Enhancing Productivity and Storage Capacity in Apparel Warehouses: A Lean Approach

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Master's Dissertation

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Sumário

A procura cada vez maior de vestuário de alta qualidade por parte dos consumidores, combinada com a necessidade de reduzir os custos e os prazos de entrega, exige que as empresas se mantenham adaptáveis e flexíveis em resposta à mudança. Os rápidos avanços tecnológicos e a inovação constante enfatizam ainda mais a importância de ter uma mente aberta e empenhada na melhoria contínua.

A indústria do vestuário, em particular, caracteriza-se por uma elevada volatilidade devido à rápida evolução das tendências e ao crescimento digital significativo registado nos últimos anos. Estes factores representam desafios consideráveis para as operações logísticas, que devem evoluir continuamente para responder a estas exigências dinâmicas.

Este projeto, uma colaboração entre o Kaizen Institute e a Empresa X, uma multinacional portuguesa líder no sector do vestuário, centra-se na melhoria contínua do sector logístico da empresa. O objetivo é evitar que o seu único armazém se torne um ponto de estrangulamento, aumentando a capacidade de armazenamento e melhorando a produtividade operacional.

Foram implementadas várias ferramentas e metodologias *Lean* para atingir estes objectivos. A análise inicial identificou questões críticas, como a ocupação excessiva do armazém, processos de gestão ineficientes e procedimentos de separação de pedidos não optimizados. Com base nesta avaliação, foram desenvolvidas e executadas estratégias personalizadas.

As principais acções incluíram a reformulação da disposição do armazém, a introdução de uma caixa de nivelamento e a implementação de painéis de controlo operacionais para apoiar e simplificar as operações. Estas intervenções levaram a melhorias significativas: um aumento de 51% na capacidade de paletes e melhorias notáveis na produtividade. A introdução da caixa de nivelamento reduziu efetivamente a zero as rupturas diárias de stock no picking após um período de adaptação inicial. Além disso, a implementação de painéis de controlo para uma melhor gestão e tomada de decisão mostrou resultados promissores, aumentando a cadeia de abastecimento e produtividade do armazém por 7,2% e 12,5%, respetivamente.

Um estudo também foi realizado para avaliar a viabilidade da fusão de linhas de expedição de dois canais diferentes - físico e digital - para uma utilização mais eficiente do espaço.

O projeto sublinha a importância da melhoria contínua, da normalização dos processos e da abordagem das causas profundas das ineficiências. As soluções e ferramentas desenvolvidas, embora adaptadas à Empresa X, oferecem conhecimentos valiosos que podem ser adaptados a contextos semelhantes noutros armazéns. As perspectivas futuras incluem uma maior integração de tecnologias avançadas e o aperfeiçoamento contínuo dos processos para sustentar e melhorar os ganhos obtidos.

Abstract

The ever-growing consumer demand for high-quality clothing, combined with the need to reduce costs and shorten delivery times, requires companies to remain adaptive and flexible in response to change. Rapid technological advancements and constant innovation further emphasize the importance of being open-minded and committed to continuous improvement.

The apparel industry, in particular, is characterized by high volatility due to rapidly changing trends and significant digital growth in recent years. These factors present considerable challenges for logistics operations, which must continuously evolve to meet these dynamic demands.

This project, a collaboration between Kaizen Institute and Company X, a leading Portuguese apparel multinational, focuses on continuous improvement in the company's logistics sector. The goal is to prevent its only warehouse from becoming a bottleneck by increasing storage capacity and enhancing operational productivity.

Various Lean tools and methodologies were implemented to achieve these goals. The initial analysis identified critical issues such as excessive storage occupancy, inefficient management processes, and sub-optimal picking procedures. Based on this assessment, tailored strategies were developed and executed.

Key actions included redesigning the warehouse layout, introducing a leveling box, and implementing operational dashboards to support and streamline operations. These interventions led to significant improvements: a 51% increase in pallet capacity and notable enhancements in productivity. The introduction of the leveling box effectively reduced daily picking stock-outs to zero after an initial adjustment period. Moreover, the implementation of dashboards for better management and decision-making showed promising results, increasing supply chain and warehouse productivity by 7.2% and 12.5%, respectively.

A study was also conducted to assess the viability of merging expedition lines from two different channels—physical and digital—for more efficient space utilization.

The project underscores the importance of continuous improvement, process standardization, and addressing the root causes of inefficiencies. The solutions and tools developed, although tailored to Company X, offer valuable insights that can be adapted to similar contexts in other warehouses. Future prospects include further integration of advanced technologies and ongoing refinement of processes to sustain and enhance the gains achieved.

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"When it feels scary to jump, that is exactly when you jump, otherwise you end up staying in the same place your whole life."

Unknown

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Acronyms and Symbols

B2C	Business-to-consumer
DILO	Day In the Life Of
FTE	Full-time equivalent
IT	Information and Technology
IoT	Internet of Things
KPI	Key Performance Indicator
MVP	Minimum Viable Product
PBL	Picking by line
PBS	Picking by store
PDCA	Plan, Do, Check, Act
RFID	Radio Frequency Identification
SAP	Systems, Applications and Products in Data Processing
SLA	Service Level Agreement
VNA	Very Narrow Aisles
VSA	Value Stream Analysis
VSM	Value Stream Mapping
WMS	Warehouse Management System

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Chapter 1

Introduction

In today's business environment, characterized by rapid technological evolution and constant innovation, competition and volatility are becoming increasingly prominent. This dynamic is driven by growing consumer demand for high-quality products and services, with reduced costs and shorter delivery times. In this context, companies face the challenge of being able to thrive where all the odds seem against them.

World's top companies ensure a sustainable growth in such adverse conditions by focusing on continuous improvement while prioritizing resource efficiency. By optimizing processes and resources, they can reduce costs, increase productivity and be more competitive, while being flexible to market shifts. All that without compromising the quality of products and services offered. Such characteristics are very present in the lean philosophy which rests on three fundamental pillars - quality, cost and service (Imai, 2012). Thus, the set of lean tools aims to bring benefits such as an increase in quality, adequate service level and cost reduction.

The following master thesis' project is the result of a collaborative effort between Kaizen Institute Western Europe, a consultancy specialized in the implementation of lean methodologies and a prominent Portuguese apparel multinational company, hereinafter referred to as Company X, for confidentiality purposes.

In this chapter, a brief presentation and contextualization of the project and industry is made, alongside a thorough description of the objectives and adopted methodology to achieve them.

1.1 Contextualization of the project and motivation

The apparel industry's unpredictability and complexity present unique challenges to the companies, especially regarding warehouse management. The volatile nature of fashion trends coupled with external economic factors, creates a dynamic environment where the demand for certain goods can fluctuate rapidly. This poses challenges in terms of stock allocation, order fulfillment and inventory management.

Moreover, the growth of the digital channel, boosted by the pandemic, has added another layer of complexity to warehouse management. The expansion of e-commerce and online retail platforms has increased the volume and variety of orders as well as the amount of reverse logistics - the process of managing the flow of products, materials, or equipment from their final destination back to the point of origin or to another location for the purpose of returns, repair, recycling, or disposal - movements required, leading to greater demand for efficient warehousing and distribution processes. On top of that, it triggered the need for new processes and the renewal of existing ones, to ensure the best customer experience possible.

This project thus emerges from the company's need to increase its storage capacity in order to sustain its growth in sales and diversification, as well as the need to increase the overall productivity of the warehouse's operational teams in order to keep up with market demands.

1.2 The apparel industry

The apparel industry stands as a dynamic and ever-evolving sector, characterized by its constant adaptation to shifting consumer preferences, technological advancements, and global market forces. It encompasses every kind of clothing, from sportswear to businesswear, from value clothing to statement luxury pieces and is broken down into the following product lines: Women's Apparel, Men's Apparel, and Children's Apparel, with the Women's Apparel having the highest share. In terms of annual revenues, the market is expected to reach 1.7 trillion euros worldwide by 2024 and to register an annual growth rate of 2.81% between 2024 and 2028 (Statista, 2023).

Over the last few years, there has been a major change in the clothing industry, moving towards increased online shopping. The rapid expansion of e-commerce platforms has driven this evolution, which was further sped up by the unique challenges of the 2019 pandemic. Since 2017, the online share has doubled in size, currently accounting for around 25% of the market and expected to continue growing at a rate of 2% per year (Statista, 2023). Figure 1.1 provides an overview of the evolution of the online apparel industry.

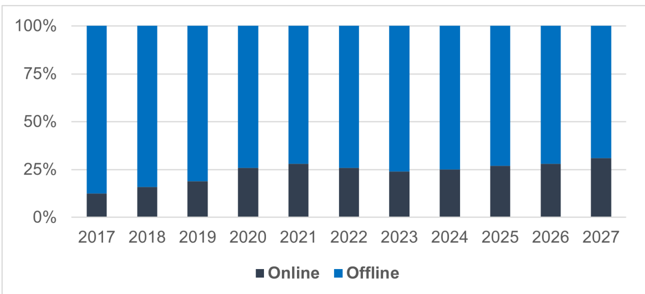


Figure 1.1: Evolution of the online channel share in the apparel industry

In Portugal's context, the fashion sector has a significant impact in the economy, largely attributed to the nation's extensive background in textile manufacturing. Nevertheless, businesses in the area are beginning to adopt the approach of larger companies by outsourcing clothing manufacturing to Asia, enabling them to diversify their offering while providing more competitive pricing.

In Portugal, the clothing industry is the fourth largest in Europe, projected to reach €5.2bn in market size by 2024 with a growth rate of 2.7% per year (IBISWorld, 2022). Additionally, the fashion sector in Portugal ranks as the 15th largest internally, employing over 92 000 individuals. Regarding the online business, Portugal lags slightly behind the global standards, with online sales accounting for approximately 13% of total sales in 2024. However, its presence has doubled since 2017 (Statista, 2024).

When it comes to the distribution of the market, the clothing sector in Portugal is dominated by global brands, with companies like Zara, Nike, and Adidas establishing themselves as the leaders in 2022. Based on GlobalData's, 2023 report, Zara is the top brand with a market share of 6.8%, while Nike follows at 2.8% and Adidas at 1.8%. There are also examples of Portuguese players well-established in the market like Tiffosi, Lion of Porsches and Sonae Fashion, however their dimension is not sufficient to compete with the aforementioned international brands. This information highlights the intense competition in the Portuguese fashion market, with no one brand holding a significant market share. The fact that the leading brand holds only a relatively small portion of the market reflects the industry's fragmentation and the intense competition among players.

It is in this market context that the company that serves as subject to this dissertation is inserted into. In the following chapter, the company will be presented together with Kaizen Institute Western Europe, the promoting company of the project.

1.3 Presentation of the companies

1.3.1 Company studied

The project described in this document was carried out in a Portuguese company, headquartered in the north of Portugal, that operates in the apparel market, both at national and international levels, and is part of the largest fashion group in Portugal. The company is designated as Company X along this dissertation, to protect its identity.

Company X was founded in Portugal about 30 years ago and is currently operating in more than 40 countries, owning around 190 own stores and being present in more than 1200 multi-brand spaces. It initially started as a dyeing and laundry company but switched focus to clothing manufacturing shortly after, which is its main focus nowadays.

During 2023, Company X sold more than 3.2 million pieces of cloth, representing around 205 million euros in sales, according to the company's annual accounts report. Since 2020, it has been growing at an average rate of 13% a year, however this value is inflated by the 30% drop in sales experienced during the pandemic. Moreover, out of the total sales in 2023, 30% is relative to the Portuguese market. Regarding the online channel, it currently represents 15% of the sales volume, with an expected growth to 25% in the next 3 years, according to the company's forecast. Regarding the workforce, as of 2023 Company X employed 1200 people.

Transitioning to an internal analysis of the company, its focuses are centered around four pillars: “Clothes for everybody”, “Proudtuguese”, “Craftmanship” and “People & Planet”. Their mission is to be people’s second skin and empower their constant renewal. These principles can be translated into a people-oriented culture with focus on sustainability, quality, and innovation, while preserving their roots and essence.

In order to achieve such objectives, it is essential to focus on increasing efficiency while maintaining quality and promoting transformation, which fits the continuous improvement and lean philosophy advocated by Kaizen Institute Westen Europe.

1.3.2 Kaizen Institute Western Europe

Kaizen Institute is a global organization that provides training and consultancy services specialized in lean implementation and the practice of Kaizen methodology (a Japanese word meaning continuous improvement). Founded by Masaaki Imai in 1985, the mission of Kaizen Institute is "to improve the world with all people, in all areas, every day".

This project was carried out as part of the company’s branch based in Porto, which belongs to Kaizen Western Europe. The Kaizen Institute’s projects are the result of collaboration with companies from a wide range of sectors, from industry to logistics, services and health, among others. The aim of the projects is to promote the efficiency of the companies’ processes, working on the pillars of the philosophy - quality, cost and service. These pillars translate at an operational level into improvements such as reducing lead times, cutting operating costs, increasing quality indicators, increasing productivity, among others.

Kaizen Institute’s work is based on fundamental principles such as identifying and creating value for the customer and flow efficiency by reducing waste and adapting to demand. To achieve this, the presence of consultants in the field, a focus on addressing problems at their root causes, and the standardization of processes are essential. On the other hand, Kaizen is characterized by transparency, involvement, and development of the teams in the companies it works with, from a perspective of not blaming mistakes and defining actions for improvement. Finally, great importance is given to objectivity and the use of data in decision-making.

In short, the company’s focus is to support leaders in creating and implementing processes that enable performance improvement. This is done by implementing a culture of continuous improvement, through direct collaboration with its clients in order to understand their problems, and training employees to provide them with the necessary skills to solve them.

Once the companies involved in the project have been introduced, a brief background and description of the project will be presented.

1.4 Project description and objectives

This project focuses on Company X’s finished goods stock warehouse, located in northern Portugal. The high complexity of the operations due to the variability of the products stored (associated with the seasonality of the business) and the change in the sales channels used by customers due to the growth of the online business, combined with an ever-increasing limitation of space due to growth of sales, raised the need for greater stock capacity and the increase of productivity. That being said, by adding the importance of keeping up service levels and competitive prices, it is crucial to adopt tactics and actions to enhance warehouse capacity and overall operational efficiency, which is attainable with the utilization of Kaizen methodologies.

The theme explored in the project consists of increasing warehouse efficiency through initiatives that increase the productivity of the operation and space utilization. These efforts mainly involve creating and putting into action dynamic operational control panels, establishing a system for planning and balancing internal logistics staffing, and re-configuring storage layouts. Moreover, there is a lack of processing and monitoring of data regarding stock management, SKU quantities and operator productivity, which is also within the scope of the project and will be addressed by the operational dashboards.

The project's success depends on tracking indicators for each objective to measure the results of actions taken. For productivity, the key metric is the overall productivity of the supply chain, defined as the number of pieces shipped per person per hour in the warehouse. To account for the potential influence of sales on this metric, a supporting KPI is used: the number of actions performed in the warehouse, measured by the number of lines completed by each person per hour. Additionally, the warehouse's stocking capacity is determined by the number of pallets.

For both indicators, a baseline and a target value were defined. Because productivity is linked to sales volume, which has a trend and seasonal pattern, the baseline is dynamic and monthly-based. In other words, each month's baseline is set to the number of shippings per person per hour recorded during the same month in the previous year. Hence, it can be inferred that the goal is also subject to change, resulting in a 10% growth in that factor. The warehouse's base pallet capacity is 2952 pallets, with the goal of reaching 3698 pallets, which represents an increase of 25%.

1.5 Dissertation structure

This document is divided into eight chapters, providing detailed descriptions of the project and its context, methodology, identified problems, and implemented solutions. The first chapter introduces the project, describing the sector it is part of, the involved companies, and the project objectives. The second chapter details the methodology used in the study, addressing the challenge encountered as part of the dissertation project at Company X. The third chapter reviews the state of the art on topics related to warehouse operations, including factors impacting productivity, the application of Kaizen methodologies, and strategies to increase storage capacity. The fourth chapter characterizes Company X's warehouse operations before the project's initiation and outlines the encountered problems. The fifth chapter describes the design of proposed solutions to mitigate these challenges. The sixth chapter covers the implementation process and new challenges faced. The seventh chapter summarizes the main results obtained, and the eighth chapter presents the key conclusions and future perspectives arising from the project.

Chapter 2

Methodology (case study based)

This dissertation aims to study a problem, which is the implementation of lean strategies in warehouses, specifically the case of a company in the apparel industry. This research is based on theoretical knowledge, attempting to develop a lean approach to improve the operations in an apparel warehouse as well as increase its storage capacity, benefiting the entire value chain and operation of the respective organization. This chapter aims to describe the methodology used in this study, which led to addressing the challenge encountered as part of the dissertation project at Company X: increasing warehouse productivity and storage capacity. First, the implemented method will be explained, along with the rationale for choosing this method, and then the steps taken to obtain the results will be outlined, aligned with the case study methodology.

This dissertation is conducted from a qualitative perspective since it deals with a specific case of a certain company in a specific industry and aims to answer the question: "How to increase productivity and storage capacity in a clothing warehouse?". The case study methodology is recognized as particularly useful in analyzing 'How' and 'Why' questions, such as the one at hand (Yin, 2003). Thus, with a more inductive research approach and an attempt to answer a 'How does...?' question, this study is designed as a qualitative approach (Pope and Mays, 1995). Although qualitative research can be inductive or deductive, this study refers to the latter case due to its analysis strategy (Creswell, 2018). Furthermore, the sampling method for this research, i.e., the source of information to draw conclusions, is theoretical rather than statistical (Pope and Mays, 1995). Therefore, this dissertation will be conducted with a qualitative approach and an exploratory study in the field of implementing lean solutions in an apparel warehouse.

When conducting qualitative analysis, defining the chosen strategy for the problem becomes a key aspect since there are several possibilities for this type of research (Creswell, 2018). According to Patton (2002), there are five different types of strategies for conducting qualitative research: basic research, applied research, formative evaluation, summative evaluation, and action research. Identified by this author, applied research uses theory to try to solve real-world problems(Patton, 2002). The purpose of applied research is to reach conclusions that will help solve real-world problems (Dudovskiy, 2022). Despite the usefulness of this type of research in solving specific challenges, its findings may sometimes not be applicable to other areas, limiting the potential impact to a specific case or area. Due to the purpose of this research, the adopted methodology follows an applied research approach. Although one of the drawbacks of this methodology is the lack of applicability of the developed methodology in other areas due to its specificity, this study aims to develop a list of requirements, sequence, and best practices that, if implemented, will facilitate the integration of lean solutions into the operations of companies in this sector, as well as the apparel industry in general.

Voss et al. (2002) emphasize the importance of having a well-defined research question from the beginning of the study, as it guides the research process, particularly in selecting the steps of solution design, a decisive step in ensuring that the identified question is adequately answered. A case study investigation may involve a single case or multiple cases. A case may be purposefully chosen depending, for example, on the richness of its information, how critical, unique, or extreme it is. One of the traditional concerns in case studies, as previously mentioned, is precisely the generalization of their conclusions.

Before detailing the plan for the project methodology, it is important to first contextualize the problem. As mentioned earlier, this study was conducted at Company X's warehouse, which, due to the rapid growth, is experiencing storage capacity problems as well as inefficiencies in the operation, as explained in this dissertation. This topic thus becomes challenging since it deals with this specific case of Company X, along with the fact that we are dealing with a warehouse (lean methodologies were originally created for manufacturing processes). Therefore, the proposed challenge is key to defining the requirements and steps for executing this type of project. In order to answer the research question "How to increase productivity and storage capacity in a clothing warehouse?", the following methodology was developed, consisting of 5 phases:

- Phase 1: Theoretical Research and Exploration
- Phase 2: Characterization of the Current Situation
- Phase 3: Solution Design
- Phase 4: Solution Implementation
- Phase 5: Solution Design Validation

From now on, the work will follow the methodology presented above. The first phase of the project, phase 1 aims to carry out a theoretical investigation in order to assess the current state of the art on problems similar to the one presented. Phase 2 aims to characterize the current situation of the case under study. Phase 3, based on the generalized knowledge gathered from different literature and the current situation, aims to analyze different possible methods and design a solution for the case under study. Subsequently, in phase 4, the solution design will be implemented to validate the proposed solution. Finally, in phase 5, the obtained results are evaluated, and the necessary conclusions are drawn. The following chapters, chapters 3 to 7, correspond to phases 1 to 5 of the methodology, respectively.

Chapter 3

Literature Review

In this paper, the PRISMA ("Preferred Reporting Items for Systematic Reviews and Meta-Analyses") framework was used to structure the approach for the literature review with the objective of improving its transparency and quality. The following steps are discussed:

- Definition of the research questions: guidance for identifying relevant papers;
- Search process: research strategy and selection of scientific sources;
- Screening process: criteria applied to select the most relevant papers.

For additional details, refer to Appendix A.

3.1 Definition of research questions

The definition of the research questions was oriented towards the enlightenment of the current state of art, success stories, applications and difficulties, regarding not only the solution to the problems presented but also the methodologies to structure the problem-solving approaches. With that said, the following research questions were formulated to guide the literature review:

- *How can warehouse productivity be measured?*
- *What factors have the greatest impact on the overall performance of a clothing warehouse?*
- *What are the best practices on operations management and decision-making in warehouses?*
- *What are the most efficient ways to gain storage capacity in a warehouse?*
- *How can Kaizen methodologies be applied in the context of a warehouse?*

3.2 Theoretical background

3.2.1 Overview of warehouse activities

Warehouses are an integral part of the supply chain infrastructures. Their management is not only a critical operational part of the supply chain management, but also a strategic one since it coordinates different aspects of the business, such as production, suppliers, customers and products.

In general, warehouse activity is divided into five main processes: receiving, put away, storage, picking and shipping (Frazelle, 2001), with the essential resources that support the operation being space, equipment and manpower (Min, 2015).

Receiving is the operation that involves the assignment of trucks to dock and the scheduling and execution of unloading activities, including necessary checks and documentation. Put away is the activity of moving the received goods from the staging area to their designated storage locations within the warehouse. Storage includes proper organization, moving and storing of materials to help streamline subsequent operations. Picking is the operation in which the orders are prepared, with the collection of the specific quantities of each product requested. Finally, shipping represents the activity that involves scheduling and assignment of truck to docks, packing of the orders and the loading of trucks.

Managing such different tasks can be challenging, therefore it is important to develop initiatives and systems to facilitate it.

3.2.2 Warehouse productivity measurement

The existence of a formal productivity measurement system has several advantages, both in terms of the process of creating and criticizing indicators, as well as controlling them. This process generates discussion and makes it possible to challenge existing paradigms in the organization, as well as highlighting potential problems and creating motivation among the employees involved in the process of continuous improvement. In addition to that, it is seen as a clear and unbiased method, both for the evaluator and the evaluated (Pritchard et al., 2008).

Subsequently to the definition of indicators, comes the tracking and controlling of those parameters, to ensure that the operations are running smoothly and the company is in a favorable position, in comparison to the competition. Furthermore, at an operational level, emerges the possibility of comparing different teams, shifts or units of the organization, allowing problems to be identified, prioritized and resolved more in advance (Pritchard et al., 2008).

Definition of KPIs

Warehouse performance evaluation has been studied in different ways by many researchers, each of those focusing on different aspects, in term of objectives, indicators, warehouse systems and measuring instruments. Given all this diversity, there is no consensus on the best group of measures to evaluate warehouse performance, mainly due to the fact that different types of warehouses may have distinct operations and specific particularities.

According to Chow et al. (1994), performance warehouse measures include 'hard' and 'soft' metrics. The first one treats quantitative measures such as order cycle time, fill rates and costs; the second deals with qualitative measures like the manager's perceptions of customer satisfaction and loyalty. However, the most utilized and consensual KPIs tend to be the 'hard' ones due to the elimination of subjectivity from the measure.

Frazelle (2001) classifies performance in a warehouse according to a model that includes a total of 25 KPIs, all of them considered to be 'hard', as it is shown in Table 3.1.

Table 3.1: Warehouse key performance indicators (retrieved from Frazelle, 2002)

	Financial	Productivity	Utilization	Quality	Cycle Time
Receiving	Receiving cost per line	Receipts per man-hour	% Dock door utilization	%Receipts processed accurately	Receipt processing time per receipts
Putaway	Putaway cost per line	Putaways per man-hour	% Utilization of putaway labor and equipment	% Perfect putaways	Putaways cycle time (per putaway)
Storage	Storage space cost per item	Inventory per square foot	% Locations and cube occupied	% Locations without inventory discrepancies	Inventory days on hand
Order picking	Picking cost per order line	Order lines picked per man-hour	% Utilization of picking labor and equipment	% Perfect picking lines	Order picking cycle time (per order)
Shipping	Shipping cost per customer order	Orders prepared for shipment per man-hour	% Utilization of shipping docks	% Perfect shipments	Warehouse order cycle time

Kusrini et al. (2018) analyzed the performance of warehouses using the 25 key performance indicators introduced by Frazelle (2001), and concluded that the most important KPI for receiving is productivity, for putaway is cycle time, for storage is utilization, for order picking is cycle time and for shipping is productivity. In contrast, Karim et al. (2021) reviewed experts' opinions regarding the most important and impactful KPIs in a warehouse and determined that the consensual ones were picking productivity and inventory space utilization.

Gwynne (2014) suggests that each company will have different priorities, a different customer base and a different method of operation. So, the choice of the most suitable KPIs will depend on the industry, the business strategy, the objectives and the level of alignment between the different warehouse processes.

KPI tracking tools

After the definition of the most suitable KPIs for each situation, it is necessary to start measuring them and saving the records for further analysis.

The integration of advanced technologies such as artificial intelligence can contribute to the measurement of KPIs in a warehouse. For example, artificial intelligence application in human resource systems can aid in storing KPIs and providing instant informed management decisions based on the results of the tracked measures (Ćormarković et al., 2022).

Aljedaani et al. (2022) highlights the importance and usefulness of digitalization as a method to measure and track KPIs. The integration of WMS systems to collect KPIs is advantageous to have access to quick and precise information and provides greater visibility into warehouse operations to the managers.

In the end, the measurement of the KPIs will be a personal choice of the warehouse managers, being strongly influenced by the level of technology that is present in the facility and the desired metrics. It is also possible to keep a manual recording or calculate them based on the warehouse entry and exit logs, however those are highly time consuming methods and sometimes unreliable.

3.2.3 Factors that impact overall performance of a clothing warehouse

When evaluating a warehouse performance, a good indicator is the warehouse efficiency, which can be described as the process of creating the highest amount of outputs by using less inputs (Potocan, 2006).

Factors impacting warehouse efficiency

Priyamali and Mudunkotuwa (2018) highlight six factors as having the greatest impact on warehouse efficiency in apparel industry. Such factors are quality (of the operations), warehouse planning, productivity, inventory control, cost and labor satisfaction. Priyamali and Mudunkotuwa (2018) also developed a study to identify how the efficiency factors depend on the scale of the company and number of employees and to identify the relationship between number of customer complaints and the efficiency factors. The conclusions of the study indicate that the number of customer complaints is dependent from all the factors except warehouse planning and cost. Furthermore, larger companies had a consensual agreement that cost and quality have a direct impact on efficiency, while small scale companies did not have a clear idea regarding the importance of those factors. Finally, regarding the number of employees, companies with 11-20 employees were more concerned about productivity and warehouse planning, in comparison to companies with less than 10 or more than 50 employees. Warehouses with a manpower higher than 50, focused more on labor satisfaction to increase efficiency.

Aminoff et al. (2002) suggest that the warehouse efficiency should be measured according to three pillars: work efficiency, space utilization and cost efficiency. Concerning warehouse efficiency, three important outcomes were found. Firstly, it was found that the order structure (described as an average number of item lines per order) has a strong impact on both the work and cost efficiency. Secondly, space utilization significantly influences cost efficiency. Lastly, the working methods in a warehouse strongly affect the work efficiency as well as cost efficiency.

Wanjari (2020) conducted a survey to find the major human and technological factors and their impact on warehouse productivity, and the results showed the most statistically significant correlated factors are efficiency and effectiveness of the operators and the equally capable and optimized Warehouse Management Systems (WMS) system.

Other authors, such as Mostafa et al. (2019), emphasize that warehouse management is the factor with the greatest impact in warehouse productivity. With efficient management practices, companies can reduce costs and delivery time while increasing quality and customer service ,leading to an increase of profit and customer satisfaction (Kusrini et al., 2018). Furthermore, appropriate management ensures that warehouses are capable of adapting to market shifts and challenging times, making it possible to survive and even thrive in adverse conditions (Mahdzir et al., 2023).

Alternatively, Staudt et al. (2015) suggest that the level of automation and technology inclusion in warehouse is a significant factor influencing warehouse performance. Automation implementations in warehouses have the potential to improve cost, service, and flexibility, although there are concerns about operational start-up disruptions and ongoing flexibility (Baker and Halim, 2007).

Besides the factors that might impact the performance of a warehouse, understanding the activities that consume the most resources and where there is actual value being added, is beneficial to guide efforts into strategical targets of the improvement actions.

Warehouse activities' resource consumption

From the activities presented in the beginning of this sub-chapter, picking (order picking) arises as the most expensive in terms of costs and time allocation (Gwynne, 2014). In order picking, the operator in charge, known as the cashier or picker, receives an order corresponding to a set of items and quantities, and goes through the warehouse layout in order to collect the articles corresponding to the information received. In fact, it is estimated that its costs can reach up to 36% of the overall structure of warehouse costs (Gwynne, 2014). Figure 3.1 provides an estimation of the percentage of the warehouse costs that each activity represents.

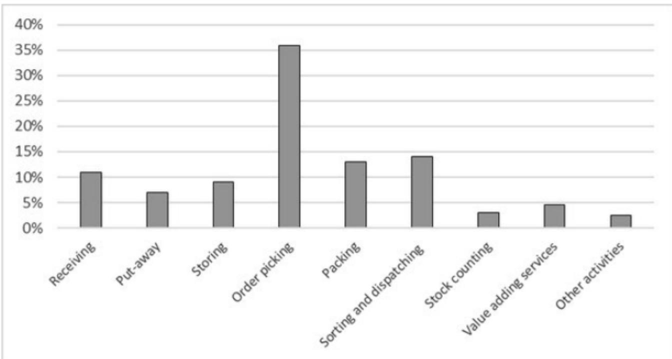


Figure 3.1: Warehouse activities as a percentage of warehouse costs (Gwynne, 2014)

Other than picking, the activities that represent the higher costs are related to sorting and dispatching of goods, which are involved in roughly 14% of the overall costs in a warehouse. Sorting involves the arrangement of goods within the warehouse, while dispatching focuses on the timely and accurate shipment of goods to their destinations (C.Y. Tsai and Huang, 2008).

According to Koster et al. (2007), among the various warehouse activities, order picking is the most time-consuming and labor intensive activity. Coyle et al. (2003) adds that the order picking can take up to 60% of the operators workload. Additionally, the activity of allocation of goods within the warehouse is a critical one, with a strong influence in the human workload and overall warehouse performance (from Kudelska and Pawłowski , 2019).

Being the activity with greater impact in the costs and time allocation, not to mention it's value adding nature, several authors studied the order picking activity more in depth.

For the case of manual picking, Tompkins et al. (2010) presented a distribution of the time spent by the picker on the various activities of the picking operation. Their conclusions are shown in Figure 3.2.

Of all the activities presented, the only one that adds value to the operation is picking the items from their positions. However, only 15% of the picker's time is actually dedicated to this.

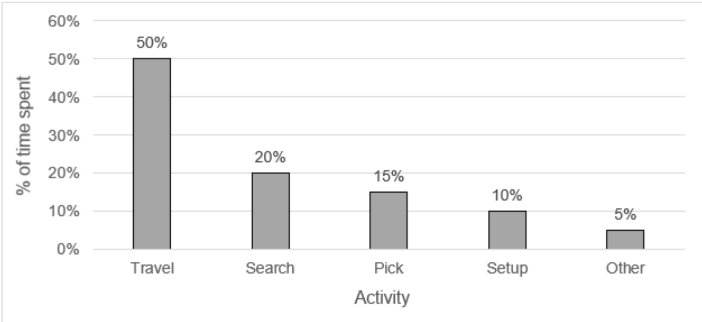


Figure 3.2: Percentage of time spent by the clerk on different order picking activities (adapted from Tompkins et al. , 2010)

Of the remaining activities, the one that consumes most of the operator's time, roughly half, is moving around the warehouse in order to pick the items. The second largest percentage is spent looking for the positions of the products to be picked, which accounts for 20% of the time. Setup operations take up to 10% of the picker's time, and these can include tasks such as printing labels or identifying the next picking position to go to.

In summary, it is possible to conclude from the available literature that one of the factors that has the greatest impact in a warehouse performance is the management of its operations. In addition, the activities that represent the highest cost and time consumption are the collection, sorting and dispatch of goods, so special attention should be paid to these activities, from a management point of view.

3.2.4 Warehouse management and decision-making

Warehouse management encompasses a wide array of activities and processes aimed at ensuring the efficient operation and control of a warehouse. The key elements involving warehouse management are: inventory tracking and management, which corresponds to the monitoring of stock level, allowing the warehouse staff to know how much product is ready to be shipped to the customer and how much should be ordered/produced; order fulfillment, where by overseeing the picking, packing and shipping of products managers ensure that orders are processed accurately, efficiently and in time; receiving inventory from trucks at loading docks and stowing materials in their short or long-term location; reporting, in order to access performance indicators; and calculation and analysis of logistics costs (Lopienski, 2019).

It is know that management and decision-making are intricately linked, and in a warehouse context is no exception, with decisions influencing every aspect of warehouse operations, from inventory management and resource allocation to facility design and technology adoption (Çetinkaya and Akdaş, 2022). By making informed decisions based on data, analysis, and operational objectives, warehouse managers are able to guide the operations towards greater efficiency and overall performance.

Regarding warehouse management there are several suggestions available in literature, varying from the application of specific strategies to the introduction of technological solutions.

Atieh et al. (2016) argue that deploying advanced WMS can significantly improve warehouse operations by automating processes, optimizing resource management, and enhancing overall efficiency. The term "Warehouse Management System (WMS)" refers to a software application that supports the day-to-day operations in a warehouse, including inventory management, order fulfillment, and receiving. WMS provides functionality to handle complex warehouse processes such as the transaction of goods, record of inventories, monitoring, and control of workflow through the use of computer technology (Hao et al., 2022). Nevertheless, due to the high complexity, users often find it hard to handle WMS. The design, choice and operation of a WMS requires extensive know-how and experience because of the large variety of solutions and system requirements (Ten Hompel and Schmidt, 2008).

In the era of industrial revolution 4.0, Jarašūnienė et al. (2023) explored the application and impact of IoT on Warehouse Management. The Internet of Things (IoT) is a technology designed to process large amounts of data with maximum efficiency in real time. This technology can facilitate the implementation of smart identification, tracking, tracing, and management using radio frequency identification (RFID), infrared sensors, global positioning systems (GPS), laser scanners, and other detection tools (Jarašūnienė et al., 2023). The aim of IoT is to perform administrative work, i.e., to efficiently manage warehouse data. IoT can be used to monitor and track goods, forecast demand trends, manage inventory, and perform other warehouse operations in real time. Jarašūnienė et al. (2023) developed a questionnaire to assess the impact of the IoT in different warehouses' performance. The respondents were required to have a Masters' degree in management, at least 5 years of experience in the field and worked in different companies at the time. The results are presented in Figure 3.3.

Figure 3.3: Participants' response on impact of IoT on multiple warehouse management metrics (adapted from Jarašūnienė et al. , 2023)

All the surveyed experts agreed that there was an increase of productivity and quality of work, with the implementation of IoT in the warehouses. Moreover, 90% of them answered that it had a positive impact in inventory accuracy and also led to a reduction on inventory maintenance costs. Regarding order lead time, 17 out of the 18 participants agreed that there was a decrease and 1 perceived no change.

Saad (2021) suggests a simpler strategy to optimise warehouse management, based on lean practices. The first step is measuring and keeping track of the performance of the warehouse, both from a macro and micro perspectives. The workforce performance, industry growth and trends, competitive performance and competitive costing should be assessed. Secondly, comes the simplification of processes. Making the layout simpler, with the objective of both optimising the flow of operations, but also to improve inventory tracking, is a strong facilitator of warehouse managers' tasks. Regarding that, Wang et al. (2018) propose class based storage strategies, considering the characteristics and requirements of different materials. In addition, it is fundamental to simplify the processes and workforce tasks, by reducing the functions-on-functions that have been layered over time and to save time on unnecessary actions. Finally, Saad (2021) believes in encouraging growth and an optimization culture among the warehouse staff. This way, every clerk starts managing the simplest tasks and improving them autonomously. Moreover, they provide a different vision on the operations that can be translated into constructive feedback to the managers.

3.2.5 Warehouse storage capacity increase methods

In order to increase warehouse storage capacity two approaches can be distinguished: warehouse expansion and storage optimisation (Rose, 2021).

Warehouse Expansion involves purchasing land to construct additional physical buildings and infrastructure or leasing/renting more space to increase overall storage capacity and throughput capabilities. It requires substantial upfront capital expenditure on construction, materials, equipment, technology and labor to support the new space. Expansions typically take anywhere from 6 months to over a year to complete depending on the scope.

Storage optimization encompasses various methods and technologies to maximize utilization of current warehouse space and assets. The goal is to significantly boost usable storage capacity within existing four walls, without the need for facility expansion. Optimization is achieved through improvements including more efficient layouts, higher-density storage equipment, streamlined workflows, workforce training, slotting optimization, and integrating automation technologies. It aims to gain capacity rapidly and cost-effectively by enhancing operations versus expanding infrastructure.

Regarding warehouse expansion, Irwansyah et al. (2022) propose the application of a shared storage method, which refers to the practice of multiple tenants or users sharing storage space within a single warehouse facility. Instead of each tenant having their own dedicated storage area, they share common storage resources such as racks, shelves, or storage zones. This would allow to increase storage capacity at more accessible prices compared to the construction of a new warehouse.

Mukhopadhyay and Setaputra (2006) argue that the use of a fourth-party logistics (4PL) as a return service provider, is the most beneficial way of warehouse expansion, since it also allows not only to gain storage capacity, but also eases the complex task of managing reverse logistics (process of managing the return, disposal, or re-purposing of products or materials from the point of consumption back to the point of origin).

Storage optimization techniques are more varied and are widely adopted in the available literature. Shah and Khanzode (2018) explore the utilization of lean thinking in warehouse storage policies, in order to have a more efficient space utilization and improved storage capacity. By exploiting a dynamic storage assignment decision support system, which identifies the most efficient way of assigning non-uniform units to storage locations, it was possible to assign goods to their most suitable storage positions, reducing empty spaces and gaining storage capacity.

Newton (2022) explores technology as a tool to increase warehouse storage capacity. It is argued that the use of data analytics is useful for predicting demand and space requirements, which can be used to improve inventory practices such as adapting storage choices to the needs in the near future. Furthermore, it is suggested that the integration of automation can be used to reduce aisle widths and therefore maximize warehouse space utilization. A common practice is VNA (very narrow aisles) racking. Instead of reducing the number of aisles, the space that they occupy is reduced to gain as many centimetres as possible on the racking. To maximize the space occupation, the distance between racks is minimized, which can be achieved with the use of automated retrieval systems, that can operate in smaller spaces than forklifts or people.

Galbreth et al. (2008) investigated a different approach to gain warehouse storage capacity. Instead of trying to increase space or using strategies that allow you to store more objects in the same space, the idea was to not store the items at all. The concept exploited is called cross-docking and it involves the direct transfer of incoming goods from inbound transportation vehicles to outbound transportation vehicles with minimal or no storage time in between. This way, there is a minimization of inventory and a lower need for space in the warehouse, with the added benefit of decreasing lead times. Such strategy, involves a great synchronization between the materials arriving and expedition.

Summing up, there isn't one strategy that performs superiorly. Naturally, expanding the warehouse offers a larger space increase, but it also comes at a higher cost compared to storage optimization methods. Additionally, there are approaches that may be ineffective in certain warehouses, because of the operations, product needs, or the overall organization and efficiency of the storage facility. Therefore, it is important to discover the most appropriate method considering the balance between cost and space gains, along with the unique features of the warehouse being considered.

3.2.6 Application of Kaizen methodologies in the context of a warehouse

Kaizen corresponds to the Japanese philosophy of continuous improvement involving all organization members (Imai, 1986). The word combines "kai" (change) and "zen" (good), together meaning "change for the better" (Kaizen Institute, 2021). While often linked to industrial processes, Kaizen methodologies can be applied in various sectors, including logistics.

Process Mapping

In the context of warehouse operations involving various activities and material flows, it's crucial to ensure a comprehensive understanding of all relevant processes and their sequence.

Value Stream Mapping (VSM) serves this purpose by mapping processes. In a VSM, the flow of material and information in a process is faithfully represented, covering the entire operation (Rother and Shook, 2003). For a warehouse, this encompasses activities from receiving goods to delivering to the customer. Subprocesses or activities are classified based on whether they add value from the customer's perspective. Value-added processes involve transforming material or information for which the consumer is willing to pay, while non-value-added activities consume resources without directly contributing to desired outcomes (Jacobs and Chase, 2011).

VSM employs graphical elements representing different process stages. In this dissertation, elements for inventory, operations (value-added and non-value-added), transportation, suppliers, and customers were utilized. The nomenclature used is illustrated in Figure 3.4.

Figure 3.4: Nomenclature used in Value Stream Mapping.

Through this mapping, a better understanding of the process is attained, facilitating the identification of areas requiring focus for improvement implementation. VSM serves as the initial step in waste elimination projects, originating the reduction or elimination of non-value-added tasks (Alsyouf et al., 2011). Additionally, tools like spaghetti diagrams can visualize movements made by participants, aiding in operation analysis (Bastos and Sharman, 2019). With defined focus and enhanced process comprehension, identifying and addressing problems becomes more straightforward.

Problem Solving

Kaizen methodologies emphasize the importance of a deep understanding of the current state of the object under analysis through a survey of problems and identification of their root causes. There are several tools that allow for a structured approach to problem resolution. A frequently used tool is the A3 9 Steps, which is a variant of the A3 Problem Solving Process. The A3 process provides a systematic and structured approach to problem-solving, ensuring that issues are thoroughly analyzed and addressed, while fostering collaboration, continuous improvement and standardization. The nine steps of the A3 problem-solving process involve defining the problem, analyzing the current condition, setting a goal statement, conducting root cause analysis, developing countermeasures, testing solutions, following up on progress, standardizing successful solutions, and reflecting on the problem-solving journey to drive continuous improvement. Appendix B illustrates the 9 steps of the framework.

Due to its relevance in achieving positive results, root cause identification can be carried out using additional tools in cases where it is not easy to identify them. Thus, the "5 Whys" technique can be employed, which involves questioning the causes presented for the problems multiple times until their root causes are reached. For more complex issues, causes can also be explored through an Ishikawa diagram, also known as Fishbone due to its shape, which is a problem-solving tool that allows mapping all possible causes that may arise from an effect (Bastos and Sharman, 2019).

Chapter 4

Problem Description

In this chapter, a contextualization of the warehouse under study is presented, as well as a description and analysis of the operational status before the start of the project. An examination of the warehouse design will be carried out, followed by an overview of the inventory movement and a thorough explanation of the key operations.

Aside from describing the starting point, the primary issues and their root causes are also pinpointed, that served as the foundation for introducing enhancements throughout the project's timeline.

4.1 Warehouse layout

The warehouse in question is located in northern Portugal, where Company X's headquarters are also located. This is the sole stock warehouse that belongs to the company, so all of the company's operations revolve around it. The warehouse covers approximately 14000 m^2 in total, with 12000 m^2 designated for storage use. At the start of the project, it was able to accommodate 2952 pallets and approximately 3.25 million items, from a range of more than 30k SKUs. The warehouse's layout is presented in Appendix C.

The warehouse has four primary sections: receiving, storing, picking, and expedition.

In the receiving area there are the receiving dock, the checking stations and the quality control room.

The storing area, also known as *A's*, consists of a collection of 28 racks, each with four levels, where products are stored until a replenishment in the picking area is required. Three of those racks are exclusively dedicated to advertising items (which is a non-core product) and the remaining are fully dedicated to clothing items. The positions in each rack, are represented by a code that indicates the warehouse area, the rack, the slot and the shelf level. There are 4 levels per rack, each one with a height of 2 m. Table 4.1 shows an example of the coding of a storing position.

At levels 2,3 and 4, each pallet corresponds to a slot. However, at the ground level (level 1), each pallet is divided into two slots, with each position containing boxes of a single SKU. It is possible to observe an illustrative example of these positions in Figure 4.1.

Table 4.1: Example of the identification code for a storing position

Code	Area	Rack	Slot	Level
AM-024-4	A	M	24	4

Figure 4.1: Illustrative example of level 1 and 2 of the storage area racks

The picking zone is split into two main areas: PBS (picking by store) and PBL (picking by line), where two different types of picking are performed. In PBS, the worker moves through different picking zones within the warehouse to gather items for a specific order. Each zone may contain different SKUs, and the worker collects the required items from each zone to complete the order. This method is more efficient for fulfilling specific store orders that might vary in items and quantities. While in PBL, the worker carries a box of a specific SKU and distributes that SKU among various orders. The worker moves from one order to another, placing the needed quantity of that SKU into each order's designated container. This approach is generally more efficient for high-volume, uniform orders. In this particular warehouse, the productivity of PBL significantly surpasses that of PBS. A worker performing PBL can separate approximately 1000 pieces per hour, whereas a picker in PBS manages to separate only about 250 pieces per hour.

The PBL zone consists of an extensive corridor with a rack on each side. Each rack has multiple boxes distributed across two levels. Each box represents a picking position, meaning it corresponds to a specific order.

The PBS zone consists of three additional smaller sections, the *S's* zone, the outlet zone and the *J's* zone.

The collection items are stored in the *S's* zone, which is composed of multiple racks, each with four levels. Each level holds different boxes, with each box containing a single SKU. Additionally, there is a fifth level at the top that serves as a repository for empty boxes to be used later during picking. Past collection clothing pieces are kept in the outlet area in smaller boxes known as *alveoli* due to their size and configuration. This setup is necessary because these items typically have low stock remaining and low turnover, necessitating picking positions tailored to their specific needs.

Finally, pieces on hangers, primarily jackets and coats, are stored in the *J's* zone. These items need to be hung to meet quality requirements set by the sales team, ensuring they remain undamaged during storage. An illustrative example of each picking zone can be observed in Figure 4.2.

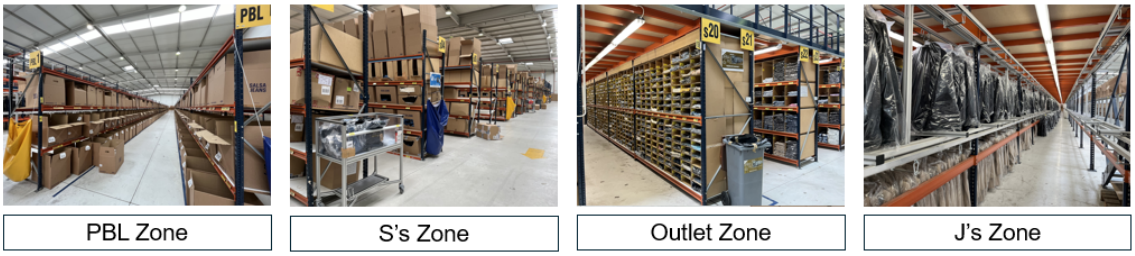


Figure 4.2: Illustrative example of the picking zones

The positions across the picking zones are also identified by a code, with a similar structure to the one used in the storing area. This code indicates the warehouse area, the rack, the slot and the shelf level. Table 4.2 shows an example of the coding of a picking position, respectively.

Table 4.2: Example of the identification code for a picking position

Code	Area	Rack	Slot	Level
PBL-124-2	PBL	-	124	2
S02-030-2	S	2	30	2
S19-310-3A	S	19	310	3A
J03-004-1	J	3	4	1

The outlet zone is actually a sub-division of the *S's* zone, with the racks 18 up to 27 entirely dedicated to it. In addition, codes that include a letter at the end, such as the one shown in the third row of Table 4.2, represent sub-levels that result from splitting a slot in smaller pieces, each one represented by the letter.

Lastly, there is the expedition area that is composed by the expedition dock and two expedition lines, the multi-channel expedition line and the B2C expedition line. An illustrative example of each expedition line can be observed in Figure 4.3.

Figure 4.3: Illustrative example of the expedition lines

4.2 Operational teams

The warehouse operation is based on teams with five different functions: reception, storage and replenishment, picking and expedition. The picking is further divided by type, into PBL and PBS. All functions contribute to a flow in the warehouse and it is essential to ensure their coordination to guarantee the operation as a whole. All the teams operate in a 8-hour single shift, from 7h00 to 16h00, five days a week.

The reception team, made up of four people, is responsible for receiving and checking products from suppliers for subsequent storage.

The picking team is the largest, accounting around forty people, and has the main function of fulfilling customer orders or internal requests, being the ones that add the most value inside the warehouse. The PBS team is also responsible for checking and packing B2C orders at the stations on the B2C expedition line as well as helping with the handling of the returns, by allocating returned items to their respective positions in the picking zone.

Additionally, the storage and replenishment team, is composed by five Mizusumahis (dedicated to the logistic trains) and two reach truck operators. Their main functions are to manage the material's storage, replenish the picking zones and to move materials to places in need, across the warehouse. In other words, they ensure the flow of the operations and materials, throughout the warehouse, with the objective that there is no downtime in the operations due to material shortages, specially in the order picking.

Finally, there is the expedition team, consisting of four members. Their primary responsibility is to conduct a final check on all orders and load the trucks for dispatch to their respective destinations.

Each of these teams is overseen by a dedicated leader, whose role is to ensure the smooth operation of their respective teams. They provide support and coordination, ensuring effective communication and collaboration between the teams.

Figure 4.4 summarizes the structure of the teams operating in the warehouse and their functions.

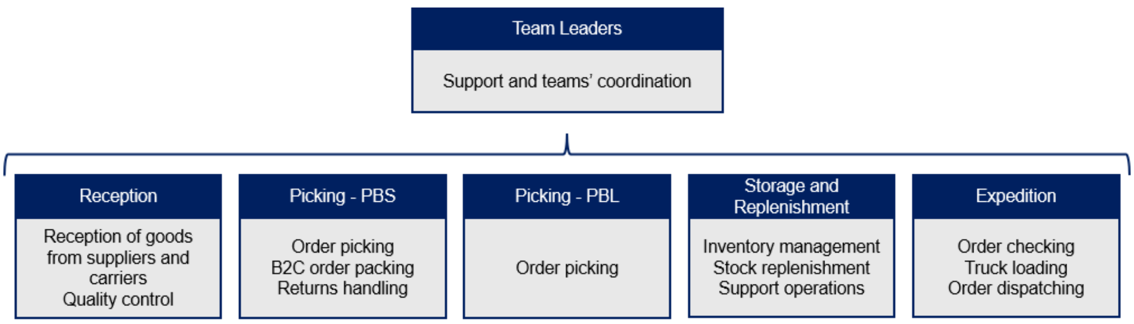


Figure 4.4: Teams that operate in Company X's warehouse

4.3 Operational flow

The production process of stock warehouse consists of various smaller processes, each of which is important for the overall success of the operation.

In order to provide a deeper insight into the production process, it will be described using the Value Stream Mapping (VSM) tool, along with a description of the main sub-processes, from the receipt of goods from suppliers to the loading for stores.

The VSM is a tool that provides a macro view of the process through the mapping of the material flow. Figure 4.5 shows the operations' VSM.

Figure 4.5: Value Stream Map of the production process

The flow begins with the supplier transporting goods to the warehouse. These items originate from both factories and reverse logistics processes, such as instances where stores return unsold clothing pieces from the current season collection. Once the trucks arrive at the reception docks, the reception team is responsible for unloading them and validating every package to ensure the match between the received goods and the reception documents. In this stage, the operators also label the boxes, for storing purposes, and pre-assign the most suitable storing space for them in the warehouse. Furthermore, a quality control inspection is also performed by members of the team who are specifically responsible for it. This staff guarantees that the pieces comply with the quality standards and are in good conditions to be sold.

After that, the items are ready to be moved by the Mizusumashis. Depending on the existing stocks in each zone and the demand for that specific SKU, the new arrivals can either be directly utilized to replenish the picking zones or be stocked in the *A's*. If those items correspond to returned pieces, the Mizusumahis only transport them to the entrance of the picking zone, and the picking team handles the replenishment.

Once the items are correctly stored, further movements depend on the picking activity. The type of picking performed depends on the total quantities ordered for a specific SKU to be shipped on that day. PBS is more advantageous for fulfilling orders with a wide variety of SKUs in low quantities, whereas PBL is better suited to orders with a low variety of SKUs but in large quantities. Therefore, this analysis is made at the beginning of each day to assign orders to a specific picking type. Additionally, there is the possibility to mix both picking types, with part of the order fulfilled in PBS and the other part in PBL, requiring further consolidation. As the quantity of specific items available in the picking positions starts to get low, the Mizusumashis replenish those positions by retrieving boxes from *A's* and delivering them to the *S's*.

Upon finishing picking, the operators place the boxes corresponding to orders in carts located in the central corridor. The Mizusumashis then transport these carts to the expedition area and drop the boxes on the expedition line for inspection.

The B2C orders undergo a different process as the order checking procedure is integrated with packing, and is processed by the picking team.

At the conclusion of the production process, the expedition team meticulously inspects each order to ensure conformity with item specifications and total weights. Following inspection, the boxes are sealed and placed on pallets. The process culminates with loading the trucks to deliver the orders to the customers.

4.4 Initial situation assessment

Having a macro view of the warehouse operations, it is relevant to explore in depth some of the activities that are more impactful in the process and were more relevant to the project. Therefore, a comprehensive description of the activities as they were originally found will be provided in this section.

4.4.1 Picking

The pickers' activity is primarily overseen by the team leader in collaboration with the WMS system. At the start of each day, integrated IT systems provide essential information about the day's orders. Additionally, the company has developed a report, which recommends which items should be separated in PBL based on predefined conditions that make the operation smoother and more productive. This report is generated before the shift begins and automatically sent by email to the team leaders. This way, they have time to separate the picking load, between PBS and PBL.

The team leader for each picking zone then takes responsibility for creating picking rounds by assigning orders within the WMS system. Important to note that, B2C orders cannot be allocated to PBL and are exclusively managed by PBS. Consequently, the PBS leader divides the picking rounds by channel to optimize operations, paying special attention to B2C orders. These orders are dynamic, with new ones constantly entering the system. B2C orders received until 2 pm must be fulfilled within the same day, in accordance with the brand's SLA.

Furthermore, to assess the status of a picking round, the leader must manually consult the WMS system, comparing orders marked as ’closed’ with those marked as ’open’. When all of them are closed, a new picking round can be generated.

Since the picking of multi-channel orders differs significantly from B2C orders, it is important to describe each of them individually.

Picking by store - Multi-channel

The picking process begins with the pickers obtaining a cart, and the operator selecting two orders to generate a route using the picking monitor worn on their forearm. Each route is carefully planned to ensure that the picker follows a sequential path, minimizing unnecessary travel through the same positions. The cart can only accommodate two orders at a time, limiting the number of orders loaded onto each route.

Once the route is generated, the pickers proceed to the first picking position. Here, they retrieve two empty boxes from the top of the shelf and place them in the cart to serve as containers for the items of each order.

Next, they locate and retrieve the required items from the position, scanning each item from its location to the respective order box to update the data in the WMS system. After each scan, the monitor suggests the next position, and the picking process continues until all necessary items for both orders are collected.

Upon picking the last item, the route is considered complete, and the pickers place the boxes on the trailers of the logistics trains in the central corridor. These boxes are later moved to the PBL for order consolidation or directly to the expedition line. Order consolidation occurs when the same order is picked in both PBL and PBS using separate boxes. To optimize box utilization, all items are transferred to a single box.

After dropping off those orders, the picker immediately restarts the process from the beginning, if there are still available orders.

Figure 4.6, shows the most relevant steps of the multi-channel order picking operation.

Figure 4.6: Steps of the multi-channel order picking operation

Picking by store - B2C

Regarding B2C orders, the picking process begins with the pickers selecting a different type of cart, known as a tank, specifically designed for B2C orders. Each tank can accommodate multiple orders, depending on the number of clothing pieces in each order. Due to uncertainty about the number of orders that will fit in the tank, the operator selects an estimated number from the picking monitor to generate a route.

The route generation follows the same principle of minimizing travel distance. Upon reaching the first picking position, the picker places the item in the tank and scans the movement to update the system.

Once all items for the loaded orders are gathered, the picker assesses the available space in the tank. If there is still considerable free space, the operator loads more orders and proceeds to pick them. In this case, the travel path is no longer optimized since the orders were added after the creation of the initial route, requiring the picker to revisit positions previously visited.

After filling the tank, the picker takes it to a B2C expedition station. In this case, the picker is responsible for checking each order and packing it to be shipped.

The items for each order are taken from the tank, packed together, and placed on the queue for later palletization. As the tank gets empty, the picker starts another picking round if there are still B2C orders to be fulfilled.

Figure 4.7, shows the most relevant steps of the B2C order picking operation.

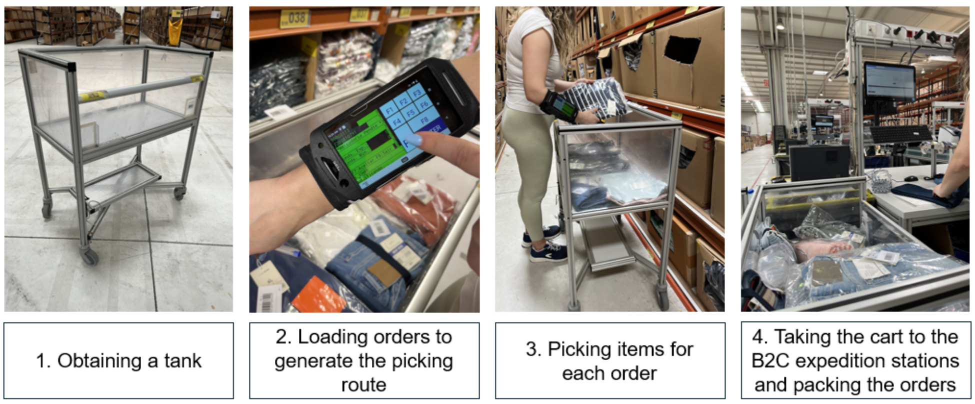


Figure 4.7: Steps of the B2C order picking operation

For further clarification, Appendix D represents the spaghetti diagram of both PBS activities.

4.4.2 Mizusumahis' routes

At the start of the project, the distribution of work for the logistic trains was organized based on specific routes. Each Mizusumashi was responsible for a particular route, typically taking between 15 to 30 minutes to complete. These routes operated in a continuous cycle throughout the entire shift.

Route 1 involved forming new boxes using the designated machine and replenishing the empty new boxes on the top shelf of the *S* racks. While traveling through the picking corridors, the assigned logistic operator was also responsible for collecting damaged boxes that had become empty due to picking activities. These boxes, which had previously held items in the picking positions, were transported to the recycling container.

Route 2 involved transporting the previously prepared orders from the central corridor to the expedition line. Typically, this route's function was simply to move these orders. However, the responsible Mizusumashi could also transport the filled boxes to the PBL zone to carry out the consolidation process. Only after this consolidation were the boxes transported to the expedition line.

Route 3 assigned the operator to store boxes of items that had arrived and passed the quality control process. Some of these items were used directly to replenish the picking stock in the *S* zone, while the rest were stored in the *A* zone, either at ground level, if there were no existing SKUs at that level, or at height. Since the Mizusumashi did not operate the reach trucks, boxes needing to be stored on higher shelves were left on pallets for later storage by team members responsible for those machines.

Route 4 was designated for the *machinist's work*, a term used by the operators to describe tasks automatically generated by the WMS system and instructed through the barcode scanner monitors. The designated operator received information about the boxes that needed to be retrieved from the *A* racks and moved to the *S* zone to replenish the picking positions, based on a condition that evaluated the predefined minimum picking stock quantity of each SKU.

Additionally, there was *free work* not designated by a specific route. This included various tasks that were the Mizusumashis' responsibility but not included in the predefined routes. Most of these tasks were related to organizing storage positions and reallocating boxes from one storage position to another.

After completing their designated routes, operators would meet the team leader at the station to receive new orders and information regarding the next route. Orders were given verbally, and the necessary information to perform tasks was either provided by operational reports scheduled to be received via email at specific times of the day or manually gathered from the WMS system by the leader and transferred to Excel files, which were then printed and handed to the operators. These files typically included lists of items that needed to be moved to ensure operational efficiency.

The movements of the logistic trains for each route can be observed in the spaghetti diagram shown in Figure 4.8

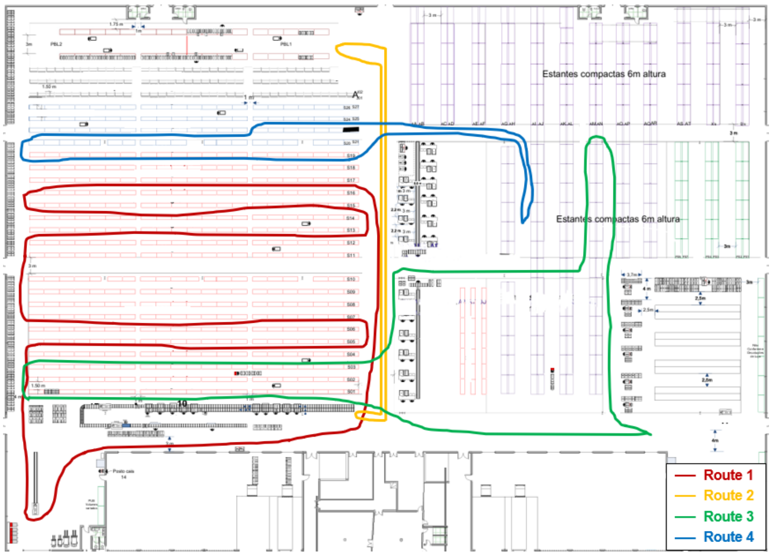


Figure 4.8: Spaghetti diagram of the initial logistic trains' routes

4.4.3 Key Performance Indicators

In order to assess the performance of the teams, it is necessary to have indicators that reflect their daily performance in the operation. In the case of Company X, productivity is calculated for the various teams that contribute to the warehouse operation.

At the start of the project, although each team had clearly defined KPIs, the evaluation format varied significantly and was primarily conducted manually. Leaders would extract data from the WMS system and, based on the number of movements by operators over a certain period, calculate and store productivity data in an external Excel file. This method was quite effective for warehouse operations that were clearly identified in the WMS system, such as picking. However, some operations in the warehouse were not included in the system, making it difficult to directly calculate productivity. For instance, the reception area did not routinely measure productivity, and the tasks from the replenishment and storage team were self-reported by the operators. They would inform the leader of the number of boxes moved in a given period, and the leader would then record that information in a file.

Furthermore, only leaders had access to this data. There was no direct communication to the clerks about their productivity on working days; they only found out at the end of the month whether or not they had met the target set by the manager.

The KPIs tracked by each team in the beginning of the project are shown in Table 4.3. Such KPIs are crucial not only for operational decision-making but also for effective project management. If the project's productivity KPI is stagnant, these metrics can help identify which areas require improvement actions.

Table 4.3: Key Performance Indicators (KPIs) tracked by each team at the start of the project

Team	Tasks	Measurement unit
Reception	New arrivals reception	boxes/hour
Picking by Store	Picking	pieces/hour
	Picking B2C	pieces/hour
	Packaging	orders/hour
Picking by Line	PBL sorting	pieces/hour
Storage and Replenishment	Overall movement of boxes	boxes/hour
Expedition	Checking	pieces/hour

4.5 Problem identification

Before the start of the project, it is a standard procedure in Kaizen Institute to perform a Value Stream Analysis (VSA), a lean manufacturing technique designed to analyze and optimize the flow of materials and information necessary to deliver a product or service to the consumer. During this intensive five-day procedure, the primary wastes within the processes are identified, and opportunities for improvement are highlighted.

Once the macro-level improvement opportunities are listed, they are presented to the client, accompanied by a proposal for action and a business case, highlighting the expected return of the proposed initiatives. The responsibility then falls on the allocated consultants to delve deeper into the major problems identified. Using the A3 9 Steps framework, along with other problem-solving and root cause analysis methodologies, they break down these larger issues into smaller, more manageable problems and identify their root causes.

With a clear definition of the problems and their underlying causes, the consultants can then design solutions, which will subsequently be tested and implemented.

The author of this thesis was not present during the VSA phase; however, he was responsible for the investigation and deconstruction of the problems that arose during the VSA, which are presented below.

4.5.1 General problems

From a general perspective, the warehouse's storage occupation averaged 80% throughout the year. Out of the 2952 pallet slots available in the storage racks, an average of 2300 were occupied. This value tended to fluctuate throughout the year due to the seasonality of the apparel industry. Particularly when preparing for the winter season around August and September, the warehouse receives a large volume of outerwear pieces, such as coats and jackets. These items are bulkier and require more storage space, often utilizing larger boxes called flat-packs, which occupy the same area size as a pallet. Furthermore, when stored in standard boxes, the number of pieces per box is substantially lower than usual, due to the pieces' volumes. Consequently, warehouse storage occupation levels rise to unsafe levels during the summer months. Compounding this challenge, the sales and marketing department forecasts a 25% growth in sales over the next three years. Consequently, the existing storage capacity issues may be converted into a significant problem in the future, necessitating proactive measures to mitigate potential constraints.

One significant issue affecting overall operations was the inefficiency of data retrieval and KPI measurement systems. Management decisions in various areas often lacked accurate and timely information. Some decisions were based on leaders' perceptions and experience, while others relied on outdated and misleading reports, scheduled to be received via email during shifts. These reports, based on queries built years ago, often failed to provide real-time data, making operations inflexible and less adaptive. This was particularly problematic for the replenishment and storage team. For instance, if a leader needed to instruct its staff which boxes to move and their original and final destination, they had to wait for a report that would list all the information required. This dependency on delayed reports hindered timely decision-making, and the system's occasional failures further exacerbated the issue. Additionally, if boxes were moved shortly after the report was generated, the information became obsolete.

Other decisions were based on manual data extraction from the Warehouse Management System (WMS). While the WMS was reliable and updated in real-time, this method was time-consuming and dependent on the leader's judgment. Leaders manually searched the software datasets and sometimes exported data to files for printing and distribution to clerks. This approach lacked standardization, leading to inconsistencies in decision-making when different leaders were involved. Consequently, replacing one leader with another often resulted in different operational flows due to varying perceptions of relevant information.

Furthermore, there was no transparent or direct method to visualize daily workloads and operators' productivity. This lack of visibility led to uncertainty about completed tasks and remaining work, resulting in unbalanced resource allocation across areas. Such imbalances caused increased lead times in order fulfillment due to misalignment between areas. For example, if picking was incomplete and the expedition leader was unaware, workers could be allocated to truck loading prematurely, leaving the expedition line understaffed. This misallocation would lead to a buildup of unchecked boxes, disrupting the workflow. Additionally, if operators were less productive than required, this would go unnoticed until the end of the shift, when unfulfilled orders would reveal the shortfall, preventing timely corrective actions.

Once presented the problems that affect all areas and the operations as a whole, it is important to also highlight operational problems affecting the warehouse's teams productivity. The most affected teams in the beginning of the project were the picking and replenishment and storage ones, so a greater emphasis to those will be given.

4.5.2 Process specific problems

4.5.2.1 Picking

Starting with the picking team, specifically the PBS team, the picking process was significantly impacted by out-of-stock items in picking positions. This issue arose when pickers were performing their rounds and consumed all items from specific positions. Consequently, these positions would become completely empty or would not have enough items for the next picker to fulfill their order. Since it is uncommon to have duplicate positions of the same SKU in the picking areas, if the restocking process was not occurring at that moment, the picker would either retrieve the box of the SKU from the storage area to replenish the picking stock or end the current picking round and restart it later. These disruptions not only slowed down the picking process but also caused delays and inefficiencies in the overall workflow, as subsequent pickers had to spend additional time locating alternative positions or waiting for restocking, thereby reducing operational productivity and increasing lead times for order fulfillment. As shown in Figure 4.9, the distribution of picking stock-outs per day in 2023 exhibits variability, with several outliers indicating days with exceptionally high stock-outs and an average of 1,17 stock-outs per day.

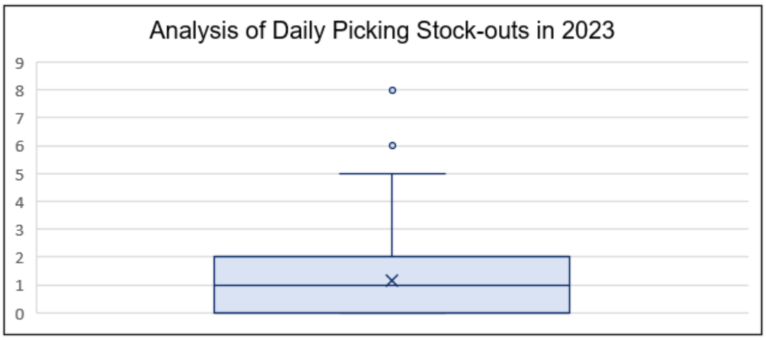


Figure 4.9: Box plot of the Distribution of Picking Stock-outs per Day in 2023

A specific issue affecting the picking of B2C orders was the high variability in the operation, leading to a consequent decrease in productivity. When orders included items such as hanged garments or footwear, it was challenging to transport them in the tanks used for picking. So, operators wasted time during picking rounds trying to find suitable places inside the tank to better accommodate these items. Additionally, orders with multiple items introduced further complications. Since operators did not know in advance how many orders would fit into a tank (unlike single-item orders where this was less common), it was usual to have considerable empty space left in the tank at the end of each round. To maximize tank usage, operators would repeatedly add rounds to the system to generate new picking routes and fill the tank. This process often resulted in operators revisiting corridors they had already traveled through to fulfill previous orders, creating significant inefficiencies. Time was wasted due to the need to repeatedly load new routes into the system and retrieve items from previously visited positions, which was considered rework. This inefficiency in the picking process significantly impacted overall productivity and operational flow. On top of that, when it came time to check and pack these orders, operators wasted unnecessary time searching for the products that belonged to the same order within the tank, as all items were mixed together. This led to increased lead times for B2C orders, which was particularly problematic given the high service level standards of the company.

4.5.2.2 Storage and Replenishment

Moving on to the storage and replenishment team, several opportunities for improvement were identified. The role of the Mizusumashi, while productive in terms of efficiency, was found to be very ineffective due to the rigid nature of the logistic trains' fixed routes throughout the day. This lack of flexibility in response capacity meant that during critical moments in a sector, the number of operators remained constant, regardless of the increased workload. For example, if a picking position was at risk of stock-out, only one operator would be assigned to the replenishment task, while other operators continued their fixed routes, even if there was no immediate work. This sometimes resulted in operators having nothing to do after completing their routes, as there was no more workload during that time slot.

Another issue was the imbalance in productivity and duration of the routes, which not only varied among themselves but also with other operations. This imbalance contributed to stoppages and productivity drops in other operations, especially in picking, which contradicts the fundamental purpose of a Mizusumashi's role.

Finally, there was a gap in the management process of this team. Tasks within each route were communicated verbally by the leader to the Mizusumashi, making it difficult to monitor work progress throughout the day. Since many of the workers' movements were not registered in the system, tracking productivity was challenging. Productivity was often estimated based on the operators' verbal reports to the leader, indicating how many boxes they moved on their specific route and the time taken.

The main problems and root causes presented were mapped in workshops and are summarized in Table 4.4. An example of the analysis resulting from a workshop can be seen in Appendix E.

Table 4.4: Problems and causes impacting Company X's warehouse operations

Problem	Cause	Impact	Impacted areas
High warehouse storage occupation	Rapid sales growth	Potential significant storage constraints	Entire warehouse
Inefficient management decision making	Outdated and delayed reports Manual data retrieval	Inflexible and less adaptive operations Productivity drops	Entire warehouse
Lack of visibility of daily workloads and operator productivity	Manual data retrieval No transparent method for visualization	Uncertainty and unbalanced resource allocation	Entire warehouse
Picking stock-outs	Untimely replenishment	Delays and inefficiencies	Picking team
High variability in B2C order picking	Difficulty transporting items and unpredictable tank capacity	Decreased productivity and increased lead times	Picking team
Inefficiency in storage and replenishment routes	Fixed logistic train routes	Lack of flexibility and resource misallocation Stoppage of other processes	Entire warehouse
Gap in management process of storage and replenishment	Verbal communication of tasks and lack of registration	Difficulty in tracking productivity and inconsistent reports	Storage and replenishment team

Chapter 5

Solutions Design

Once the major problems of the operation were identified, it was necessary to proceed with the design of solutions that would contribute to achieving the project's objectives: increasing storage capacity and enhancing operational efficiency, thereby increasing productivity and reducing warehouse costs.

This chapter presents a detailed explanation of the designed solutions in descending order of scope, starting with solutions that impact the entire warehouse and then addressing solutions for specific operational processes.

5.1 Storage capacity increase

At the start of the project, Company X's warehouse already had an efficient storing procedure that maximized pallet occupation in the existing storage racks. Therefore, adopting a completely lean approach presented a complex challenge.

Four hypotheses for increasing storage capacity were explored: in-house expansion, outsourcing, automation, and establishing a new warehouse. The in-house solution aimed to increase the number of racks in the warehouse by optimizing floor space utilization. The outsourcing option involved externalizing part of the operation to an external distribution center. The automation solution entailed investing in automated infrastructure to enhance storage capacity. Lastly, the new warehouse proposal considered establishing a facility in Central Europe to expand the logistics network.

After a thorough evaluation of these hypotheses, it was concluded that in-house capacity expansion was the most viable solution. It required less investment, maintained operational flexibility, and posed minimal associated risks. Consequently, this hypothesis warranted further investigation to determine how it could and should be implemented.

5.1.1 Re-purposing an old warehouse

To begin, there was an underused old fabrics warehouse connected to the administrative building. This warehouse, which once served as a manufacturing facility, was currently being utilized for storing old machinery and fabrics for production.

A considerable number of available racks in this warehouse were not being utilized. Thus, it was decided that part of the pallets that would not fit inside the main warehouse in the future would be assigned to these racks.

This opportunity is considered a quick win—a solution that is easy to implement, with high, visible, and immediate impacts—aligning with Kaizen and lean philosophies.

5.1.2 Re-designing the warehouse layout

Regarding the main warehouse, it was also necessary to implement changes to increase its capacity.

5.1.2.1 Introducing an order picker machine in the operations

Initially, the warehouse employed a labor-intensive process where all incoming boxes were individually checked. This method was highly resource-consuming, requiring significant time, workforce, and equipment. To optimize this process, a sampling method was introduced. Consequently, the number of checking stations was reduced from seven to four, and the accumulation of stock awaiting inspection was significantly minimized. By relocating the remaining stations and decreasing the space required for pending stock checks, an additional 500 square meters of space was made available for additional storage racks.

The existing racks stored materials on pallets, although the units were boxes. This prompted the author to realize that introducing racks specifically designed to accommodate boxes instead of pallets would enhance space utilization, allowing for more material to be stored within the same area. Changing the existing racks was deemed out of scope due to the significant investment required and the associated risks of potentially slowing down operations by handling each box individually instead of by pallets. Consequently, the designed solution included utilizing the newly gained area with racks that store boxes directly.

To retrieve material from the new racks, the reach truck was no longer viable since it is designed to handle pallets. Hence, it was necessary to invest in an order picker machine, which lifts the operator to the height of the storage location, allowing efficient manual retrieval of goods. Additionally, the required aisle width for the order picker is 1.20 meters, substantially smaller than the 3 meters required for the reach truck. By placing the new racks closer together, it was possible to increase the number of racks within the same area as well.

This significant investment would likely be justified not only by the increased storage capacity but also by the productivity benefits from integrating the order picker into the overall operation. For example, the replenishment task for outlet items requires retrieving boxes from the higher levels of the *A's* racks, as the stock is organized such that only collection items are stored at ground level. Previously, during these replenishment tasks, it was necessary to lower entire pallets from the upper levels, retrieve the required box, and then raise the pallets again. This process was highly inefficient. However, by integrating an order picker into the operation, specific boxes can be retrieved much more quickly and without the need to move unnecessary stock. With this in mind, the location of the new racks was strategically chosen to be adjacent to the PBL zone, one of the areas that most frequently requires this type of replenishment.

A visual representation of the layout modifications is shown in Figure 5.1.

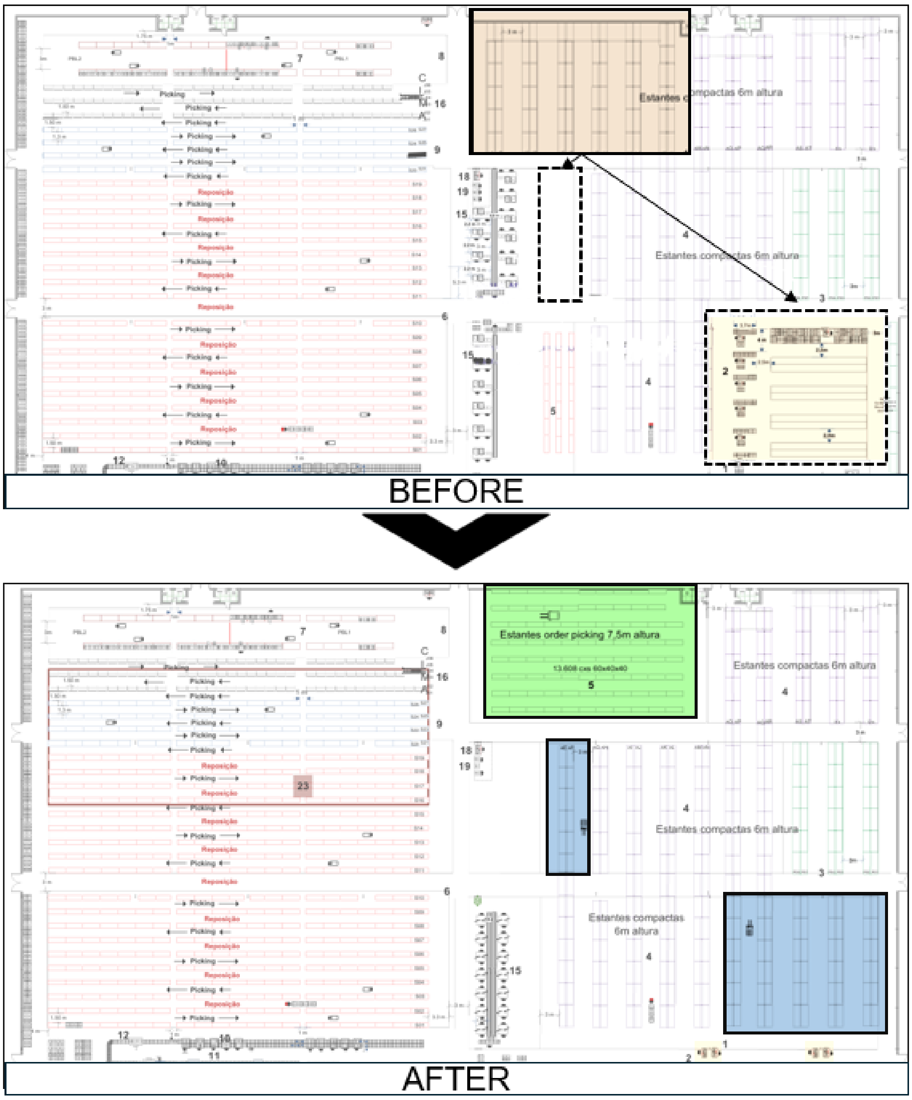


Figure 5.1: Layout before and after the introduction of the new racks

Pictures of the order picking machine and the new rack, as well as further explanation of the warehouse's layout modifications can be found in Appendix F.

5.1.2.2 Reviewing the typology of the outlet picking locations

To evaluate the possibility of gaining space in the outlet picking zone, the author of this thesis was responsible for reviewing the typology of the outlet picking locations. Although this task would not directly increase storage capacity, it was necessary to assess whether these locations were over-dimensioned and efficiently occupied. By optimizing these areas, the amount of boxes of outlet SKUs present in the *A's* racks could potentially be decreased and more space for other boxes would be created. The *S's* locations destined for collection items were not reviewed, as the current system is already optimal and a common practice among warehouses.

The outlet zone is composed of ten racks in total, from S18 to S27. The S20 rack is assigned to last items; that is, if an outlet SKU has fewer than a pre-defined threshold (by category) of items in the entire warehouse, it is stored there. The S21 rack is dedicated solely to footwear. The S26 and S27 racks have 75 positions specifically for outerwear items, such as coats and jackets, or items with larger dimensions than usual.

As previously mentioned, items are stored in small containers known as *alveoli*, which can present four different typologies, as shown in Figure 5.2

Figure 5.2: Different typologies of *alveoli* in the Outlet Picking Zone

The *Cherry Alveoli* exist only in S20. The *Standard Alveoli* are present in all other racks at levels 1, 2, and 4. The *Level 3 Alveoli*, as the name suggests, are located on the third level of each rack and are meant to stock outlet SKUs that no longer have any boxes left in the storage racks (*A's* zone). Finally, the *Outerwear Alveoli* are exclusive to S26 and S27, located in outerwear-specific zones.

For a more comprehensive and accurate analysis, it was necessary to consider all pending movements from the storage stock to the picking stock, as well as the outlet pieces in circulation with transportation partners.

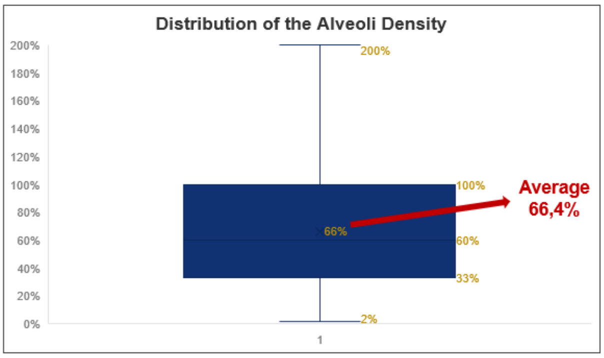
Data regarding the quantities of each SKU and their respective picking positions was gathered from the WMS system. However, the volume data for each piece of clothing was incomplete in SAP, requiring the use of average calculations based on the number of pieces of each SKU that fit in the standard 60x40x40 box when they arrive from suppliers. The sizes of the *alveoli* were measured directly and the pieces in circulation were retrieved from SAP. It was found that the *standard*, *level 3*, and *cherry alveoli* all had the same width and proportional heights. The height of the *standard alveoli* is double that of the *level 3 alveoli*, which in turn is double the height of the *cherry alveoli*. The *outerwear alveoli* had the same height as the *standard* ones but were 1.5 times wider.

With the gathered data, it was possible to evaluate the occupancy percentage of the entire outlet zone, as well as the density (ratio between the occupied volume and the total volume) of each *alveolus*.

The results are displayed in Table 5.1 and Figure 5.3.

Table 5.1: Occupancy rate of the *alveoli* in the Outlet zone

Shelves	#Alveoli	#SKUs	Occupancy Rate
S18	1980	0	0,00 %
S19	1980	1864	94,14 %
S20	3168	1979	62,47 %
S21	1980	1230	62,12 %
S22	990	863	87,17 %
S23	990	707	71,41 %
S24	990	711	71,82 %
S25	990	707	71,41 %
S26	756	605	80,03 %
S27	756	637	84,26 %
Total	**12600**	**9303**	**63,81 %**



Quartile	Alveoli Density
1º	2% - 33%
2º	33% - 60%
3º	67,8% - 100%
4º	100% - 200%

Figure 5.3: Box plot of the density of the *alveoli* in the Outlet zone

It is important to mention that the items in circulation were virtually assigned to the *alveoli*, if those SKUs were not present in the picking stock yet. Such assignment, was based on volume criteria, by allocating the items to the *alveoli* that would better fit the respective quantities and volume occupied.

By analyzing the results, it was observed that approximately 36% of the *alveoli*, corresponding to 3297 *alveoli*, were empty. Regarding the occupation of each *alveolus*, it was concluded that, on average, only 66.4% of the total volume was occupied. The presence of *alveoli* with densities higher than 100% was explained by the fact that the volume measure of the pieces of clothing was based on average calculations, thus not being completely accurate. However, this variability impacted the results both negatively and positively, and a quick *Gemba walk* confirmed the reliability of the values obtained.

These findings suggested that not only was the number of *alveoli* excessive, but they were also oversized. A deeper analysis was then performed to understand the density of each *alveolus* typology. The *cherry alveoli* had an average density of 58.7%, the *level 3 alveoli* 44.8%, the *standard alveoli* 65.8%, and the *outerwear alveoli* 87.7%. There was a clear underutilization in the *level 3 alveoli*, with only half of their volume occupied, while the *outerwear alveoli* showed a relatively higher density.

Before proposing any solution, it was essential to consider the expected growth of outlet items in the coming years. During the Value Stream Analysis (VSA), the company internally performed a forecast, predicting a 20% increase in outlet sales volume by 2027. This forecast suggested a proportional increase in the number of outlet SKUs. The expected peak was projected for September 2027, with a total of 12685 SKUs. Without any changes, the current outlet zone would not have sufficient positions to accommodate such growth.

The proposed solution was to replace both the *level 3* and *standard alveoli* with *cherry alveoli*. This change would result in fuller containers and overall greater space utilization. SKUs with quantities exceeding the capacity of a single *alveolus* would be distributed across multiple *alveoli*, thereby creating duplicated picking positions. Additionally, due to the high number of unused *alveoli* and the insufficient space in the *outerwear* alveoli, it was recommended to increase the number of *outerwear* alveoli by reallocating space from other typologies. This adjustment was necessary because increasing the height of the *outerwear* alveoli was not feasible due to the physical constraints of the racks, and increasing their width would not be beneficial.

While these solutions would create additional space in the picking zone, they would not directly affect the storage area. However, the *J's* zone, dedicated to hanging pieces, frequently lacked sufficient space, requiring the use of improvised chains placed in the *A's* storage racks to hang these items and occupying spaces dedicated to the pallets. By reducing the space required for the outlet zone, it would be possible to expand the *J's* corridors, thereby increasing the capacity for hanging pieces and freeing up storage racks.

To solidify the solution, the expected space occupied was quantified and is presented in Table 5.2. The procedure to calculate it consisted in allocating the SKUs based on the volume they occupied, the current *alveoli* they were placed in and the comparison of sizes between the current *alveoli* and the *cherry alveoli*. For instance, an SKU that was occupying 67% of a *level 3 alveolus*, would occupy three *cherry alveoli*, since the later *alveoli* are half the size of the first one.

Table 5.2: Comparison between the initial outlet zone space occupation and the expected occupation after replacing the *alveoli*

	Criteria	Cherry	Level 3	Standard	Total
Initial scenario	Quantity of alveoli occupied	1979	2197	5127	9303
	Quantity of shelves occupied	0,62	1,39	6,47	8,49
Post-implementation scenario	Quantity of alveoli occupied	21625	-	-	21625
	Quantity of shelves occupied	6,83	-	-	6,83

A total of 1.66 shelves would be freed, allowing for 4,084 units of hanged items to be stored if such space were replaced with structures similar to those in *J's* zone. This amount of items would occupy approximately 24 positions in the *A's* storage racks during times of space shortage in picking.

The implementation of this solution would not be problematic, as the *alveoli* are made from recycled cardboard boxes, making them inexpensive to replace.

5.1.2.3 Studying the consolidation of the expedition lines

This section addresses a study conducted by the author, aiming to enhance space utilization by merging the existing multi-channel and B2C expedition lines into a single, streamlined process.

Multi-channel order processing

In the multi-channel order processing workflow, orders are picked using standard boxes. These boxes are then placed on the expedition line, where they are conveyed to the checking stations via rollers. At the checking stations, operators inspect the orders.

The inspection process begins with the operator placing an empty box on the line, next to the filled order box and scanning the label of the original box. This scan informs the system about which order is being checked. The operator then individually transfers the items from the original box to the empty one, scanning each item during the transfer. The monitor provides real-time feedback, indicating whether each SKU belongs to the current order.

If all items are correctly assigned and none are missing, the operator prints a packing list and places it inside the box along with a protective cardboard. The box is then sealed with Kraft tape and moved to the out-feed roller conveyor. If any discrepancies were found, the order is placed open on the rollers and moved to a final station for error correction.

As the checked box progresses along the rollers, it passes through automated systems that seal it in multiple directions, weight it, and apply the appropriate labels. Once these steps are completed, the box is ready for palletization by an operator.

B2C order processing

In the B2C order processing workflow, orders are picked using tanks—a type of cart with an open container at the top for holding items (see the first picture of Figure 4.7 for reference). After picking, the picker transports the tank to a B2C checking station.

At the checking station, the tank is parked next to the workstation for order checking and packing. The operator retrieves an item from the tank and scans its label. The complete order details then appear on the monitor. The operator gathers the respective items and places them on the work desk before beginning the checking and packing process.

Given that B2C orders are shipped directly to customers, accuracy is paramount, so the checking process is more rigorous. It starts with the removal of any plastic coverings from each item. Both the interior and exterior labels of each item are then scanned to ensure they match. For footwear orders, the sizes of both shoes are verified to ensure they match. Any specific customer requests, such as removing price tags for gift orders, are also addressed.

The items are then wrapped in sulphite paper and either placed in envelopes or boxes, depending on their volume. Finally, a transport guide is attached to the package, and the order is moved to the conveyor belt for palletization at the end of the line.

Lines comparison

After mapping each process, relevant data was retrieved for a comparison between the expedition lines.

Historic data on the quantity of orders per channel over the past two years was analyzed and is presented in the plot in Figure 5.4.

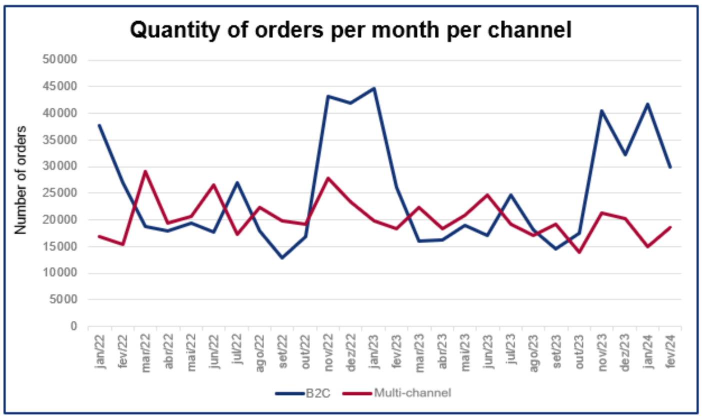


Figure 5.4: History of quantity of orders per channel in 2023 and 2024

Upon comparing the quantity of orders from both channels, it was observed that there is minimal variation throughout the year, with an average of 20000 orders per channel. However, B2C orders exhibit higher peaks during Black Fridays and Christmas holidays, corresponding to increased sales.

Given the differing order sizes between channels, the number of orders alone can be misleading. Therefore, it is crucial to also compare the number of pieces shipped.

Figure 5.5 illustrates the comparison between the shipped quantities by channel and the projected increase in demand for each channel over the coming years. These projections were based on historical order quantities and expected growth values defined during the Value Stream Analysis (VSA).

History of shipped quantities (2023 - 2024)		
	B2C	Multi-channel
Monthly Avg.	49 187	234 327
Daily Avg.	2 236	10 651
Hourly Avg.	298	1 420
Max. Daily Peak	7 788	36 285

Forecast of shipped quantities (2027)		
	B2C	Multi-channel
Monthly Avg.	81 651	276 506
Daily Avg.	3 711	12 569
Hourly Avg.	495	1 676
Max. Daily Peak	12 928	42 816

+ 66% + 18%

Figure 5.5: Comparison between the shipped quantities by channel and year

As anticipated, the quantity of pieces shipped for the B2C channel is significantly lower than for the multi-channel, with B2C handling approximately 50000 pieces monthly compared to 235000 pieces for the multi-channel. However, the expected growth rate for B2C is 3.5 times higher. The daily peaks represented correspond to Black Fridays - a major annual retail event offering steep discounts.

In accordance with the presented data and the opinions of the managers, the metric employed to evaluate the productivity of both production lines was the number of pieces checked per station per hour, with the assumption of a single operator per station.

The efficiency of the B2C line and the multi-channel line was assessed using this productivity measure. The B2C line exhibited a productivity rate of 67 pieces per station per hour. In contrast, the multi-channel line demonstrated a markedly higher productivity rate of 568 pieces per station per hour. This substantial difference can be explained by the fact that the B2C orders require extra customization and additional steps.

During the analysis phase, the line sides were also evaluated, as well as the materials listed and the micro-tasks timed. The B2C stations were much more complete, with a bigger line side and more materials provided. In fact, it almost had all the required materials to check a multi-channel order as well. Figure 5.6 represents a figurative example of a station of each channel.

Figure 5.6: Figurative example of multi-channel and B2C stations

In considering the merging of both lines, various options were explored regarding the type of station to be used. The final line could consist of a mix of the two existing types of stations, exclusively B2C stations, or exclusively multi-channel stations. However, it was evident that retaining the multi-channel stations would necessitate modifications to accommodate B2C orders, such as integrating a work desk and expanding the line side. Tests were conducted to assess the efficiency of B2C stations handling multi-channel orders, and the results indicated that this adaptation had a negligible impact on productivity. Therefore, the most suitable type of station was determined to be the existing B2C stations. These stations required no redesign, were already abundant in the warehouse (with 16 active and 12 inactive stations available for future needs), and were capable of handling multi-channel orders effectively.

With the selection of the B2C stations, it became necessary to consider the overall operation processing. Three picking scenarios were evaluated:

- Maintaining the current picking methods: multi-channel picking using two standard boxes and B2C picking using tanks.
- Option A: utilizing two standard boxes for both types of orders.
- Option B: keeping the multi-channel picking the same, performing B2C single-item order picking using two standard boxes, and using smaller boxes (25x25x40) for multi-item B2C orders, allowing six boxes to fit in a picking cart.

Multiple simulations were conducted to evaluate the viability and productivity impact of each picking scenario while keeping the original lines intact. Additionally, projections were made to estimate the required number of stations, both for the present and the future, based on anticipated maximum daily peaks in order volume. The results of these simulations and projections are presented in Table 5.3.

Table 5.3: Comparison of the productivity of different picking scenarios and required number of checking stations

		Original	Option A	Option B
B2C	Picking productivity (pieces/person/hour)	50	62	64
	Checking/Packing productivity (pieces/station/hour)	67	60	64
	Number of stations currently required	16	17	16
	Number of stations required in the future (2027)	26	29	27
Multichannel	Picking productivity (pieces/person/hour)	250	250	250
	Checking/Packing productivity (pieces/station/hour)	568	532	539
	Number of stations currently required	9	9	9
	Number of stations required in the future (2027)	10	11	11

Although the picking productivity slightly increased — primarily because two boxes have a higher capacity than the tanks, thus allowing more orders to be fulfilled in a single picking round - the productivity in the expedition lines decreased for both types of orders.

Additionally, merging both lines resulted in higher lead times for B2C orders due to shared line usage with the multi-channel orders. This setup also increased the potential for errors, as operators needed greater focus to manage the differing order types.

Given the anticipated growth of the B2C channel and the stringent requirements associated with these orders, it is crucial to avoid any degradation in their processing efficiency. Therefore, the final recommendation provided was that maintaining distinct processes for B2C and multi-channel orders remains essential to ensure optimal performance and accuracy, thus the expedition lines should remain separate.

Nevertheless, if in the future Company X's top management determines that storage capacity has become a critical issue again and decides that the trade-off between potential space savings and the associated loss of productivity and increased lead times is acceptable, two designs for a future merged line have been developed and can be found in Appendix G.

5.2 Productivity increase

To enhance the productivity of the warehouse, a strategic emphasis was placed on optimizing the picking activity. This decision is rooted in the understanding that picking is not only one of the highest value-adding activities, but also widely recognized in existing literature as the most resource-intensive task within a warehouse. The underlying hypothesis is that increasing the efficiency of picking operations will yield significant benefits for overall warehouse productivity.

As discussed in the previous chapter, the root causes of the issues affecting the picking activity are often not inherent to the activity itself. Instead, they stem from inefficiencies in management and other related operations that collectively impact the entire process. Therefore, addressing these broader aspects is essential to achieving meaningful improvements in order picking.

This section will present the designed solutions aimed at addressing these inefficiencies and enhancing the overall efficiency of the picking process and warehouse operations.

5.2.1 Introducing a leveling box to the storage and replenishment operation

A leveling box, also known by its Japanese term *Heijunka*, is a technique commonly used in lean manufacturing to achieve a smooth and consistent flow of production. This method involves distributing production evenly over a certain period, thereby balancing the workload to avoid fluctuations in production schedules. The box is divided into columns and rows, the columns representing time periods and the rows represent different workstations. Cards or kanban tickets representing specific tasks or production orders are placed into the slots within the grid according to when they should be worked on.

Although *Heijunka* is not traditionally applied in logistics, the author identified its potential benefits for the current state of warehouse operations, particularly for the storage and replenishment team. The objective was to transition the replenishment team from a route-based approach to a task-based approach. This shift enables employees to carry out tasks more effectively by responding to specific needs within the warehouse through a pull flow system, aligning with lean methodologies. The primary goal was to enhance team flexibility and response capacity, thereby eliminating picking stock-outs.

In addition, implementing a leveling box would facilitate more objective and visual communication with the Mizus' team. This tool would provide better oversight and control over their tasks, addressing gaps in the management process of that team. By adopting a leveling box, the warehouse operations could benefit from improved efficiency, better workload distribution, and enhanced team coordination.

The first step in implementing the leveling box was to gain a comprehensive understanding of all the tasks that the Mizusumahis are responsible for on a daily basis. This required deconstructing the four existing routes into smaller tasks. With the help of the team leader and by conducting a DILO (Day In the Life Of) study with the storage and replenishment team over the course of a week, detailed information was gathered. This data included the frequency and duration of each task, as well as the number of boxes moved.

After collecting this information, the configuration and location of the leveling box were determined. To enhance visual perception and communication, it was decided to use a board instead of a traditional box. The columns would represent 30 minutes time periods and the rows operators. To ensure ease of access and continuous updating, the board was strategically placed next to the team leader's station.

The tasks were represented using small magnetic cards affixed to a whiteboard. Each card clearly indicated the task to be performed and included the baseline productivity for that specific task. To ensure easy identification, each card was assigned a unique number and color, allowing operators to quickly distinguish between different tasks. The more frequent tasks required a higher number of cards, to ensure that there were enough cards to feed the board. A visual representation of the cards is shown in Figure 5.7.

Figure 5.7: Figurative example of the task cards

To optimize the flexibility of the team, tasks were dimensioned to 15-minute intervals. This time frame struck a balance, providing sufficient time to complete a task effectively without sacrificing agility.

Subsequently, the introduction of the leveling box into the process required careful planning. The whiteboard would be regularly updated by the team leader, who would be tasked with populating it with tasks every half hour. Each time slot would accommodate two cards, and the team leader would hand-write the corresponding task numbers beneath each card for their own reference, so it would not lose track of the tasks being performed in the moment.

Mizusumahis would then consult the board, retrieving the two assigned cards for their designated time slot. After completing both tasks, they would return to the board, reattach the utilized cards, and retrieve the next set of tasks from the subsequent time slot.

Ensuring precise adherence to the instructions provided on the card by the Mizusumashis is crucial for aligning their implementation of the leveling box with its main objective. This precision is paramount as it enables them to remain flexible and responsive to unforeseen tasks that may arise in real-time operations. While it may seem that allowing them to move more boxes could potentially improve efficiency, such deviation could inadvertently disrupt the delicate balance of task allocation and readiness. In essence, prioritizing efficacy over efficiency ensures that the Mizusumashis remain readily available to address any emerging needs within the warehouse, thereby mitigating the risk of inefficiencies stemming from over-commitment to tasks. Alternatively, if the Mizusumashis move fewer boxes than instructed, it compromises both efficacy and efficiency, which is also undesirable. However, this new approach requires additional managerial oversight and informed decision-making to maintain operational effectiveness. The forthcoming section outlines a comprehensive solution designed to streamline task management while concurrently addressing the other pertinent challenges within the warehouse.

For clarification, Figure 5.8 shows a picture of the leveling box populated with tasks.

Figure 5.8: Picture of the leveling box populated with tasks, at the end of a shift

5.2.2 Creating dashboards to support the operations

A dashboard is a visual display of key information and data points, typically represented through charts, graphs, and tables, designed to provide an at-a-glance overview of an organization's performance, processes, or activities. It consolidates and presents data from various sources in a clear and concise manner, enabling users to monitor, analyze, and make informed decisions based on real-time or periodic updates.

To improve the efficiency of warehouse management, it is crucial to equip managers with updated and accurate data about each sector of the warehouse and the overall flow of operations. This data should be automatically collected and processed into actionable information that supports decision-making. Additionally, the information must be presented in a clear and meaningful manner.

By leveraging the existing Warehouse Management System (WMS) to supply data for dashboards, operational efficiency could be significantly enhanced. These dashboards would provide real-time insights, enabling managers to monitor performance, identify inefficiencies, and make informed decisions swiftly. The integration of dashboards would ensure that complex data is transformed into easily understandable visuals, facilitating better communication and more effective management practices.

The solution presented involved developing a set of dashboards focused on each team within the warehouse. The author of this dissertation was specifically responsible for creating the storage and replenishment dashboard using Power BI software, which was chosen due to the company's existing familiarity and experience with it.

The initial step was to gain access to the WMS database through Power BI, a task accomplished with the assistance of the IT team. Once access was secured, it was imperative to thoroughly understand the database structure, including the attributes, values, and relationships between datasets. This analysis was complex and required significant collaboration with the warehouse manager, whose extensive experience with the system and operations was invaluable.

After acquiring a deep understanding of the WMS system and its databases, the next step was to correlate the recorded data with the physical movements within the warehouse. This involved shadowing the Mizusumashis throughout their daily activities to observe how their movements were recorded in the system and how physical locations were represented digitally. Such task was very complex and time-consuming, required many iterations throughout the development of the dashboard, as new types of needs kept emerging.

To enhance the effectiveness of team management and decision-making processes, an assessment was conducted on the team leader's decision-making framework, which involved identifying tasks that could be controlled and organized based on data provided by the WMS system. These tasks were categorized into two main groups: replenishment and storage.

Within the replenishment group, further subdivision revealed three distinct categories: PBS replenishment, PBL replenishment, and ground replenishment. PBS replenishment involved transferring boxes from storage in *A's* area to *S's* zone, aiming to replenish stock in picking positions. PBL replenishment entailed moving boxes from storage in area A to the PBL zone to facilitate order picking via PBL sorting. Lastly, ground replenishment encompassed the movement of boxes from upper storage levels to level 1 of the storage area racks.

The storage group comprised tasks related to box movement to higher levels, organization of boxes in storage corridors, and transfer of boxes from the reception area to storage.

Once the necessary information for the dashboards was delineated, the development process commenced. Beginning with the design layout, each dashboard encompasses a section dedicated to the team's overall operations, followed by specific pages tailored to the requirements of each team's role. For example, the replenishment and storage dashboard comprises five pages: "General Operations", "PBS Replenishment", "PBL Replenishment", "Ground Replenishment" and "Storage".

The structure of the replenishment and storage pages adheres to a consistent framework: each page includes a table displaying the productivity of each operator assigned to that task, a table with information on the task requirements (with optional filters), a visual indicator of the total boxes associated with that task, and the number of operators needed to move those boxes within the upcoming 30 minutes.

The "General Operations" page features gauge charts depicting the productivity of each operation, accompanied by a pie chart illustrating the distribution of boxes moved by operation. Additionally, a visual card displays the number of picking stock outs recorded during the day. This KPI gained significant importance following the implementation of the leveling box and task-oriented work in the Mizusumashis team. Monitoring this KPI provides instant insights into the team's performance.

To enhance visual perception, both the gauge charts and the picking stock outs card change color based on their proximity to the target. Green indicates favorable performance, while red signifies areas of concern. This color-coded system allows for quick and intuitive assessment of performance levels, enabling timely intervention and adjustment as needed, through agile countermeasures.

Figure 5.9 shows a visual representation of the "General Operations" page of the "Storage and Replenishment Dashboard".

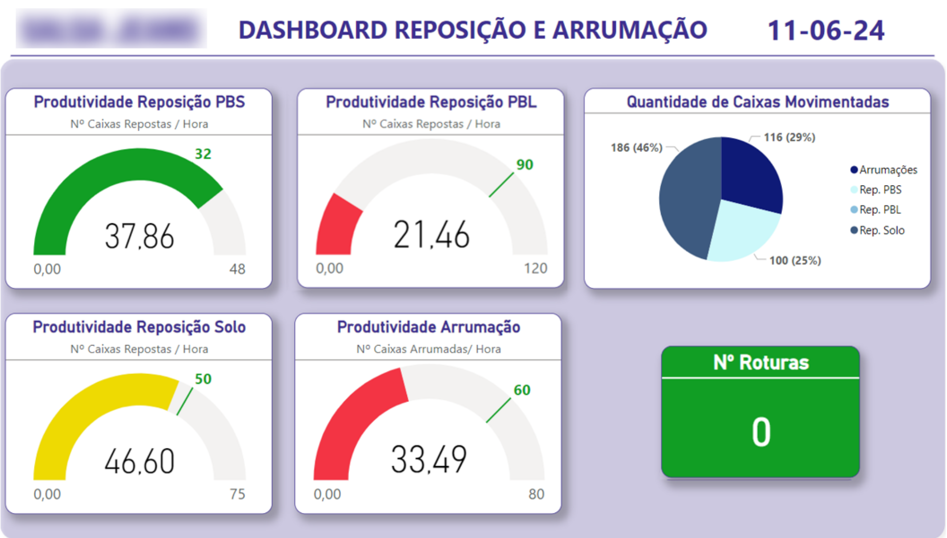


Figure 5.9: General Operations page of the Storage and Replenishment Dashboard

All the pages from the "Storage and Replenishment Dashboard" can be visualized in Appendix H.

To demonstrate the process of building each page, a detailed analysis of the PBS Replenishment page is provided in the following section.

PBS Replenishment page

The replenishment of boxes to the S's zone was a task not directly visible from the data retrieved from the WMS system. There was a dataset containing all actions performed by operators in the warehouse but it included excessive information that needed organization and filtering. For instance, the table provided keys for the operator, warehouse location, container, SKU, and type of action, among others. It was necessary to relate this dataset with others to extract the relevant information associated with each key. Power Query and the construction of relationships between datasets were fundamental in this process.

Once the relationships were built and tested, data filtering commenced. The initial step was to create a query that selected only the operators corresponding to the respective team. Next, it was crucial to identify matches between actions in the storage area and the picking area. A query was constructed to join movements of the same box performed by the same operator in both the *A's* zone and the *S's* zone. The storage zone action had to occur first, followed by a logically timed action in the picking zone.

The result was a table containing the operator's name, the box moved, the starting position, the final position, and the time of the actions. The number of rows in this table represented the number of boxes moved. The hours dedicated to the task were calculated by summing the rows in the time column, where the time difference was less than 10 minutes. This principle was defined by the team, stipulating that if more than 10 minutes have passed between two actions of an operator for this task type, it indicated the operator had performed another task or taken a break in-between, and that time should not be included in the task's dedicated hours.

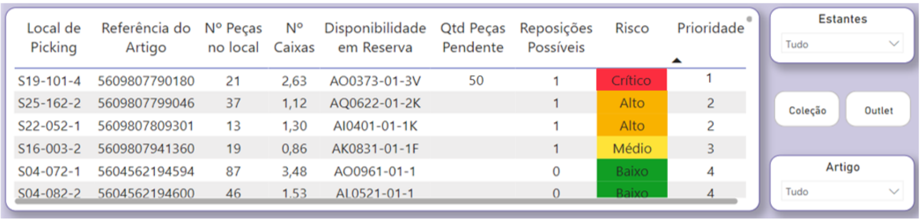
The productivity would then be the ratio between the number of boxes moved and the hours dedicated to that task. The productivity is displayed in a visual table, as shown in Figure 5.10.

Nome	Nº Caixas Repostas	Horas Trabalhadas	Produtividade (Caixas/Hora)
Joao Gonzaga	29	0,71	40,81
Artur Dias	29	0,96	30,33
Joao Moura	32	1,23	26,12
Fábio Castro	11	0,51	21,44
Total	**115**	**3,54**	**32,45**

Figure 5.10: Productivity table from the PBS Replenishment Dashboard

The first column displays the names of the operators who performed PBS replenishment tasks. The second and third columns represent the number of boxes moved by each operator and the amount of time required to move those boxes, respectively. The final column indicates individual operator productivity, with color coding based on proximity to the target: green signifies the target was reached, yellow/orange indicates the target is halfway or nearly reached, and red denotes a significant shortfall from the target.

On the same page, there is a table containing information about replenishment needs in the picking stock. This table includes each occupied picking position's SKU code, the number of pieces in the position, the estimated number of full boxes (calculated as the ratio between the number of pieces in the position and the average number of pieces, per box, for the same SKU in the warehouse), the availability in the storage racks (prioritizing the ground-level), and the amount of pieces pending in today's orders. Based on this information, the visual provides suggestions on the number of replenishments needed for each position, along with associated risks and priority levels. Additionally, the table is filterable, allowing the team leader to customize the view based on rack, SKU type (collection or outlet items), and SKU code. The table and filters are represented in Figure 5.11.



Local de Picking	Referência do Artigo	Nº Peças no local	Nº Caixas	Disponibilidade em Reserva	Qtd Peças Pendente	Reposições Possíveis	Risco	Prioridade
S19-101-4	5609807790180	21	2,63	AO0373-01-3V	50	1	Crítico	1
S25-162-2	5609807799046	37	1,12	AQ0622-01-2K		1	Alto	2
S22-052-1	5609807809301	13	1,30	AI0401-01-1K		1	Alto	2
S16-003-2	5609807941360	19	0,86	AK0831-01-1F		1	Médio	3
S04-072-1	5604562194594	87	3,48	AO0961-01-1		0	Baixo	4
S04-082-2	5604562194600	46	1,53	AL0521-01-1		0	Baixo	4

Figure 5.11: Table of replenishment requirements and filter menus, from the PBS Replenishment Dashboard

The number of replenishments and associated risks vary based on the type of SKU—whether they are collection or outlet items. The priority is determined in ascending order of risk, with higher-risk items being assigned higher priority (i.e., the highest risk is given priority number 1, and so forth). The criteria used to determine these priorities are presented in Table 5.4.

Table 5.4: Criteria used to determine the number of PBS replenishments needed and associated risks

Type of SKU	Criteria	Number of Replenishments	Risk
Collection	Picking Stock < Pending quantity in today's orders	2	Critical
	Picking Stock < Pre-defined minimum quantity	2	High
	Number of full boxes < 1	1	Medium
	-	0	Low
Outlet	Picking Stock < Pre-defined minimum quantity & Level ≠ 3	1	High
	-	0	Low

With the table of replenishment requirements created, the objective is to enable the team leader to quickly access information and export and print it (if needed), eliminating the need to wait for reports or manually search for information in the WMS system. This streamlined process saves time and facilitates more objective and accurate decision-making, allowing the Mizus to receive timely and precise instructions.

Additionally, the same page includes two visual cards indicating the total number of boxes with a critical or high level of associated risk and the number of operators needed to perform the task in the next 30 minutes, based on baseline productivity metrics. These visual aids further enhance the leader's ability to make informed decisions quickly and efficiently and can be found in each replenishment and storage page. In conjunction with the leveling box, these visuals prove immensely valuable. The leader can effortlessly allocate the corresponding task cards to the precise number of operators required, slotting them into the leveling box as needed. Figure 5.12 shows an example, for further clarification.

Figure 5.12: Example of the workload and team sizing visuals from the PBS Replenishment Dashboard

The final result of the "PBS replenishment" page of the "Storage and Replenishment Dashboard" is visually represented in Figure 5.13.

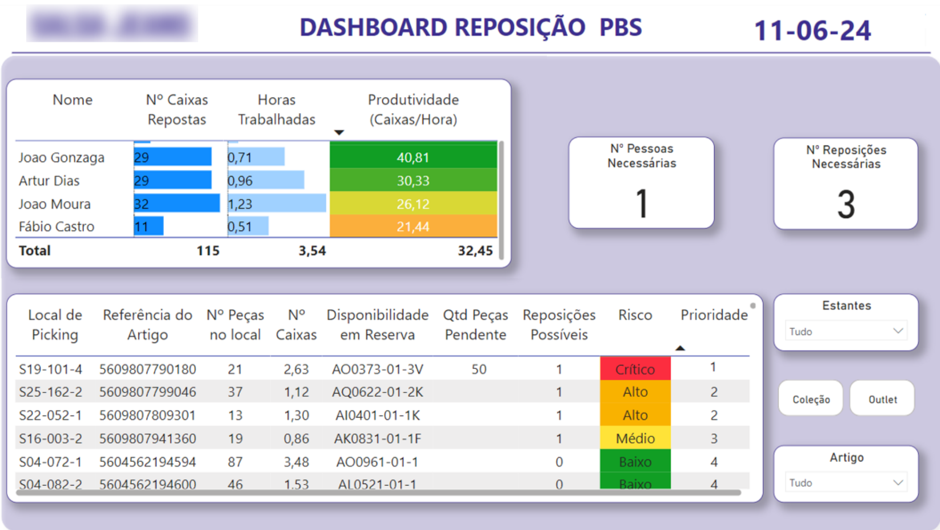


Figure 5.13: PBS replenishment page of the Storage and Replenishment Dashboard

Other teams' dashboards

Although the author of this dissertation was primarily responsible for designing and creating a dashboard to assist the storage and replenishment team, due to their interconnections and synergies with the leveling box, it is also important to acknowledge the significance of the dashboards designed for other teams.

The other operations significantly enhance the utility of these dashboards. For instance, the dashboards supporting picking operations enable direct visualization of the number of orders already fulfilled and those still pending during a shift. With this information and its details at their disposal, team leaders can swiftly reorganize their teams and focus efforts on B2C orders or prioritize more critical destinations. This capability ensures that the most important tasks are addressed promptly, optimizing overall productivity.

Moreover, the implementation of dashboards across various teams facilitates workload balancing and operational flow leveling. If a particular team's workload exceeds that of others and they are lagging behind, this can be easily identified through the dashboards. This visibility allows for inter-team cooperation, where operators can be temporarily reassigned to assist with other operations, thus preventing bottlenecks and ensuring a smoother workflow.

The dashboards also enable real-time visualization of teams' productivity KPIs. This functionality is invaluable for daily monitoring, allowing for immediate corrective actions if performance deviates from targets. Additionally, it provides insights into the impacts of improvement initiatives on operations, both during the current project and in future continuous improvement efforts within the organization, ensuring the company remains flexible and adaptive to changes.

5.2.3 Re-designing the B2C order picking carts

As noted by Tompkins et al. (2010), during picking activities, travel accounts for 50% of the time spent by clerks. While this figure was not directly confirmed in Company X's warehouse, observations indicated a significant amount of time was indeed consumed by pickers traveling through the corridors. This issue was particularly evident when picking B2C orders, due to the frequent need to revisit corridors when the picking container was not full at the end of each route.

The root cause was identified as a lack of visibility into the capacity of the tanks used during picking. This presented an opportunity to improve picking productivity by rethinking the picking method, specifically the carts used to transport picked orders.

During a workshop with warehouse supervisors, the idea of repurposing old picking carts that had fallen into disuse emerged. These carts featured 24 small compartments on each side, totaling 48 slots for picked items, along with two supports for hangers. A picture of one of these carts can be found in Figure 5.14.

Figure 5.14: Picture of the old alveoli picking carts

Multiple tests were conducted using different order types and quantities to compare the tanks with the "alveoli" carts, as the team called them. The tanks proved more efficient for picking single-item orders without hanging pieces or footwear, while the alveoli carts excelled in picking multi-item orders and those including hanging pieces. This result was expected, as the alveoli carts had a well-defined capacity, allowing the exact number of orders to be loaded for each picking route. Additionally, the alveoli carts facilitated item searches during the packing process in the B2C expedition line, as items from the same order were placed in the same compartment.

The tests clearly indicated that the alveoli carts should be reinstated in picking operations. However, several issues had previously led to their abandonment. Firstly, the carts were too tall, obstructing the operators' view of the corridor ahead, which increased the time needed to locate picking positions and occasionally caused accidents. Additionally, their excessive width prevented two carts from passing side by side in narrower corridors, such as those in the outlet zone, resulting in further inefficiencies. The carts were also quite heavy, requiring extra effort from operators to move them. Although the compartments were useful, they were sometimes too small to hold all items from a single order, which would cause errors later in the process, leading to inefficiencies. Lastly, the structure used to hold hanging items was positioned in front of the compartments, necessitating extra effort to insert items into the slots for each new order.

A redesign of the alveoli cart was undertaken to make it shorter, lighter, and narrower. Additionally, the number of compartments was reduced while their size was increased to accommodate larger multi-item orders. The hanger support was also repositioned to facilitate easier use. A concept of the new picking cart is shown in Figure 5.15.

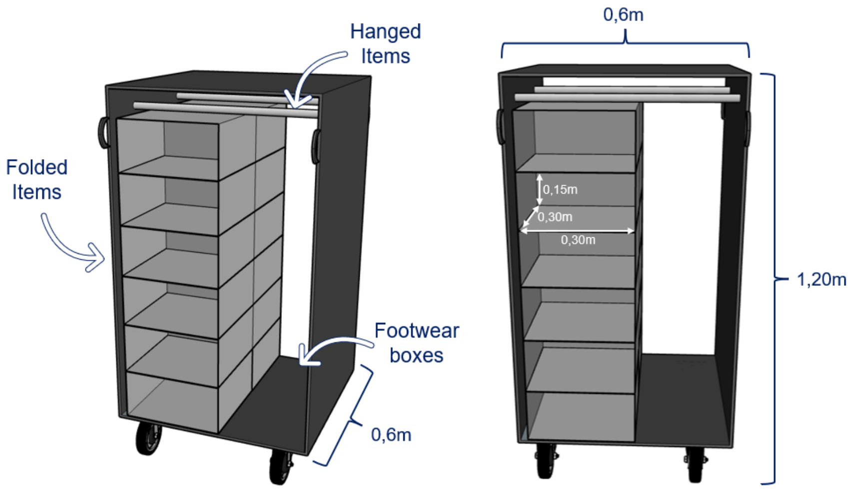


Figure 5.15: Concept design of the new alveoli picking carts

After deciding to reintegrate the old picking carts into operations, it was necessary to establish criteria for their use and evaluate if there were enough carts available.

Four different B2C order clusters were defined and their percentage of the total number of orders calculated:

- Single-item orders without footwear or hanging items - 60.7%
- Single-item orders exclusively of footwear or hanging items - 11.1%
- Multi-item orders without footwear or hanging items - 24.9%
- Multi-item orders exclusively of footwear or hanging items - 3.2%

Picking routes would now be generated by grouping orders within the same cluster, allowing for better management of order variability within a small number of specific picking routes. It was determined that tanks would be used for single-item orders, while alveoli carts would be designated for multi-item orders. This strategy ensures that each type of cart is used optimally, enhancing the overall efficiency and productivity of the picking process.

Taking into account the relative percentages of each type of order and the expected peak of B2C orders, it was concluded that 18 tanks and 7 alveoli carts would be needed. At the time of the project, there were 22 tanks and 32 alveoli carts available, which meant that no further investment in carts would be required.

Chapter 6

Solution Implementation

6.1 Implementation process

Alongside the design of a solution to address a specific problem, it is necessary to define a sequence of steps that guide the implementation of the solution in a real-world context. This corresponds to Phase 4 of the steps proposed in the case study methodology outlined in Chapter 2. Accordingly, a schedule was established at the project's outset for implementing the Kaizen project at Company X, intending to phase the implementation of the project's improvement actions.

Each improvement action involves two important steps for implementation: the actual implementation, which includes the respective workshop steps, and the follow-up. The workshops should be conducted with the presence of a pre-determined team that will be responsible for the specific improvement action, and a leader should be appointed for each workshop. Subsequently, follow-up work is carried out. This step ensures the adherence to and sustainability of the solutions created, as well as their continuous innovation and improvement.

Due to the substantial investment required, the introduction of the order picking machine and the construction of new racks did not follow the standard procedures, as these changes involved considerable bureaucracy and administrative decision-making. The team's contribution to this implementation involved conducting workshops to define how the machine would be integrated into the operation, ensuring a smooth and efficient process flow. However, at the time this dissertation was being developed, the order picker corridors were not yet operational, so it was not possible to provide follow-up information.

Regarding the modifications to the outlet picking locations, implementation was on hold due to the introduction of the above mentioned solution. The company's efforts were focused on integrating the new racks and the order picker into the operation first, and only afterward modifying the remaining warehouse structures.

In contrast, the implementation of the productivity-oriented solutions required direct intervention from the consultants, involving workshops and constant follow-up until the team was fully comfortable and aligned with the new work methodologies.

The introduction of the leveling box into the storage and replenishment team was approached with caution. It began with a training session for the entire storage and replenishment team, as well as the warehouse team leaders. The aim was to introduce them to Kaizen methodologies, explain the concept of Heijunka, and the objective of its introduction, while also attempting to break some existing paradigms.

Subsequently, the leveling box was implemented in the warehouse. For a week, the leader was closely assisted in updating the tasks, and the Mizus were shadowed to ensure that the tasks were clear and the target productivity was well dimensioned. Additionally, two follow-up workshops with the team were conducted afterwards to identify and raise improvement opportunities.

The implementation of the dashboards was carried out gradually, through multiple iterations. The initial MVP for each team was developed and presented to the respective leader, who then provided suggestions for a more comprehensive and useful display of information. After incorporating these suggestions and making significant modifications, the leader needed guidance on how to utilize the new features effectively. To facilitate this, the responsible consultant would accompany the leader for half a shift, ensuring they understood how to work with the updated dashboards and leverage them for better decision-making.

Finally, the new B2C order picking carts were yet to be re-built by the time this dissertation is being written, so its integration in the operations is not described.

6.2 Challenges encountered and Countermeasures applied

Both the design and implementation of the solutions proved to be complex and challenging in various aspects, necessitating the total commitment of the team to devise quick and effective countermeasures to ensure the success of the project.

In particular, the design of the dashboards faced significant challenges, not only because the WMS was developed by a Spanish company, resulting in a database entirely in Spanish, but also due to its complexity and detailed structure. The source database comprised 21 datasets, totaling 368 attributes, and 20 relationships connecting them. This intricate structure required extensive deconstruction and deep understanding. Additionally, the variability in task execution by different operators in the warehouse led to inconsistent inputs in the system, as they used different methods or sequences for performing movements. To address these challenges, daily meetings with the warehouse supervisor, who possessed exceptional knowledge of the system, were conducted. Recurring Gemba walks were also undertaken to ensure alignment between physical actions and their digital outputs.

Regardless of the problems faced during the design of solutions, the most challenging phase was definitely the implementation, more specifically the implementation of the leveling box.

The main challenge was convincing the Mizus that the proposed changes would benefit the overall operations of the warehouse. Having worked based on established routes for years, transitioning their workflow within months was expected to be difficult. The Mizus were skeptical that focusing on effectiveness rather than efficiency would benefit operations, as their mindset was geared towards maximizing output in the least amount of time. This skepticism needed to be addressed thoroughly.

Workshops, coupled with demonstrations of how the changes positively impacted the KPIs, proved to be very effective. Team leaders also played a crucial role in persuading the Mizus that the changes would ultimately enhance operations. They emphasized that although the new methods might be challenging initially, they would result in a lighter and more manageable workload during peak times by allowing for better resource allocation to high-demand areas.

It was also crucial to understand their complaints and make them feel heard. To this end, Daily Kaizen meetings were implemented at the end of each shift within the team. These meetings aimed to assess improvement opportunities, evaluate daily performance based on the picking stock-outs KPI, and update the action plan with any measures that emerged. This approach ensured that the Mizus felt involved in the process, provided a platform for their feedback, and facilitated continuous improvement in operations.

Another problem was that the implementation of the leveling box was initially slow and consumed a significant amount of the leader's time, as it required close monitoring to ensure tasks were performed correctly. Tracking individual performance also became challenging because not all tasks were digitally recorded, complicating the assessment process.

To improve and quicken the control over the digitally stored tasks, two new pages were included in the dashboard and are presented in Figure I.2 and Figure I.3 of Appendix I.

In contrast, other tasks were controlled sporadically through audits conducted by different warehouse supervisors. The results of these audits were displayed using a Kamishibai card, a visual tool commonly used in Lean methodologies. The Kamishibai card has two sides: a green side indicating that all evaluated points meet the established standards, and a red side indicating that at least one point is not in compliance. During the daily meetings, the color of the Kamishibai card was also taken into consideration, and appropriate actions were defined based on the audit results. Kamishibai cards are crucial for the sustainability of processes, fostering a culture of continuous improvement and consistent countermeasures based on the Deming cycle (PDCA). A visual representation of the Kamishibais is shown in Figure I.1 in Appendix I.

Finally, as the team leader missed work for a week, it became apparent that no one else in the warehouse was equipped to coordinate the leveling box. To address this, a rotation plan was proposed. Initially, team leaders would each be responsible for the leveling box for a day, with the primary leader providing instruction at the start. In a subsequent phase, the Mizus would take on this responsibility, ensuring everyone gained the necessary skills and knowledge to manage the leveling box effectively.

Chapter 7

Results

This chapter presents the findings from implementing the proposed solutions at Company X's warehouse. The results are categorized according to the specific objectives outlined in previous chapters: increasing storage capacity and enhancing operational productivity. Tracking the respective KPIs is crucial to determine the project's success and guide continuous improvement efforts.

7.1 Increase in storage capacity

Relative to the capacity increase objective, the repurposing of the old warehouse and the introduction of new racks substantially contributed to achieving the goal. The first action allowed for an additional storage capacity of 720 pallets, representing a 24% increase compared to the initial warehouse capacity. The introduction of the new racks provided space for an additional 12600 boxes. Given that each pallet in the storage area holds 16 boxes, this translates to an increase of 780 pallets, which corresponds to a 26% increase over the initial capacity.

The projected impact of changes in the picking outlet locations and the merger of the expedition lines, although not yet implemented, has been calculated. The first action will free up 99.6 m^2 in the picking area. If this space is utilized for hanging items, it will release 24 pallet positions in the storage area. The merger of the expedition lines, would free up 90 m^2, if implemented. By equipping that space with standard storage racks, it would increase pallet capacity by 72 units. The results of the above-mentioned actions are summarized in Table 7.1.

Table 7.1: Summary of the impact of the actions to increase storage capacity

Action	Gained Area	Increase in Pallet Capacity
Re-purpose of an old warehouse	800 m²	720 (+24%)
Re-location of checking stations and introduction of new racks for the order picking machine	685 m²	780 (+26%)
Changes in the outlet picking locations*	99,6 m²	24 (+1%)
Merger of the expedition lines*	90 m²	72 (+2%)
Total	**1674,6 m²**	**1596 (+53%)**

* These actions were not yet implemented, so the presented results are predictions

The initial target for the increase in pallet capacity was 3698 pallets, or an increase of 25%. At the moment, the total pallet capacity is equivalent to 4452 pallets, which translates in an increase of 51% in relation to the initial capacity of 2952 pallets, meaning that the goal has been achieved.

7.2 Increase in productivity

The success of the leveling box was tracked using the initially defined KPI of the picking stock-outs. The results are displayed in Figure 7.1.

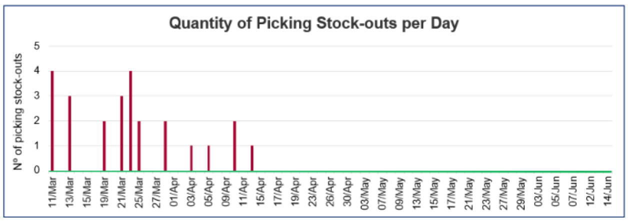


Figure 7.1: Quantity of daily picking stock-outs, after the implementation of the leveling box

Initially, there was an adjustment period during which operators were learning to use the leveling box, resulting in high daily picking stock-outs. However, after the first month of implementation, the leveling box proved to be very effective, reducing daily picking stock-outs to zero.

The direct impact of the dashboards is more challenging to measure. Therefore, their effectiveness will be assessed through the project KPIs, focusing on the main KPI, supply chain productivity, and the support KPI, warehouse productivity. The results are displayed in Figure 7.2.

Figure 7.2: Evolution of the project's productivity KPIs, throughout the months

Although the project began in November, the author joined in February, when the first dashboards were introduced. Since then, supply chain productivity has exceeded the baseline twice and the target once but fell below the baseline twice, with negative results in April and May due to an unusual sales drop. Warehouse productivity exceeded the baseline three times and hit the target twice, but declined in the last month due to excess staff during reduced sales.

On average, supply chain productivity increased by 7.2% and warehouse productivity by 12.5% since February. These results are close to the 10% target, which is expected to be surpassed in both KPIs with upcoming actions like the order picking machine integration.

The re-design of the B2C picking carts although not implemented yet, has an expected increase of 24% in B2C multi-order picking productivity and 19% in the corresponding order packing, based on data retrieved from the several testings performed.

Chapter 8

Conclusion and Future Prospects

The project for this Master's dissertation aimed to improve the storage capacity and enhance the operational productivity of Company X's warehouse, a Portuguese multinational apparel company. Currently, the growth in sales and diversification threatens the availability of storage space and operational efficiency. To address these challenges, various Kaizen methodologies were employed.

Although the models and tools developed for this case study were tailored for a specific warehouse, they offer valuable insights into the application of lean methodologies within a logistics context. These methodologies can be adapted and applied to other warehouses' contexts with similar initial conditions.

The analysis of the company's initial situation unveiled the primary challenges impacting warehouse operations. These included excessive storage occupancy, deficiencies in management processes and decision-making, and inefficiencies in picking procedures, exacerbated by stock-outs and lengthy travel distances. This assessment facilitated the formulation of improvement strategies tailored to meet the needs of Company X. To address the storage space issue, solutions were implemented such as repurposing an older warehouse, introducing an order picker machine, and redesigning outlet picking locations. Operational productivity was enhanced through the introduction of a leveling box, implementation of dashboards, and redesigning picking carts.

Following the diagnostic phase, the implementation of the aforementioned actions ensued, namely the repurposing of the older warehouse, the introduction of the leveling box and the creation of operational dashboards. The later tools allied, would allow to enhance the efficiency of the most important task in the warehouse: the order picking. The remaining solutions were yet to be fully implemented, by the time this dissertation is being elaborated. However, it is estimated that once fully implemented, such action will be very beneficial at various levels, to attain the projects' objective.

In this case study, warehouse capacity increased from 2952 pallets to 4452 pallets, representing a 51% increase. Additionally, supply chain productivity rose by an average of 7.2%, while warehouse productivity improved by 12.5%.

The increased capacity eliminated the need for outsourcing operations, resulting in annual savings of 77k€, as determined by internal benchmarks and previous partnerships with logistics providers, previous to the start of the project.

Regarding productivity, if the target is consistently met each month, annual gains of approximately 87k€ are expected, based on hours saved and the cost of FTEs.

To conclude, the implementations resulting from this project have proven to be transformative, achieving the primary objectives of enhancing storage capacity and productivity within Company X's warehouse operations. However, beyond these immediate gains, the project has also laid the foundation for a spectrum of potential future improvements.

As far as the experience of developing a Master's dissertation in a business environment is concerned, it was extremely useful for my development as an engineer and manager. The possibility of being able to apply the knowledge learned during the Integrated Master's Degree in Industrial Engineering and Management in a real industry context proved to be a huge challenge, but it was a very interesting one and definitely had an impact on the rest of my professional career

As for the future, integrating the leveling box digitally with dashboards and the Warehouse Management System (WMS) emerges as a pivotal step forward. This integration empowers Mizus operators to receive task allocations and specifications seamlessly through their devices, streamlining their workflow with precise instructions including initial and final box locations. Consequently, this transformation would transition the role of team leaders from decision-makers to controllers, fostering operational efficiency.

Expanding the concept of the leveling box to the picking team holds immense promise, particularly in the context of the growing B2C channel. By prioritizing orders based on type, this extension promises enhanced order management and route optimization. This strategic alignment not only meets current demands but also anticipates future growth, positioning the organization for sustained success.

Furthermore, a strategic investment in an internal IT project to optimize dashboard-WMS connectivity is imperative. Presently, the reliance on manual updates for queries poses a challenge to system longevity and efficiency. For instance, the absence of team attribution for operators within the WMS necessitates manual adjustments in Power BI queries, introducing inefficiencies. So, if a new operator was to be added to the storage and replenishment team, the dashboard would not automatically reflect such addition. A systematic solution to automate this process is essential for maintaining operational agility and accuracy.

Looking ahead, potential expansions in storage capacity beckon the consideration of innovative solutions. Consolidating expedition areas and implementing efficient storage structures, such as the racks utilized for order picking machines, presents a viable strategy. This proactive approach ensures scalability while optimizing spatial utilization, aligning with the organization's evolving needs and objectives.

Finally, developing a long-term resource planning tool would be highly beneficial. This tool would enable the calculation of monthly resource requirements for each team, ensuring that productivity KPIs are more accurate and meaningful. By aligning the workforce with the workload, the warehouse would avoid operating with an excessive number of employees, optimizing efficiency and productivity.

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Appendix A

Literature Review Framework

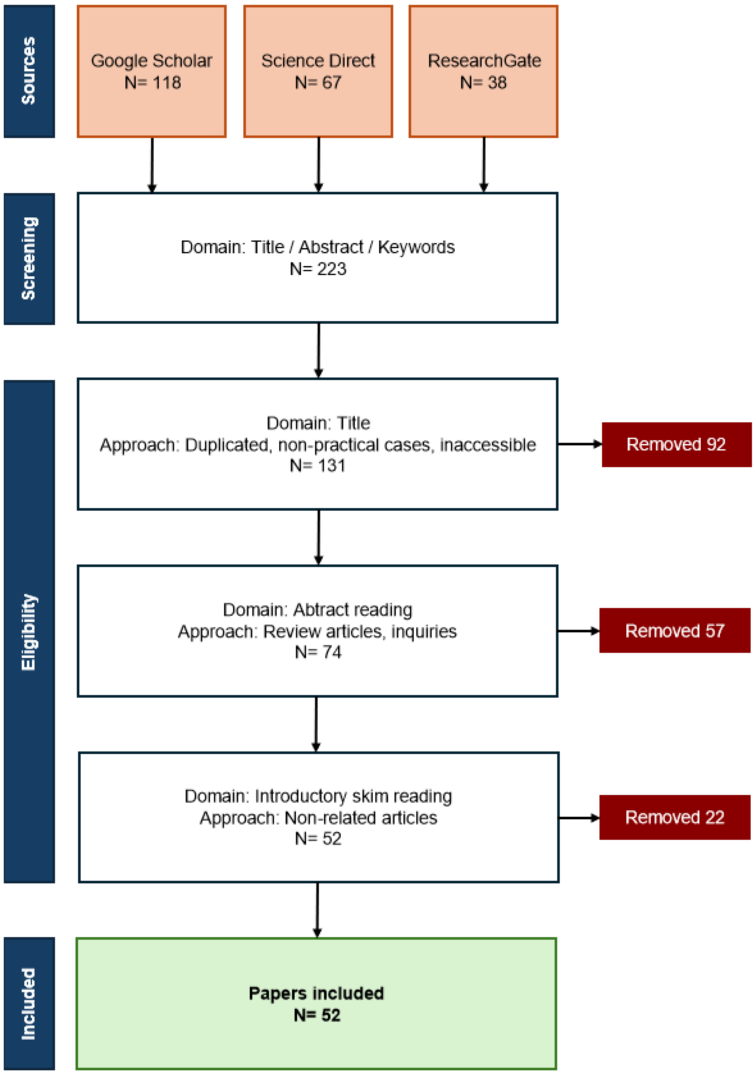

Figure A.1: Literature review framework (adaptation from PRISMA framework)

Appendix B

Methodology followed during the project

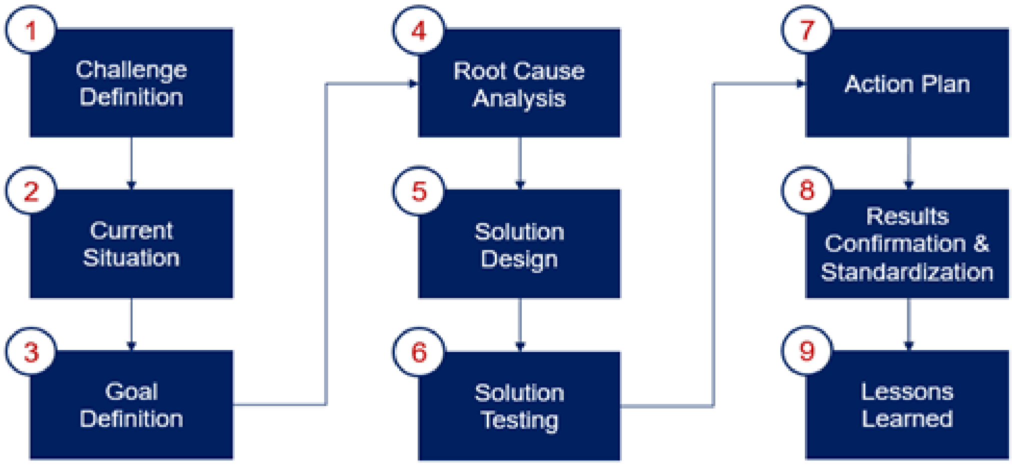

Figure B.1: A3 9 Steps - Methodology followed during the project

In delineating the A3 framework, its nine steps can be categorized into three distinct phases:

- Preparation Phase: Encompassing Steps 1 through 3, this initial phase lays the groundwork for the subsequent actions by focusing on preparatory measures and problem definition.
- Solution Design Phase: Spanning Steps 4 to 6, this phase is dedicated to crafting and refining potential solutions to identified problems or challenges.
- Monitoring and Implementation Phase: Encompassing Steps 7 through 9, this final phase involves the establishment and execution of a monitoring system to track progress and ensure the effective implementation of chosen solutions.

Appendix C

Initial layout of company X's warehouse

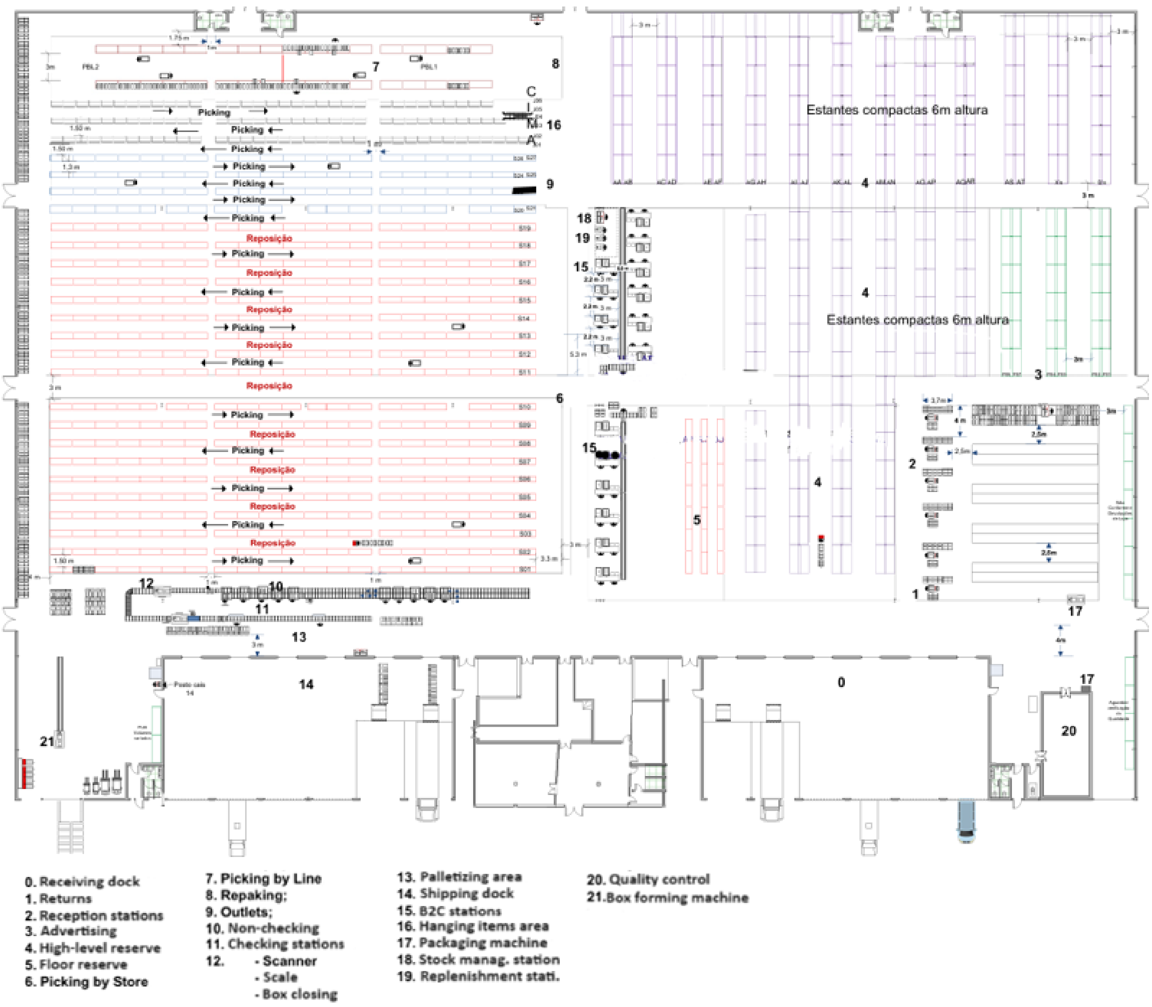

Figure C.1: Initial layout of company X's warehouse

Appendix D

Spaghetti diagrams of both types of Picking By Store - Multichannel and B2C

In the multichannel picking round, the orders were all loaded to the machine at once, at the beginning of the round. This way, the clerk followed an optimal picking route, only visiting each position once.

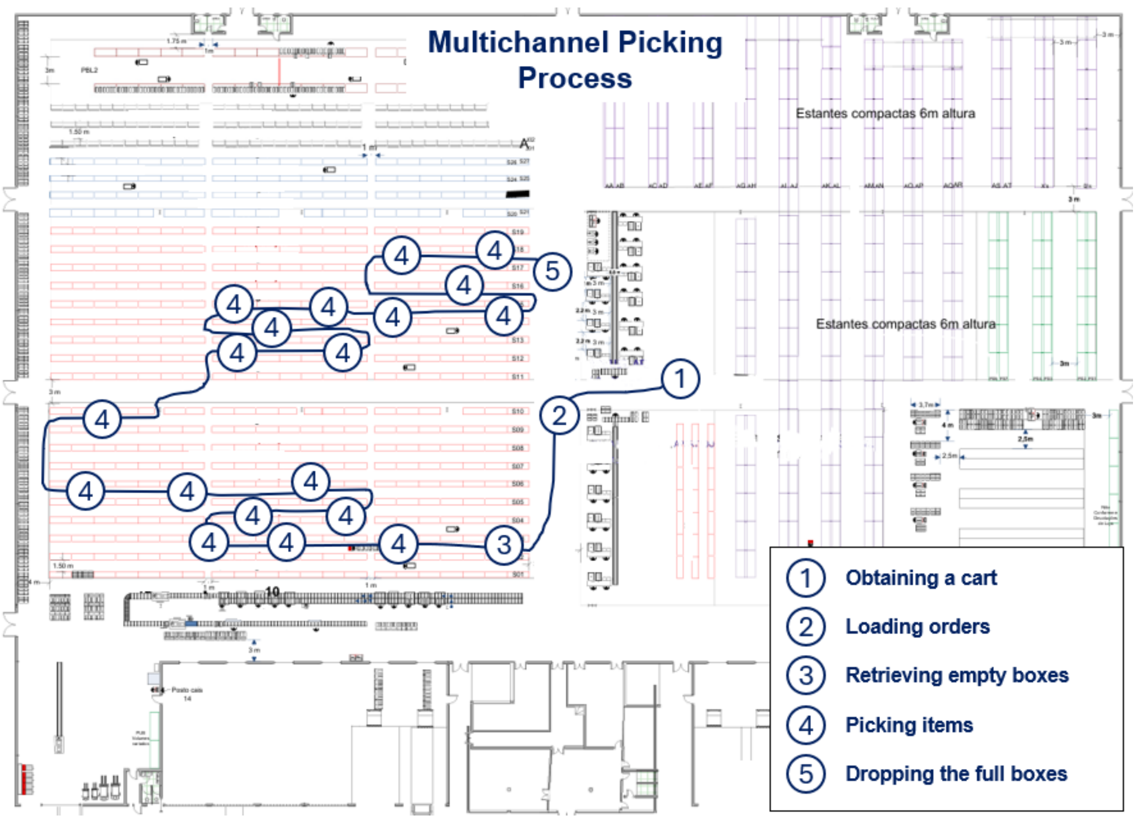

Figure D.1: Spaghetti diagram of the multichannel picking process

In the B2C picking round, orders were initially loaded into the machine separately. As the round commenced, a batch of orders was loaded. Once these orders were picked, the clerk noticed available space in the tank and loaded additional orders into the machine. This process generated a new route, necessitating the clerk to revisit previously covered positions.

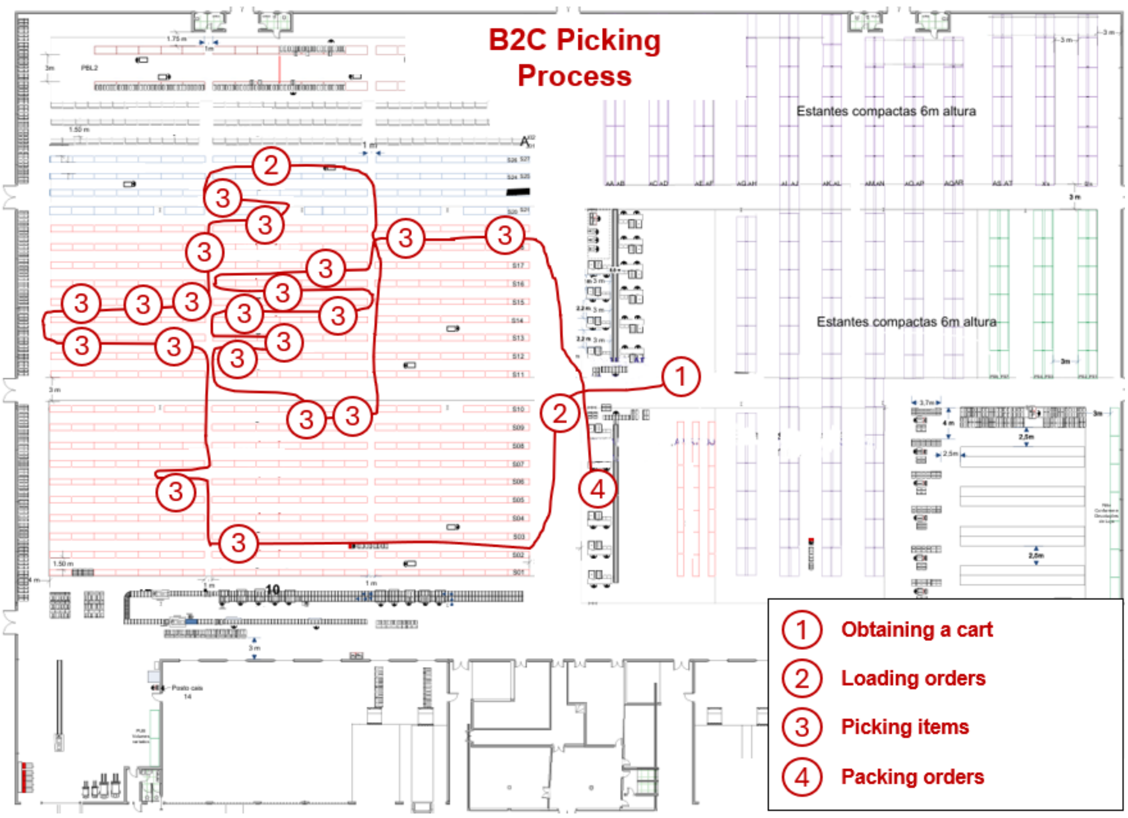

Figure D.2: Spaghetti diagram of the B2C picking process

Appendix E

Problem identification and root cause analysis using the "5 Whys" technique

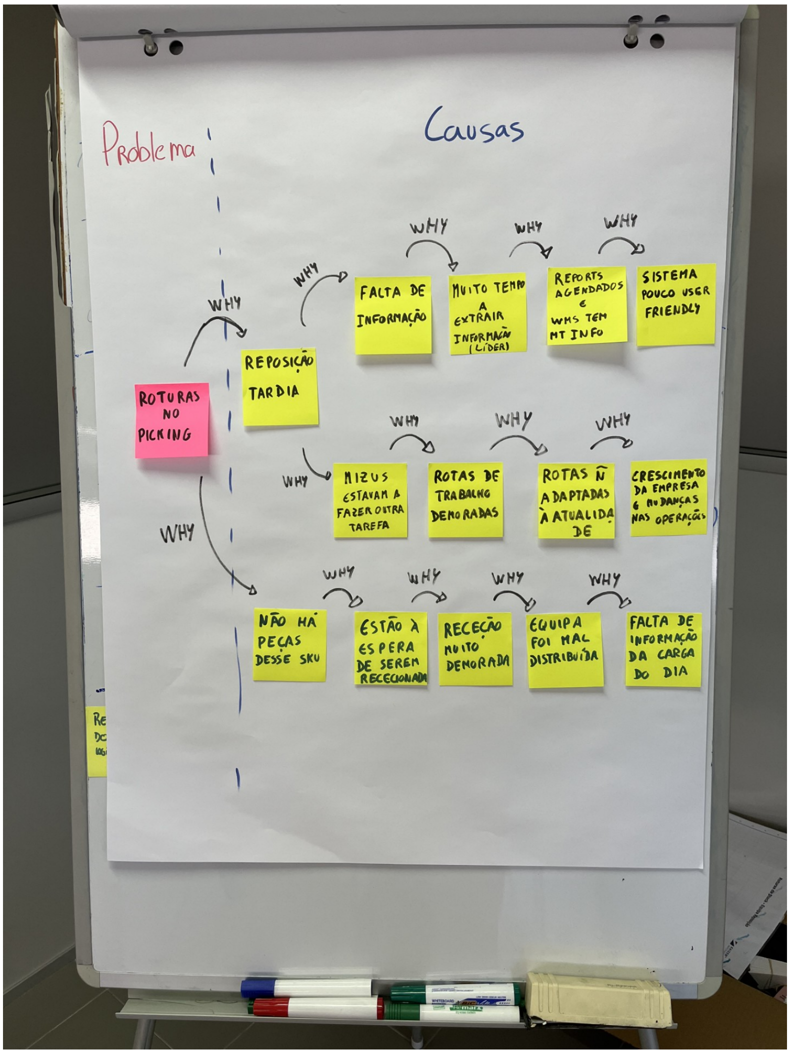

Figure E.1: Output of a workshop where the "5 Whys" technique was applied

Appendix F

Order picking machine and layout changes due to its introduction

Figure F.1: Picture of the order picking machine

With the introduction of sampling in the reception checking, the number of checking stations (yellow area), was reduced, allowing to reposition them. Consequently, the racks initially located in the red area were redistributed across two new areas. The vacated space was then used to install new racks designed for direct box storage. These new racks are situated in the green area, which is also designated for the operation of the order picker machine.

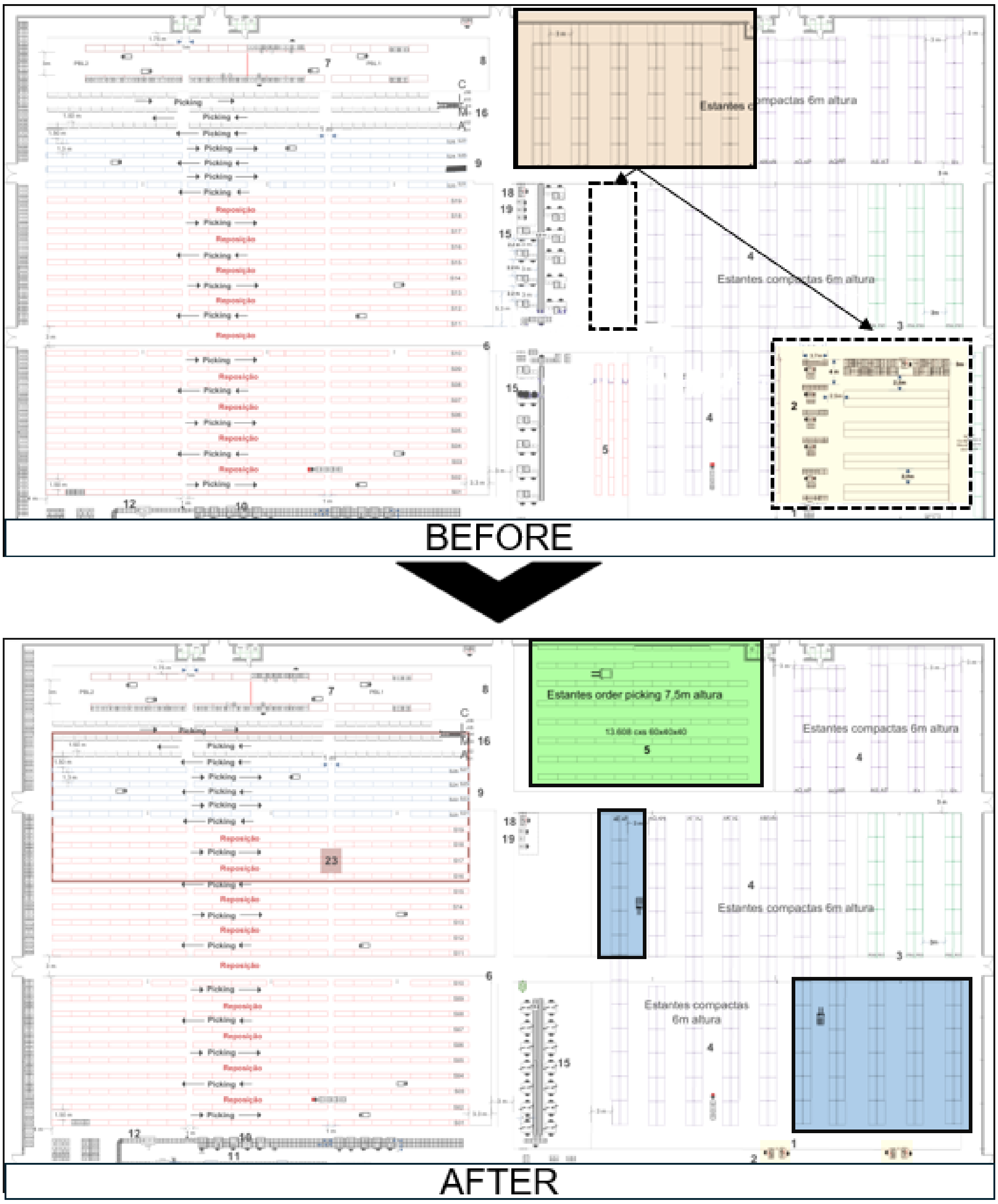

Figure F.2: Layout before and after the introduction of the new racks

The following image depicts the new racks, highlighted in green in the figure on the previous page.

Figure F.3: Picture of the new racks, where the order picking machine will be used

Appendix G

Future vision designs of the merged expedition lines

Figure G.1: Future expedition line design - Option 1

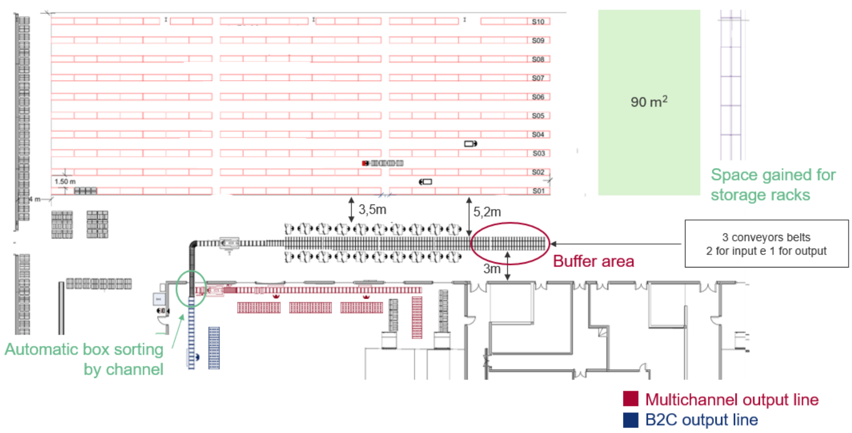

Figure G.2: Future expedition line design - Option 2

Appendix H

Storage and Replenishment dashboard

The "General Operations" page allows for the control of the whole operation of the storage and replenishment team. In this page, the productivity of the team in the current day is displayed in gauge charts, for each type of task. For each task, there is a target value visually represented, that was defined based on historic data. The color of the charts varies depending on the closeness to the target. The number of picking stock-outs is also displayed, as well as a pie chart of the distribution of the total number of boxes moved per type of task.

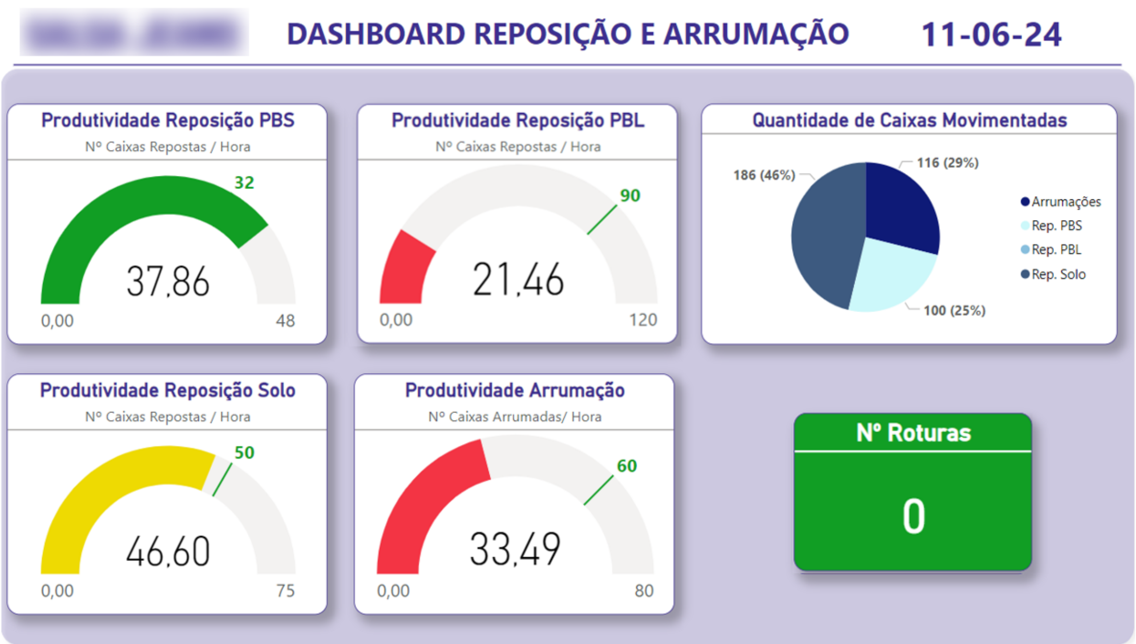

Figure H.1: General Operations page of the Storage and Replenishment Dashboard

The "PBS Replenishment" page offers comprehensive insights into operator productivity related to replenishing PBS positions. It highlights current replenishment needs and calculates the number of workers required to meet these needs within the next 30 minutes. Additionally, this page includes robust filtering options, allowing team leaders to focus on specific PBS zones or search for particular SKUs. These features enable leaders to make informed decisions quickly and efficiently, ensuring optimal resource allocation and timely replenishments.

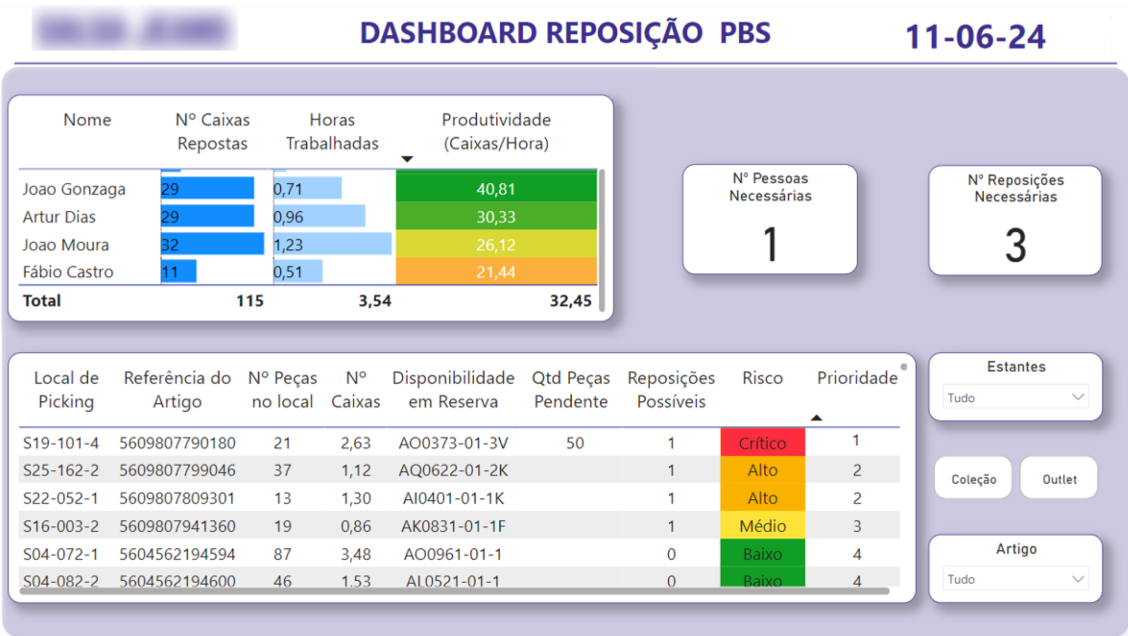

Figure H.2: PBS replenishment page of the Storage and Replenishment Dashboard

The PBL replenishment page follows the same principle as the PBS replenishment page. It includes a table representing operator productivity for the task, a table detailing replenishment requirements, and two visual cards indicating the total number of boxes to be replenished and the number of operators needed to perform the task.

For this task, the movements considered for productivity were from the *A's* zone to the PBL zone, rather than the *S's* zone. Additionally, creating the table of requirements for PBL replenishment did not require extensive information or criteria for the number of replenishments and associated risks. Since there was no stock in the PBL zone, it was only necessary to identify which boxes needed to be moved from the storage area to be separated in PBL. This was achieved by mirroring, in Power BI, the algorithm behind the reports previously developed by the company that define which items should be separated in PBL based on predefined conditions.

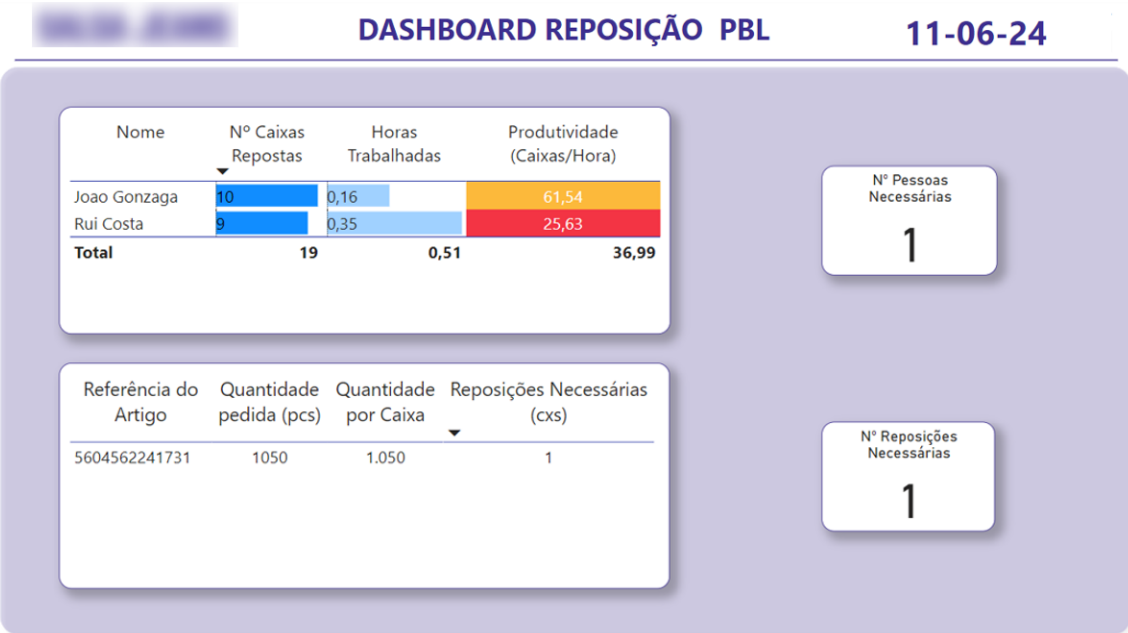

Figure H.3: PBL replenishment page of the Storage and Replenishment Dashboard

This page outlines the requirements for relocating boxes from higher levels to ground levels of the storage racks, ensuring efficient replenishment. It features two groups of tables:

1. Replenishment Needs for PBS and PBL Zones: These tables specify the necessary boxes to replenish the PBS and PBL zones when ground-level boxes are unavailable. Each entry includes the SKU code, the number of boxes needed, and their high-level storage locations.

2. Ground-Level Stock Overview for A's Racks: This table provides a comprehensive overview of the ground-level positions in *A's* racks, identifying which collection items should be present but are currently missing. Ideally, each SKU in storage should have at least one box at the ground level, with a preference for maintaining more than five boxes per SKU. This table aids leaders in effectively organizing ground-level stock in the *A's* zone. Multiple filter options are available for customized views.

Additionally, the productivity table tracks the movements of boxes from higher shelves to the ground level. It utilizes queries to identify storage positions by their codes and the last digit to determine the corresponding level. This functionality ensures accurate tracking and efficient organization of stock movements.

Overall, the page provides critical information and tools to optimize the replenishment process, enhance stock organization, and improve overall productivity through customizable filters and detailed tables.

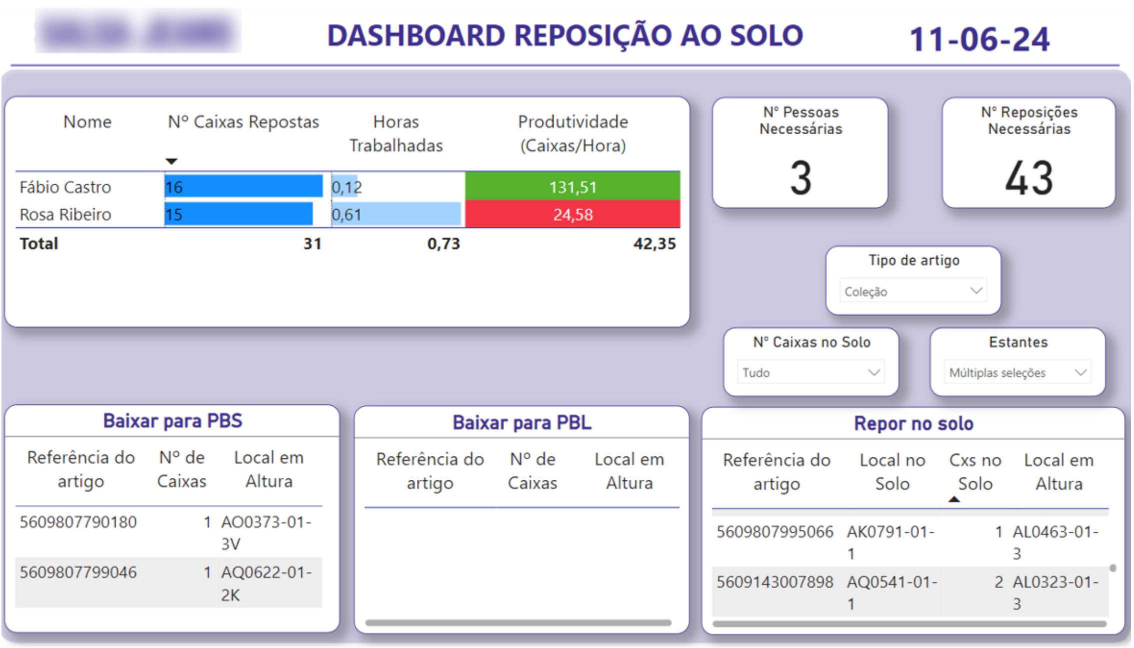

Figure H.4: Ground replenishment page of the Storage and Replenishment Dashboard

On the storage page, three types of movements are considered: lifting boxes to higher levels, tidying up boxes from the corridors, and storing boxes from the reception area. Accordingly, three tables are presented, each corresponding to one of these tasks.

The first table identifies boxes that need to be moved to upper pallets. These boxes are initially placed in specific ground-level positions by the Mizusumashis. The table lists all boxes in these positions according to the WMS system, recommending them for relocation to upper levels. Details such as SKU codes and current positions are provided.

The second table focuses on boxes that need to be tidied up from the corridors. These boxes were placed in designated corridor positions by reach truck operators after being retrieved from upper levels and are awaiting movement to other warehouse positions. The table lists these boxes along with their SKU codes and current positions, ensuring efficient organization and clearance of corridor spaces.

The third table lists boxes from the reception area that are ready for storage. These boxes in the reception bay have specific codes associated with them in the system. Once they are checked and validated, their status changes to "CE" in the system. Boxes that match both conditions—being in a reception dock and having the "CE" status—are eligible to be moved to the storage area. The table provides details such as SKU codes and current positions for these boxes.

By presenting these three tables, the storage page provides a comprehensive overview of necessary box movements, facilitating efficient organization and management of warehouse operations.

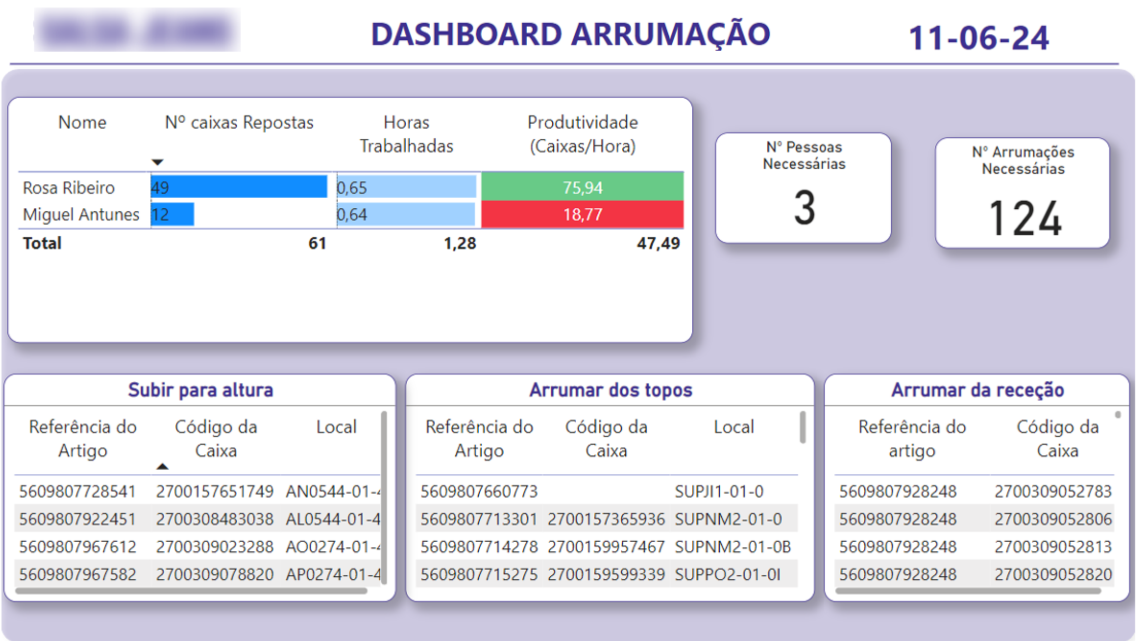

Figure H.5: Storage page of the Storage and Replenishment Dashboard

Appendix I

Countermeasures applied to face the challenges during implementation

Figure I.1: Visual representation of the Kamishibais introduced to control the leveling box

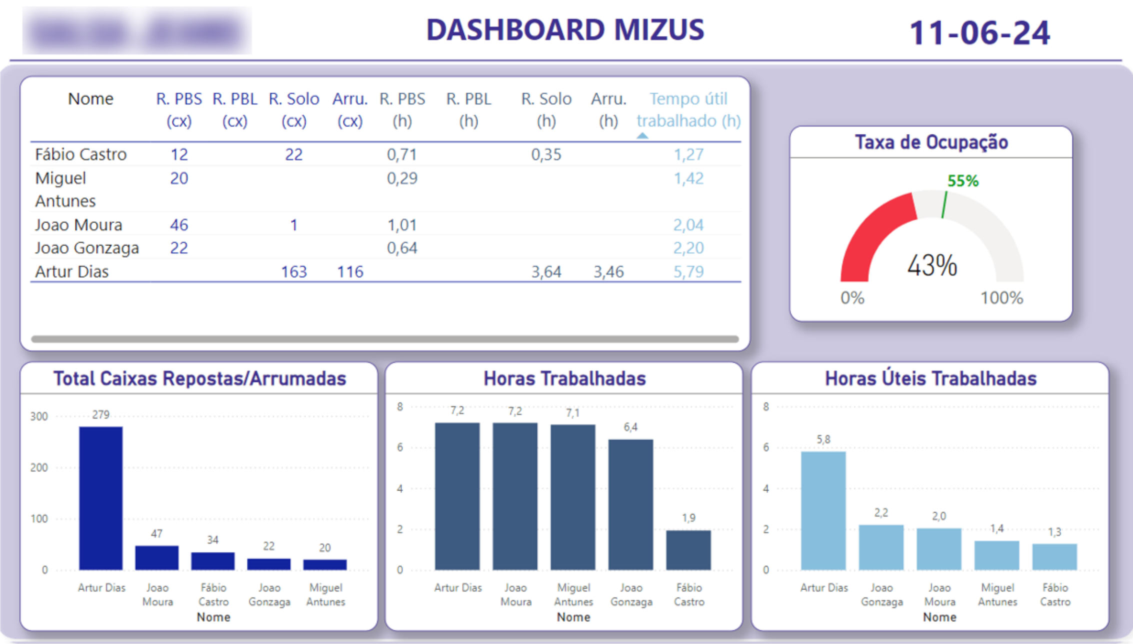

Figure I.2: Mizusumashis' page of the Storage and Replenishment dashboard

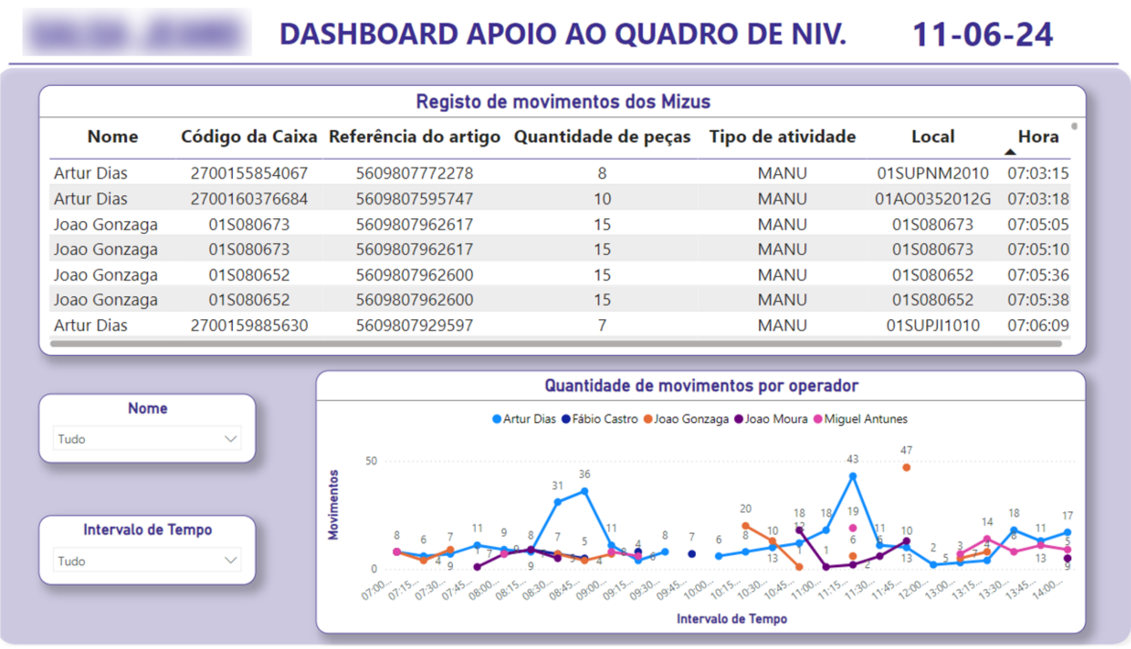

Figure I.3: Leveling box support page of the Storage and Replenishment dashboard