metodologia aplicada foi Design For Six Sigma que seguiu a estrutura DAMDV. Assim sendo, iniciou-se a investigação através de observações diretas e entrevistas semiestruturadas que, nos permitiu compreender o processo, identificar as suas necessidades e consequentemente os fatores críticos para a qualidade do mesmo. As falhas e ineficiências detetadas e os casos práticos estudados através de entrevistas e benchmarking, permitiram o desenvolvimento consciente sobre as soluções. O conjunto de soluções propostas será avaliado à luz de múltiplos critérios, incluindo a sua adequação para a resolução das causas raiz e CTQs. Esta avaliação final permite concluir que o conjunto de soluções propostas fornece uma respostas adequada às causas raiz e CTQs identificados. Uma vez que a alternativa proporciona melhorias significativas na eficiência e eficácia do processo, estando em conformidade com os objetivos definidos.

Palavras-chave: Cuidados de Saúde, Processo de *Picking*, Design for Six Sigma, DMADV.

Abstract

Currently, the term 'efficiency' is widely discussed and valued, and the healthcare sector is no exception. Within this setting, both the public and private interests are focused on ensuring the best healthcare provision through the efficient use of resources while simultaneously minimizing their costs.

The present study took place in the advanced warehouses of CUF Tejo Hospital in Lisbon, Portugal, where it was proposed the challenge of redesigning the picking process carried out by healthcare assistants in the hospital's advanced warehouses to improve its efficiency and effectiveness.

Considering the stated objective, a case study methodology was applied, and the Design for Six Sigma based on the DAMDV cycle was followed for the redesign of the process. Thus, the research began with direct observations and semi-structured interviews, allowing to understand the process, identify its needs, and consequently, the critical factors for its quality. The underlying problems and their root causes are afterwards identified, followed by a proposal of solutions, with such solutions being based on benchmarking and interviews with the interested parties. The set of proposed solutions will then be evaluated in light of multiple criteria, including their suitability for addressing the root causes and CTQs. This final evaluation allows us to conclude that the proposed solution provides an appropriate response to the identified root causes and CTQs. Once the alternative offers significant improvements in process efficiency and effectiveness, aligning with the defined objectives.

Key words: Healthcare, Picking Process, Design for Six Sigma, DMADV.

INDEX

Table index

Figure Index

List of abbreviations

BPR – Business Process Redesign

CTQ – Critical to Quality

DFSS – Design For Six Sigma

DMADV – Define, Measure, Analyze, Design, Verify

HoQ – House of Quality

SIPOC – Suppliers, Inputs, Process, Outputs, Customer

TQM – Total Quality Management

VOC – Voice of the customer

1. INTRODUCTION

1.1. Context

It is undeniable that the term *quality* in the provision of health care is indispensable. If there is a sector where the space for error is quite limited, it is in healthcare, since a large part of the failures may directly influence the patient´s health (Breuker et al., 2017).

Therefore, it is important to work constantly and intensively to improve processes so that the capacity of the hospital is exploited to the fullest. It is important to understand that it is of great interest to any healthcare leader to provide top-notch patient care since that will result in extremely well-pleased and devoted clients (Scotti et al., 2007).

Like many other sectors, healthcare has been battling with growing expenditures and declining income for some time. International healthcare systems are under more and more pressure to save costs and waste while maintaining high standards of patient care (Boelman et al., 2021). One method for responding to such pressure is by increasing operational efficiency (Boelman et al., 2021). Healthcare organisations must continuously enhance and redesign their processes when needed, both for clinical and non-clinical processes. In fact, an organization is able to provide the greatest quality of care only when focusing its efforts on improving both types of processes. As a result, both practitioners and academics are closely scrutinising healthcare logistics and supply chain management (Piccinini et al., 2013).

Inefficient management of inventory within healthcare companies results in substantial financial losses and adversely affects the quality of patient care, either through overstocking or stockouts (Balkhi et al., 2022). This deficiency in inventory management is one of the most evident sources that contributes to inefficiency in the health sector, as a consequence, numerous healthcare organizations are actively exploring innovative solutions to enhance their supply chain processes, reducing costs without sacrificing the high calibre of their services (Balkhi et al., 2022).

With this in mind, and similarly to many other hospitals interested in making their supply chain more efficient, the hospital logistics department of the CUF Tejo aims at improving warehouse operations, particularly, improving the picking process in its advanced warehouses. This picking process is done by healthcare assistants, and it was established that it would be done the collection and barcode scanning of the items to be picked at the same time, with this scanning being key to having updated information about the inventory. In other words, every time an assistant goes to the advanced warehouse to remove products from the shelf, the slaughter of the inventory would have to be registered through the device they have available for this purpose.

The picking process is very important for the proper functioning of the CUF Tejo Hospital once the supply of material to the hospital depends on the correct execution of the picking process. Additionally, only through its correct execution is it possible to have access to a real number of the existing physical inventory. As we know, this information is essential for any manager, to reduce unnecessary expenses and make the most of the assets they have.

However, this process is not being executed as it should, and the inventory is not being updated in the system whenever the material is removed from the advanced warehouse. What happens is that the healthcare assistants pick the material from the advanced warehouse when they need it, without introducing that information in the system. O An attempt to regularize this information in the system is done later, usually once a day - for example, considering a drawer that contains syringes, if the assistant recognizes that the drawer is half full or less, then the assistant will update the inventory to reflect that half of the syringe stock was picked.

It is important to understand that this process is not being properly executed due to a set of factors. First, healthcare assistants do not introduce information about the volume that was picked during the picking process because they consider it as a time-consuming process, and in certain circumstances, that particular material might be required for urgent healthcare provision. Another factor is that healthcare assistants consider the process to be slow, difficult, and non-intuitive, and therefore it is not executed at that time. Finally, with the non-execution of the process, the different clinical services have established specific moments and healthcare assistants to attempt to regularize the inventory. Once these moments were created by the chief nurses, the deduction at the time of withdrawal fell by the wayside. With these moments established by the chief nurses, the healthcare assistants themselves no longer felt obliged to make the deduction at the time of withdrawal of the material.

The fact that this process is not being done as intended brings different constraints to CUF Tejo Hospital. Stock-outs and overstocking will be two of the problems that arise immediately. Since the inventory levels shown in the system are not in line with the physical stock, these two situations inevitably arise, causing direct problems in patient care. On the other hand, another constraint created by the non-execution of the established process is the lack of visibility, which is inevitably a complex problem to manage. When examining the supply chain of CUF Tejo Hospital as a set of processes that are integrated, we understand that this integration means collaboration and that collaboration only exists when there is, in fact, information sharing. The information we are referring to, in this case, is the one related to the updated inventory levels, which, due to the wrong execution of the process, do not reach the logistics management departments. This creates a management problem: inefficient stock control, which leads to stockouts and overstock situations. Without access to reliable data, they cannot understand at what speed they are using a certain material, for example, or make management decisions.

Given the clear significance of the picking process at Hospital CUF Tejo, the current approach and the consequences of its non-execution as planned, we are able to assert that Hospital CUF Tejo faces a management problem.

Taking these problems into consideration, the purpose of this project is to propose alternative methods for the picking process in advanced warehouses, with the objective of improving the efficiency, effectiveness and overall comfort of this process for healthcare professionals. It is recognized that the current picking process can be uncomfortable for healthcare professionals, and as such, it is important to explore alternative methods that can enhance the workflow and reduce the physical and mental burden associated with this task. In the end, the real challenge will be to redesign the current picking process while considering the needs of the people who perform this task, as well as of the remaining health professionals who inevitably depend on these consumables to perform their work. The project is going to be carried out in the four advanced warehouses of four clinical services: the Intensive Care Unit, Ward 4 of Medicine and Surgery, the Outpatient service and finally Ward 3 of Medicine and Surgery.

As far as literature is concerned, few studies were found focused on redesigning or improving picking processes in a hospital environment. This obstacle, despite representing a challenge, is also seen as an opportunity to contribute to literature.

Against this backdrop, this project aims to answer the following research question: "How to redesign the picking process in the Advanced Warehouses at the CUF Tejo Hospital to improve its efficiency, effectiveness and overall comfort of this process for healthcare professionals?".

This investigation will undoubtedly be a difficult challenge but more importantly, it is a very required one. Required for a large company like CUF, so it can take another step towards excellence and to the top when it comes to the provision of health services in Portugal.

1.2. Objectives

Considering the aforementioned, the main objective is to propose one or more alternative methods for the picking process in advanced warehouses, with the objective of improving the efficiency, effectiveness, and overall comfort of this process for healthcare professionals.

More detailed specific objectives have been defined to be achieved through the development of this dissertation. These objectives have been established with the aim of charting the course to be pursued in order to attain the general objective. Thus, the following specific objectives (SO) have been identified:

- SO1 – Define the *as-is* situation for the current process – by observing, mapping, and acquiring an in-depth understanding of the process.
- SO2 - Pinpoint wastages and inefficiencies in the current process.
- SO3 - Explore and examine alternative methods for the process through relevant literature and benchmarking and create one or more solutions to the current process.
- SO4 – Propose a *to-be* scenario for the future process and proceed to evaluate the of suggested solutions.

1.3. Research Methodology

Considering the above-stated specific objectives (SO), in section 1.2. Objectives, for this research project at CUF Hospital a case study approach is to be employed to address these. As such the proposed research design encompasses various phases (bellow described), and a combination of descriptive, once it describes characteristics of the current situation, correlational, by determining the relationship between variables and causes, and experimental, by establishing cause-and-effect relationships between variables, research designs.

This research employs a case study approach by applying the Design for Six Sigma DMADV (Define, Measure, Analyse, Design, Verify) methodology, aiming to provide a practical and contextual understanding of the current process, and allowing for the detailed exploration of inefficiencies and potential improvements to *picking process* in CUF Tejo Hospital. Additionally, this approach will allow for a variety of data types (qualitative, quantitative, observational) to be collected, to support the application of the DMADV cycle as well as force engaging with stakeholders, ensuring their perspectives are considered in the analysis and solution design.

To support the research design and approach defined, the following phases were set as the methodology for thesis:

1. **Process assessment and scope definition:** Identify the process that requires redesign. Define the scope and objectives of the improvement initiative, ensuring they align with the organization's overall goals.
2. **Stakeholder analysis and engagement:** Identify key stakeholders that participate and are affected by the process. Consult and involve with the stakeholders to understand their problems and needs as well as, expectations, and ideal results.
3. **Literature review and methodology identification:** Review theoretical foundations, and previous research that can be used to sustain and validate the thesis.
4. **Preliminary data collection:** Collect relevant information about the process and its performance, inconsistencies, limitations, and inefficiencies.
5. **Process data collection and analysis, redesign, and solution development by employing DFSS DMADV, it is possible to:** Identify and prioritise areas that need improvement by analysing the data, designing and creating potential solutions that address the identified issues aligned with the defined objectives. Also, collaborate with stakeholders to validate and confirm the suggested solutions ensuring these changes may lead to tangible and measurable improvements.
    a. Define Phase
    b. Measure Phase
    c. Analyse Phase
    d. Design Phase
    e. Verify Phase

6. **Project closure and review:** Conduct a thorough analysis and consider the results, accomplishments, and lessons learned.

1.4. Structure

This thesis document is structured into five chapters, as follows:

Chapter 1 - Introduction: The purpose of this chapter is to provide context to the reader about the in-company project that will be the subject of study throughout the dissertation, as well as the formulation of the research question. This chapter also defines the objectives that we propose to achieve, the methodology chosen to develop a solution, and the structure of the dissertation.

Chapter 2 - Literature Review: In this chapter, we will draw conclusions from scientific articles and books that served as theoretical support in the development of the project.

Chapter 3 - Methodology: This chapter describes in detail how the research is conducted, the various steps required to achieve all the objectives we have set out to accomplish, as well as all the tools and working methods used to analyze and understand the process.

Chapter 4 - Case Study: In this chapter, context will be given about the company where this project is taking place, as well as the process under analysis and change. The problem will be explained in detail, as well as the tools used in each step of the chosen methodology.

Chapter 5 - Conclusions: The main objective of this chapter is to provide an answer to the research question, as well as the objectives we have set out to achieve. This is also the point where the limitations that existed throughout the project are made known.

2. LITERATURE REVIEW

Considering that the objective of this case study is to redesign the picking process in the advanced warehouses of a hospital to make it more efficient and effective, we deemed it essential to begin the literature exploration with three available design approaches that could serve as the foundation for this case. These are Total Quality Management (TQM), Business Process Redesign (BPR), and Design for Six Sigma (DFSS).

After studying and analysing them, we concluded that the most suitable for this study would be the Design for Six Sigma methodology. Since it wasn't possible to find case studies that used the DFSS methodology in the redesign of a picking process in the healthcare sector, we chose to study the applicability of DFSS in the healthcare sector in different processes. Finally, we felt the need to explore case studies that delve into the picking process in the healthcare sector.

2.1. Redesign Approaches

In order to comprehend and explore the various possibilities regarding process redesigning approaches, it is important to know and understand the foundations of the following frameworks: Total Quality Management, Business Process Redesign and Design for Six Sigma (DFSS).

These management fads could appear to an outsider as separate ideas that developed independently. The majority of these management concepts, in reality, frequently built upon one another and had reoccurring elements.

2.1.1. Total Quality Management

The functional organizational structure, proved to be highly effective for corporations during the early decades of the century and throughout the prosperous post-war period of the 1950s and 1960s (Marinetto, 1999; ; Norcliffe, 1997)

However, post-war recovery boosted Europe and Japan's economies raising household incomes and reducing trade barriers in the 1970s. In the midst of global stabilization and growth, consumer demands surged, this marked the shift from supplier-driven to customer-driven economies (Chang, 2006).

The paradigm shift resulted in a transformation of management thinking and focus. One of the management initiatives that emerged to aid corporations in competing in this customer-driven economy was total quality management (TQM) (Wicks, 2001). Deming, Juran, and Ishikawa pioneered the idea of total quality management (TQM) in the 1940s. Initially undervalued, it gained traction when Deming implemented it during Japan's reconstruction, with significant results. (Majchrzak & Wang, 1996; Wicks, 2001)

Deming's emphasis on organizational practice and behaviour to attain quality through his 14 points was complemented by Juran's emphasis on the crucial role of senior management in quality improvement (Zairi, 2013). Juran also expanded the scope of quality improvement to encompass business processes (Zairi, 2013). Furthermore, Ishikawa made significant contributions to the field by introducing the notion of the quality circle organization, advocating for a philosophy of continuous improvement, and implementing bottom-up analytical techniques such as cause and effect diagrams (Chang, 2006). The total quality management concept is a management framework that relies on the conviction that every member connected with an organization plays a role in improving quality, including employees, executives, customers, and suppliers. Additionally, its primary focus is quality, since it is essential in any competitive market, where the outstanding product decides the future of the business world and the companies that will succeed or collapse (Hietschold et al., 2014). TQM is a long-term-oriented approach that has the goal of improving an existing process and impact on entire organisation (Erić & Stefanović, 2008).

2.1.2. Business Process Redesign

In order to discuss the concept of business process redesign today, we must go back to the late 1980s and early 1990s. The concept gained popularity with the definition given by Hammer and Champy in 1993, known as Business Process Reengineering. However, literature is not limited to this definition. The concept has evolved to the point where different authors have examined the topic and constructed their own definitions of business process redesign, as shown in Table 1:

Table 1 - Definitions of Business Process Redesign

Morrow & Hazell, (1992)	"The examination of the flow activities and information that make up the key business process in an organization with a view to simplification, cost reduction or improvement in quality or flexibility"
Short & Venkatraman, (1992)	"The company´s actions to restructure internal operations to improve product distribution and delivery performance to the customer."
Davenport & Short, (1990)	"The analysis and design of workflows and processes within and between organizations."

Despite their variations, all these authors essentially discuss the same idea, which entails completely re-evaluating crucial process characteristics in order to produce considerable improvements in it.

Hammer, (1990) believed utilising information and technology will allow firms to make changes in their operations. And the truth is, in the 90s, with the leap that information technology took, large companies began to see and perceive information technology as something that could make them more competitive (Chang, 2006).

Understanding the defects in the current processes, identifying the underlying causes of inefficiencies, and redefining the procedures to increase efficiency or minimise mistakes is essential for successfully implementing business process redesign. (Goel & Chen, 2008) However, process redesign is narrower in focus compared to reengineering. Reengineering projects often involve process redesign, but reengineering may be associated with more radical and disruptive change programs while redesigning gradual enhancements. (Mansar & Reijers, 2007)

Best practices in business process redesign

Mansar & Reijers (2007) examined 29 best practices that can be used in business process redesign. We selected 9 of the 29 best practices that were considered relevant and studied their advantages and possible weaknesses as shown in Table 2:

Table 2 - Best Practices in Business Process Redesign

Best Practice	Key advantages	Potential drawbacks
Task elimination “Eliminating unnecessary tasks from a business process.”	Increase the speed of processing; Reduce costs.	Quality of services deteriorating.
Task Composition “Combine small tasks into composite tasks.”	Reduction in set-up time; Higher quality; Reduce costs.	Less run-time flexibility and lower quality (when tasks become too large and unworkable).
Resequencing “Move tasks to more appropriate places.”	Saves costs; Shorter setup times.	-
Parallelism “Consider whether tasks may be executed in parallel.”	The processing period may be minimized.	Increased execution costs; Reduced quality due to complex management; Limited adaptability to unforeseen changes.
Exception “Design business process for typical orders and isolate exceptional orders from normal flow.”	Enhanced quality with requisite expertise; Time savings.	Due to a potentially more complex process, flexibility may be reduced.
Integration “Consider the integration with a business process of the customer or a supplier.”	Yield cost and time-efficient execution; Better coordination, enhancing	Mutual dependence grows and, therefore, flexibility may decrease.

	decision-making and outcomes.	
Numerical Involvement "Minimize the number of departments, groups and people involved in a business process."	Reduced coordination time leads and process duration; Reduced task overlap enhances job performance quality.	Reducing resources can increase queuing time.
Task Automation "Consider automating tasks."	Faster task completion; Lower execution expenses; Tasks can be completed more expertly.	High investing expenses: Decreased flexibility (is not humans dealing with variations that occur).
Integral Technology "Try to elevate physical constraints in a business process by applying new technology."	Time saving; Higher quality service; Revolutionize business by enabling new possibilities.	Cost of maintenance of technology; New technology can create workers resistance, decreasing quality.

The three predominant best practices, characterized by their extensive adoption, encompass task composition, integral business technology, and task elimination. We may also comprehend how business professionals view how best practices affect the quality, time, cost, and flexibility of business processes. "Integral business technology" is the best practice with the most significant impact on quality. To support the business process, information technology is used. "Task elimination" is the best procedure that reduces costs the most. This entails getting rid of extraneous tasks from the business process. "Integration" is the best practice with the most effect on time. This entails streamlining and minimizing the number of steps in the business process in order to increase its efficiency. The best practice that has the highest impact on flexibility is "empower". Giving employees more autonomy and freedom to take initiative entails doing this. (Mansar & Reijers, 2007)

2.1.3. Design For Six Sigma (DFSS)

The use of Six Sigma to improve product or service quality addresses two primary concerns. The risk of waste from design flaws, with costly and ineffective corrections and the complexity of design issues, where Six Sigma may not be suitable or sufficient. These problems show the necessity for an approach that emphasises quality assurance throughout the design phase, which led to the creation of "Design for Six Sigma" (DFSS). DFSS emphasises design thinking, preventative issue solutions, and breakthrough innovation. (Yang et al., 2022). Design for Six Sigma (DFSS) is a structured approach that employs tools and metrics to and can be highly beneficial in the design or redesign products and processes that achieve Six Sigma quality standards while meeting customer expectations (Patil et al., 2013)

In DFSS, it is deemed vital to comprehend customer needs and offer options to customers by delivering new products and services with superior performance, as assessed by customers. This approach places strong emphasis on customer analysis, ensuring a seamless transition from customer needs to product and service requirements, all the way down to process specifications (Jenab et al., 2018)

This methodology can be implemented through various methods, which may not necessarily introduce many new tools and activities. The diversity of methods is largely related to the organization and combination of tools that can be applied to each activity. Below are some of the commonly used methods:

DMADV - Define, Measure, Analyze, Design and Verify.

IDOV - Identify, Design, Optimize and Verify.

DIDOV - Define, Identify, Design, Optimize and Verify.

The three frameworks described above were studied with the aim of understanding which methodology might best suit the present case study. As the aim of this study is to redesign the picking process currently in place at the advanced warehouses of Hospital CUF Tejo, taking into account the needs of the professionals who carry it out, rather than just making marginal improvements to it and based on the analysis conducted, we are in a position to assert that Design For Six Sigma through the DMADV cycle is the one that aligns most closely with the proposed research. Although business process redesign is a possible and robust tool when it comes to optimizing processes, it was considered that DFSS would be a better fit due to its inherent characteristics. These include its approach to customer needs and their translation into critical success factors that will constitute the necessary conditions for future design. Despite the strength of the tool, BPR does not exhibit all of these characteristics that we consider essential in this context. As for Total Quality Management, this framework is typically widely used for continuous process improvement, involving all areas of an organization, as it is better suited for the development and refinement of existing processes. Since the present case study does not concern minor adjustments and corrections, we once again concluded that the characteristics of DFSS would serve this case study best.

2.2. Design for Six Sigma in Healthcare

As this case study aims to make the picking process in the advanced warehouses of a hospital more efficient and effective through the methodology selected in the previous section, design for Six Sigma, it was considered essential to explore its applicability. Since we couldn't find any case studies addressing the picking process in a hospital environment through the Design for Six Sigma methodology, it was decided to study its applicability in other processes within the healthcare sector.

In the study Mandahawi et al. (2010), the DFSS methodology was utilised in the development of a triage process for an emergency department at a Jordanian Hospital. This process transformation had the primary objective of creating a process where the illness level would be the primary concern in patient treatment rather than arrival times. The case study followed the Define, Measure, Analyze, Design, and Verify (DMADV) cycle. The project began by establishing a project team and creating a project charter to organize and clarify objectives with the hospital management team. Subsequently, critical success factors were identified through surveys filled out by a random sample of patients. Once the Critical to Quality factors CTQs had been defined, measurements of these factors were taken. Following the case study, they resorted to the Quality Function Deployment tool to understand which variables in the process had the most impact on the CTQ factors. With all the gathered information, an alternative process to the existing one was designed, implemented, and subsequently verified using a discrete event simulation model.

Gremyr et al., (2012)also resorted to using the Design for Six Sigma tool, this time to design the medication process at Skaraborg Hospital in Sweden. The chosen cycle was Define, Measure, Analyze, Design, and Verify (DMADV).

The case study began by defining the needs of various stakeholders. Subsequently, the identified problems were associated with the steps included in the Suppliers, Input, Process, Output, Customer (SIPOC) diagram that was constructed. Then, the identified needs and problems were converted into Critical to Quality (CTQ) factors using the Quality Function Deployment tool. Due to the specificities of the process, the authors considered it necessary to transform the CTQs into crucial process activities.

The solutions devised for the design of the medication process were created through brainstorming and visits to other hospitals. Finally, they were prioritized and categorized. Additionally, an action plan was developed, and various risk assessments were conducted on a computerized order-entry system (one of the ideas that comprised the solutions). To conclude the design phase, the authors decided to proceed with the creation of an implementation plan. However, due to certain process limitations, some of the solutions could not be included and were postponed. In the last phase, a permanent process organization was established for the new medication process, enabling the verification and implementation of the new design.

More recently, Kovach & Pollonini, (2022) turned to Design for Six Sigma to identify the fundamental aspects of a device that detects hospital-acquired pressure injuries. In addition to an interest in understanding the elements of this device, their aim was also to comprehend how these elements should interact. The ultimate goal was to reduce the number of incidents and their severity concerning hospital-acquired pressure injuries in Intensive Care Units.

The case study commenced by identifying and prioritizing the requirements of ICU nurses as the foundation for designing essential components of the device, ensuring its seamless integration within existing nursing processes. Needs were identified through direct observations during their shifts to understand their environment and workflow. Prioritization was conducted through a survey.

Subsequently, brainstorming sessions were used to generate various possible designs. The initial designs were analyzed by focus groups to obtain feedback. To make the final selection of a single design, an additional focus group was employed.

2.3. Picking in Healthcare

While an extensive study has been conducted on the general order-picking problem, less research has been carried out on order-picking for healthcare warehouses. Nevertheless, we proceed to select some case studies that demonstrate different approaches regarding picking process in the warehouses of several Hospitals around the world. It was also considered a case-study that despite of not being implemented in a real Hospital, had a very interesting perspective.

Kanban method in Padua´s City Hospital

A Kanban approach was implemented in Padua's City Hospital to reduce the possibility of employee mistakes. This method is based on the one-move 'card' approach. Baskets split into two halves were employed in this investigation as containers. The basket's front half carries items in use, while the rear half stores safety stock. (Rafele et al., 2008)

These containers are housed in organiser cabinets, which are only used to store hospital supplies. Ward employees are only permitted to collect things from the front of the baskets. When the items in use are close to running out, the hospital staff moves the content of the back part to the front. The FIFO (first-in-first-out) policy is so guaranteed. The basket's two distinct components ensure that the items utilised in the wards are constantly up to date. Thus, expiry issues are avoided (Rafele et al., 2008).

There are two cards of various colours for each product. The first is white and is used to identify the type of hospital material by using an item code, a brief description, and the amount. The second card is blue and is at the basket's bottom. Its purpose is to initiate the refilling process (Rafele et al., 2008).

Fully automated inventory system simulated in a virtual hospital.

The model described by Jebbor et al. (2023) outlines an advanced automated system for managing medical supplies and medications simulated in a virtual hospital under a mass casualty incident. This system is designed to enhance efficiency, minimise manual intervention, and ensure the timely and accurate replenishment of supplies. This model has some key components and functionalities that are important to outline.

Firstly, there is a Central Pharmacy, which is a central hub equipped with a "Box-Picker", a type of automated dispensing technology, responsible for replenishing medical supplies in the departments.

One important part is the Automated Gravity-Flow Racks (AGFRs) that are strategically placed near patient care rooms and operating rooms. AGFRs employ a two-bin system with Radio Frequency Identification (RFID) technology. Each consumable has two bins, and the second bin is activated when the first is depleted. RFID readers and sensors monitor the item's consumption and stock levels in real-time, transmitting this data to the IT system.

The empty and full bins are transported between AGFRs and the Central Pharmacy without human intervention, through the Automatic Transportation System. This system involves conveyor belts, and automated storage and retrieval systems (ASRSs). It ensures a continuous flow of supplies.

The "Box-Picker" robot starts by identifying empty containers in the hospital and then goes to the location where it has identified one. The robot picks up the empty container and an ASRS loads them into the 'empty bins' to the central pharmacy for a replenishment area. At the central pharmacy, the empty container is filled with the required medical supplies. After replenishment, the "Box-Picker" robot transports the filled container back to the original location where the empty container was picked up, making the supplies available for use. The “Box-Picker” robot is equipped with an RFID tag that continuously communicates with the system. It's the system that detects when the bin is empty and needs to be replenished, and it sends the robot to the location where the empty bin is, so it can be refilled.

The IT system is the central control and management system for the entire automated supply chain. It includes databases, various entities, and computer programs that handle the real-time management and control of the entire system. Suppliers and distributors are integrated into the system to replenish supplies promptly.

This automated system aims to improve the efficiency and accuracy of supply management in healthcare settings, reduce manual labour, and ensure a constant supply of critical medical items. It combines RFID technology, automated storage, and retrieval systems, and conveyor systems to create a seamless and highly efficient supply chain. This advanced approach also fosters transparency and collaboration with suppliers and distributors.

Kanban and RFID method in a public hospital in Canada

Bendavid et al. (2010)developed a project in a public hospital in Canada in the year 2010, that integrated Radio Frequency Identification (RFID) technology and the Kanban method to manage the inventory in the hospital warehouses. The implemented system works as follows: there are two bins allocated to each supply and the clinical staff removes them from the front bin whenever necessary. When the front bin runs out of material, the tag that is clipped to that bin is taken out, and it will be put on the board (that reads the tags) to alert of diminishing stock and trigger a replenishment procedure. During the period when the stock has not yet been replenished, it is taken from the second bin. When the middleware detects the tag signal, it correlates the tag ID with the bin, a specific medical supply, and the amount to be supplied to the location.

When replenishment stock comes, any remaining stock from the secondary bin is transferred to the primary bin to guarantee stock rotation, while more recent material is sent to the secondary bin. The system is then reset by reinserting the bin tags from the board into their original positions, on the bins.

After the implementation of the RFID technology system in healthcare settings, notable observations and conclusions can be drawn. The introduction of this system yielded significant time gains, allowing nurses to optimize their workflow and enhance efficiency in their responsibilities, thereby increasing their capacity to allocate more time towards patient care.

Furthermore, the system implementation markedly reduced backorder and stockout situations, improving the quality of service provided to patients. The reliance on manual processes was substantially reduced, mitigating associated errors. Consequently, the need for rounds at storage locations diminished, leading to a decrease in manual requisitions and a notable reduction in errors related to data transcription.

Another noteworthy benefit is the enhanced control and visibility over existing inventory, which minimises losses, such as disappearances of stock, and mitigates the presence of products with expired shelf life. Additionally, the system facilitates the identification of excessive usage of high-value products, promoting effective resource management. The implementation of this system also yielded notable consequences in central store areas. A discernible decrease in the number of orders placed was observed, accompanied by improved control over ordered quantities and more efficient management of urgent orders.

Comparison of manual and technological integrated methods in a hospital in Singapore

Chikul et al., (2017) aimed to implement and compare a manual model, which was the one that was running, and models that had incorporated technology, namely Radio Frequency Identification (RFID) technology and Automated Guided Vehicles (AGVs), the two models that were implemented.

The initial model operates entirely through manual processes. Inventory verification necessitates the meticulous examination of each service point by hospital personnel to identify items requiring replenishment. Subsequently, these employees return to the storage facility to manually generate and pick each order. The retrieved items are then transported back to the service location employing manual trolleys.

The inventory verification process was automated through the adoption of an RFID-enabled two-bin replenishment system. In this model, each warehouse featured two containers for each supply. The initial bin served as a storage unit for supplies, and when depleted, an RFID tag was placed on the RFID board, signaling the need for replenishment, all while allowing the continued use of the second bin. The newly implemented information system interconnected with RFID technology was responsible for order creation.

In the third model, known as automated delivery, transportation was mechanized through the utilization of AGVs that are electronic conveyances designed to autonomously transport medical supplies from storage to the point of use. While inventory assessment, order creation, item retrieval, and replenishment at service points remained manual, the precision timed AGVs greatly enhanced the predictability of medical supply deliveries, an essential aspect of hospital operations. Additionally, AGVs could be optimized to transport supplies for multiple departments concurrently, thus elevating overall productivity.

The authors conducted a comparative analysis of the three aforementioned methods, delineating the benefits attainable by the hospital. Concerning RFID technology, this system boasts the lowest overall expenses when considering the combined costs of labour, equipment, and information technology systems, as opposed to the manual system and the AGV system. However, the extent of cost savings hinges on the total utilization of staff. Departments with lighter workloads may struggle to achieve the requisite staff utilization necessary to maximize financial gains. When compared to the manual approach, this technology augments efficiency by overseeing staff utilization and ensuring resource availability.

As for the AGV model, prior industry studies indicate that AGVs offer ergonomic advantages to employees by minimizing the distances they must traverse while transporting loads. This yields intangible, long-term benefits, such as the adaptability to an older workforce and improved outcomes, including reduced workplace injuries, employee turnover, and medical leave rates. Though the introduction of RFID technology yields substantial cost savings and reduces dependence on human resources, the integration of AGVs with RFID technology decreases reliance on personnel while introducing a somewhat higher cost compared to employing RFID in isolation.

Overview

Table 3 - Case studies of the picking process in the healthcare sector

Study	**Tools / Strategies**
Rafele et al. (2008)	Kanban Method
Jebbor et al. (2023)	Conveyor belt Box- Picker Automated Transportation System
Bendavid et al. (2010)	Kanban method and RFID technology
Chikul et al. (2017)	Model 1: Fully manual Model 1: Kanban method and RFID technology Model 2: AGVs

As is evident from the Table 3, a fundamental conclusion drawn from these four case studies is the crucial role played by radio-frequency identification (RFID) technology in automating and optimizing supply chain management within healthcare settings. RFID has undoubtedly proven its capacity to optimize processes and reduce physical labour time by raising efficiency to an extent few technologies can rival.

Finally, these case studies demonstrate how important it is for everyone in the position of managing healthcare supply chains to be flexible and technologically creative, as the optimum strategic course will rely on the particular requirements and resource availability of each facility.

2.4. Conclusion

The literature review conducted allows us to first conclude that there are various options when it comes to the methodology used in process redesign, such as total quality management, business process redesign, and Design for Six Sigma. However, considering the specificities of the present case study, the decision was made to opt for Design for Six Sigma. The second major conclusion we can draw is that despite there being studies using the DFSS methodology in the healthcare sector, it was not possible to find a study that explored the applicability of DFSS in the healthcare picking process. Therefore, this study aims to contribute to filling this gap in the literature.

3. METHODOLOGY

In this chapter, it is described the research methodology employed to achieve the objectives defined. Considering the complex nature of healthcare operations and the role of efficient inventory management for CUF Hospital, it is imperative to adopt a robust and systematic approach. This chapter provides an in-depth explanation of the chosen framework, Design for Six Sigma, through the cycle DMADV, data collection methods, and data analysis procedures, ensuring alignment with the specific objectives of the project.

3.1. Organization´s context

The present in-company project was conducted with CUF (*Companhia União Fabril)*, specifically with the CUF Tejo Hospital in the hospital logistics department. The network currently comprises 12 hospitals and 12 clinics across the national territory, including both the mainland and the Azores archipelago. CUF Tejo Hospital is a recent establishment, inaugurated in September 2020. However, it was built with the aim of replacing the Infante Santo Hospital, which had been part of the CUF hospital network since 1945.

One of the challenges in hospital logistics that CUF aimed to achieve with the introduction of this new infrastructure was a different stock management model compared to what it had practiced before. The main difference is the absence of a warehouse within the hospital infrastructure. In other words, all the stock in the hospital arrives at the unloading dock and goes directly to small, advanced warehouses located near the points of use, i.e., in the various departments where healthcare is provided to patients.

The establishment of a central warehouse, the CUF Logistics Centre (CLCUF), enabled this change in stock management. The logistics centre serves various hospitals and clinics within the network, one of which is the CUF Tejo Hospital that gave rise to the in-company project developed.

3.2. Case Study Framework

Robert K. Yin, (2009) states that "the case study method allows investigators to retain the holistic and meaningful characteristics of real-life events,”. The focus on a specific situation clearly becomes an important feature of a case study methodology. This method is intended to focus on an isolated subject of analysis therefore, it can be very useful to examine the remarkable profundity of a specific process and activity or a particular problem within an organisation.

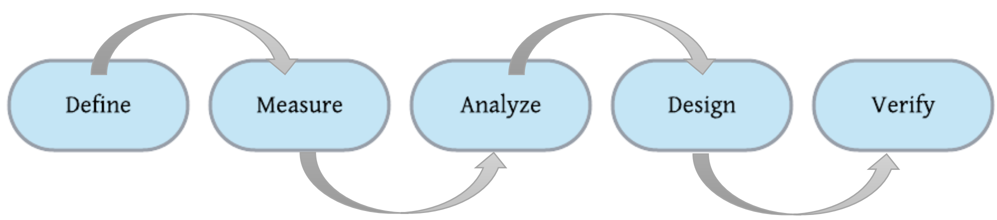
Regarding case study methodology the present case will include descriptive, correlational, and experimental research designs that will be concretized through the DMADV cycle. Define and measure phases will align with descriptive research design once it describes the characteristics of the current situation. Analyze will align with correlational research, by determining the relationship between variables and causes. Finally Design and Verify phases will align with experimental research, by establishing cause-and-effect relationships between variables, and research designs.

3.3. Design for Six Sigma framework

This in-company project is based on the Design for Six Sigma (DFSS) framework. DFSS relies on analytical methods that empower users to anticipate and avoid flaws in the design of a product, service, or process. (De Feo & Bar-El, 2002)

The objective of DFSS is to enhance customer satisfaction by reducing defects and inconsistencies observed in existing processes, while also concentrating on comprehending customer requirements, to develop a new product or process that is more gratifying and groundbreaking (Liverani et al., 2019). In order to achieve this, a cycle that encompasses five phases known as DMADV shown at Figure 1:

Figure 1 - Steps of the DMADV approach



Define

The initial phase is the Define phase, and the primary objectives typically encompass the identification of the process requiring redesign and the assembly of the project team.(Okpe & Kovach, 2017)

In this case study, it was chosen to initiate this phase by creating a project charter document. The main objective of this tool is to record essential information regarding the project, namely, the project scope, the project objectives and a project plan, where the project directives are established, and the project's organizational structure is outlined. (Dzulinski et al., 2023; Johnson et al., 2006)

Then, a high-level representation of the current picking process at the CUF Tejo Hospital is established through Suppliers, Inputs, Processes, Outputs, and Customers, (SIPOC) diagram. This diagram was done through a semi-structured interview where was asked the following questions: Q1) Could you describe how the process happens, from the beginning until the end? and Q2) Who is involved in the process from the beginning of it until it ends? These questions were asked to two elements of the logistic team and four healthcare assistants of four clinical services: the Intensive Care Unit, Ward 4 of Medicine and Surgery, the Outpatient service and finally Ward 3 of Medicine and Surgery. This tool proved to be very useful for getting to know all the players involved in the process, i.e., all the people who would have to be taken into account during the development of the project. It should be noted that this diagram gives an overview of how the process is realised.(Patel & Chudgar, 2020)

Measure

In the "Measure" phase there are two main objectives. To listen to the "Voice of Customer" and to know, map and measure the state "as-is" of the process (Gitlow & Levine, 2006; Ramasubramanian, 2012). Regarding the "Voice of Customer," the primary objective is to capture and comprehensively comprehend the requirements perceived by those who participate in and rely on the process. Subsequently, these needs are translated into quantifiable project specifications (Gitlow & Levine, 2006). The "as-is" process definition provides an assessment of the current state of the picking process (Ramasubramanian, 2012).

To fulfil these two main objectives, three primary data collection methods were used: Direct observations, semi-structured interviews, and measurements. Eight direct observations were carried out, two in each service. One was to observe the picking of consumables in the advanced warehouse and the other was to observe the updating of stock in the system, using the appropriate device. The semi-structured interviews took place in person and were recorded and transcribed. A total of 11 people from five different departments were interviewed. Three members of logistic department (two technicians and the coordinator) and eight members of clinical services (one healthcare assistant and one chief nurse for each of the following clinical services: the Intensive Care

Unit, Ward 4 of Medicine and Surgery, the Outpatient service and finally Ward 3 of Medicine and Surgery.).

Questions were prepared for two types of interviews, those conducted with hospital logistics staff and with clinical services staff since the elements of these services end up playing a very different role in the picking process. The questions prepared for the staff of the four clinical services were as follows:

Q1) What role do you play in picking in the advanced warehouses? Could you describe to me in as much detail the work you do when you go to the advanced warehouses? Q2) How do you start the picking process in the advanced warehouses? Is it already predefined when and who carries out this task? Does this employee have a pre-made list of the materials they need to pick? Q3) What difficulties do you encounter in this whole process? Q4) Do you think the current process is practical? If not, why not?

The questions prepared for the hospital logistics staff were as follows:

Q1) How involved is the hospital logistics team in the picking process and to what extent is this involvement due to failures on the part of the clinical team? Q2) Are there any tasks that the hospital logistics team is responsible for when it comes to picking? Q3) Which failures are most repeated and have the greatest influence on the good performance of the hospital logistics team?

The data gleaned from these two activities were used for two purposes. First, to build the swimlane diagram using the Microsoft Visio tool. These diagrams were validated by the coordinator of the logistics department at CUF Tejo Hospital. The primary objective of this diagram is to systematically delineate the process steps. By furnishing a sufficient level of detail to the process map, the swimlane is employed to facilitate a more comprehensive scrutiny of the process's status. A swimlane diagram can also prove to be advantageous to illustrate the presence of challenges. (Vanzant-Stern et al., 2011). Secondly, this information is also used to identify Critical to Quality factors (CTQs), which should be done as follows:

1^{st}: The interviews with the 11 key stakeholders were transcribed.

2^{nd}: Each interview was first analysed and then the needs expressed by the interviewees in relation to the process were identified.

3^{rd}: After the needs had been identified, an affinity diagram was drawn up, which made it possible to organise and categorise the various needs identified.

4^{th}: Reflection began on how the needs could be realised and delivered to the users. Therefore, were assigned one or more drivers to each of the needs.

5th: Following this process, Critical to Quality factors (CTQs) were assigned to the drivers.

After these five steps, we were left with the critical success factors for the picking process.Upon the establishment of the CTQs, the third and concluding activity alluded to earlier was initiated, entailing the measurement of the CTQs, essentially comprehending the "as-is" state in accordance with the defined CTQs. To facilitate measurement, objective, binary, and quantitative metrics were initially delineated. These designated metrics underwent validation by the coordinator of the logistics division at CUF Tejo Hospital. The primary objective of this measurement process was to gain insights into the present performance status of the identified CTQs.

Analyze

In this phase, the main objective was to analyse all the information that was extracted and worked on in the two previous phases, define and measure. As well as the tools that have materialised from this information.

This analysis enabled us to clarify the behaviour of the process and identify the root causes of the major problem identified, the inefficiency of stock control. To identify the root causes, an Ishikawa diagram (also known as a Cause-Effect diagram) was constructed through direct observation and semi-structured interviews where it was asked: Q1) What are the causes that contribute the most to the inefficient stock control that exists, in your opinion? A total of 11 people from five different departments were interviewed. Three members of logistic department (two technicians and the coordinator) and eight members of clinical services (one healthcare assistant and one chief nurse for each of the following clinical services: the Intensive Care Unit, Ward 4 of Medicine and Surgery, the Outpatient service and finally Ward 3 of Medicine and Surgery.).

This diagram is achieved through the collection of data and helps to structure causes and categorise them, simplifying the process of idea generation. It also enhances idea coherence by removing redundancies, and it aids in subsequently ranking the ideas using suitable methods (Lunau Christian Staudter et al., 2013).

To conclude this third phase, the project team deemed it necessary to prioritise the identified root causes on the Ishikawa diagram. It was important to understand which causes should be addressed with greater swiftness and urgency.

The prioritisation was carried out through questionnaires done to 24 healthcare assistants, 12 from the service Ward 4 of Medicine and Surgery and 12 from the service

Intensive Care Unit. Questionnaires were filled out by the healthcare assistants in person and individually to aid in case they required additional explanations. The project team considered these professionals to be the most appropriate respondents since they are the ones responsible for executing the process that is intended to be redesigned.

The questionnaire is structured into four categories, following the ones used in the Ishikawa diagram: 'Process,' 'People,' 'Environment,' and 'Technology.' In each category, the relevant parties were asked to rank the root causes from most to least important for elimination. It was possible to determine which causes of the problem healthcare assistants considered most important to address and eliminate. By combining the 12 rankings carried out by the 12 healthcare assistants from each department, a general ranking of the most important root causes to eliminate was obtained for each department, as shown in Annex B. Once these two general rankings were obtained (one for Service "Ward 4 of Medicine and Surgery" and another for the Service "Intensive Care Unit"),

Design

The Design phase encompasses the generation and practical application of strategies aimed at addressing the primary requirements identified in the analysis phase. The overarching aim of this phase is the formulation of an innovative design (Lunau Christian Staudter et al., 2013).

A comparative analysis, also known as benchmarking, was conducted with a focus on best practices in the field. This process enables the discernment of both strengths and weaknesses. Leveraging the insights acquired from evaluating the relative merits of these compared systems, one can devise methodologies for the construction of their own system (Lunau Christian Staudter et al., 2013).

Investigations were carried out regarding case studies related to the redesign of the picking process in a hospital environment. However, it is important to note that the availability of case studies on the subject was limited. Additionally, a visit to Braga Hospital was conducted, guided by its logistics coordinator. This hospital was chosen due to its national prominence in stock control and innovative picking processes for products in its advanced warehouses.

Finally, it was asked through semi-structured interviews the following question Q1) Given your experience, how could this process be improved? A total of 11 people from five different departments were interviewed. Three members of the logistics department (two technicians and the coordinator) and eight members of clinical services (one healthcare assistant and one chief nurse for each of the following clinical services: the Intensive Care Unit, Ward 4 of Medicine and Surgery, the Outpatient service and finally Ward 3 of Medicine and Surgery).

As a result, the process of generating ideas to address the identified root causes of the problem began. Subsequently, the created solutions were presented and then validated by the coordinator of the logistics division at CUF Tejo Hospital. Subsequently, an adaptation of the House of Quality diagram was created. The primary objective of using this diagram is not the application of the original tool, rather it is to recognise that this tool can be useful to identify solutions that combine, complement, and promote certain characteristics. Accordingly, in the "roof" of the house, the correlations between various solutions were demonstrated. This area of the diagram was filled with either a plus sign ("+") or left blank. Depending on whether the solutions in question exhibit a relationship of complementarity or not.

It is also extremely helpful to understand the correlation between the solutions and the root causes selected by the healthcare assistants as the most important to eliminate, in the previous phase. This evaluation of the solutions was made through the following scale: "9" when a solution directly and strongly addresses a specific root cause; "3" when a solution addresses the root cause moderately, and finally, "1" when the solution addresses the root cause but in a more superficial manner. This evaluation was validated with the logistics coordinator of Hospital CUF Tejo. Finally, the adaptation of the House of Quality allowed us to assess the solutions in light of evaluation multi criteria created within the project team and subsequently validated with the logistics coordinator of Hospital CUF Tejo. The defined criteria were as follows: "Time required for implementation", which the project team decided to evaluate with 100 points if the implementation period ranged from one to three months, 75 points for a period between three and six months, and 50 points for implementation within nine to 12 months. Solutions were assigned 25 points if the expected implementation time was between 12 and 24 months. "CAPEX" as for the required investment to implement certain solution, it was decided to award 100 points to solutions with an expected investment value below 1,000€. Solutions requiring an investment between 1,000€ and 7,500€ received 75 points, while those necessitating an investment between 7,500€ and 15,000€ were allocated 50 points. Solutions with an expected investment exceeding 15,000€ were given a score of 25 points. Finally, concerning the last defined criteria "Change Management", solutions expected to have a relatively easy change management during implementation were awarded 100 points. Scores of 75, 50, and 25 were assigned to solutions where it was deemed their implementation would entail mid-easy, mid-hard, and hard change management, respectively.

Each defined criterion was assigned a weight that it will have in the final score. The decision on the weight to be assigned to each criterion was made by the logistics coordinator of Hospital CUF Tejo. A weight of 10% was given to the criteria "Time required for implementation", "CAPEX", and "Change Management", while a weight of 70% was assigned to the "Root Causes Adequacy" criteria.

To conclude this phase of the project, we included the redesign of the picking process that will be achieved if the proposed solutions are implemented, that is, the "to-be" process.

Verify

The final stage of the project, the Verify phase, aims to formulate and supervise the execution of the process design to ensure a seamless initiation of full-scale production. Disseminate information to all stakeholders regarding the updated workflows, roles, and interactions. The project is formally transferred to the Process Owner, along with the associated responsibilities for the newly devised process (Lunau Christian Staudter et al., 2013).

Regrettably, the implementation of this project was impeded by challenging circumstances, specifically, time constraints. Nonetheless, we persevered by advancing the construction of a matrix that delineates the relation between the Critical to Quality Criteria (CTQs) and the solutions conceived and presented during the preceding phase. The principal objective of this matrix is to elucidate the capacity of the proposed solutions in addressing the CTQs stipulated in the initial Define phase.

Additionally, to conclude the project, it was decided to include the change management model, Adkar. This model is realized through five stages: 1) Awareness: The stage where the goal is to raise awareness among the professionals involved about the need for change. 2) Desire: This is the stage where the aim is to stimulate the professionals' interest in the change so that they desire it. 3) Knowledge: In this phase, the objective is to impart practical knowledge to the professionals to enable them to carry out the change. 4)Ability: This is the stage where it is expected that the professionals involved in the change will train their skills and have the ability to execute the change with quality. 5)Reinforcement: The final stage aims to perpetuate and even enhance the change that has already been implemented (Paramitha et al., 2020).

Tools and Activities

To summarize all the tools and activities carried out in each phase of the project that were previously detailed, Table X is presented:

Table 4 - DMADV Tools and Activities

Phase	*Tools*	*Activities*
Define	Project Charter SIPOC	Semi-structured Interviews
Measure	Swimlane Diagram Needs Affinity Diagram Critical to Quality factors (CTQs) Metrics State "As-is" of the picking process	Direct Observations Semi-structured Interviews Measurements
Analyze	Ishikawa Diagram Survey for Prioritization of Root Causes	Direct Observations Semi-structured Interviews
Design	Adaptation of House of Quality "To-be" picking process	Benchmarking Semi-structured Interviews
Verify	Matrix CTQs – Solutions Adkar – change management model	

4. CASE STUDY

4.1. Define

This project began with a meeting with the logistics coordinator of the CUF Hospitals group and the logistics coordinator of CUF Tejo Hospital. During this meeting, the "Order Picking in Advanced Warehouses - CUF Tejo Challenge" project was introduced, which is the challenge that the project sponsors aimed to address. As clarified in the Introduction chapter, the project aims to address the management problem of inefficient stock control, leading to stockout and overstock situations. This problem arises from an order-picking process in the advanced warehouses of CUF Tejo Hospital that is not being executed as originally intended. This prompted the project sponsors to challenge us to redesign the order-picking process to make it more efficient and effective and seamlessly integrated into the daily work of healthcare assistants. The aforementioned meeting helped clarify important aspects of the project, including the project plan.

Project Plan

1. Map the picking process through direct observation.
2. Interview the healthcare professionals who perform the picking process, the ones that influence it, and some elements of the hospital logistics team to identify their needs.
3. Pinpoint wastages and inefficiencies in the current process.
4. Organize the needs and formulate Critical to Quality factors of the process through the information obtained from interviews.
5. Develop metrics to measure the state "as-is" of the process.
6. Conduct a comparative benchmarking analysis by visiting peer hospitals and performing complementary research.
7. Organize the design ideas obtained through comparative benchmarking.
8. Select the "best" design idea(s) that fulfils the top-rated needs.
9. Evaluate solutions selected considering the defined needs and CTQs as criteria.

To grasp the process from a high-level perspective, two suppliers, inputs, process, outputs and customers (SIPOC) diagrams were created. It's important to highlight that the reason for creating two diagrams instead of just one is because the process is not happening as originally defined. More specifically, the process should occur in a single moment and not in two separate moments, as it currently does. To delve deeper into this, the moment when healthcare assistants go to the advanced warehouse to withdraw materials for transportation to the clinical service is distinguished from the moment when the units consumed are slaughtered in the device. This process should happen continuously, but for various reasons, it does not occur in such a way (as detailed further on).

Regarding the SIPOC that depicts the part of the process involving the withdrawal of consumables (Figure 2) the following can be observed: the process begins with the arrival of the healthcare assistant at the advanced warehouse. Subsequently, based on a previously prepared list, the assistant selects one of the consumables from the list and removes it from the shelf. Once removed, the consumable is placed on a trolley. This procedure is repeated until the list of consumables is completed, and then they leave the advanced warehouse. The inputs required for this process are the healthcare assistants, the trolleys, and the consumables. These are supplied by the human resources and logistics departments, as well as the consumables suppliers. The output resulting from this process is the replenishment of stock in the nursing units. It's worth noting that the customers of this project are the healthcare assistants and the nurses who use the consumables on patients, making them the ultimate customers to consider.

Figure 2 - High level view of materials picking process

Suppliers	**Inputs**	**Process**	**Outputs**	**Customers**
Human Resources Department Logistic Department SAP company	Healthcare Assistants Barcode label Device with barcode reader SAP software	**1.** Arrive at the advanced warehouse **2.** Remove the PDA device **3.** Insert credentials in the PDA device **4.** Open the drawer **5.** Have a close look or count item units in the drawer **6.** Read item´s bar code available in a drawer using a PDA device **7.** Enter the number of units in the PDA device **8.** Save the order in the PDA device **9.** Stow PDA device **10.** Leave the advanced warehouse	Updated inventory levels in SAP	Hospital logistics team Healthcare assistants Nurses Patients

Regarding the SIPOC that portrays the part of the process involving stock updating (Figure 3) the process begins with the arrival of the healthcare assistant at the advanced warehouse and the retrieval of the device used for stock updating. After unlocking the device by entering a code, the assistant opens one of the drawers on the warehouse shelves and counts (if it's a small number of units) or closely examines to estimate the quantity of the consumable in the drawer. Subsequently, using the previously unlocked device, the assistant scans the barcode related to the product. The barcode is located on a label attached to the drawer. The assistant enters the number of units deemed necessary to adjust and update the stock. After performing this procedure for all the drawers, the healthcare assistant places the device in its designated location and leaves the warehouse. The inputs required for the execution of this described process include the healthcare assistants, the device used for reading barcodes, the labels containing the barcodes, and the "SAP" software that enables system updates. These inputs are provided by the human resources and logistics departments and the company SAP. On the other hand, the output of the process is the update of stock levels in the SAP system. Lastly, regarding the customers of this output, they include the hospital logistics team since in the system, a restocking requirement is generated only when a product reaches its minimum stock level. It is through the creation of this requirement that consumables are obtained for restocking by the logistics team. Healthcare assistants, nurses, and patients are also considered customers of this process since they need consumables that are only delivered through the execution of the process.

Figure 3 - High-level view of inventory update

Suppliers	Inputs	Process	Outputs	Customers
Human Resources Department Logistic Department SAP company	Healthcare Assistants Barcode label Device with barcode reader SAP software	**1.** Arrive at the advanced warehouse **2.** Remove the PDA device **3.** Insert credentials in the PDA device **4.** Open the drawer **5.** Have a close look or count item units in the drawer **6.** Read item´s bar code available in a drawer using a PDA device **7.** Enter the number of units in the PDA device **8.** Save the order in the PDA device **9.** Stow PDA device **10.** Leave the advanced warehouse	Updated inventory levels in SAP	Hospital logistics team Healthcare assistants Nurses Patients

4.2. Measure

As previously explained in the previous chapter, this second phase of the project addresses two main objectives: acknowledge, map, and measure the current state of the process and listen to the "Voice of Customer."

To address these two objectives, three activities were carried out: direct observations, semi-structured interviews, and measurements.

Direct Observations

It was considered essential for the project's development to conduct direct observations of the picking process in the advanced warehouses of each service. Coordination was made with four assistants, one from each service, to determine suitable hours and days for observing the picking process without disrupting the normal routine of healthcare assistants. Visits to the warehouses had to occur in the morning, afternoon, and evening.

Observations began with healthcare assistants retrieving the consumables they needed or updating the system through the designated device. Questions were asked during or after the observation to gain a detailed understanding of the process from start to finish. Through these direct observations, we identified the challenges faced by each service and the various organizational systems surrounding this process. Once again, these direct observations confirmed that the process occurred in two distinct stages: the retrieval of consumables from the advanced warehouses and the system stock update with the designated device. The system update did not happen at the time of retrieval.

Consequently, eight direct observations were conducted, with two in each service. One observation was focused on consumable retrieval from the advanced warehouse, while the other allowed for the observation of the system stock update through the designated device, in the advanced warehouse.

Semi-Structured Interviews

Semi-structured interviews were conducted, as they offered the flexibility needed to adapt questions based on previously given responses, ensuring an in-depth understanding of the process and its issues. This interview format provided space for interviewees to express their perspectives on the topic, leading to valuable insights for the project's development.

These interviews took place in person, were recorded, and subsequently analysed. A total of 11 people from five different departments were interviewed. Three members of the logistic department (two technicians and the coordinator) and eight members of clinical services (one healthcare assistant and one chief nurse for each of the following clinical services: the Intensive Care Unit, Ward 4 of Medicine and Surgery, the Outpatient service and finally Ward 3 of Medicine and Surgery.).

Questions were prepared for two types of interviews: those conducted with the hospital logistics staff and those conducted with the various clinical services staff, as their roles in the picking process differ significantly. Following the completion of these two activities, some essential tools for the project's development were created.

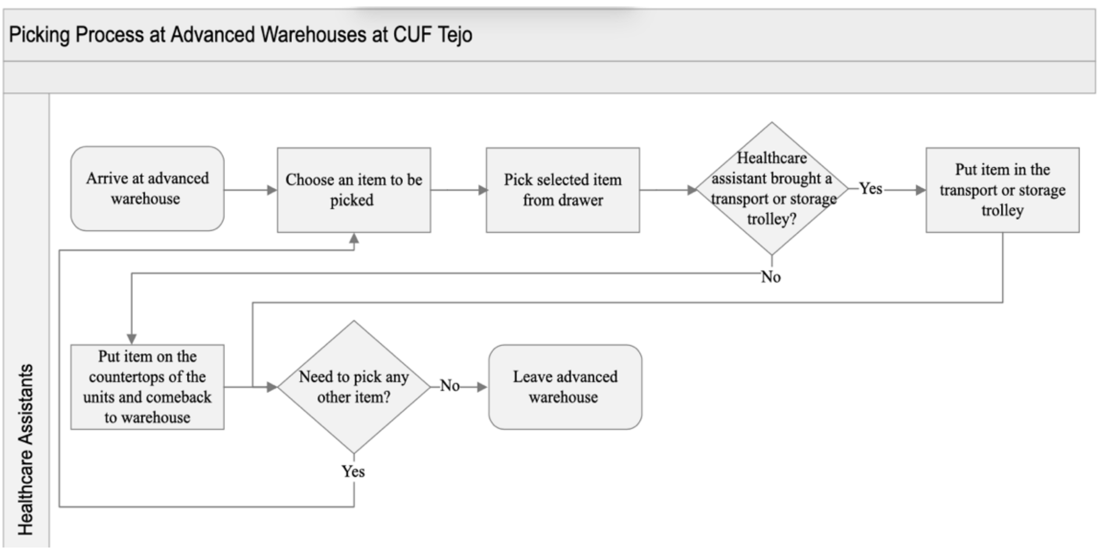
Swimlane Diagram

The first tool created was the Swimlane diagram. This tool proved to be quite useful as it allowed us to understand and clarify how the process unfolds. Similar to what happened with the SIPOC diagram explored in the previous phase, two Swimlane diagrams had to be created, one for each stage of the process.

The first Swimlane diagram (Figure 4) provides a detailed representation of the part of the process where consumables are retrieved from the advanced warehouses, more specifically:

The process begins with healthcare assistants heading to the advanced warehouse. The healthcare assistant will start by selecting items from the list prepared beforehand (based on an assessment of what was needed in the nursing units) and retrieve the respective consumables from the drawers in the advanced warehouse. If necessary, the consumables that were taken will be placed in a trolley or on the countertops of the clinical unit. Once all the items from the list have been retrieved from the drawers, the assistant leaves the warehouse.

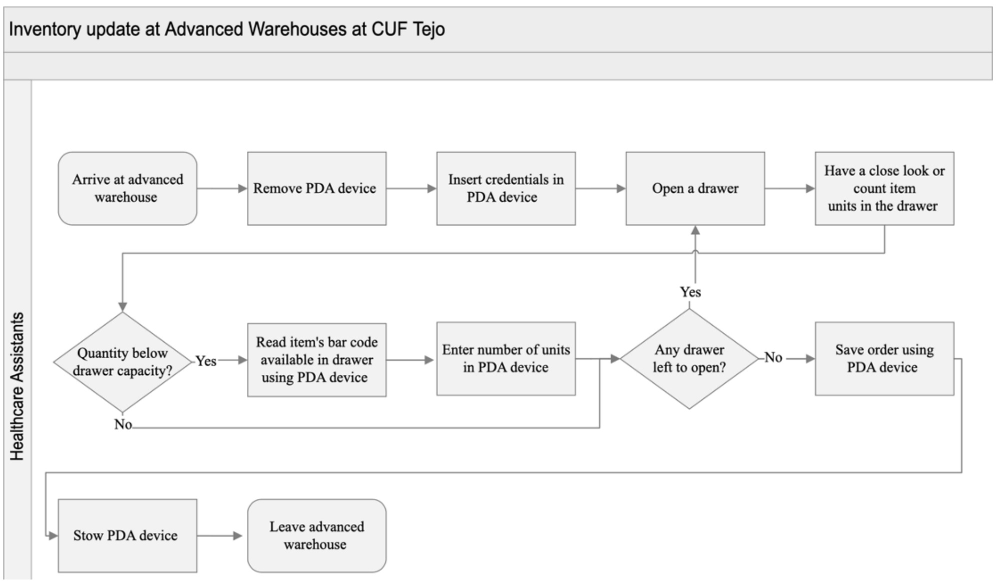
Figure 4 - Steps of the material picking process at the advanced warehouse



The second Swimlane diagram (Figure 5) describes a process that, while not the picking process itself, is quite relevant since both are directly related. It will provide a detailed representation of the process related to updating stock levels in the system, more specifically:

The process begins with healthcare assistants heading to the advanced warehouse. At that moment, the assistant will retrieve the PDA device, and insert their credentials to unlock the device. The next step is to start by randomly selecting a drawer from the advanced warehouse. At this point, the assistant will pass the device reader next to the barcode of the selected drawer. Once the drawer is opened, the assistant will count the units available for that consumable (this count is not always accurate, depending on the item and quantities in question), and will check the label on that drawer. The label displays the barcode and the maximum number of units supposed to be in the drawer. If the number of units counted is less than the maximum allowed in the drawer, the healthcare assistant, using the device, scans the barcode and enters the quantity they erroneously believe it corresponds to “an order that they are placing”. If the drawer already contains the maximum or more units, they move on to the next drawer. When there are no more drawers or shelves to review and update the stock, the healthcare assistant will place the device in its designated location and leave the advanced warehouse.

Figure 5 - Steps of Inventory Update at the advanced warehouse



Regarding the number entered in the device to update the stock:

Healthcare assistants should match the number of units displayed on the device to the number of units in the drawer. If the device's number is higher than the number of units in the drawer, the assistant should enter the value of the difference into the device. For example, if there are 4 units in the drawer, and after scanning the barcode, the device indicates that there are 10 units in the system, the healthcare assistant should enter the number 6 so that there are also 4 units in the system. If the number on the device is lower than the actual number of units of the consumable in the drawer, the healthcare assistant should not take any action. In other words, if there are 4 units in the drawer, and after scanning the barcode, the device indicates that there are 3 units of that consumable in the system, the assistant should not enter any number because the information is already incorrect, as if one unit had already been removed when it hasn't. However, it is not what is being done. Through direct observations, it was noticed that the part of entering the number into the device to match physical stock with the inventory system was not being done correctly in the vast majority of cases. It was not done correctly for two main reasons:

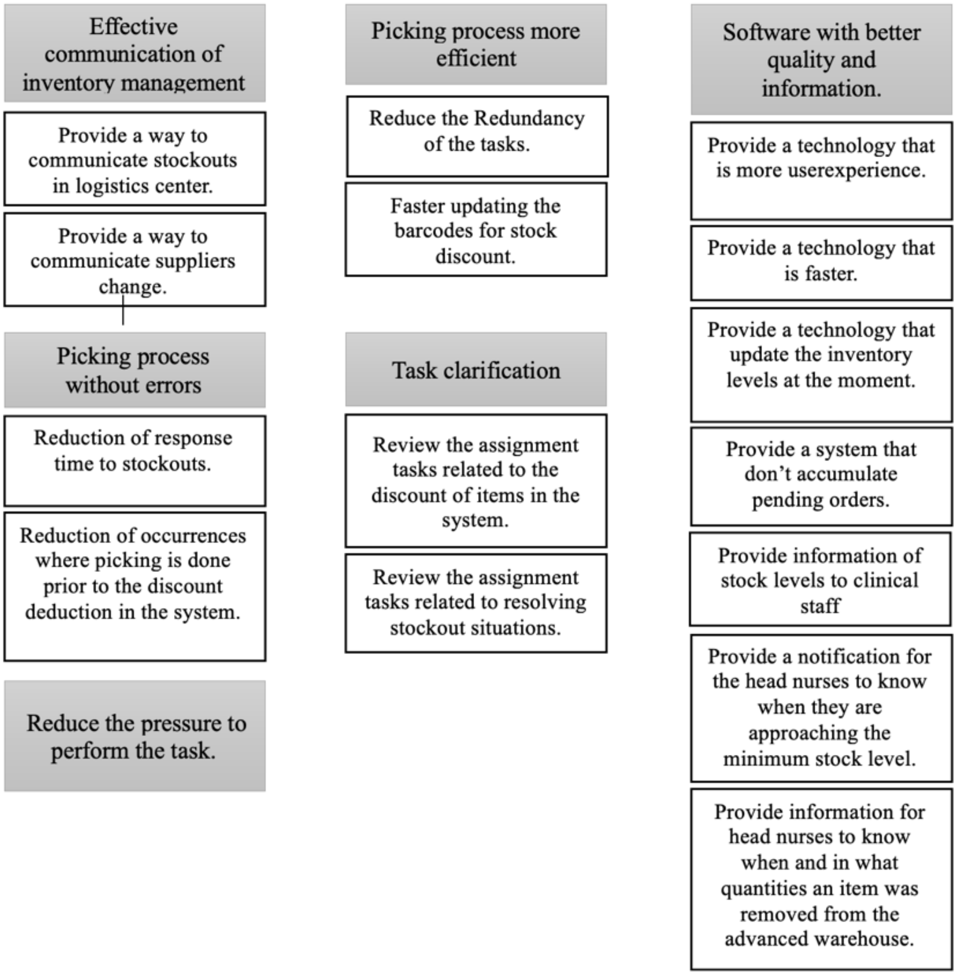
1. Healthcare assistants intentionally do not enter the correct number out of fear that they will run out of stock. They would enter the number necessary for the system's inventory to show zero when there were units in the drawer.
2. The majority of healthcare assistants do not understand that when they input a value into the device, they are supposed to be informing the system that they have taken x units of that consumable. Most healthcare assistants believe that by entering the number, they are placing orders. They are under the impression that the number displayed on the device is the maximum they can request for that consumable, when in reality that number is the stock level of the consumable.

Needs definition and Affinity Diagram

Once the 11 interviews were completed, they were listened to and transcribed. Subsequently, phrases that in some way conveyed a need related to the picking process were highlighted. In Annex A, in the left column "Excerpts from the interviews," all the statements made by the interviewees, identified as expressing a need, are listed. In the right column, "Identified needs," the excerpts are converted into more concrete needs.
Following this, an affinity diagram was created (Figure 6). The main objective of this diagram was to organize and group the identified needs to facilitate working on these

issues. Once grouped, we can conclude that the needs expressed by the interviewees from both the logistics and clinical areas can be summarized in five general needs: (1) Effective communication of inventory management. (2) Picking process more efficient. (3) Software with better quality and information. (4) Task clarification. (5) Reduce the pressure to perform the task.

Figure 6 - Needs affinity diagram



Critical to Quality and Metrics

Following the organization and grouping of the needs, a reflection began on how these deficiencies or requirements expressed by the various interviewees could be realized, that is, how it would be possible to meet and implement the needs felt on a daily basis. It was through this reasoning and approach that the "Drivers" column was created in Table 5.

After associating one or more drivers with each need, the Critical to Quality factors (CTQs) were developed. In other words, based on the needs extracted from the interviews and the associated drivers, specific characteristics and features were thought of to ensure the quality of the picking process. It was through this contemplation and evaluation that the CTQs column was created in Table 5.

While developing the CTQs, it was deemed necessary to establish metrics for the subsequent assessment of the defined CTQs, which are listed in the last column of Table 5.

Table 5 - Needs, Drivers, CTQs and Metrics

Need	Driver	CTQ	Metrics
Software with better quality and information	Updated stock	Stock updated every 12 hours	1. The percentage of times the stock was updated (every 12 hours).
	User experience optimization	Stock data availability for head nurses.	2. Number of profiles that have access to stock level of advanced warehouses.
		Fewer steps to select in the system.	3. Number of steps to select in the system.
		Notifications sent to chief nurses when there are changes in the system related to advanced warehouses (safety stock, the occurrence of stockout)	4. Notifications sent to chief nurses when: 4.1. Safety stock is reached. 4.2. Stockout is reached. 4.3. Consumables are withdrawn.
	Non-accumulated pending orders	System does not allow stock to be written down beyond its maximum.	5. The system allows or does not allow the stock to be written down beyond its maximum.
Picking process more efficient	Faster and Simpler picking process	Faster picking process	6. How much time it takes to perform the task.
		Picking and system deduction not being two separate processes	7. How often are picking and deduction done at different moments?
	Available barcodes for stock discount	All the stock in the warehouse must have a barcode	8. Number of SKUs that have a barcode associated.
Task clarification	Define responsibilities	Work instruction that is accepted by all that	9. The work instruction how to proceed in

and Effective communication of inventory management	and procedures in case of stockout	defines how both parties (clinical team and logistics team) should proceed in case of stockout.	stockout situations exist or doesn´t exist?
			10. Number of parties complying with the work instruction.
	Create a communication channel between the logistics centre and the hospital logistics team	Information Anticipation: Ensuring that the logistics team receives detailed information about the content of deliveries in advance.	11. Logistics centre previously warn the team about the content of deliveries in advance?
	Communication method between clinical services and logistics team in case of changing suppliers.	Timely and accurate communication between logistics team and clinical services regarding suppliers.	12. Logistics team communicate changes in suppliers to clinical services?
Picking process without errors	Reduction of occurrences where picking is done prior to deduction in the system.	Picking and system deduction not being two separate processes	7. How often are picking and deduction done at different moments?
Reduce the pressure to perform the stock deduction			

Measurements

Following the work done up to this point, the third and final activity in the Measure phase has been initiated, which is the measurements. The measurements carried out had the sole purpose of measuring the 'as-is' state of the defended CTQs. Therefore, the metrics created and mentioned above were used.

It's important to note that during the measurements, two out of the four services were disregarded and as a result, they were no longer included in the project. The warehouse of Ward 3 of the Medicine and Surgery Service was disregarded because, between the initial direct observations and the direct observations made at the time of time counting, they started executing the process as initially prescribed by the hospital logistics department. The Outpatient Service warehouse was excluded because it operates in a unique way by accommodating various specialties within the same service (as if they were several small services within the same service), which prevented the measurement of several defined metrics. Therefore, the project team, in collaboration with the logistics department coordinator of CUF Tejo Hospital, decided to exclude both services from the project. The measurement of CTQs happened as demonstrated in Table 6:

Table 6 - Metrics assessment

Metrics	How were they measured?
1., 2., 3., 4.1., 4.2., 4.3., 5., 7., 9., 10., 11. and 12	The measurement of these metrics was done using all the information and data extracted from the previous direct observations and interviews. Additionally, "visits" were made to the logistics and clinical services again to confirm the previously collected information
6.	Hours and days were coordinated for each of the two services to appear, in person, at a convenient time to observe the picking process. Because it was necessary to observe this process without disrupting the normal routine of healthcare assistants, visits took place in the morning, afternoon, and evening. Warehouse of the Ward 4 of Medicine and Surgery Service: 12 measurements were taken, 6 of which correspond to the withdrawal of materials from the warehouse and the other 6 correspond to stock updates in the system using the appropriate device. An arithmetic mean was calculated based on the 6 measurements taken for each activity described above. Intensive Care Unit Warehouse: 18 measurements were carried out, where 6 corresponded to stock updates in the system using the proper device, 6 corresponded to the withdrawal of consumables for partial replenishment of the service, and the other 6 corresponded to the withdrawal of consumables for total service replenishment. In this service, there are two types of unit replenishments, one where partial service replenishment is carried out, which requires fewer consumables compared to what would be required to withdraw from the warehouse if consumables were withdrawn for the total service replenishment. An arithmetic mean was calculated based on the 6 measurements taken for each activity described above.
8.	Visits were made to the advanced warehouses to determine whether there were consumables with or without an associated barcode (which

	would allow the stock consumed to be deducted in the system through the device scan). A total of 24 observations were made, 12 in Ward 4 of the Medicine and Surgery service warehouse and 12 in the Intensive Care Unit service warehouse.

State "As-is" of the picking process.

The measurement of all CTQs in light of the defined metrics resulted in data that allows us to somehow clarify and quantify the *"As-is"* state of the process regarding the defined CTQs. The following information was gathered and organised in Table 7 as follow:

Table 7 – Measurements of state "As-is" of the process

Metrics	**State "As-is"**
The percentage of times the stock was updated (every 12 hours).	Despite an attempt to update, the stock never truly gets updated. Stock levels in the system never match the actual stock in the warehouse.
Number of profiles that have access to the stock level of advanced warehouses.	1 profile, for the logistics department.
Number of steps to select in the system.	Seven steps/menus to go through.
Notifications sent to head nurses when: Safety stock is reached. Stockout is reached. Consumables are withdrawn.	None of these notifications are sent.
The system allows or does not allow stock depletion beyond what exists in the system.	Yes, the system allows.
How much time it takes to perform the task.	On average: - Withdrawal of items in Ward 4 takes 13 minutes. - Ward 4 stock update in the system takes 26 minutes. - Withdrawal of items in ICU (partial) takes 24 minutes. - Withdrawal of items in ICU (total) takes 1 hour and 11 minutes. - ICU stock update in the system takes 43 minutes.
How often are picking and deduction done at different moments?	100% of the time picking and deduction of the consumables are done at different moments.
Number of SKUs that have a barcode associated.	> 95% of the SKUs have a barcode associated.

The work instruction how to proceed in stockout situations exist or doesn't exist?	Doesn't exist for none the clinical services.
Number of parties complying with the work instruction.	-
The logistics centre previously warn the team about the content of deliveries in advance.	No.
Logistics team communicate changes in suppliers to clinical services.	No.

4.3. Analyze

The third phase of the project began with the analysis and assimilation of all the information gathered we had access to via direct observations and interviews conducted, what were the determining causes for the previously identified management problem: inefficiency in stock control. To clarify and streamline the process, it was used an Ishikawa diagram as shown in Figure 7, contains all the root causes that are considered to contribute in some way to the existence of the identified management problem.

Regarding the "Process" category, the identified root causes were as follows: 1.1.1. Inefficient communication between the logistics team and the clinical team. There is no communication channel through which the teams can report shortages, either from clinical staff regarding shortages in the advanced warehouse or from the logistics team regarding shortages in the central warehouse. There is also no means to report situations such as changes in suppliers or issues with the device used for stock deduction. 1.1.2. There are no defined work instructions when a stock shortage occurs in the advanced warehouse. 1.2.1. Too many steps in the picking process, that contribute to its non-execution or incorrect execution, leading to inefficient control. 1.3.1. The inventory is updated based on estimates rather than actual supply consumption. 1.4.1. When the medical supply cart is out of stock, it increases the number of trips to the warehouse in emergencies, where there is usually no time for proper execution. 1.4.2. Certain items are only available in the advanced warehouse and are not stored in the medical supply cart, which increases the number of trips to the warehouse in emergencies where there is no time for proper execution of the process.

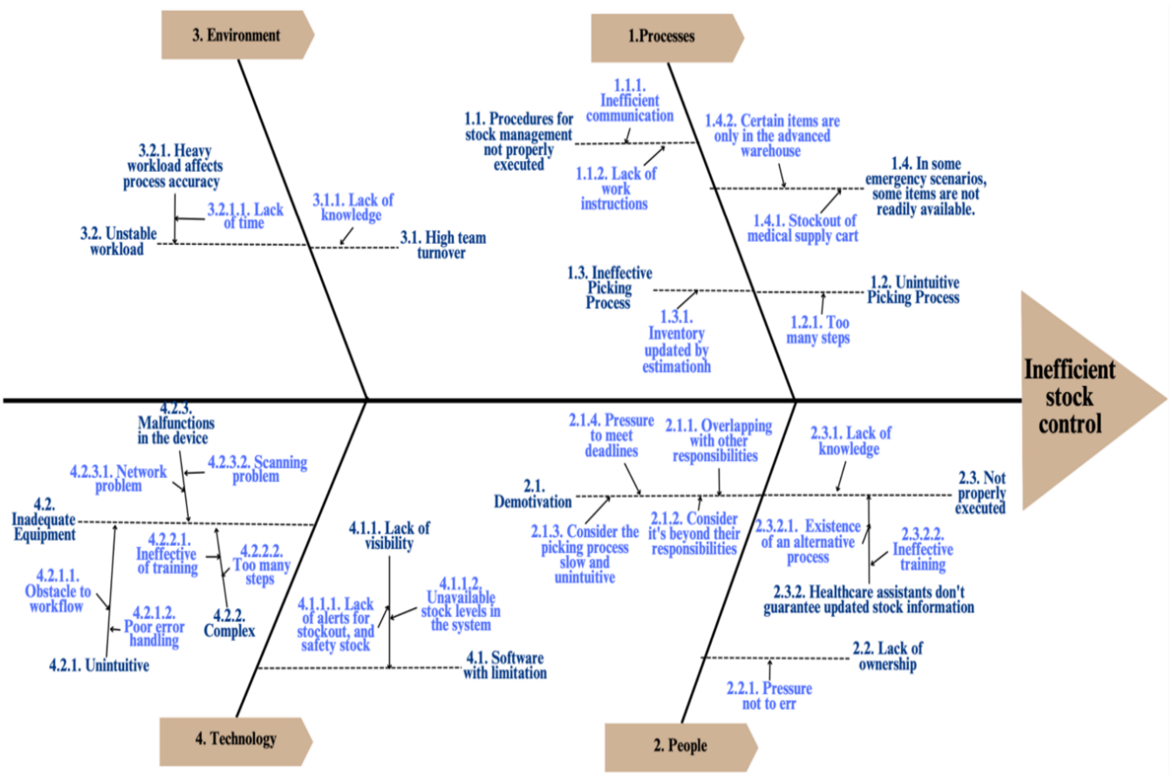
Regarding the "People" category, the identified root causes were as follows: 2.1.1. Healthcare assistants are demotivated to perform the picking process correctly because they feel overwhelmed due to the overlap of various responsibilities. 2.1.2. Healthcare assistants consider it is beyond their responsibilities, meaning that maintaining updated stock should not be their responsibility. This leads many of them to lack interest in performing the process effectively or to refuse to do so. 2.1.3. Healthcare assistants find the picking process slow and unintuitive, which demotivates them from executing the picking process correctly. 2.1.4. Pressure to meet deadlines is exerted on healthcare assistants to update the stock on the designated device by 12 o'clock on the day prior to consumable deliveries. After this time, updates will only affect the following supply. However, this time is challenging for healthcare assistants to meet because it coincides with the peak patient workload hours. 2.2.1. Pressure not to make mistakes is imposed on healthcare assistants because the arrival of consumables at the service depends on their correct execution of the picking process, which causes many of them to be reluctant to perform the process. 2.3.1. Lack of knowledge, is important to note that several healthcare assistants do not understand the stock disposal system. The vast majority believe that the number they enter the device is the quantity they are requesting from the central warehouse, not the quantities consumed. Additionally, they believe that the number displayed on the device represents the maximum quantity they can request from the central warehouse for replenishment, whereas, in reality, this number represents the warehouse stock level. 2.3.2.1. Existence of an alternative process, meaning that the picking process is not carried out correctly because nursing chiefs have allowed alternative processes to the one recommended by the logistics department, which involves periodic updates after the removal of consumables from the warehouse. 2.3.2.2. The picking process is not executed correctly due to ineffective training, as the vast majority of healthcare assistants do not know how to perform or are not familiar with the picking process recommended by the logistics department.

Concerning the “Environment” category, the identified root causes were as follows: 3.1.1. Due to the high turnover of healthcare assistants, there are always many professionals who do not know how to execute the picking process correctly. 3.2.1.1. When the workload is high, as in emergencies, which are common in the hospital services in question, the picking process cannot be executed as expected due to a lack of time.

Regarding the “Technology” category, the identified root causes were as follows: 4.1.1.1. Lack of alerts for stockout and safety stock: Nurse managers do not receive any kind of notification to alert them to these situations. Therefore, they only become aware of the reality of their service's stock levels by physically visiting the warehouse. 4.1.1.2.

Unavailable stock levels in the system, in other words, nurse managers need to visit the warehouse to know the levels of their stock, as they lack data to understand whether they are using certain items excessively or sparingly. 4.2.1.1. Obstacle to workflow: The device is not considered agile by those executing the process; it is viewed as an impediment that doesn't fit into these professionals' workflow. 4.2.1.2. Poor error handling, specifically, when more quantities are deducted than what is recorded in the system, the device does not alert the user, preventing further deductions of that item until manual correction by the logistics team. 4.2.2.1. Ineffective training, as it does not enable them to understand the operation of the device used for stock deduction. 4.2.2.2. The device used for stock deduction has many menus and steps to complete before the deduction process can begin, which deters many assistants from using it. 4.3.2.1. The device used for stock deduction in the system relies on a network, which occasionally experiences interruptions. 4.2.3.2. The scanner incorporated into the device used for the stock deduction, which allows for barcode reading of items, does not always function properly, making the process significantly more time-consuming.

Figure 7 - Root causes of inefficient stock control



As detailed in the previous chapter, we then focused on prioritizing the root causes, which was achieved through the completion of questionnaires by healthcare assistants. The following steps were taken for each of them: the top three root causes chosen by the healthcare assistants in the “Process”, “People”, and “Technology” categories were selected. Regarding the “Environment” category, there were only two root causes, and even though a prioritisation was performed between the two, both were selected.

The phrases included in the questionnaire presented to healthcare assistants and its results are included in Annex B. The questionnaire allowed us to determine that the root causes considered the most important to eliminate in the Intensive Care Unit department and Ward 4 of the Medicine and Surgery department are shown in Table 8:

Table 8 - Root causes´ prioritization

Service	**Intensive Care Unit**	**Ward 4 of Medicine and Surgery**
Most important root Causes to eliminate.	Category “Process”: 1.1.1., 1.1.2. and 1.3.1. Category “People”: 2.1.1., 2.1.2. and 2.2.1. Category “Environment”: 3.1.1. and 3.2.1.1. Category “Technology”: 4.1.1.1., 4.1.1.2. and 4.2.1.2.	Category “Process”: 1.1.1., 1.1.2. and 1.3.1. Category “People”: 2.1.1., 2.1.2. and 2.1.3. Category “Environment”: 3.1.1. and 3.2.1.1. Category “Technology”: 4.1.1.1., 4.1.1.2. and 4.2.1.1.

4.4. Design

Benchmarking

In order to gather ideas for the redesign of the picking process, the benchmarking tool was used. This was realized through two activities. Firstly, case studies related to the picking process in hospitals were researched in order to understand different processes that have already been implemented in real hospitals. Through this research and investigation, it was possible to learn about various alternatives as well as their advantages and disadvantages. The conducted research is explained in detail in Chapter 2, Section 2.3.

Secondly, benchmarking was carried out through a visit to Hospital de Braga, a Portuguese public hospital. It is important to note that the system implemented and observed at Hospital de Braga coincides with one of the systems that we learned about through one of the aforementioned case studies. The main objective of this visit was to understand the picking process in their advanced warehouses and to learn about their stock management.

Hospital de Braga has a central warehouse within the building, unlike what occurs at Hospital CUF Tejo, which has 72 advanced warehouses (Hospital CUF Tejo has 18). The picking system that we learned about includes a combination of the Kanban method and a panel with Radio-Frequency Identification (RFID) technology. In these warehouses, the clinical staff retrieves the items they need in the quantities required from the front lot (each item is distributed in a minimum of two lots). When the front lot becomes empty, the label fixed to it is removed and placed on the RFID panel. This is how the system is informed that the quantity in that lot has been consumed, and a need is automatically triggered. The second lot is considered safety stock, so when the second tag of the same consumable is added, the RFID panel reads the second label, and the system becomes aware of an emerging need. These needs appear in the system that the logistics department employees have access to. The logistics department employees daily assess the needs of the advanced warehouses. They then retrieve the necessary products from the central warehouse and replenish these products in the advanced warehouses. The products are placed in the empty lots, and the label is removed from the RFID panel and placed in the corresponding lot where it initially belonged.

In conclusion, through these two benchmarking activities, we learned about picking systems that use only the Kanban method, and systems that combine the Kanban method with RFID technology. We also had the opportunity to learn about a system that uses automated transportation of consumables through Automated Guided Vehicles. Lastly, the benchmarking research allowed us to become familiar with a 100% automated system, meaning it operates without the need for human intervention. This is achieved through the integration of "box-picker" technology and an automated transportation system.

Proposed Solution

At this stage of the project, the conditions are in place to commence the development of ideas for potential solutions applicable to the picking process at Hospital CUF Tejo. The root causes chosen by the healthcare assistants as the most important to eliminate as soon as possible, demonstrated in Table 7 were the ones we focused on the most during the ideation phase for the redesign of the picking process. As it was with this purpose in mind that the various root causes were prioritized in the previous project phase.

It is essential to emphasize that when we initiated the process of creating, formulating, and developing solutions for the redesign of the picking process, we had a foundation in all the enriching visits to Hospital CUF Tejo, whether for direct observations, conducting interviews, or surveys. This also includes all the research conducted through benchmarking, where we learned about best practices and even a real case in a Portuguese public hospital. Additionally, were also taken into account the responses from the semi-structured interviews conducted to ascertain potential insights from the stakeholders were also considered.

Having said that, we have developed a possible response approach. The alternative presented integrates several solutions:

1. The use of a system that combines the Kanban model and Radio-Frequency Identification (RFID) technology. Each medical supply will be divided into 2 or 3 lots, depending on what is more suitable, for applying the Kanban method. When the front lot runs out of medical supplies, the label (which includes RFID technology) is removed from the empty lot and placed on the RFID panel. This panel reads the label and deducts the quantities in the system. When a second label of the same consumable is added, the RFID panel reads it, and the system becomes aware of an emerging need. This is how the deduction of consumed medical supplies will be recorded.
2. The allocation of logistics team members responsible for each warehouse. In other words, each advanced warehouse will have a logistics team member assigned to it. This person will be responsible for assessing the needs of the advanced warehouses under their care, particularly to determine if any medical supplies are in shortage, and to implement the defined work instructions for this situation (mentioned later). Additionally, they should replenish these medical supplies in the advanced warehouses, remove the labels from the RFID panel, and place them in the corresponding lots.
3. Alerting supplier shortages by placing warning labels. When a medical supply is not arriving in the shipments from the central warehouse due to shortages, logistics team members should place a label to indicate this situation. The label should be affixed near the front lot of that medical supply.
4. Creation of a point of contact through applications that allow messaging or voice calls, such as "WhatsApp" or "Hangouts" (the latter is already used for other purposes at

Hospital CUF Tejo). This point of contact will serve as a communication channel for clinical staff in a specific department to interact with the logistics team member responsible for their department's warehouse. This easily accessible point of contact will enable them to raise questions related to stock, convey important stock-related information, and report issues requiring resolution.

5. Training sessions for all employees. These training sessions, delivered by logistics staff, should provide comprehensive information about the picking process, specifically the combination of the Kanban method with RFID technology and how to use it. They should clarify roles and responsibilities. Additionally, head nurses should include a specified number of hours with the hospital logistics team in the training for new healthcare assistants to both educate and prevent the perpetuation of errors.
6. Displaying work instructions related to the picking process in the advanced warehouse. This measure aims to remind healthcare assistants of crucial details that need to be considered to execute the picking process without errors.
7. Adding information fields regarding stock levels and stock movements to the profiles of nursing heads in each clinical department. This means that when a lot is depleted or restocked, these information fields will allow nursing heads to know stock levels without having to visit the warehouse. They can also understand the speed at which different medical supplies are consumed.
8. Creating alerts or notifications that inform nursing heads of certain situations, especially when a medical supply goes out of stock or reaches the safety stock level. These alerts are intended to make nursing heads aware of these situations as quickly as possible so they can take appropriate action if necessary. This enables more efficient stock management through the anticipation of problems like future shortages.
9. Establishing communication that provides advance notice to the CUF Tejo hospital logistics team of shipment notes, meaning there is a prior notification of what will be sent by the central warehouse in the next shipment. This communication is important so that the logistics team knows as far in advance as possible if all the required consumables will arrive as expected. This way, if not all the medical supplies requested from the central warehouse can be delivered in the expected shipment, the logistics team can act accordingly, with the ultimate goal of ensuring that the clinical department does not run out of stock.

10. Creating work instruction for stock-outs in the advanced warehouse. This work instruction should primarily define the steps to be followed when a healthcare assistant identifies a stockout of a medical supply. It should clearly outline the responsibilities of both clinical department professionals and logistics service personnel.
11. Equitably distributing responsibility for the picking process among all healthcare assistants to ensure that certain professionals are not overloaded while others have a lighter workload.

Adaptation of House of Quality

As explained in the previous chapter, the project team recognized as an interesting option to implement an adaption of the House of Quality diagram. Two adaptations were created, one for the "Intensive Care Unit" service shown in Annex C and another for the "Ward 4 of Medicine and Surgery" service shown in Figure 8. This distinction was necessary because, although the root causes selected by each service as the most important to eliminate largely coincided, they did not match 100%. In the columns, the 11 solutions described earlier were inserted, and in the table rows, the 11 most important root causes to eliminate, as determined by the healthcare assistants in each service.

Starting with the "roof" of the house, in this area of the diagram, the correlations between various solutions were demonstrated. This area of the diagram was filled with either a plus sign ("+") or left blank. When two solutions complement each other in some way, a "+" is placed in the space. For example, the correlation between Solution 1, "Automating the task through RFID and the Kanban method", ' and Solution 7, "Training sessions for employees", is positive, meaning these solutions complement each other since implementing this new picking model will require associated training for the professionals to correctly execute the new model. When a space is left blank, it signifies that the two solutions have no positive or negative relationship. For instance, the correlation between Solution 1, "Automating the task through RFID and the Kanban method", and Solution 3, "Notification of inventory depletion at the logistics centre utilising signalling tags", shows that they do not complement each other because implementing a tagging system to signal central warehouse shortages has no impact on Solution 1, and vice versa. Although not applicable in this case, a minus sign ("- ") would be used if there were conflicting relationships between two solutions, meaning it wouldn't make sense to implement both solutions simultaneously because they have opposing final objectives.

To describe the relationship between the solutions and the selected root causes, the following scale was created: “9” when a solution directly and strongly addresses a specific root cause; “3” when a solution addresses the root cause moderately, and finally, “1” when the solution addresses the root cause but in a more superficial manner, meaning the connection between the solution and the root cause is light. If there is no connection between a root cause and a solution, there will be no associated number to link these two variables.

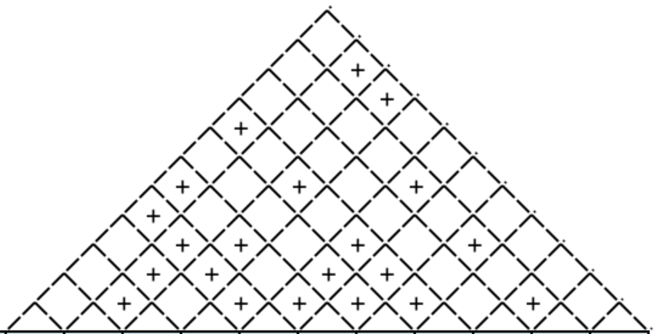
The “Root Causes Adequacy” row presents the sum of all the numbers in the respective column, which is why it is identified as the adequacy of the solutions. The higher the value indicated there, the greater the suitability of the solution concerning the various root causes. For example, the first solution is one that exhibits the highest adequacy regarding root causes because it not only addresses a higher number of root causes, but its response is also consistently considered strong. In addition to the “Root Causes Adequacy” parameter, three more evaluation criteria were established for each solution: “Time required for implementation”, which aims to evaluate the time needed to implement the solution; “CAPEX” which corresponds to the investment required to implement the change in question. “Change Management” is the name given to the criteria that assesses the level of complexity when implementing the solution at hand. For each of the evaluation criteria, a scale was assigned, which is displayed below the diagram, allowing us to complete the assessment of each of these criteria for each of the 11 solutions.

Finally, by combining the four above-mentioned evaluation criteria, a “Final Score” was obtained, providing an overall evaluation (ranging from 0% to 100%) for each proposed solution. The higher the score, the better the solution in light of the defined criteria. As explained in the previous chapter calculating the “Final Score”, weights were assigned to each of the criteria, depending on the level of importance attributed to each of the four criteria. This adaptation of House of Quality facilitated some conclusions. Firstly, several solutions that were proposed have a coplanarity relationship, that is many solutions will affect others. Secondly, three solutions stand out as addressing a greater number of root causes and contributing significantly to their resolution. These solutions are: 1. “Automating the task through RFID and the Kanban method” 6. “Training sessions for employees”, and 7. “Equitable distribution of responsibilities within the process”. In terms of the final score, these three solutions also stand out, as they have the highest final score among the 11 solutions presented.

Figure 8 - Adaptation of House of Quality for service "Ward 4 of Medicine and Surgery"

Correlations	
Positive	+
Negative	–
No Correlation	

Relationships	
Strong	9
Moderate	3
Weak	1



Row #	Maximum Relationship	Column # / Problem Causes (Customer Requirements - in HoQ) \ Solutions (Functional Requirements - in HoQ)	1 Automating the task through RFID and the Kanban method	2 Allocation of logistics team members to each of the warehouses	3 Notification of inventory stockout at the logistics centre utilizing signalling tags.	4 Point of contact between logistic and clinical staff	5 Creating a work instruction for stockouts in the warehouse	6 Training sessions for employees	7 Equitable distribution of responsibilities within the process	8 Posting of work instructions on the picking process to be followed by auxiliaries in the warehouses	9 Adding information fields for chief nurses	10 Creating an alert to notify chief nurses of certain situations (stockouts and safety stock)	11 Advance Shipping notifications delivered to the logistic team
1	9	Inefficient communication between clinical and logistics staff		9	3	9	3	1					3
2	9	Lack of work instructions in stockout situations in advanced warehouses		3	3	3	9	3		3		3	
3	9	Stock is not updated based on actual consumption	9					9	9	1			
4	9	Healthcare assistants are unmotivated to carry out the picking process correctly because it is slow and unintuitive.	9					3	3				
5	9	Healthcare assistants are unmotivated to carry out the picking process correctly due to the overlap of various	9	1					9				
6	3	Medical assistants believe it goes beyond stock control goes beyond their responsibilities	3	3							1		
7	9	The process is unable to cope with high workload days	9				3	1	9	1			
8	9	High turnover can results in some assistants not knowing how to execute the	9			1	1	9	9	9			
9	9	Head nurse do not have access to stock levels				1					9	3	
10	9	Head nurse do not receive alerts in case of stockout situations in the advanced warehouse				1					1	9	
11	9	The device is not agile enough, making the picking process less fluid.	9		1								
		Roots Causes adequacy	57	16	7	15	16	26	39	14	11	15	3
	10%	Time required for implementation	25	75	100	100	100	75	100	100	75	75	100
	10%	CAPEX	25	100	100	100	100	100	100	100	50	75	100
	10%	Change Management	50	75	100	100	75	75	75	100	75	75	100
	70%	Root Causes Adequacy	57,58	16,16	7,071	15,15	16,16	26,26	39,39	14,14	11,11	15,15	3,03
		Final Score	50,3	36,31	34,95	40,61	38,81	43,38	55,08	39,9	27,78	33,11	32,12

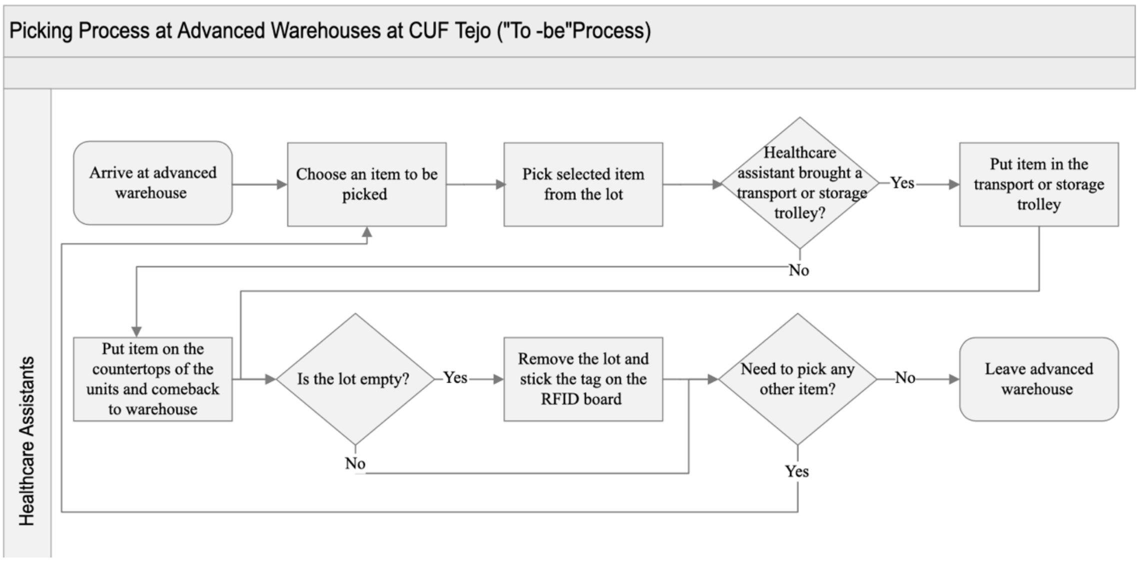
Time required for implementation :	CAPEX:	Change Management :
1 - 3 months - 100 pts	< 1000 - 100 pts	Easy - 100 pts
3 - 6 months 75 pts	1000 - 7500 - 75 pts	Mid-easy - 75 pts
9 - 12 months - 50 pts	7500 - 15 000 - 50 pts	Mid-hard - 50 pts
12- 24 months 25 pts	> 15 000 - 25 pts	Hard - 25 pts

"To-be" picking process

If the set of solutions presented and studied earlier is implemented, the process will proceed as shown in Figure 9, that is, the process begins with healthcare assistants heading to the advanced warehouse. The healthcare assistant will start by selecting items from the list prepared beforehand (based on an assessment of what was needed in the nursing units) and retrieve the respective consumables from the lots in the advanced warehouse. If necessary, the consumables that were taken will be placed in a trolley or on the countertops of the clinical unit.

Then, if the batch from which the medical supplies were taken becomes empty, the healthcare assistant removes the batch from the shelf and places the tag, which is fixed to it, on the RFID board. If the batch from which the medical supplies were taken does not become empty, the healthcare assistant will repeat the previous steps for all the medical supplies on their list. Once all the items from the list have been retrieved from the batches, the healthcare assistant leaves the advanced warehouse.

Figure 9 - Steps of the "To-be" picking process at the advanced warehouse



4.5. Verify

As detailed in the previous chapter, it was not possible to implement the proposed redesign solution for the picking process. However, a matrix was created to assess the suitability of the proposed solutions in light of Critical to Quality (CTQ) factors, as shown in Figure 10. The following matrix allows us to conclude that once again, three out of the 11 proposed solutions stand out for more robustly meeting the CTQs. It is worth noting that the three solutions with greater suitability for the CTQs are the ones that had higher suitability regarding the root causes. These solutions are 1. “Automating the task through RFID and the Kanban method”, 6. “Training sessions for employees” e 7.” Equitable distribution of responsibilities within the process”.

Figure 10 - Matrix CTQs - Solutions

CTQs \ Solutions	Automating the task through RFID and the Kanban method	Allocation of logistics team members to each of the warehouses	Notification of inventory stockout at the logistics centre utilizing signalling tags.	Point of contact between logistic and clinical staff	Creating a work instruction for stockouts in the warehouse	Training sessions for employees	Equitable distribution of responsibilities within the process	Posting of work instructions on the picking process to be followed by auxiliaries in the	Adding information fields for chief nurses	Creating an alert to notify chief nurses of certain situations (stockouts and safety stock)	Advance Shipping notifications delivered to the logistic team
Stock updated every 12 hours	9					9	9	1			
Stock data availability for head nurses	9								9	3	
Fewer steps to select in the system	9										
Notifications sent to chief nurses when there are changes in the system related to		1		1						9	
System does not allow stock to be written down beyond its maximum	9										
Faster picking process	9					9	9	3			
Picking and system deduction not being two separate processes	9					9	9	1			
All the stock in the warehouse must have a barcode		3		3							
Work instruction that is accepted by all that defines how both parties should proceed in case of stockout				3	9	1		3			
Information Anticipation: Ensuring that the logistics team receives detailed information about the content of shipments											9
Timely and accurate communication between clinical services and the logistics team regarding suppliers		9	9	9							9
Total	54	13	9	16	9	28	27	8	9	12	18

Additionally, it is recommended that Hospital CUF Tejo follows a change management model, specifically the Adkar model, which is explained in more detail in the previous chapter. In the first phase, where the goal will be to create awareness and the need for change, the organisation should create a presentation and a video that explain the reasons why it is necessary to change the picking process. This presentation should be shared with all employees who are involved in or affected by the change in the process.

In the second phase, the objective should be to promote the desire for change among the professionals so that they support it. In this regard, the organisation should convene meetings with each department to provide a space for professionals to express their ideas, concerns, and questions. The purpose of these meetings will also be to acknowledge the commitment and motivate their involvement in the change. The third phase aims to provide the tools and knowledge necessary for the change to materialise. For this, Hospital CUF Tejo will need to organise various training sessions for each clinical department, where professionals will be taught how to correctly execute the new picking process.

The fourth phase aims to reinforce the knowledge acquired in the previous phase. Therefore, Hospital CUF Tejo should create an experimental phase where the process is already practised by professionals; however, they will be accompanied by colleagues (likely from the logistics department) who will supervise and correct if necessary.

In the final phase, where it should be ensured that the change remains as expected and improvements are developed, if possible, Hospital CUF Tejo should reward clinical departments that have fewer errors in the execution of the process. Additionally, they should meet with the heads of each department to monitor the change, detect potential issues, and consequently implement any necessary improvements.

5. CONCLUSION

The picking process or stock control is not the predominant topic of discussion in the healthcare sector, probably and understandably because the spotlight is more on its greater purpose, which is the delivery of excellent healthcare. Nonetheless, efficient stock management is vital for delivering high-quality healthcare because the absence of readily available medical supplies would significantly constrain the capabilities of healthcare professionals intending to their patients. In fact, the present case study demonstrates the complexity that stock management. This study illustrates the challenges of the picking process in the advanced warehouses of CUF Tejo Hospital.

This picking process is carried out by healthcare assistants, and it was established that the collection and barcode scanning of the items should be done simultaneously, with this scanning being crucial for having updated information about inventory. However, this process is not being executed as initially envisaged, as the assistants do not update the removal of medical supplies at the time they are taken, due to various reasons, namely, lack of time or knowledge. There are only attempts at periodic updates afterwards. We refer to "attempted updates” because, the actual stock levels (in the advanced warehouse) are rarely in sync with the stock levels in the system. This creates a management problem, inefficient stock control.

Therefore, it is reasonable to conclude that the main objective of this project is to make this process more efficient, which aligns with the research question initially posed, 'How to redesign the picking process in the Advanced Warehouses at the CUF Tejo Hospital to improve its efficiency and effectiveness?

In the context of this project, several literary sources were analysed, serving as the foundation for redesigning the picking process. Through the conducted research, it was possible to understand the relevance, utility, and impact that business process redesign can have on a process and how questioning the foundations on which a particular process is built is essential for making significant changes to its current state. The literature also allowed us to become familiar with and comprehend the various methodologies used by academics and experts in the field of process redesign, including the Design for Six Sigma methodology. Subsequently, literature regarding best practices in business process redesign was studied. This enabled us to understand various practices used in process redesign and gain insights into which ones were frequently adopted and valued by practitioners, along with their effects on a process in terms of cost, time, and quality.

Therefore, it was deemed essential to search for case studies that shared best practices concerning the picking process in a hospital environment. The examined case studies allowed us to explore different possible paths by identifying best practices and incorporating solutions used in real-life cases. This information facilitated a more conscious and informed decision-making process, broadening our horizons and stimulating our creativity in the development of potential solutions.

With that said, it was considered that the Design for Six Sigma methodology would be the most suitable for the redesign of the picking process in the advanced warehouses of CUF Tejo Hospital, based on the DMADV framework.

Based on the methodology used throughout the case study chapter, the specific objectives that we initially established were progressively achieved. Firstly, SO1 and SO2 were achieved by defining the current process through various activities. These included direct observations and individual interviews, that allowed us to understand the process and the people involved in it. It also facilitated the identification of Critical to Quality factors for the process and the flaws and inefficiencies that would lead to inefficient stock control problems. It was crucial to understand the root causes of the problem so that we could consciously address them and present solutions that could effectively tackle the structural causes. SO3 and SO4 were achieved through the gathering of information on the practical cases identified through benchmarking and semi-structured interviews, enabling creative and informed thinking about solutions and allowing the proposal of an alternative to the existing process. Then the solutions were examined in light of the identified root causes and predefined criteria such as time, investment, and complexity. These solutions ultimately culminate into a concrete proposal that offers a potential alternative to the picking process in the advanced warehouses of CUF Tejo Hospital. The alternative is realised through a range of measures, including the incorporation of the Kanban method and RFID technology, along with the establishment of contact points and work instructions.

The comparison of the swim-lane diagrams describing the "as-is" and "to-be" states of the process already allows us to understand that the process now occurs in a single moment, as envisaged, improving speed and fluidity in execution, and having the ability to integrate into the hospital environment where time for logistics-related tasks is limited. Most importantly, the work completed, and the solutions presented enable us to address and mitigate the initially stated problem of inefficient stock control by proposing mechanisms that focus on process automation, the allocation of logistics team members as accountable for each warehouse, equitable distribution of responsibilities, and the creation of contact points and work instructions, thus enabling process automation and systematisation. Making it possible for the logistics department of the CUF Tejo Hospital to regain control over its stock.

However, regrettably, it was not possible to implement the proposed solution. Nevertheless, it was considered valuable to present the suitability of the proposed activities in light of the initially defined CTQs. The organisation was also advised to implement the solution based on the Adkar change management model. We are now able to respond to the research question initially established, "How to redesign the picking process in the Advanced Warehouses at CUF Tejo Hospital to improve its efficiency and effectiveness?" Through the application of the DMADV methodology and the various tools described that it enables, together with an in-depth study of the existing literature related to the process and its best practices.

In conclusion, this case study adds to the existing literature by providing a deep analysis using a case study in a critical sector and by exemplifying the use of set of tools (and new applicability for some tools) for process redesign in the healthcare sector, using the Design for Six Sigma methodology.

5.1. Limitations and Recommendations

Nevertheless, the developed project has certain limitations. Firstly, it is important to note that the existing literature regarding practical cases of redesign and implementation related to the picking process in a hospital environment is quite limited. However, the limitation goes beyond the quantity of existing case studies, as the diversity of alternatives found concerning implemented solutions and methods is also limited. Specifically, a significant portion of the case studies ended up resorting to RFID technology, which significantly constrained our creative thinking for the proposed solutions.

Secondly, the evaluation of the proposed solutions in terms of the defined criteria, time, investment, and complexity, was not based on scientific criteria or foundations. In other words, the critical analysis was developed based on subjective assessment. Empirical or scientific records were not utilised to support the decisions made in the evaluation of the recommended alternatives. Therefore, it is essential to acknowledge the limitation of the evaluation performed.

Finally, it is important to mention that it was not possible to carry out the implementation of the proposed solutions during the project. Consequently, we were unable to perform a final verification of the recommendations. More specifically, it prevented us from understanding the true impact and influence of the proposed solutions on the Critical to Quality (CTQ) factors and identified root causes.

Regarding future recommendations, we suggest proceeding with the implementation of the proposed solutions and conducting a subsequent evaluation of the same to determine if the proposed solution addresses the initially declared management problem. Additionally, it is recommended that ongoing efforts be dedicated to improving the picking process within the healthcare sector. This can be achieved through the exploration of best practices in both national and international hospitals as well as the investigation and utilisation of emerging technologies and existing advancements in the field of the picking process.

6. REFERENCES

Balkhi, B., Alshahrani, A., & Khan, A. (2022). Just-in-time approach in healthcare inventory management: Does it really work? *Saudi Pharmaceutical Journal*. https://doi.org/10.1016/j.jsps.2022.10.013

Bendavid, Y., Boeck, H., & Philippe, R. (2010). Redesigning the replenishment process of medical supplies in hospitals with RFID. *Business Process Management Journal*, *16*(6), 991–1013. https://doi.org/10.1108/14637151011093035

Boelman, V., Hockmeyer, W., Nortrup, K., & Vogl Matt. (2021). The importance and improvement of systemness in healthcare. *ISE: Industrial & Systems Engineering at Work*.

Breuker, C., Abraham, O., di Trapanie, L., Mura, T., Macioce, V., Boegner, C., Jalabert, A., Villiet, M., Castet-Nicolas, A., Avignon, A., & Sultan, A. (2017). Patients with diabetes are at high risk of serious medication errors at hospital: Interest of clinical pharmacist intervention to improve healthcare. *European Journal of Internal Medicine*, *38*, 38–45. https://doi.org/10.1016/j.ejim.2016.12.003

Chang, J. F. (2006a). *Business process management systems : strategy and implementation*. Auerbach Publications.

Chikul, M., Maw, H. Y., & Soong, Y. K. (2017). Technology in healthcare: A case study of healthcare supply chain management models in a general hospital in Singapore. *Journal of Hospital Administration*, *6*(6), 63. https://doi.org/10.5430/jha.v6n6p63

Davenport, T. H., & Short, J. E. (1990). The New Industrial Engineering: Information Technology And Business Process Redesign. *Sloan Management Review*.

De Feo, J., & Bar-El, Z. (2002). Creating strategic change more efficiently with a new Design for Six Sigma process. *Journal of Change Management*, *3*(1), 60–80. https://doi.org/10.1080/714042521

Dzulinski, A. C., Braghini Junior, A., & Chiroli, D. M. G. (2023). Design for Six Sigma: A Review of the Definitions, Objectives, Activities, and Tools. *EMJ - Engineering Management Journal*, *35*(2), 161–180. https://doi.org/10.1080/10429247.2022.2041964

Erić, M., & Stefanović, M. (2008). *Comparative Characteristics of TQM and Reengineering*.

Gitlow, H. S., & Levine, D. A. (2006). *Design for Six SIGMA for Green Belts and Champions: Applications for Service Operations--Foundations, Tools, DMADV, Cases, and Certification.*

Goel, S., & Chen, V. (2008). Integrating the global enterprise using Six Sigma: Business process reengineering at General Electric Wind Energy. *International Journal of Production Economics*, *113*(2), 914–927. https://doi.org/10.1016/j.ijpe.2007.12.002

Gremyr, I., Gustavsson, S., & Gideberg, A. (2012). The medication process-a design for Six Sigma project. In *Int. J. Six Sigma and Competitive Advantage* (Vol. 7, Issue 1).

Hammer, M. (1990). *Reengineering Work: Don´t Automate, Obliterate*.

Hietschold, N., Reinhardt, R., & Gurtner, S. (2014). Measuring critical success factors of TQM implementation successfully-a systematic literature review. *International Journal of Production Research*, *52*(21), 6254–6272. https://doi.org/10.1080/00207543.2014.918288

Jebbor, S., Chiheb, R., El Afia, A., & Gallab, M. (2023). Designing a fully automated and integrated inventory and replenishment system for hospitals. *International Journal of Systems Science: Operations and Logistics*, *10*(1). https://doi.org/10.1080/23302674.2021.1962429

Jenab, K., Wu, C., & Moslehpour, S. (2018). Design for six sigma: A review. In *Management Science Letters* (Vol. 8, Issue 1, pp. 1–18). Growing Science. https://doi.org/10.5267/j.msl.2017.11.001

Johnson, J. A., Gitlow, H., Widener, S., & Popovich, E. (2006). *Designing New Housing at the University of Miami: A "Six Sigma"® DMADV/DFSS Case Study* (Vol. 18).

Kovach, J. V., & Pollonini, L. (2022). Designing devices to communicate effectively with intensive care nurses to prevent pressure injuries: A qualitative study. *Intensive and Critical Care Nursing*, *71*. https://doi.org/10.1016/j.iccn.2022.103244

Liverani, A., Caligiana, G., Frizziero, L., Francia, D., Donnici, G., & Dhaimini, K. (2019). Design for Six Sigma (DFSS) for additive manufacturing applied to an innovative multifunctional fan. *International Journal on Interactive Design and Manufacturing*, *13*(1), 309–330. https://doi.org/10.1007/s12008-019-00548-9

Lunau Christian Staudter, S., von Hugo Philipp Bosselmann Jens-Peter Mollenhauer Renata Meran, C., & Roenpage, O. (2013). *Management for Professionals Design for Six Sigma +Lean Toolset Mindset for Successful Innovations Second Edition*. http://www.springer.com/series/10101

Majchrzak, A., & Wang, Q. (1996). Breaking the Functional Mind-Set in Process Organizations. *September-October* , 93–99. http://ssrn.com/abstract=2537034

Mandahawi, N., Al-Shihabi, S., Abdallah, A. A., & Alfarah, Y. M. (2010). Reducing waiting time at an emergency department using design for Six Sigma and discrete event simulation. In *Int. J. Six Sigma and Competitive Advantage* (Vol. 6, Issue 2).

Mansar, S. L., & Reijers, H. A. (2007). Best practices in business process redesign: Use and impact. *Business Process Management Journal*, *13*(2), 193–213. https://doi.org/10.1108/14637150710740455

Marinetto, M. (1999). The historical development of business philanthropy: Social responsibility in the new corporate economy. *Business History*, *41*(4), 1–20. https://doi.org/10.1080/00076799900000342

Morrow, M., & Hazell, M. (1992). *Activity Mapping for Business Process Redesign*.

Norcliffe, G. (1997). Popeism and Fordism: Examining the roots of mass production. *Regional Studies*, *31*(3), 267–280. https://doi.org/10.1080/00343409750134683

Okpe, O., & Kovach, J. V. (2017). A Redesign Approach for Improving Animal Care Services for Researchers. In *Journal of the American Association for Laboratory Animal Science* (Vol. 56, Issue 4).

Paramitha, T. A., Tobing, D. K., & Suroso, I. (2020). ADKAR MODEL TO MANAGE ORGANIZATIONAL CHANGE. *International Journal of Research Science & Management*, *7*(1). https://doi.org/10.5281/zenodo.3633128

Patel, A., & Chudgar, C. (2020). Understanding basics of Six Sigma. *International Journal of Engineering Research & Technology*, *9*(05). www.ijert.org

Patil, V. S., Andhale, S. R., & Paul, I. D. (2013). A Review of DFSS: Methodology, Implementation and Future Research. *International Journal of Innovations in Engineering and Technology*, *2*(1).

Piccinini, P., Gamberini, R., Prati, A., Rimini, B., & Cucchiara, R. (2013). An automated picking workstation for healthcare applications. *Computers and Industrial Engineering*, *64*(2), 653–668. https://doi.org/10.1016/j.cie.2012.11.004

Rafele, C., Persona, A., Battini, D., & Rafele, C. (2008). Hospital efficiency management: the just-in-time and Kanban technique Cite this paper Hospital efficiency management: the just-in-time and Kanban technique. In *J. Healthcare Technology and Management* (Vol. 9, Issue 4).

Ramasubramanian, P. (2012). Six Sigma in Educational Institutions. In *International Journal of Engineering Practical Research IJEPR* (Vol. 1, Issue 1).

Robert K. Yin. (2009). *Case Study Research: Design and Methods : Vol. volume 5* (fourth edition). SAGE Publications, Inc.

Scotti, D. J., Harmon, J., & Behson, S. J. (2007). *Links Among High-Performance Work Environment, Service Quality, and Customer Satisfaction: An Extension to the Healthcare Sector*.

Short, J. E., & Venkatraman, N. (1992). Beyond Business Process Redesign: Redefining Baxter's Business Network. *Haravar*.

Vanzant-Stern, T., Fultus, ϖ A, & Books, TM. (2011). *Lean Six Sigma Practical Bodies of Knowledge*. http://writers.fultus.com/stern/

Wicks, A. C. (2001). The Value Dynamics of Total Quality Management: Ethics and the Foundations of TQM. *Business Ethics Quarterly*, *11*(3), 501–535.

Yang, C. C., Jou, Y. T., Lin, M. C., Silitonga, R. M., & Sukwadi, R. (2022). The Development of the New Process of Design for Six Sigma (DFSS) and Its Application. *Sustainability (Switzerland)*, *14*(15). https://doi.org/10.3390/su14159294

Zairi, M. (2013). The TQM legacy - Gurus' contributions and theoretical impact. *The TQM Journal*, *25*(6), 659–676. https://doi.org/10.1108/TQM-06-2013-0069

7. ANNEXES

Annex A - Excerpts from the interviews and identified needs.

Excerpts from the interviews	Identified needs
"O problema de espaço do armazém condiciona depois uma série de práticas que hoje em dia poderiam ser evitadas se nós estivéssemos um armazém que fosse amplo que permitisse tudo lá dentro"	Work better on the SKU´s/items that are in advanced warehouse.
"Nós queríamos muito que a gestão dos avançados não fosse feita só em picking, queríamos uma solução que desse o abate em stock e em faturação simultâneo."	Reduce the redundancy of the tasks
"A falta de espaço é aquela que nos mais preocupa desde o início, desde a construção do hospital. A ausência de espaço para que pudéssemos ter um armazém que pudesse funcionar no modelo que se pretende que funcione."	Work better on the SKU´s/items that are in the advanced warehouse.
"O PDA às vezes funciona de forma complexa demais para alguns colegas. "	The technology used needs to be more user-friendly and user experience.
"A minha visão disto era um bocado ao contrário, ou seja, aqui a regra esta é o serviço é que tem de picar para que tenha material este é o modus operandi da coisa. A minha reflexão é um pouco o contrário que era eu acho que a logística é que devia picar e nós iriamos lá nas exceções, nos fins de semana ou algo do género. "	Review the assignment tasks related to the discount of items in the system
"Eu acho que a grande dificuldade tem a ver com hardware porque os nossos PDA estão sempre a ir abaixo a rede desaparece as listagens são longuíssimas, às vezes aquilo não dá o user não entra."	The technology used needs to be more user-friendly and user experience.
"Mudança de mentalidade que é os serviços de suporte são isso mesmo é para dar suporte aos serviços"	Review the assignment tasks related to the discount of items in the system.
"Porque é muito desagradável para um chefe dizer assim olha não tenho fraldas e a resposta que vem do outro lado, é se não tem fraldas é porque não picou isso até pode ser verdade, mas na prática isso não resolve o problema porque eu preciso das fraldas à mesma para colocar nos doentes."	Review the assignment tasks related to resolving stockout situations. Provide a way to communicate stockouts in logistics center.
"Nós não conseguimos ter informação em tempo real ou de véspera ou antecipadamente de quais é que são os níveis dos meus materiais no armazém eu neste momento não sei se tenho muitas faltas tenho poucas."	Provide information of stock levels to clinical staff
"Se Eu tivesse como a bateria do telemóvel que eu percebo assim, as fraldas estão a ficar nas lonas, hoje devia ter vindo os níveis já estavam em cima."	Provide a notification for the head nurses to know when they are approaching the minimum stock level. Provide information of stock levels to clinical staff
"A falta de tempo para o realizar."	Reduce the pressure to perform the task.
"No meu entender deveria ser uma pessoa apenas dedicada ao armazém e roupa."	Review the assignment tasks related to the discount of items in the system.
"Que não houvesse o limite de picagem até ao 12h."	Reduce the pressure to perform the task.

"Várias vezes o sistema vai abaixo várias vezes o PDA bloqueia várias vezes nem sequer conseguimos aceder ao menu que pretendemos."	Provide technology that has more user experience.
"Sistema não colabora e muitas das vezes vou tirar coisas porque preciso de repor que preciso para o momento e não tenho qualquer tempo porque informaticamente não colabora muitas vezes."	Provide technology that is faster.
"Chegam 1200 batas por exemplo eu retiro essas 1200 batas porque efetivamente já precisamos delas nos serviços e eu quero atualizar em PDA ele não tem stock zero por que informaticamente ainda não foi carregado com os Stock de 1200."	Provide technology that updates the inventory levels at the moment.
"Pedidos pendentes nós ficamos vamos picando e depois vêm os pedidos, ou seja, vêm a acumulação de pedidos pendentes porque em termos informáticos tem dado como zero. O que resultado em excesso de stock."	Provide a system that doesn't accumulate pending orders.
"Às vezes ainda está introduzido em avançado, mas eu não tenho etiqueta de picagem porque o departamento de LH ainda não colocou a etiqueta de picagem para poder começar a fazer as picagens e daí gerar um pedido novo."	Faster updating the barcodes for stock discount.
"O grande desafio é mesmo tornar as coisas mais ágeis em termos de informática."	Provide technology that has more user experience.
"Agilizar o processo informático, mas o processo de comunicação interna porque eu acho que às vezes é muito o tema de comunicação. "	Provide a way to communicate stockouts in logistics center.
Como não temos feedback caso esteja em rutura por parte do armazém temos de estar a ligar e tentar saber o que se está a passar.	Review the assignment tasks related to resolving stockout situations. Provide a way to communicate stockouts in logistics center.
"Muitas vezes os PDA´s têm falhas elas no material e quando vão gravar e apaga toda a informação, outras vezes é falta de rede."	Provide technology that has more user experience.
"Quando há material esgotado eles não conseguem dizer que esse material foi debitado e que não é fornecido, temos de ser sempre nós a perguntar, não há essa proatividade por parte da equipa, portanto nós ficamos um bocadinho sem saber o que se está a passar."	Provide a way to communicate stockouts in logistics center.
"E depois também não temos resposta em tempo útil, ok está esgotado, qual é a solução, não vão tentar arranjar outra coisa."	Reduction of response time to stockouts
Portanto nós estamos a consumir, mas não conseguimos debitar por falta de código.	Faster updating the barcodes for stock discount.
"Não, não considero prático. Acho que este processo não deveria recair sobre a atividade assistencial deveria ser o armazém a fazer isso."	Review the assignment tasks related to the discount of items in the system.

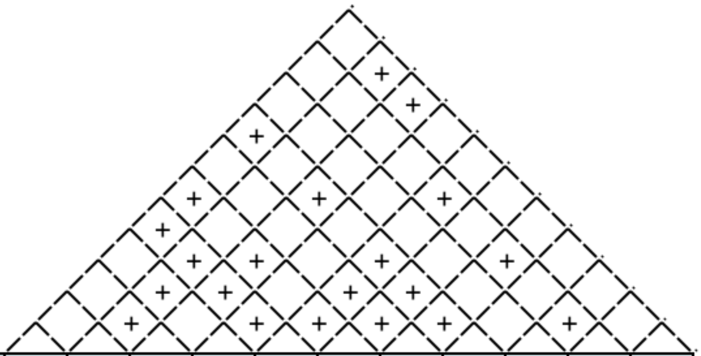
"Alguém que ficasse responsável de fazer os débitos do piso. E depois fizesse a articulação connosco, olhem não foi fornecido porque não há, uma pessoa que ficasse só responsável pelo piso 3 ou todo o internamento e que nos desse feedback das falhas que há ou de mudança de fornecedor, qualquer coisa. E que assegurasse sempre independentemente de haver rutura arranjar uma solução para não nos faltar o material."	Review the assignment tasks related to the discount of items in the system. Provide a way to communicate stockouts in logistics center. Provide a way to communicate suppliers change. Review the assignment tasks related to resolving stockout situations.
"Eu não consigo cruzar a lista dos pedidos que as minhas auxiliares fazem com a lista que a logística repõe, isto devia ser possível."	Provide information for head nurses to know when and in what quantities an item was removed from the advanced warehouse.
"Nestes momentos não sabemos quanto estamos a consumir, que quantidade estamos a consumir de qualquer coisa."	Provide information for head nurses to know when and in what quantities an item was removed from the advanced warehouse.
"É o timing de picagem que muitas vezes não é o correto."	Reduction of occurrences where picking is done prior to the discount deduction in the system
"Devido a não terem tempo propriamente e o sistema não ser prático ou pelo menos um bocado mais rápido acaba por gerar que não se faça logo a picagem de certas coisas no momento."	Provide technology that has more user experience. Provide technology that is faster.
"Profissionais no momento da retirada da prateleira conseguissem sinalizar que aquele material está a sair."	Reduction of occurrences where picking is done prior to the discount deduction in the system
"O objetivo ideal era que houvesse uma sobreposição entre a movimentação física do produto e a movimentação em sistema do produto esse para mim é que era aquilo que eu mais valorizava"	Provide technology that updates the inventory levels at the moment.
"Efetivamente vemos limitações e existe aqui oportunidade de facilitar o utilizador porque eu acho que vai ter sempre de passar pelo utilizador fazer qualquer coisa, temos é de facilitar efetivamente, porque acho que está um bocadinho longe de ser uma coisa de utilização fácil."	Provide technology that has more user experience.

Annex B – Phrases included in the questionnaire and their prioritization by healthcare assistants from “Ward 4 of Medicine and Surgery” and “Intensive Care Unit”

Phrase for questionnaire	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	Ward 4	TOTAL Ward 4	Scale
A comunicação entre equipa de logística e equipa clínica é ineficiente. Não existe um canal de comunicação para as equipas possam reportar ruturas seja staff clinico referente a ruturas no armazém avançado ou seja equipa logística referente a ruturas no armazém central. Para reportar também situações de mudanças de fornecedores, problemas com dispositivo utilizado para abate de stock .	2	4	2	1	1	1	5	1	1	1	1	1	21	1
Não existem instruções de trabalho defenidas quando se entre em rutura de stock .	1	5	5	2	2	2	6	5	4	2	2	2	38	2
O processo de picking tem demasiados passos, desde que se entra até que se sai do armazém avançado.	6	6	6	3	6	5	4	6	2	6	3	3	56	6
O stock é atualizado por estimativa (e não à unidade, com base nos consumos reais).	3	3	1	4	4	6	1	4	3	5	4	4	42	3
Numa situação de emergência médica, por vezes os carrinhos que estão juntos do doente não têm todo o material necessário porque os carrinhos estão em stockout, sendo necessário ir ao armazém avançado.	4	1	3	5	5	3	2	2	5	4	5	5	44	4
Numa situação de emergência médica, por vezes os carrinhos que estão juntos do doente não têm todo o material necessário porque há material que se encontra apenas nos armazéns avançados sendo necessário deslocar-se até lá.	5	2	4	6	3	4	3	3	6	3	6	6	51	5
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque se sentem sobrecarregados devido à sobreposição de diversas responsabilidades.	1	1	3	2	2	2	2	2	2	2	7	2	28	2
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque consideram que executar este processo vai para além das suas responsabilidades.	2	2	1	1	1	1	3	1	3	1	2	1	19	1
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque é lento e não intuitivo.	4	4	7	4	3	3	4	8	4	3	3	4	51	3
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque estão sob pressão para cumprir prazos (até às 11h do dia anterior à chegada de material)	6	3	2	3	5	5	5	4	5	5	8	3	54	4
Existem auxiliares de ação médica que não querem assumir responsabilidade pelo processo devido à pressão existente para executar o processo de picking sem falhas.	3	5	4	8	4	4	6	3	6	4	4	8	59	5
Os auxiliares de ação médica não conseguem executar corretamente o processo de picking (abate das quantidades retiradas, cada vez que alguém retira material do armazém) por falta de conhecimento.	5	8	5	6	7	7	7	6	7	6	6	6	76	7
O processo de picking não é executado corretamente (ou seja, retira-se material sem dar abate do mesmo no PDA) pois os enfermeiros chefes definiram que a atualização do stock com recurso ao PDA deveria ser feita numa altura específica do dia, e não em simultâneo com o picking	8	7	8	7	6	6	8	5	8	7	1	7	78	8
O processo de picking não é executado corretamente (abate das quantidades retiradas, cada vez que alguém retira material do armazém) porque a formação dada aos auxiliares de ação médica não foi eficaz.	7	6	6	5	8	8	1	7	1	8	5	5	67	6
A elevada rotatividade da equipa de auxiliares faz com que existam sempre auxiliares que não sabem executar o processo corretamente.	2	2	2	1	2	2	1	1	1	1	2	2	19	2
Quando a carga de trabalho é elevada, como em situações de emergência, os auxiliares não conseguem executar o processo de picking da forma esperada, por falta de tempo.	1	1	1	2	1	1	2	3	2	2	1	1	18	1
O software não alerta as chefias quando se entra em rutura ou em stock de segurança de determinado item no armazém avançado	4	8	1	2	3	3	1	1	4	3	2	2	34	1
As chefias de enfermagem não tem acesso, no seu perfil SAP, aos níveis de stock no armazém avançado. Assim sendo precisam de se deslocar ao armazém para poder ver as quantidades existentes.	5	4	8	1	1	1	8	2	2	1	1	1	35	2
O dispositivo (PDA) não é ágil o suficiente, tornando o processo de picking menos fluído.	3	3	2	3	4	4	5	8	1	4	3	3	43	3
O dispositivo (PDA) não tem a capacidade de lidar com erros de forma eficiente. Exemplo: quando são abatidas mais quantidades do que as que há em sistema, o dispositivo não avisa o utilizador do erro.	1	5	5	5	2	2	6	3	3	2	4	8	46	4
A utilização do dispositivo (PDA) é demasiado complexa em comparação coma formação básica que é dada aos auxiliares.	8	7	4	8	6	6	7	6	8	6	6	5	77	8
O dispositivo (PDA) tem demaisados passos e menus a ser preenchidos.	7	1	3	6	5	5	2	5	5	5	5	6	55	5
O dispositivo (PDA) tem problemas técnicos, como a falta de rede.	6	6	7	4	7	7	3	4	7	7	7	4	69	6
O dispositivo (PDA) tem problemas técnicos, como o scanner que nem sempre consegue ler os códigos de barras.	2	2	6	7	8	8	4	7	6	8	8	7	73	7

Phrase for questionnaire	ICU	ICU	ICU	ICU	ICU	ICU	ICU	ICU	ICU	ICU	ICU	ICU	TOTAL ICU	Scale
A comunicação entre equipa de logística e equipa clínica é ineficiente. Não existe um canal de comunicação para as equipas possam reportar ruturas seja staff clinico referente a ruturas no armazém avançado ou seja equipa logística referente a ruturas no armazém central. Para reportar também situações de mudanças de fornecedores, problemas com dispositivo utilizado para abate de stock .	1	1	1	1	3	2	1	2	1	5	3	1	22	1
Não existem instruções de trabalho defenidas quando se entre em rutura de stock .	4	4	2	2	2	3	6	4	2	1	4	2	36	2
O processo de picking tem demasiados passos, desde que se entra até que se sai do armazém avançado.	2	2	7	6	6	6	4	3	3	6	5	3	53	4
O stock é atualizado por estimativa (e não à unidade, com base nos consumos reais).	3	3	4	3	1	1	5	6	4	3	2	4	39	3
Numa situação de emergência médica, por vezes os carrinhos que estão juntos do doente não têm todo o material necessário porque os carrinhos estão em stockout, sendo necessário ir ao armazém avançado.	6	5	3	4	5	4	3	1	5	4	6	5	51	5
Numa situação de emergência médica, por vezes os carrinhos que estão juntos do doente não têm todo o material necessário porque há material que se encontra apenas nos armazéns avançados sendo necessário deslocar-se até lá.	5	6	5	5	4	5	2	5	6	2	1	6	52	6
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque se sentem sobrecarregados devido à sobreposição de diversas responsabilidades.	2	2	1	1	5	5	6	2	4	2	8	7	45	3
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque consideram que executar este processo vai para além das suas responsabilidades.	3	3	6	6	7	7	1	1	3	1	3	2	43	2
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque é lento e não intuitivo.	5	5	5	5	4	4	7	5	1	7	1	3	52	4
Os auxiliares de ação médica estão desmotivados para executar corretamente o processo de picking porque estão sob pressão para cumprir prazos (até às 11h do dia anterior à chegada de material)	8	8	4	4	8	6	8	6	7	8	2	8	77	8
Existem auxiliares de ação médica que não querem assumir responsabilidade pelo processo devido à pressão existente para executar o processo de picking sem falhas.	1	1	2	2	3	3	2	3	2	3	7	4	33	1
Os auxiliares de ação médica não conseguem executar corretamente o processo de picking (abate das quantidades retiradas, cada vez que alguém retira material do armazém) por falta de conhecimento.	6	6	3	3	2	2	5	7	5	4	4	6	53	5
O processo de picking não é executado corretamente (ou seja, retira-se material sem dar abate do mesmo no PDA) pois os enfermeiros chefes definiram que a atualização do stock com recurso ao PDA deveria ser feita numa altura específica do dia, e não em simultâneo com o picking	7	7	8	8	1	1	3	4	6	5	5	1	56	6
O processo de picking não é executado corretamente (abate das quantidades retiradas, cada vez que alguém retira material do armazém) porque a formação dada aos auxiliares de ação médica não foi eficaz.	4	4	7	7	6	8	4	8	8	6	6	5	73	7
A elevada rotatividade da equipa de auxiliares faz com que existam sempre auxiliares que não sabem executar o processo corretamente.	1	1	2	2	1	1	2	2	1	2	2	2	19	2
Quando a carga de trabalho é elevada, como em situações de emergência, os auxiliares não conseguem executar o processo de picking da forma esperada, por falta de tempo.	2	2	1	1	2	2	1	1	2	1	1	1	17	1
O software não alerta as chefias quando se entra em rutura ou em stock de segurança de determinado item no armazém avançado	7	7	1	1	2	2	4	1	1	2	5	2	35	2
As chefias de enfermagem não tem acesso, no seu perfil SAP, aos níveis de stock no armazém avançado. Assim sendo precisam de se deslocar ao armazém para poder ver as quantidades existentes.	2	2	2	2	3	3	3	6	2	1	3	1	30	1
O dispositivo (PDA) não é ágil o suficiente, tornando o processo de picking menos fluído.	8	1	6	6	1	1	7	4	4	5	4	3	50	4
O dispositivo (PDA) não tem a capacidade de lidar com erros de forma eficiente. Exemplo: quando são abatidas mais quantidades do que as que há em sistema, o dispositivo não avisa o utilizador do erro.	3	3	3	3	5	5	2	3	3	3	6	4	43	3
A utilização do dispositivo (PDA) é demasiado complexa em comparação coma formação básica que é dada aos auxiliares.	4	4	4	4	4	4	1	8	7	6	7	6	59	5
O dispositivo (PDA) tem demaisados passos e menus a ser preenchidos.	5	5	7	7	8	8	6	7	5	4	8	5	75	8
O dispositivo (PDA) tem problemas técnicos, como a falta de rede.	6	6	8	8	7	7	8	2	6	7	1	7	73	7
O dispositivo (PDA) tem problemas técnicos, como o scanner que nem sempre consegue ler os códigos de barras.	1	8	5	5	6	6	5	5	8	8	2	8	67	6

Annex C – Adaptation of House of Quality of the service "Intensive Care Unit"



Correlations	
Positive	+
Negative	–
o Correlation	

Relationships	
Strong	9
Moderate	3
Weak	1

Row #	Maximum Relationship	Problem Causes (Customer Requirements - in HoQ) / Solutions (Functional Requirements - in HoQ)	Automating the task through RFID and the Kanban method	Allocation of logistics team members to each of the warehouses	Notification of inventory stockout at the logistics centre utilizing signalling tags.	Point of contact between logistic and clinical staff	Creating a work instruction for stockouts in the warehouse	Training sessions for employees	Equitable distribution of responsibilities within the process	Posting of work instructions on the picking process to be followed by auxiliaries in the warehouses	Adding information fields for chief nurses	Creating an alert to notify chief nurses of certain situations (stockouts and safety stock)	Advance Shipping notifications delivered to the logistic team
		Column #	1	2	3	4	5	6	7	8	9	10	11
1	9	Inefficient communication between clinical teams and logistics		9	9	9	3	9					3
2	9	Lack of work instructions in stock shortage situations		3	9	3	9	3		3		3	
3	9	Stock is not updated based on actual consumption	9					9	9	3	1		
4	9	Healthcare assistants are unmotivated to carry out the picking process correctly due to pressure not to make mistakes is imposed on them	9						1				
5	9	Healthcare assistants are unmotivated to carry out the picking process correctly due to the overlap of various responsibilities.	9	3				3	9	3			
6	3	Medical assistants believe it goes beyond their responsibilities		3				3					
7	9	The process is unable to cope with high workload days	9				3	1	9	1			
8	9	High turnover can results in some assistants not knowing how to execute the process	9	3			3	9	9	9			
9	9	Head nurse do not have access to stock levels				1					9	3	
10	9	Head nurse do not receive alerts in case of stockout situations in the advanced warehouse				1					1	9	
11	9	Technology used does not have the capability to handle errors efficiently	9		1	3							
		CTQs adequacy	54	21	19	17	18	37	37	19	11	15	3
	10%	Time required for implementation	25	75	100	100	100	75	100	100	75	75	100
	10%	CAPEX	25	100	100	100	100	100	100	100	50	75	100
	10%	Complexity / Management Change	50	75	100	100	75	75	75	100	75	75	100
	70%	CTQs adequacy	54,55	21,21	19,19	17,17	18,18	37,37	37,37	19,19	11,11	15,15	3,03
		Final Score	48,18	39,85	43,43	42,02	40,23	51,16	53,66	43,43	27,78	33,11	32,12

Time required for implementation :

1 - 3 months - 100 pts
3 - 6 months 75 pts
9 - 12 months - 50 pts
12- 24 months 25 pts

CAPEX:

< 1000 - 100 pts
1000 - 7500 - 75 pts
7500 - 15 000 - 50 pts
> 15 000 - 25 pts

Change Management :

Easy - 100 pts
Mid-easy - 75 pts
Mid-hard - 50 pts
Hard - 25 pts