Redefinition and Improvement of the Internal Logistics of a Manufacturing and Distribution Cosmetic Goods Company

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Abstract

For a company to be successful in the modern day and age, it needs to focus on the constant improvement of its operations, and it is important for a company to be able to understand its shortcomings and to improve them and reduce the inefficiencies of those shortcomings.

In the cosmetic industry, an industry with a very volatile market, where there is a lot of difficulty to predict the future of sales, it is important for a company to react quickly to market changes and to expedite the products as fast as possible.

Utilizing an approach of identifying the areas where the process has flaws and seeking solutions to improve them, the picking time could be shortened and the costs of the activity lowered. The picking process was studied and reviewed to seek those improvement areas and some analysis of the data of the orders and clients was done.

To better understand the problems of the process, several orders were accompanied and observations were taken about the inefficiencies found. With the problems identified and the help of the literature and seeing how other warehouses of the industry were operating some scenarios were created to analyze possible improvements to the process. These improvements included the use of carts, the change of the SKUs locations, the integration of a WMS in the system, and the possible change of the warehouse responsible for the picking.

With a great focus on the optimization of the picking time and studying which scenarios would perform better in this metric, some budget options for these scenarios were sought to better understand the cost that would imply to the company and to understand which gains would appear with the different choices.

Despite the results not being able to be implemented in the company, a suggestion was done for the implementation of the picking scenarios.

Resumo

Redefinição e melhoria da logística interna de uma empresa de fabrico e distribuição de produtos cosméticos

Para uma empresa ser bem sucedida nos dias de hoje, precisa de se concentrar na melhoria constante das suas operações, e é importante para uma empresa ser capaz de compreender as suas deficiências e melhorá-las e reduzir as ineficiências dessas deficiências. Na indústria cosmética, uma indústria com um mercado muito volátil, onde há muita dificuldade em prever o futuro das vendas, é importante para uma empresa reagir rapidamente a mudanças no mercado e expedir os produtos o mais rapidamente possível.

Utilizando uma abordagem de identificação das áreas onde o processo tem falhas e procurando soluções para as melhorar, o tempo de separação de pedidos pode ser reduzido e os custos da atividade diminuídos. O processo de separação de pedidos foi estudado e revisto para procurar essas áreas de melhoria e foi efectuada alguma análise dos dados das encomendas e dos clientes.

Para melhor compreender os problemas do processo, foram acompanhadas várias encomendas e efectuadas observações sobre as ineficiências encontradas. Com os problemas identificados e com a ajuda da literatura e vendo como outros armazéns da indústria estavam a operar, foram criados alguns cenários para analisar possíveis melhorias no processo. Estas melhorias incluíam a utilização de carrinhos, a alteração das localizações dos SKUs, a integração de um WMS no sistema e a possível alteração do armazém responsável pelo *picking*.

Com um grande foco na otimização do *picking time* e estudando quais os cenários que teriam um melhor desempenho nesta métrica, procuraram-se algumas opções de orçamento para estes cenários para perceber melhor o custo que implicaria para a empresa e perceber quais os ganhos que surgiriam com as diferentes escolhas.

Apesar dos resultados não poderem ser implementados na empresa, foi feita uma sugestão para a implementação dos cenários de *picking*.

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"It does not do to dwell on dreams and forget to live."

Albus Percival Wulfric Brian Dumbledore

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Acronyms and Symbols

KPI	Key Performance Indicator
WMS	Warehouse Management System
ERP	Enterprise Resource Planning
SKU	Stock Keeping Unit
SLAP	Storage Location Assignment Problem
FTE	Full Time Equivalent

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Chapter 1

Introduction

The pursuit of operational excellence and continuous improvement is crucial for companies in the fast-paced and competitive field of manufacturing and distribution. In line with this objective, this dissertation project was undertaken within the context of Higicol, a cosmetic company specializing in the production and distribution of beauty and personal care products. The focus of this project is to improve the picking process within Higicol's operations, aiming to enhance efficiency, reduce errors, and optimize overall productivity.

This dissertation was carried out in the scope of the Masters' degree in Industrial Engineering and Management. The dissertation was carried out in a company, providing direct contact with an entrepreneurial environment.

This chapter provides a concise overview of Higicol's background and its position within the industry. It also discusses the context and goals of the project. Furthermore, the methodology employed to achieve improved outcomes for the project will be outlined. Lastly, the structure of the dissertation will be presented.

1.1 Framework of the Project and Motivation

The picking process in the context of the distribution industry is a topic that is constantly in development and new technologies and policies arise constantly to improve one of the most time-consuming and money-losing activities of the distribution chain.

Due to the changing technological landscape, the picking process, which involves sorting and extracting products from inventory to fulfill customer orders, has undergone significant changes. The picking process has been transformed by the development of cutting-edge technologies like artificial intelligence (AI), machine learning, robotics, and automation, making it more effective, accurate, and adaptable to shifting customer demands.

The introduction of intelligent picking systems and robotic automation has greatly enhanced the speed and accuracy of order fulfillment. Automated guided vehicles (AGVs) or autonomous mobile robots (AMRs) are being employed to navigate warehouse aisles, locate products, and

transport them to the picking stations. These technologies minimize the reliance on manual labor, reduce the risk of errors, and increase overall picking productivity.

Furthermore, technologies like barcode scanning, RFID tagging, and computer vision have improved the traceability and identification of products, enabling faster and more accurate picking operations. Real-time data capture and analysis facilitate inventory management, ensuring optimal stock levels and reducing the chances of stockouts or excess inventory.

Besides the new technologies, picking policies are crucial in the distribution sector. These policies act as guidelines that specify the best methods and techniques for choosing and removing goods from stock to fulfill customer orders. Companies can minimize errors, lower operational costs, and raise general customer satisfaction by implementing effective picking policies.

Amidst these policies and new technologies, the project of this dissertation arose. The chance to implement some of these tools to improve the time-consuming nature of the picking process was the perfect opportunity to apply some of the concepts studied in the scope of the degree of Masters in Industrial Engineering and Management.

1.2 Higicol Presentation

Higicol, SA is the leading company in the nail cosmetic market in Portugal. This company focuses on producing and distributing cosmetic goods for the professional market. Based in Porto, Higicol was created in 1987, with a focus on cosmetic products for nails, it rose to the leading figure in this area in the domestic market. Recently it began to branch out to other cosmetic areas such as Makeup and hair coloration.

Now, having a greater focus on internationalization, Higicol is present in various international trade fairs, showing their products in the global market. Having products that are environmentally conscious, the brand has a compromise of environmental sustainability, with campaigns to combat the CO2 emissions produced by their products, which are vegan and non-tested in animals. These points make Higicol a carbon-neutral and cruelty-free company. Employing 62 employees, Higicol internal organizational chart, in Figure 1.1, shows the principal areas of activity, the creation of new products, their marketing, and the logistics of the operations, where this project was introduced.

1.3 Project Objectives

Higicol has been facing a steady growth in the last years leading to a strain in the picking area operations, having difficulty in facing the increase in quantity and size of orders. With a scope on the future of the company, Higicol decided that change in the picking area was in order and an improvement to their system needed to happen in order to remain competitive in the market.

The objectives of the project are, to understand the working method of the company and their typical orders, and after identifying the problems in the picking process to make an improvement to said process.

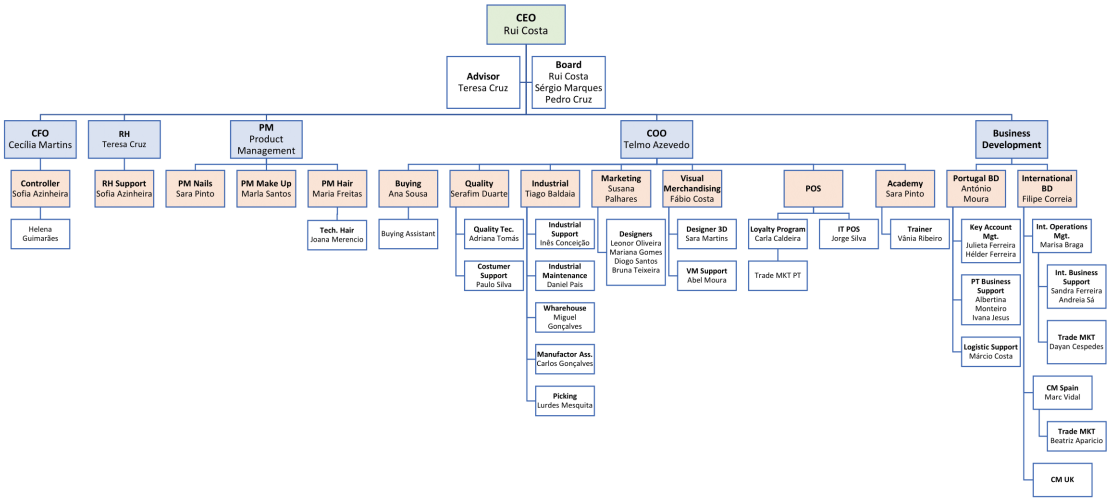


Figure 1.1: Organizaton Chart of Higicol

1.4 Methodology

To start the project, a Gantt chart, in figure 1.2, was created to structure the process. The first part

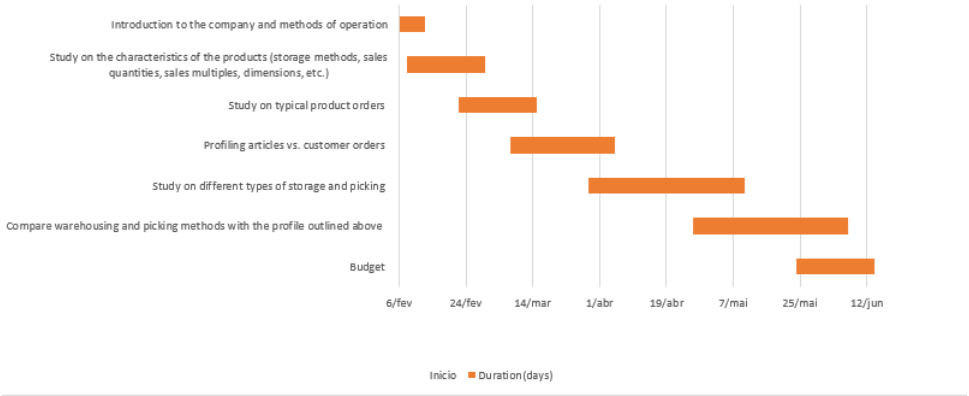


Figure 1.2: Gantt Chart

of the project is a full observation of the method of working in the picking and production area, to have a deep immersion of the work of the company. Afterward it is important to get a knowledge of the dimensions of the products used in Higicol, and the dimensions of the arrival boxes, to get

a better understating of how much stock of each product can be kept in the picking area.

Following this information, the next step is to, by observing the picking process and being involved in the process, get an understanding of the problems of the picking process as well as the opportunities for improvement. This step should be combined with a deep analysis of the data of the orders, with a focus on SKUs and clients to better understand the type of transactions needed for Higicol to remain a top competitive company.

Utilizing the knowledge gained by the literature review in the field of warehouse picking and the research of new methods of picking, several scenarios of possible improvements should be created and the times of the new scenarios should be calculated to access the time improvement of the changes. These scenarios should focus on a short-term improvement and a medium to long-term one. After having new scenarios with different solutions, budgets should be asked to have a clear cost of implementation of the scenario and to calculate the gains with the investment of said scenario.

Finally, some Key Performance Indicators should be studied and added to the company to keep track of the development of the changes.

1.5 Dissertation Structure

This dissertation has been divided in five chapters, focusing on the research of the concepts of the picking and the application of said concepts in a real-world application.

In the first chapter a brief introduction of the project was presented, explaining the motivations and goals of the project, the company where the project will be designed, and a summary of the methodology that will be used.

The second chapter is focused on the research and explanation of the core concepts related to logistics and more specifically to the picking process. Afterward, in the third chapter, the context of the project and the current state of the company is explained, with a focus on the type of orders and the present picking and routing process.

The methodology of the project will be presented in the fourth chapter, focusing on an analysis that prepared the information for the creation of scenarios that would make changes to improve the picking processes. Furthermore, a comparison of those scenarios is presented and a solution with a longer focus is studied and presented. Finally, the last chapter is focused on the conclusion and review of the whole project along with some indications for the implementation of the scenarios.

Chapter 2

Literature review

This chapter is focused on some of the concepts related to logistics, focusing on warehouse logistics. An emphasis was put on the picking policies and the new technologies that are emerging in for the facilitation of the Picking.

2.1 Supply Chain Management

Supply chain management is a vital subject that focuses on coordinating and optimizing many operations involved in the flow of goods, services, and information throughout the supply chain. Supply Chain Management encompasses the planning, execution, and control of sourcing, procurement, production, and logistics processes. It involves multiple stakeholders, including suppliers, manufacturers, distributors, retailers, and customers, all working collaboratively to deliver products and services efficiently (Chopra and Meindl, 2013) and is defined by the Council of Supply Chain Management Professionals (CSCMP) as "...the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers..." (CSCMP, 2013) A competitive advantage in the marketplace and improved operational performance are all made possible by effective supply chain management for businesses.

To establish operational synergy, it is important to integrate multiple processes and functions. This is one of the main features of supply chain management. Supply chain integration involves the close alignment and coordination of activities between different entities in the supply chain (Lambert et al., 1998). This integration increases efficiency and responsiveness through better information sharing, group decision-making, and process synchronization. The adoption of cutting-edge information systems, the formation of strategic partnerships, and the application of shared performance metrics throughout the supply chain are all examples of effective integration strategies.

2.2 Logistics

Logistics as a concept has existed for centuries, starting as a term for the military during the Napoleonic Wars, attributed to *"the modus operandi of moving and quartering armies"* (Nkunda and Odongo, 2021). The connection of the term with the military has been maintained by General of the Army, Omar Bradley saying “Amateurs study strategy, professionals study logistics” (Kane, 2001). Since then, and due to different changing periods, the term logistics has evolved to the mainstream business area (Anca, 2019)

According to Martin (2011), Logistics can be defined as ‘the process of strategically managing the procurement, movement, and storage of materials, parts, and finished inventory (and the related information flows) through the organization and its marketing channels” as for the Cambridge dictionary defines logistics as "the careful organization of a complicated activity so that it happens successfully and effectively". Logistics management is defined by CSCMP as typically including " inbound and outbound transportation management, fleet management, warehousing, materials handling, order fulfillment, logistics network design, inventory management, supply/demand planning, and management of third-party logistics services providers." (CSCMP, 2013).

Logistics has developed into a multidisciplinary field that includes a wide range of activities and functions. It is now an essential component of supply chain management, facilitating the effective transfer and storage of goods, services, and information across numerous industries.

2.3 Warehouse Logistics

Warehouse logistics, a component of the supply chain, is essential to guaranteeing effective and economical operations. It includes several elements, such as labor force management and warehouse layout, which directly affect picking procedures. Executives must look at novel solutions to streamline judged wasteful warehouse processes to lower expenses and increase operational efficiency. Storage policy, order-picking routing, and strategy, as well as the use of technology advancements like pick-by-light or pick-by-voice systems, and the use of digital tools like warehouse management systems (WMS), are all important components of these strategies.

There are several core operations in warehouse logistics, including receiving, putting away, storing, picking, and shipping. The effectiveness of each operation has a major impact on the overall warehouse efficiency even if they can be thought of as separate entities due to their close interconnection (Avdekins and Savrasovs, 2019). The effectiveness of the picking operation, for example, may be impacted by the placement of a pallet containing high-rotation products. Workers may need to utilize forklifts to store these things in inaccessible places, like high racks, which adds to the time needed compared to floor-level storage. As a result, picking operations can be significantly improved by properly allocating and organizing the items in the warehouse.

Approximately 55% of warehouse operating costs are attributed to the picking operation, which is one of the most resources- and money-intensive warehouse logistics tasks (de Koster et al., 2007). These expenses are not spread equally throughout the selection process but among

its smaller responsibilities. According to Bartholdi and Hackman (2019), the selection activity takes up roughly 55% of the time, followed by searching 15%, extracting 10%, and paperwork 20%. Because of this, many businesses place a high priority on cutting down on travel time when picking activities (Tompkins et al., 2010).

For picking operations to be optimized, warehouse logistics must be managed effectively. The deployment of technical advancements, wise order-picking routing and methods, and effective storage rules all help to lower costs and increase operational effectiveness. Furthermore, minimizing trip distances and improving overall picking operation efficiency are made possible by the right item allocation and organization inside the warehouse and by using cutting-edge technologies.

2.3.1 Warehouse Management System

The efficient operation of warehouses and distribution facilities depends heavily on warehouse management systems (WMS). They are computer programs created to streamline and improve warehouse operations, such as picking, packing, and shipping as well as inventory control and order fulfillment.

The first computer-based Warehouse Management System is attributed to the company Logisticon, renowned for its pioneering work in the logistics industry. In a significant milestone, Logisticon's WMS was initially implemented by the clothing retail giant J.C. Penney in 1975. This marked a pivotal moment, heralding the advent of the modern era of warehouse management (Armenta, 2022).

Acording to Faber et al. (2002), following Dusseldorp (1996), there are three distinguishable types of WMS:

- **Basic WMSs**: A Basic Warehouse Management System (WMS) primarily concentrates on overseeing stock and location control within a warehouse environment. This system relies on scanning technologies to identify goods and subsequently determines optimal storage locations for received items, meticulously documenting this information. Additionally, the WMS generates instructions for storing and picking items, which can be displayed on RF terminals. The warehouse management information provided by this basic system is straightforward, prioritizing throughput efficiency above all else.

- **Advanced WMSs**: In contrast to a basic Warehouse Management System (WMS), an advanced WMS extends its capabilities beyond stock and location control. It encompasses resource and activity planning to optimize the synchronization of goods flow within the warehouse. This advanced system places a strong emphasis on enhancing throughput efficiency, while also incorporating a comprehensive analysis of stock levels and capacity utilization.

- **Complex WMSs**: A complex Warehouse Management System (WMS) surpasses the capabilities of a basic system by enabling the optimization of individual warehouses or groups of warehouses. This entails providing comprehensive information regarding the location

and movement of each product through tracking and tracing functionalities, as well as facilitating planning, execution, and control of goods flow. To achieve warehouse optimization, a complex WMS employs diverse storage, replenishment, cycle counting, and picking strategies. It also seamlessly integrates with various technical systems such as automated storage and retrieval systems (AS/RS), sorters, automated guided vehicles (AGV), RF devices, robots, and data collection systems. Moreover, a complex WMS offers additional functionalities, including transportation planning, dock door planning, and value-added logistics planning. In some cases, simulation tools are available to optimize system parameter settings and enhance overall warehouse operations. By leveraging these advanced capabilities, a complex WMS enhances operational efficiency, maximizes resource utilization, and optimizes the entire warehouse management process.

As warehouse management continues to evolve, WMS will play a crucial role in adapting to changing industry demands, enhancing productivity, and ensuring efficient supply chain operations. Further research and advancements in WMS technology will continue to shape the future of warehouse management, optimizing processes and meeting the evolving needs of the logistics industry.

2.3.2 Enterprise Resource Planning

The term "Enterprise Resource Planning" (ERP) first emerged in 1990 by The Gartner Group to describe the next generation of software known as Material Requirements Planning II (MRP II) (Nazemi et al., 2012). Manufacturing Resource Planning II (MRP II) and Material Requirement Planning (MRP) systems, which were developed in the 1970s and 1980s, respectively, are the precursors of ERP (Akkermans et al., 2003). In particular business contexts, such as manufacturing, these systems sought to establish systematic connections between multiple elements of information management (Jacobs and Bendoly, 2003).

ERP is described as both a concept and a system by Jacobs and Bendoly (2003), conceptually, ERP entails integrating business processes within a company, resulting in improved order management and control, precise inventory data, improved workflow and supply chain management, and business processes within a company, resulting in their improvement as well as standardized business practices. ERP is a system that represents a technological foundation built to achieve its conceptual definition. It ought to be viewed as more than just a piece of technology; rather, it should be seen as a fundamental platform that supports and maximizes the capabilities of an organization's tools and procedures (Jacobs and Bendoly, 2003).

ERP can be characterized from a variety of angles, including functional, technical, or business-related which can encompass strategic value for the entire organization (Akkermans et al., 2003). ERP is a system that integrates conventional accounting, manufacturing, sales, and other management products to offer an all-in-one solution for thorough business management within organizations (Tarantilis et al., 2008).

ERP software is highly configurable and can be tailored to meet the various needs of users across different economic sectors. As a result, there are currently three different types of ERP software according to Klaus et al. (2000): installed, preconfigured, and generic.

- At its most comprehensive level, ERP software is designed to be generic and capable of serving multiple industries. However, before it can be utilized, it needs to be configured according to the specific needs and requirements of the organization.
- The comprehensive ERP software has been used to create packaged and pre-configured templates that are tailored to specific industry sectors or businesses of a certain size. These are tailored and customized to meet the particular requirements of sectors like automotive or retail, or small and medium size companies.
- For most users, ERP software is implemented as an operational installation following the customization and individualization of the generic or pre-configured package to align with the firm's specific requirements. This process typically takes place on-site, ensuring that the ERP software is tailored precisely to meet the organization's unique needs.

ERP supports multiple industries in two primary ways. Firstly, ERP can possess the capability to support different industries within a single solution, allowing for the coexistence of manufacturing and retailing functionalities, for example. Secondly, ERP can offer preconfigured enterprise-specific solutions tailored to the individual needs of a particular industry (Klaus et al., 2000).

2.3.3 Material Handling

Material handling plays a crucial role in the supply chain, encompassing the movement and storage of goods within and between facilities. Various types of material handling equipment, such as conveyors, cranes, and forklifts, are utilized based on factors like the nature, volume, and weight of the goods, as well as facility layout (Christopher and Towill, 2001). It comprises "short-distance movement that usually takes place within the confines of a building such as a plant or a warehouse and between a building and a transportation agency"(Coyle et al., 2003).

Manual materials handling (MMH) tasks can be categorized as single tasks such as lifting, lowering, pushing, pulling, carrying, and holding. Combined MMH tasks involve a combination of these elemental tasks performed in sequence(Li et al., 2009; STRAKER et al., 1997; Taboun and Dutta, 1989). The terms "multiple task MMH" (Dempsey, 1999) and "complex manual materials handling" (Mital and Ramakrishnan, 1999) describe tasks involving different types of MMH tasks over the duration of a job. The interchangeability and overlapping use of these terms can be streamlined by highlighting the commonality of ergonomic parameters for better classification.

Material Handling can also be achieved with the use of different equipment that can be divided into different categories according to Kay (2012):

- **Transport Equipment**: refers to the tools and machinery employed to transfer materials from one place to another, such as between different workstations or from a loading dock to

a storage facility. It includes conveyors, cranes, and industrial trucks. However, the material can also be moved manually without the aid of any equipment.

- **Positioning Equipment**: refers to the machinery and tools utilized to manage materials within a specific location. Its purpose is to facilitate the feeding and manipulation of materials, ensuring they are correctly positioned for subsequent handling, machining, transport, or storage. Unlike transport equipment, positioning equipment is typically employed within a single workplace. However, it is worth noting that materials can also be manually positioned without the assistance of any equipment.
- **Unit Load Formation Equipment**: is utilized to secure materials in order to preserve their integrity during transport and storage as a single load. In cases where materials possess inherent self-restraint, such as a single part or interlocking parts, they can be consolidated into a unit load without the need for additional equipment.
- **Storage Equipment**: Storage equipment refers to the machinery and tools employed to retain or buffer materials for an extended duration. Certain storage equipment may also involve the transportation of materials, such as the S/R machines of an AS/RS (Automated Storage and Retrieval System) or storage carousels. However, if materials are directly stacked in blocks on the floor, there is no need for additional storage equipment.
- **Identification and Control Equipment**: is utilized to gather and transmit the necessary data required to coordinate the flow of materials within a facility, as well as between a facility and its suppliers and customers. This equipment facilitates the collection and communication of crucial information.

2.3.4 Warehouse Layout Design

Warehouse layout design plays a crucial role in the overall warehouse design process. It is a complex task that involves making strategic, tactical, and operational decisions to create an efficient and effective layout. The goal is to maximize space utilization, equipment utilization, labor utilization, accessibility to all items, and the protection of stored items. The layout design of a warehouse is determined during the design phase and encompasses various tradeoffs between conflicting objectives. It is a structured approach to decision-making at different levels: strategic, tactical, and operational. Strategic decisions, which have long-term impacts and involve significant investments, include determining the process flow design and selecting the type of warehouse systems. Tactical decisions are made based on strategic choices and involve dimensioning storage systems, designing the layout, and selecting equipment. Operational decisions, made at the lower level, are focused on short-term control policies within the constraints set by higher-level decisions (Rouwenhorst et al., 2000). Warehouse layout design is a critical aspect of the overall warehouse design process. It involves making decisions about the placement of departments, equipment, storage space, paths, and more within a warehouse facility. Two types of layout decision problems can be distinguished: facility layout problem and internal layout design or aisle configuration problem

(de Koster et al., 2007). The facility layout problem focuses on determining where to place various departments within the warehouse, such as receiving, picking, storage, sorting, and shipping. The objective is to minimize handling costs, such as travel distances, or optimize based on "closeness ratings." On the other hand, the internal layout design problem deals with the placement of equipment, storage space, and paths within each department (Dukic and Opetuk, 2012).

In addition to layout design, warehousing strategies play a vital role in warehouse design. Warehouses are classified into distribution-type, production-type, and contract-type based on their functions (van den Berg et al., 1999).

- Distribution-type warehouses gather different products from multiple suppliers for delivery to various customers.
- Production-type warehouses store products with diverse characteristics within a production facility.
- Contract-type warehouses provide warehousing services for different customers.

The warehousing process involves several phases, including receiving, storage, order picking, and shipping (van den Berg et al., 1999; Rouwenhorst et al., 2000). During receiving, goods are unloaded, checked, and prepared for transport to the storage area. Storage involves allocating goods to reserve or forward storage areas. Order picking refers to retrieving goods from their storage locations when needed, typically carried out by order pickers. Shipping encompasses activities such as order checking, sorting, packing, and loading onto trucks. Additionally, cross-docking can be employed as a rapid consolidation and processing technique, involving direct transfer from receiving trucks to shipping trucks (Chen et al., 2006; Heragu et al., 2005).

warehouse layout design requires a comprehensive approach, considering strategic, tactical, and operational decisions. The objective is to achieve optimal space, equipment, and labor utilization while ensuring accessibility to all items and safeguarding stored goods.

2.3.5 Order Picking Strategy

There are three major order-picking strategies: batch picking, zone picking, and discrete picking (Ackerman, 1997).

- **Discrete Picking**: a picker takes on the responsibility of selecting all the items in a single order during a pick-tour. They navigate through the storage area, focusing on one order at a time.
- **Batch Picking**: involves grouping multiple orders together into batches. A picker is assigned a specific batch and works on picking all the items within that particular batch. This approach streamlines the process by minimizing travel time between different orders. The proximity order-batching problem in manual-pick wave-picking warehouses was addressed by GADEMANN et al. (2001) to minimize the maximum lead time of any batch. The problem was considered an NP-hard and proposed a branch-and-bound algorithm for exact

solutions in small instances, along with a 2-opt heuristic procedure for larger instances. The 2-opt heuristic produced tight upper bounds and was practical for real-world applications. Another approach by GADEMANN and VELDE (2005) extended the study of the order-batching problem in manual picking systems by considering the objective of minimizing the total travel time. They showed that even in this more general case, the problem remains NP-hard when the number of orders per batch exceeds 2. To tackle this problem, a branch-and-price algorithm for optimal solutions in moderately-sized instances was envisaged, and suggested using an iterated descent approximation algorithm for larger instances. Due to the NP-hard nature of the problem, many studies have focused on developing heuristic methods for order batching. Two common types of heuristics for manual picking systems are seed algorithms and savings algorithms. Seed algorithms construct batches through seed selection and order congruency phases. Seed selection rules define a seed order for each batch, while order congruency rules determine which unassigned order should be added next to the current batch based on a measure of distance from the seed order. Several studies have explored seed algorithms for different picking systems, including single-aisle man-on-board AS/RS systems and multiple-aisle systems (de Koster et al., 2007). Saving algorithms, based on the algorithm of Clarke and Wright (1964) for the vehicle routing problem, aim to obtain savings in travel distance by combining small tours into larger ones. Four batching heuristics which included the SL algorithm (combine Small with Large orders) generated the smallest travel distances (Elsayed and Unal, 1989).

- **Zone picking**: assigns each picker to a specific region or zone within the storage area. They are exclusively responsible for picking items within their designated zone. This method optimizes efficiency by reducing the distance traveled within the warehouse. Despite having a significant impact on order-picking systems, the zoning issue has received less attention than other planning-related issues. Zoning has benefits like reduced order pickers' travel distances, less traffic, and better familiarity with item locations. The requirement to combine orders split across zones before shipping is a significant drawback. This problem is addressed by two methods: parallel picking, in which multiple pickers work on the same order in different zones, and progressive assembly (pick-and-pass), in which orders are sequentially worked on in various zones. To maximize efficiency, zoning strategies frequently take into account product characteristics like size, weight, temperature, and safety requirements (de Koster et al., 2007).

Briefly, in discrete picking, a picker takes on the responsibility of selecting all the items in a single order during a pick-tour. They navigate through the storage area, focusing on one order at a time. Batch picking Zone picking assigns each picker to a specific region or zone within the storage area. They are exclusively responsible for picking items within their designated zone. This method optimizes efficiency by reducing the distance traveled within the warehouse (Parikh and Meller, 2008).

There are, however, some variations of these strategies like wave picking or bucket-brigade (de Koster et al., 2007; Parikh and Meller, 2008).

- **Wave Picking**: is when in zone picking or batch picking, orders for a common destination, from different areas of the warehouse are required to be picked in a predefined time window (known as a wave).
- **Bucket Brigade**: The bucket-brigades concept coordinates workers in progressive product assembly along a flow line. Orders are passed from one worker to another until completion. When the worker closest to the end finishes an order, they walk back and take over the next order upstream. This continues until the system starts with a new order. Workers' speeds must be appropriately sequenced for optimal functioning. Bucket brigades minimize idle time and enhance assembly line efficiency (Bartholdi III et al., 2001).

2.3.6 Storage Policy

Storage policies or storage location assignment problem (SLAP), "is an operational decision associated with the accommodation and picking process, influencing batch definition, classification, routing, and order sequencing." Reyes et al. (2019). This problem has various policies that can be implemented to try and solve the problem, from which the most representative are random storage, dedicated storage, and class-based storage (Hausman et al., 1976), Bahrami et al. (2019) refers to random storage policy as haphazard policy. Bahrami et al. (2019) also exposes the possible solutions in the Figure 2.1: The dedicated policy can be described as reserving specific locations for

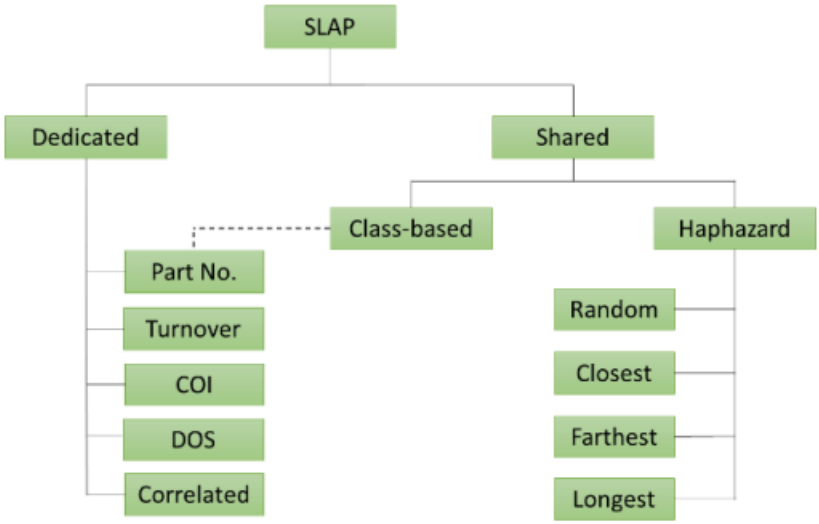


Figure 2.1: Storage Policies Classification

products, even when they are out of stock. This results in low space utilization as sufficient space must be allocated to accommodate the maximum inventory level. However, dedicated storage

offers benefits such as facilitating the familiarization of order pickers with product locations and aligning product-to-location assignments with store layouts. This arrangement can enhance efficiency by logically grouping products and potentially reducing work in the stores. Additionally, dedicated storage can be advantageous for products with different weights, as it allows for appropriate stacking sequences and routing of order pickers. In certain cases, dedicated storage can be applied in pick areas while allowing random storage in a bulk area for replenishment, mitigating some of the disadvantages associated with this storage policy (de Koster et al., 2007). In dedicated storage policies, storage locations are allocated and reserved for SKUs throughout the planning horizon based on several determinants. These determinants include compatibility, complementarity, popularity, and space. Compatibility refers to storing items in proximity to prevent the risk of contamination, infection, corrosion, or other damage. Complementary items, which are frequently ordered together, can benefit from being stored in adjacent locations. Popular items with higher demand are best stored closer to the output area as they contribute the most to the total traveled distance (Bahrami et al., 2019).

Random storage is a simple procedure that relies on the availability of storage locations. Common haphazard policies include random location assignment, closest open location, farthest open location, and longest open location (Gu et al., 2007). These policies are popular in practice due to their simplicity and advantages, such as space utilization, easy implementation, immunity to demand and assortment fluctuations, and uniform usage of aisles, which reduces congestion. However, these policies require a tracking system to manage the positioning of SKUs, and they lack a systemic view, which can impact global warehouse performance (Quintanilla et al., 2015). This policy is only feasible in a computer-controlled environment (Petersen, 1997).

The concept of class-based storage combines different methods for organizing items in a warehouse. One approach is Pareto's method, which divides products into classes based on their popularity. The fastest moving class, referred to as A-items, typically represents around 15% of the products but contributes to about 85% of the turnover. Each class is assigned to a dedicated area in the warehouse, and storage within each area is random. The classes are determined based on measures of demand frequency, such as COI or pick volume. Class-based storage, often referred to as ABC storage when using three classes, offers advantages such as proximity of fast-moving products to the depot, flexibility, and low storage space requirements (Roodbergen and Vis, 2009).

Class-based storage requires more rack space compared to random storage, as empty slots must be available in the designated class regions to accommodate incoming loads (Graves et al., 1977). However, it remains popular among practitioners due to its simple implementation, manageable maintenance, and ability to handle product mix and demand variations (Le Duc and De Koster, 2005). The strength of the class-based policy lies in its ability to leverage the logic of dedicated storage while avoiding its exhaustive tasks. Once products are classified based on specific criteria, the criteria can be neglected for the planning horizon, allowing for the simplicity and convenience of a haphazard storage policy (Petersen and Aase, 2004a).

Bahrami et al. (2019) shows how class-based policy can be implemented in Figure 2.2

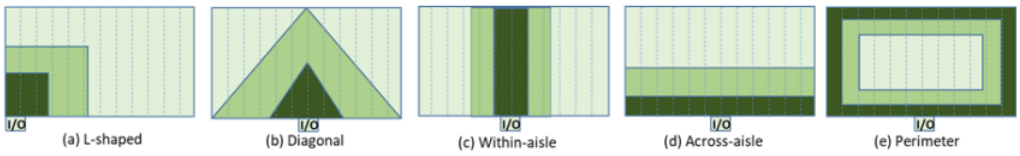


Figure 2.2: Implementation of Class-based Policy

2.3.7 Routing

Routing policies dictate the sequence in which SKUs are picked from the pick list, with the objective of minimizing picker travel distance. Optimal procedures provide the best solution but can result in complex routes (Ratliff and Rosenthal, 1983). Traversal routing, a commonly used policy in many warehouses, is simple and effective when there is a high pick density per picking aisle. It requires pickers to traverse the entire aisle once entered. Combined heuristics, such as the traversal and return routes, further reduce picker travel and yield near-optimal results (Petersen and Aase, 2004b). Some of the most used heuristics are S-shape, largest gap, Return, Mid-point, Combined, and Optimal. The S-shape and largest gap heuristics are widely employed in real warehouses because order pickers prefer straightforward and non-confusing routing schemes (Henn, 2015). Similarly, the return and midpoint heuristics are prevalent due to their ease of use and low error rates during routing and picking (Rao and Adil, 2013). The composite routing policy, a highly effective heuristic procedure, particularly excels when the pick list size is large (Petersen, 1997), as it combines elements of the S-shape and return policies. Albeit the largest gap routing and composite routing are relatively more complex than S-shape routing, they have the advantage of obtaining shorter walking distances (Cano et al., 2017).

In Figure 2.3, Ratliff and Rosenthal (1983) illustrate an example of these heuristics. The S-shape and largest gap heuristics are widely employed in real warehouses because order pickers prefer straightforward and non-confusing routing schemes (Henn, 2015). Similarly, the return and midpoint heuristics are prevalent due to their ease of use and low error rates during routing and picking (Rao and Adil, 2013). The composite routing policy, a highly effective heuristic procedure, particularly excels when the pick list size is large (Petersen, 1997), as it combines elements of the S-shape and return policies. Albeit the largest gap routing and composite routing are relatively more complex than S-shape routing, they have the advantage of obtaining shorter walking distances (Cano et al., 2017).

The **S-shape routing policy** is a simple strategy where the picker enters an aisle from one end and exits from the other (Petersen, 1997). The picker traverses the entire aisle if there is at least one requested item, and proceeds to the next aisle with requested items. Aisles without items to be visited are skipped. If the last aisle with requested items has an odd number, a return travel is performed in that aisle. The S-shape routing policy performs well in terms of minimizing travel distance when the pick density per picking aisle is high. However, it becomes inefficient for small pick-list sizes (Cano et al., 2017). Although this routing policy has the order picking transversing

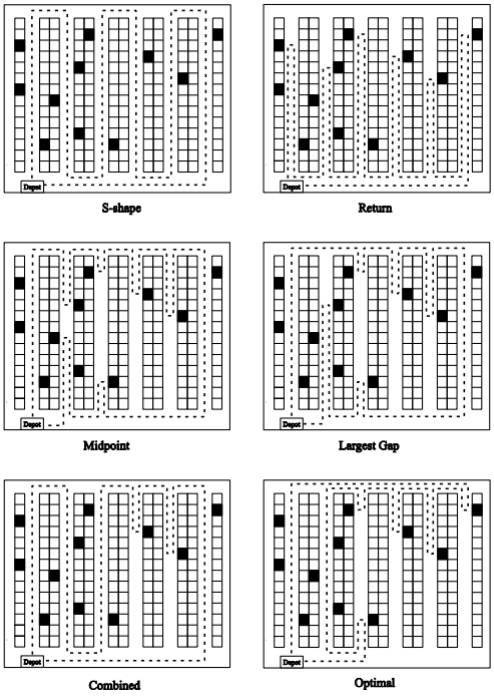


Figure 2.3: Example of Routing Heuristics

the aisle entered, making the travel non-productive, it has the advantage of reducing congestion (de Koster et al., 2007)

Developed by Hall (1993), the **Largest gap routing policy** selects the shortest distance between items to be picked and the ends of the aisles. The "gap" refers to the separation between adjacent items or between the first/last item and the front/back aisle. The picker travels in an aisle only to the largest gap between two items and uses it as a reference point to return to the cross-aisle. Aisles, except the first and last visited aisle, are abandoned on the side of the entrance. The largest gap routing policy is effective for small pick sizes and warehouses with long aisles but becomes inefficient for a large number of picks (Dukic and Oluic, 2007).

The **Mid-point strategy** divides the warehouse into two sections, and the picker can access an aisle only up to the midpoint. The picker performs return routes from the front or back aisles or both. The last aisle is traversed to enter the back aisle, while the first aisle is traversed to exit the back aisle. The mid-point heuristic is always outperformed by the largest gap, however, it hedges in simplicity (de Koster et al., 2007). This method is more effective than the S-shape if the number of items per aisle is less (Hall, 1993).

Return Routing Policy: **Return routing policy** is a simple heuristic where the picker enters and leaves every pick aisle from the front cross-aisle (van Gils et al., 2016). In the aisle, the picker enters and exits by the same end, in the aisle, the picker travels to the farthest pick location. The return policy performs better for very small order sizes but shows decreased effectiveness for large order sizes (Petersen, 1997).

The combined routing strategy combines features of the return and traversal strategies to

minimize travel distance between the farthest picks in adjacent aisles. It determines the shortest way to each aisle individually, deciding between a return or traversal strategy based on the location of items in the next pick aisle (de Koster et al., 2007). The composite routing strategy performs similarly or even better than optimal procedures, especially for larger pick list sizes (Petersen, 1997).

2.3.8 Picking Technologies

In the pursuit of operational excellence and meeting customer demands, organizations are increasingly recognizing the significance of carefully evaluating and integrating technologies into their picking operations. The following technologies have become a staple in the picking industry:

- **RFID**: One of the many technologies included in the category of Automatic Identification (Auto ID) is RFID technology. Barcodes, magnetic inks, optical character recognition, voice recognition, touch memory, smart cards, and biometrics are just a few of the technologies that fall under the umbrella of the Auto ID domain. These technologies offer new ways to regulate the movement of information and materials, especially in complex production networks. RFID technology, in particular, makes it possible to obtain data about a specific item without having to physically touch or see the data carrier. Either electromagnetic waves or inductive coupling are employed to achieve this. The data carrier, also known as a transponder or tag, is made up of a microchip attached to an antenna. The tag makes information transmission easier. The tag makes it easier for data to be transmitted from the chip to a reader (or transceiver) placed within a predetermined range. The reader can then transmit the data it has collected to a host computer. Data encryption can be used for security-critical applications to increase the capabilities of the middleware (software for reading and writing tags) and the tag itself, though doing so comes at an additional cost. Anti-collision algorithms may also be built into the tags to allow for simultaneous reading of several tags (Ilie-Zudor et al., 2006).

  RFID tags exhibit three distinct categories: active, passive, and semi-passive. Active tags are equipped with a battery that supplies power, enabling the transmission of signals to a reader within a range of up to 30 meters. In contrast, passive tags lack a battery, rendering them considerably more cost-effective than their active counterparts. Passive tags are read when they traverse the electromagnetic field emitted by a reader (Dinning and Schuster, 2003). Another classification of tags is the semi-passive type, which relies on both an internal battery and the electromagnetic waves emitted by the reader for power (Angeles, 2005). Semi-passive tags find utility in monitoring environmental variables, such as the temperature of frozen food or the level of humidity in a container. Passive tags offer a significantly more economical alternative to active tags, enabling cost-effective tracking at the pallet, case, and item levels; the predominant interest among practitioners regarding RFID technology applications to date primarily lies in passive tags; and read-write tags provide an ongoing historical record of the tracked item, thereby enhancing transparency within the supply chain

(Wilding and Delgado, 2004). Tags can further be categorized as chip-based or chipless. Chip-based tags feature a microchip for storing data and a coupling element, such as a coiled antenna, to enable radio frequency communication. In contrast, chipless tags do not have an integrated electronic chip and are used as anti-theft and anti-counterfeiting tools. There are three subtypes of chip-based tags: read-only, write once/read many times, and read-write. Read-only tags are frequently used to track assets with a persistent unique identifier over the course of their lifespan because they have unchangeable data that cannot be changed unless the chip is subject to electronic reprogramming. On the other hand, read-write tags allow changes to the data stored and are used to track items as they move through the supply chain (Li, 2006)

- **Voice-Picking**: A voice-picking system is an advanced solution that employs speech recognition technology which enables efficient communication between warehouse operators and the warehouse management system. Pickers use a headset and microphone to speak verbal confirmations of their actions back to the system as they receive voice commands for picking tasks. This system improves efficiency in warehouse operations by streamlining the picking process (Battini et al., 2015).

  According to Gleissner and Möller (2011) voice picking systems function in the following manner: each warehouse operator utilizes a battery-powered voice terminal connected to an earphone, typically worn at the belt. The operators listen to voice instructions through the earphones and use the built-in microphone to confirm their actions. Through a radio transmitter, communication with the warehouse management system is made possible. Operators are informed of the total weight of the active order and the required loading equipment before a picking session begins. Operators must recite unique verification codes and receive confirmation before continuing at each article location in order to reduce errors. Contrary to popular belief, voice recognition technology does not necessitate a voice profile for each employee (Gleissner and Möller, 2011). The program is made to account for a wide range of factors, including accent, gender, age, and even momentary speech changes brought on by illnesses like a cold. This system's ability to let users keep their hands and eyes free throughout the process is a significant benefit.

- **Automated Storage and Retrieval Systems**: Automated Storage and Retrieval Systems, or AS/RS systems, are computer-controlled facilities used for the storage and transportation of significant amounts of materials. These systems consist of aisles lined with storage racks that have either distinct or non-distinct cell conveyors. They include storage/retrieval (S/R) machines that transport items between the I/O stations and storage cells, as well as input/output (I/O) stations that make it easier to receive and send items. Storage and retrieval tasks are carried out by the automated stacker crane, which serve as the S/R vehicle, inside the aisles(Atmaca and Ozturk, 2013).

Numerous benefits are provided by AS/RS systems, including quick material storage and retrieval, effective storage space utilization, increased reliability, improved storage management, improved safety protocols, and preservation of material integrity. As a result, meticulous planning must go into the design of AS/RS systems to enable prompt responsiveness and ensure optimal system performance(Potrč et al., 2004).

- **Vision picking**: Pick-by-vision is the practice of using head-mounted displays or smart glasses for visual assistance when picking orders (Schwerdtfeger et al., 2009; Herzog et al., 2018). It entails an unauthorized picking procedure that incorporates visual components into the actual environment as seen by the device. The application of augmented reality (AR) to order picking, applicable to different augmented reality picking techniques for warehouse management systems (WMS), entails the preparation and processing of input data, the proposal of optimal picking routes, the provision of an augmented reality navigation system, the choice of suitable software and hardware resources, the transformation of picking routes into process maps within the AR software, and the execution of the picking process (Krajcovic et al., 2014). The operator must communicate during a pick-by-vision task using voice, gaze, or gestures (Jumahat et al., 2022). Virtual arrows are used by AR tools like smart glasses to direct users to the designated pickup location and then display the number of items that need to be picked. The AR system allows the operator to view virtual data such as the item's name, quantity, and location (Tang and Liu, 2021). Information in pick-by-vision systems is primarily derived from visual perception. However, it is necessary to further divide these systems into groups according to whether or not they make use of tracking technologies. Without the use of tracking technologies, systems estimate the user's location and primarily display textual data as lists of items or images. These systems are referred as Pick-by-Vision (2D) systems to make a distinction. On the other hand, systems that explicitly use augmented reality (AR) and incorporate tracking technologies are known as pick-by-vision (AR) systems (Schwerdtfeger et al., 2009).

Chapter 3

Current State

To improve the picking, it was necessary to analyze the current situation at Higicol. This company has several different processes occurring simultaneously in their different warehouses, inter alia the production of the lines related to the products of into the nail category, the logistic processes related to the inbound and outbound of materials, including receiving and handling stock, and the dispatch of orders, the last partof the focus of the analysis.

To access the problems and possible improvements of the picking process, an in-depth analysis of the picking process as well as the items and clients of the company was undertaken.

3.1 Products Sold and their Rotation

A comprehensive understanding of the types of items and their rotation patterns is crucial for developing effective picking improvement strategies. By analyzing the characteristics and rotation dynamics of company items, organizations can optimize their picking operations, minimize inefficiencies, and enhance overall productivity.

Higicol has 2490 SKUs that can be divided into three distinct bigger categories, a smaller one with less rotation, and some items that are not grouped but also do not represent a substantial part of the sales:

- **U**: This category of SKUs is the oldest one, having been launched in 1987 and the most successful out of Higicol. It clusters every SKU that is focused on nails and its sub-dived in several different lines:
  - Accessories
  - All In One
  - Builders
  - Equipment
  - Essentials
  - Gel Complements
  - Gel Polish
  - Nail Art
  - Nail Care
  - Nail Polish
  - Pro Kit
  - The Gel Polish

  This category of products produces around 80% of the total sales of the first quarter of 2023. Higicol produces most of these SKUs in their factory, outsourcing only the Equipment and

Accessories lines. The company has two brands in the nail category, one being their on-brand Andreia, and the other Kelly K. The Kelly K brand is produced and sold directly to one reseller. The nail-related SKUs are the main focus of the company, always creating more lines and selling limited edition products. The SKUs in this category that are of the Gel Polish, Nail Polish, The Gel Polish, Gel Complements, and Nail care lines have the rule that can only be sold in packs of six.

- **Hair**: The newest line of Higicol, launched in July of 2022, is related to SKUs for hair and also divided into different lines:
  - Accessories
  - Color
  - Color Care
  - Essential

  This category of SKUs is still in its growing phase, having 12% of the sales of the first quarter of 2023, the 208 SKUs of this line are outsourced and Higicol does its distribution and define the formula and the design internally:
- **Makeup**: A-line launched in 2018, focused on make-up articles and divided into the following lines:
  - Essentials
  - Eyes
  - Face
  - Geral
  - Lips

  The Makeup SKUs make 6% of the total sales of the first quarter of 2023 and it is also outsourced and distributed by Higicol which defines the formula and design as well. This ;
- **BHF** This is a smaller line of articles, with less than 1% of the sales in the time considered in the previous families. This category only has the line Care with 13 SKUs and it is focused on SKUs for the Body, Hands, and Feet.

To better understand the rotation of these products some ABC analyses were done focusing on the SKUs individually, the category of products, and the lines of products within the families.

The criteria for the ABC analysis of all the SKUs were the following:

- **T** - SKUs with cumulative percentage of 20% the value of sales
- **A** - SKUs with cumulative percentage of 50% the value of sales
- **B** - SKUs with cumulative percentage of 80% the value of sales
- **C** - The rest of the SKUs

Due to the Hair category of SKUs not having the same time in the market as other SKUs, the time for this ABC analysis was limited to the first quarter of 2023.

The results of the analysis of the SKUs are exhibited in Table 3.1

Table 3.1: Table with results of ABC analysis to the SKUs

	%consumption	number of items	%items
T	20%	10	1%
A	50%	57	3%
B	80%	193	11%
C	100%	1470	85

3.2 Type of Orders

The key to effective supply chain management is efficient order fulfillment. Understanding the various order types and their effects on picking operations is essential as the demand for quicker and more accurate order processing keeps growing. Therefore, there is a need to examine the various order types of the company. Starting by first focusing on the type of clients.

3.2.1 Type of Clients

Higicol operates as a distribution business selling their manufactured products to retailers, for them to sell to the public. The client landscape for a manufacturing company selling goods to retailers is varied and includes several retail businesses with varying traits and preferences. Understanding the many sorts of retail customers enables the business to customize its picking procedures to meet the particular requirements and standards of each client. The clients of Higicol can be divided in three central cost groups:

- **P**: This cost group is composed of a retailer of cosmetics products that had a market share of 30% of the sales of Higicol in 52 weeks. On account of this fact, Higicol has an arrangement with the retailer to facilitate the orders. Orders from this retailer enter the Higicol system on Thursday or Friday and are prepared till next Wednesday were they are shipped. Higicol is in constant contact with this retailer thinking of new approaches that can help both paths such as utilizing the retailer's standardized packaging for order-picking purposes.

- **National**: Composed by retailers based in Portugal, with 34% of the sales, this group of retailers was grouped together because of their geographical context and the similarity of the delivery of the orders.

- **International**: Retailers based outside of Portugal, with 25% of sales. These retailers are grouped together due to the added work of shipping an order outside the country, having to pass customs, and due to the rules of some countries having to go to extra steps such as changing the language of the label to that of the country where the order is being sent or having to send the batch production date of the products.

There is also an important subgroup of clients called "Corners". These retailers have an arrangement with Higicol where the distributor controls the order by following the trend of the market

and having access to the information on the sales of the retailer. The orders of these retailers have higher priority than regular orders because the company has a greater responsibility with a schedule to fulfill and less flexibility. These orders normally come through on Monday or Tuesday every two weeks.

3.3 Layout of the Warehouses

The optimization of picking performance largely depends on an efficient factory layout. Material handling, workstations, equipment and storage areas are all taken into account when designing a factory layout that facilitates seamless movement and minimizes wasted efforts. Proper factory layout is critical in maximizing overall operational efficiency and satisfying customers. By specifically tailoring the layout to optimize picking operations, organizations can ensure the best results are achieved. Understanding the current state of the facility is integral to enhancing its layout.

Higicol has at its disposal four warehouses where items can be stored, three of these warehouses are used exclusively for storage, while one, which will be called the first warehouse, albeit used for storage, is also used for picking, packing area, and as the production area of the company. On account of the first warehouse holding the production area, it has to abide by some additional rules.

The first warehouse can be divided into four distinct parts: the production area, the stock-keeping area, the picking area, and the packing and shipping area. Because of the existence of the production area which works with flammable primary materials, the warehouse needs to be equipped with safety measures such as sprinkles in that area and is limited in the changes that can be executed considering it can alter its thermal mass. The stocking area serves the purpose of being a backup for some SKUs of the picking area so that it was not needed for the restockers to visit other warehouses. The picking area is composed of four rows of back-to-back racks and a single rack paired with storage shelves for smaller products, the four rows of racks have corridors between them and one corridor at the end. After this corridor, there are other four rows of racks and a single rack. At the beginning of the picking area, there is an area where the packing of the products can be made, it consists of a long workbench, where products can be packed and then shipped. The second area consists of stock needed for the production area as raw materials. This warehouse has an area specific to stocking hazardous materials. The third and fourth warehouses were used as stock for items that were produced by outside suppliers, and the third warehouse had an area for the team responsible for quality management to work. In Figure 3.1, there is a layout for the first warehouse .



Figure 3.1: First Warehouse Layout

3.4 Type of Storage

The choice of an appropriate storage system is essential for ensuring effective and precise order-picking operations in the world of warehousing and logistics. The suitability and efficiency of various storage systems are greatly influenced by the current conditions in a warehouse. Higicol uses three different types of storage for its products:

- **Shelves**: Most of the SKUs in the U category and all of the SKUs of the Hair category that is presented in the picking area are stored on shelves. These SKUs are small to medium in size and the shelving method provides easy access for the pickers. In figure 3.2 there is an example of this type of storage.

- **Storage cabinet**: The SKUs related to the Makeup category are in this type of storage, these items are small in dimension and the use of a cabinet saves space compared to the shelves. An additional factor for this type of storage is the fact that, unlike the other SKUs the shape of the Makeup SKUs does not allow safe storage on the shelves or a good utilization of the space provided. Figure 3.3 shows an example of the storage cabinet location.

- **Floor level storage**: Some SKUs of the U category, namely some of the SKUs of the equipment line, are too large to be stored on shelves, and different methods are needed for these items, this method is showned in Figure 3.4.



Figure 3.2: Shelves Storage Location



Figure 3.3: Storage cabinet Storage Location



Figure 3.4: Floor Level Storage Location

3.5 Routing Process

The SKUs in the picking area of Higicol are divided into their lines, which means all the products within the same line will be in the same aisle. For instance, The Gel Polish line will all be in the set of racks in the same aisle, aisle M in this case. The routing process in Higicol works by giving a letter corresponding to the set of racks on the same side of an aisle as seen in Figure 3.5. The routing in Higicol consists of the pickers traversing the whole aisle multiple times to access a set

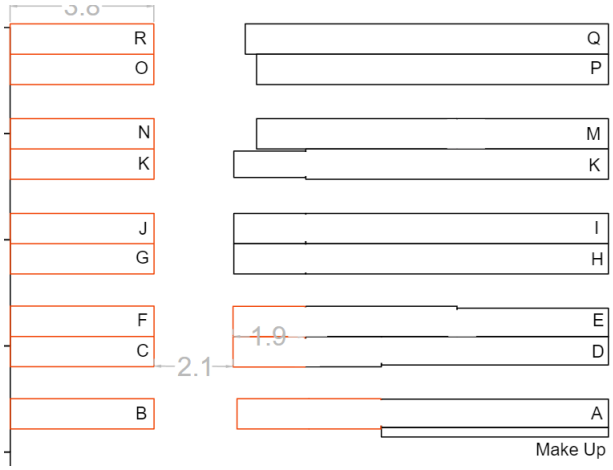


Figure 3.5: Example of the Naming of the Set of Racks

of racks. The packing list uses the lettering of the set of racks to know which aisle to be covered first. Inside the aisle, the routing of a set of racks is also done in a S-shape as shown in Figure 3.6. The SKUs are distributed in the racks by their reference number following the S-Shape referenced above.

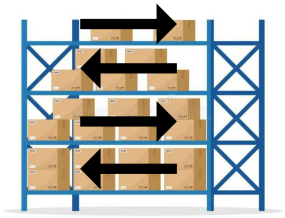


Figure 3.6: Example of Routing in a Rack

3.6 Picking Process

The picking stage at Higicol is still very elementary. The pickers receive a paper with the list of SKUs needed for the order and the quantity needed. With that paper, the picker, then, has to use his/her experience as well as the knowledge of where a line of products is stored to walk to the product, pick it by hand and carry it until he/she can not hold any more items. Following this step proceeds to the packing area where the picker drops the items, and goes for another round of picking. In the parking area, there is a person responsible for storing the items in boxes. In the packing process, every box used for an order has a number and the packer needs to confirm if the quantity of the SKUs is correct and to save the information of the box used for each product. This method is done for situations where there is a problem with an order and Higicol can use this information to know what box was sent wrong or in which box the wrong product was sent. It also

has the added benefit of sending additional information to the client about where they can find the products. Figure 3.7 shows the operative system used when the pickers have to insert an item in the system, with the option to choose the type of box that is being used, the number of the box where the item is being packed and bar code and batch of the item

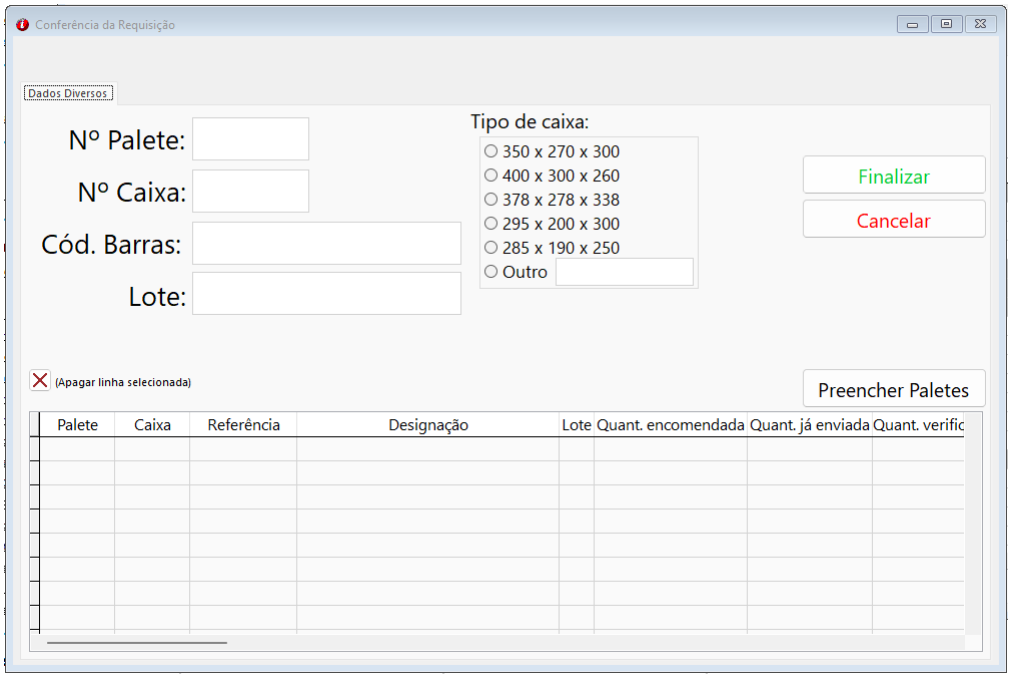


Figure 3.7: Example of the System used for the Packing

The picking process is accomplished by five pickers dived into teams of three, (two teams with two pickers and one with one picker). The teams with two pickers divided the picking and packing process between them, leading to one picker doing the part of picking and the other the part of packing. The team of one picker has to do the process alone.

The restocking of the picking area is done by necessity or by the manufacturers who, when producing a product and noticing that the quantity is not enough to fill a full box, are instructed to save those items in the picking area. The products that are delivered by the restockers are normally taken out of the arrival box and placed in the respective area.

Some orders of international clients involved extra work which makes the picking process more difficult. This extra work involves wrapping the items in bubble wrap paper, having to add new tags that have the language of the country that is receiving the items stick the SKUs with adhesive paper to prove that the products have not been opened in the journey.

In Figure 3.8, there is an example of how the lists of orders are present to be accessed by a worker in Higicol.

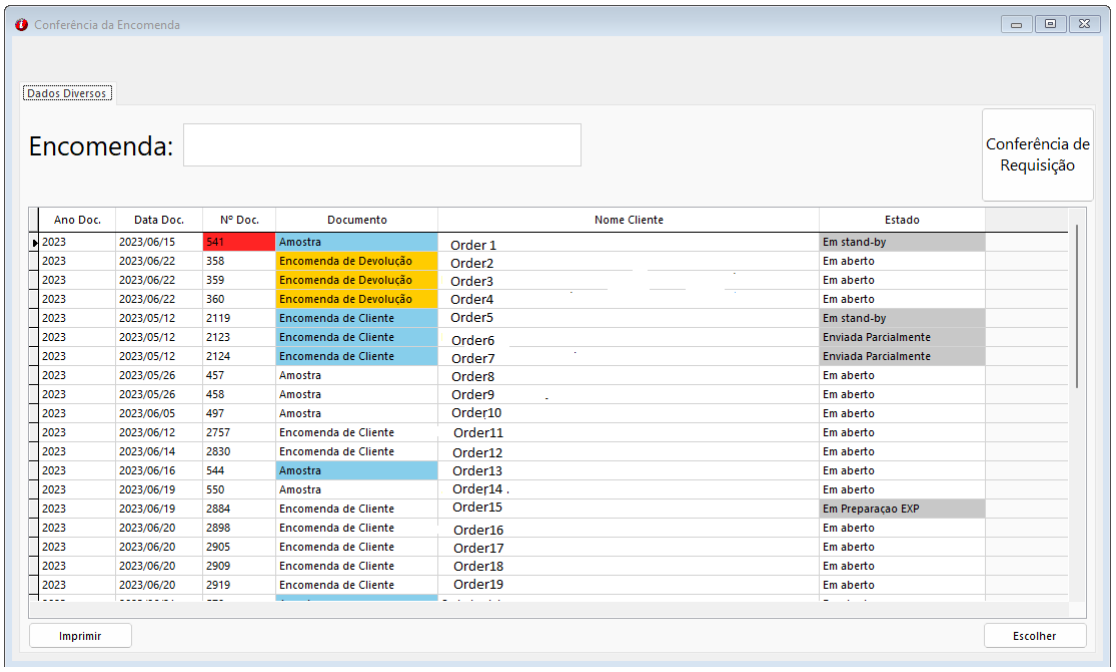


Figure 3.8: Example of the Orders in Higicol

3.7 Problems Identified

To better understand the difficulties and what needs to improve at Higicol, a close inspection of the process was done and the major problems were identified.

- **Company's growth**

  In the prior years, the company has been faced with high growth, which has brought concerns to the warehouse area dedicated to picking. With the growth, Higicol has to be able to match the new demand, which includes difficulties in fulfilling the new batch of orders.

  Higicol S.A. is currently facing stable growth in the sales of its products and with the launch of a new line of hair products, and the continued launch of new products to complement their other lines of nails and makeup. With this growth, a concern about the picking area comes to light, more specifically with the ability to hold the growth in the medium to long term. This problem also comes with the increase in the number of orders, that, with the same workforce, can lead to the overwork of the employees, delays in orders shipment, and mistakes in the fulfillment of orders.

- **Lack of information concerning the restocking of SKUs**

  Following several observations of the picking process there was a lack of information related to SKUs that were not properly being replaced in the picking area. This led to the pickers either having to stop the process to ask the restockers to restock the SKU or having to go to the stocking area to do the restock themselves. Another problem related to the restock of the SKUs was the number of boxes on the floor, which was created by the pickers who

were going to the stock area to pick up the products that had not been replaced and had no time to properly shelved them. These boxes caused difficulties in the movement of the pickers which could pose a problem in some viable solutions as well as being a risk for the safety of the pickers. As Higicol is a company that also has a focus on production, some of the SKUs are produced in the same building as the picking. Due to this, an additional problem is created by the workers. This problem bases itself on the fact that the producers if they make more product than what a standard box can hold, will put the extra directly on the picking area. This process is a standard practice in Higicol, but it comes with problems which concern the validity date of some products that come in different batches.

- **Distance covered by pickers**

  The system in place at Higicol involved the pickers receiving their packing list on paper and accomplishing the picking of those SKUs by going by foot to every location, picking the item and carrying it to the picking area to be paired. This process has the drawback of the pickers not being able to carry a lot of items either by the weight of the items or their size. The process led to the pickers having to do many journeys between the picking of the SKUs and dropping them in the picking area. These journeys meant a lot of time in the process and traveling between locations having to do the same route more than once.

- **Difficulty for newcomers to understand the system**

  The locations of the SKUs in the picking area of Higicol were organized based on an ABC analysis of the different product lines. This analysis served to organize the lines of products by racks and estimate the space needed for each SKU. Inside a corridor of racks, the SKUs were ordered by their reference. When issuing an order this method comes in play by sorting the SKUs based on the corridor of racks they are in. This method allows the pickers to cover every SKU in a corridor before going to the next one. However, while for the actual pickers, this method seems ordinary and they are accustomed to the location of the SKUs, for newcomers it has a big learning curve as there is no additional information of what rack in a corridor the SKU is in.

- **The method used is prone for mistakes**

  The picking system is a very simple one. The pickers receive a copy of the order list with the SKUs ordered by corridors of rack and go to each corridor reading the item on the list, locating it, and carrying it to the packing area. In the packing area, the SKUs are entered in the system connecting the quantity of SKUs to a box, for an easier way to check if there are problems in the orders. The first part of this method is very prone to human errors and depends heavily on the pickers and their ability to pick the quantity of the right item. However, this mistake is corrected in the second part of the picking, which is the packing. Here the pickers have to save each item of the order and the box in which they are packed. This system costs some time but gives information to the client about the order, and in case

of a mistake, it makes it easier to know which items weren't sent and which box had the problem.

- **The optimization of the usage of the packing boxes**

  After the first round of picking, with the correct quantity of the SKUs on the packing list, the pickers must pack those items in boxes to send to the retailers. This task is solely based on the experience of the pickers, having no information about the best way to fully utilize the dimension of the boxes with the items at their disposition.

Chapter 4

Methodology and Results

With the observation of the current situation of the picking process of this company documented in the previous chapter, there were some problems identified, problems which generated inefficiencies in the picking process.

With the knowledge of the existence of this problem, a process to study improvements to the picking process was started. This process began with getting more information about the dimensions of the SKUs, followed by the implementation of a system that allowed the company to better understand the rotation of the products and the study of some hypothesis that could influence the picking process. Subsequently, short to medium-term improvements were sought, and several scenarios were created to get a better grasp of the changes that would produce gains. Finally, a medium to long-term proposal was studied.

4.1 Dimensionalization of the Products

To get a better knowledge of possible changes to the picking, firstly it was needed to get a better understanding of the type of products that were used at the company and the dimensions of the products. For the products of Makeup and Hair that came from outside suppliers, the arrival box dimensions were measured and weighted, and the number of products that came in the boxed written down. The products of nails that were manufactured from outside sources also had the same methodology, however, products that were manufactured in the internal factory were treated differently, varnish and related items that were saved in a box with six units were grouped and only a box was measured. The nail polishes of 10.5ml and 14ml bottles had a slight difference in the weight but it was considered negligible. The other products that did not belong to this standard were grouped if they had similar characteristics or measured individuals. This process allowed the company to estimate the weight of the orders and to get a better understanding of the space needed for each product.

In some orders the quantity of the SKUs requested is equal to or bigger than the quantity of the arrival box, making it easier for the pickers to pick an arrival box than to pick each item. This analysis of the quantity of the arrival boxes allowed us to better understand if some products need

a lot of space in the picking area or if their demand is usually met with the use of the arrival boxes. An example of this analysis is in Table 4.1 where a SKU has 88% of its quantity being able to be completed by using the arrival boxes. The other SKU represented while having the same percentage of orders that can be done with arrival boxes, has less quantity. The particularity of this SKU is that 7% of its orders have items that would fill more than 75% of a box. The suggestion, when the clients ordered more than 75% of a box, is that the commercials ask to order some more product to fill a full box. This would improve the picking time as the pickers would not need to individually pick 10 items, and would only need to pick a full box.

Table 4.1: SKUs' Orders Completed with the use of Arrival Boxes

SKU	% quantity filled by arrival boxes	% orders filled by arrival boxes	quantity of a arrival box
1	88%	18%	12
2	44%	18%	12

4.2 ABC Analysis

After better understanding the products in a physical form, it was important to understand how the SKUs performed in terms of sales. To that effect, various ABC analyses were performed with data taken from both the sales of products and the orders. The difference in both data was created due to the shortage in products that produce orders with two different sell dates. Also, the quantity sold and the gains of selling the order were considered individually for this analysis. As some items were sold in greater quantity but at a low price, there were some differences between the results of the two analyses. Figure 4.1 shows an example of the comparison.

4.2.1 Clients Order Rotation

To get a better grasp of what the habits of the clients were, the sales of the company were studied with a focus on the clients. This analysis allowed the company to better visualize the tendencies of the clients.

Firstly a study of the rotation of the clients was made, and an ABC analysis was conducted, with the results in Table 4.2, this analysis is flawed because the client with the highest share has 30% of the quantity order only being considered an A. An important conclusion was the knowledge of what was the rotation of the orders of the clients. This was proven useful to estimate the time period in which the clients responsible for 80% of the quantity ordered would make a considerable number of orders. The results of this analysis are showed in Table 4.3 and show that in a month the companies that are responsible by the percentage of the orders previously mention have order at least once. The results of this study were later used to do the implementation of an ABC analysis.

	ABC Sales	ABC Quantity	Comparison
SKU 1	A	A	Yes
SKU 2	A	A	Yes
SKU 3	A	B	No
SKU 4	A	A	Yes
SKU 5	B	B	Yes
SKU 6	B	A	No
SKU 7	B	B	Yes
SKU 8	B	B	Yes
SKU 9	B	B	Yes
SKU 10	B	C	No
SKU 11	C	C	Yes
SKU 12	C	B	No
SKU 13	C	C	Yes
SKU 14	C	C	Yes
SKU 15	C	B	No
SKU 16	C	B	No
SKU 17	C	C	Yes

Figure 4.1: Example of Comparison between ABC of Sales and ABC of Quantity

Table 4.2: ABC analysis of the Clients

Classification	% of sales	number of clients
T	20%	0
A	50%	3
B	80%	24
C	100%	278

Table 4.3: Analysis of the Rotation of the Clients

Rotation period of orders	Number of clients
1 week	4
2 weeks	14
3 weeks	24
4 weeks	16

4.2.2 Implementation of an ABC Analysis System

It was considered very important for the company to have an up-to-date system of the classifications of the articles, to know what were the SKUs that were the best sellers of the company, and to accompany the changes in the market. A study of the correlation of the best-seller SKUs was done to understand if there was periodicity in the products. The best sellers were the products

that better accompanied the total sales of the company. However, the results show that there was no correlation, the highest being 0.3, which was consistent in the context of the volatility of the fashion market. An analysis where there was a junction of both these quantity ABC and the Sells ABC was done, but as the final analysis was to be used by other sectors of the company, it was decided to use the ABC based on the value of the sales to retailers.

To do the implementation of this analysis some assumptions were chosen. Firstly, the time frame of the analysis was 13 weeks. This time frame was chosen taking information from both the study of the rotation of orders of the clients and the lack of periodicity of the products. The classification was updated every week, always using the data of the last 13 weeks. The classification of every product was easily accessible and was shown in the ERP page of the product, and there is also the capability to access the classifications of past weeks. If in a week there was a change of either a T or A going down in classification, or a product ascending to one of these levels, the user received an email with a warning. This was implemented to have a way of understanding if a product was losing or gaining market share and allowed the company to act on that fact. The ability of exploring the past classifications made it possible to visualize if the product was stable in its classification if it was oscillating between two close ones, or if it was in an ascending or descending trend.

In Figure 4.2 , an example of the implementation of the ABC analysis in the company system is shown.

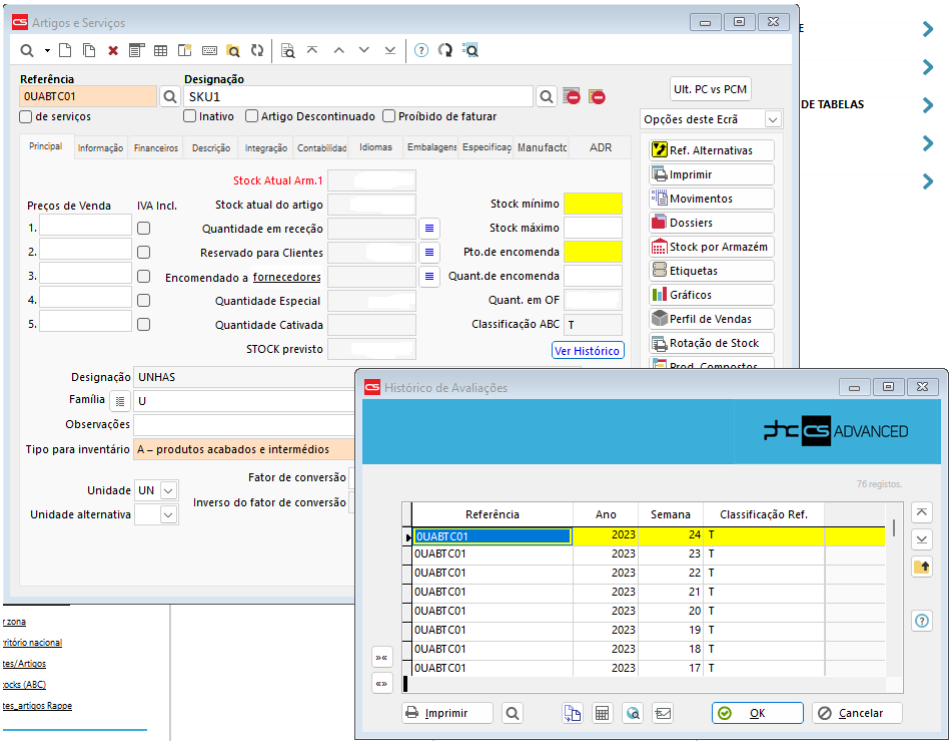


Figure 4.2: Example of the Implementation of the ABC Analysis in Higicol Program

4.3 Analysis of Picking Hypotheses

During the observation of the picking process, it was hypothesized that ordering the same or similar number of SKUs but different amounts of quantities would have different ratios of quantity and time. The hypothesis was created because of the idea that with the same number of stops in an order, it would not increase the time of the order in the same ratio as the ratio of the difference in quantity. Utilizing the picking time data, some orders were chosen to confirm if the hypothesis was correct. These orders were chosen in groups, picking orders that had equal lines of SKUs but with ratios of quantity that ranged from 1.5 to 3. After analyzing the data, the results were inconclusive and the hypothesis was considered not to be true as some orders with more quantity took the same amount of time, others more than the ratio, and others less. These results were corroborated by the fact that while they had the same lines of reference to pick the SKUs, their dimensions and the number of single SKU could be too much for the pickers to carry, which led to the pickers having to do more trips for a single SKU. There is also the case where, despite having the same number of lines of SKUs, the SKUs can be of different dimensions, and easier to carry more items in a single trip. This can lead to cases where the picking time ratio is lower than the quantity ratio. In Table 4.4, there is an example of some of the orders that were studied. Despite this study not having the intended results, it displayed that the dimensions and weight of the product would influence the optimization of the picking process.

Table 4.4: Examples of Comparison of Orders

Number of References	Quantity Ratio	Picking Time Ratio
80	1,934554974	3,894743989
58	1,914634146	1,588237163
48	1,729411765	2,444443333
36	1,789473684	0,294117439

4.4 Short-term Picking Improvement

Focusing on the problems identified in the picking process and utilizing picking process techniques, some changes to the current picking process were presented and studied but firstly an initial scenario had to be created following the initial process of picking. The new scenarios also present the cost associated with their implementation. To this cost, it will also be added the difficulty of the inertia of the pickers to use this new system.

4.4.1 Current Scenario

To create a scenario that followed the current picking process of Higicol, some observations had to be made. Firstly a spaghetti diagram presented in Figure 4.3 was created to better visualize the movements of the pickers in the warehouse. The red indicates the picker returning to the

packing area and the green represents the picker going to the product. It is possible to observe in this diagram that a picker has to do multiple visits to the same aisle to pick all its products and that some products with good rotation are stored in the back of the picking area. For the current

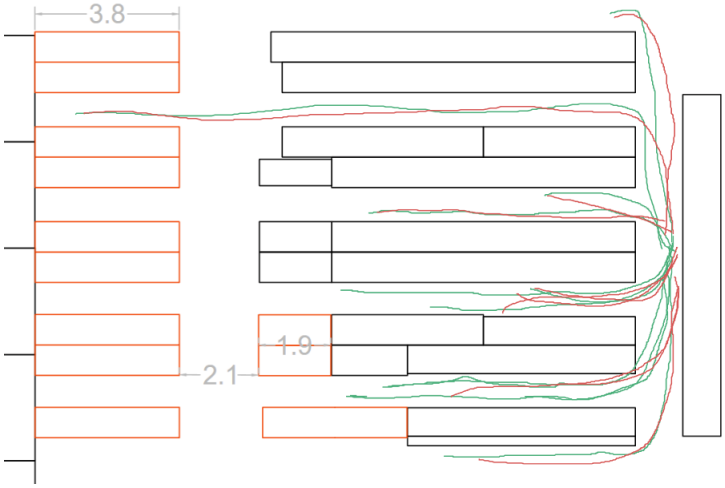


Figure 4.3: Spaghetti Diagram of an Order

scenario, the present locations of the SKU had to be updated the only information on the locations was the set of racks in which they were. Some SKUs did not have this information. After having all the SKUs with a set of racks, a single rack was attributed to each SKU based on how they were displayed in the set of racks, from left to right following the descending order of their references.

After having the locations of the SKUs, some assumptions based on observations about the creation of a simulation were made:

- Speed of the picker during the routing was set to 2 meters per second.
- The picking time was established as 5 seconds.
- The return speed of the picker was considered 1 meter per second.
- The length of the racks was fixed at 1.8 meters.
- A limitation to the picker was created in which, the picker could only carry 15 items each time and if it reached that quantity, it had to return to the packing area.
- The picker can walk back and forth in the aisle.
- The picking routing was created to find the next SKUs following the S-Shape routing method.

The implementation of the assumption of the pickers being able to walk back and forth while having to follow an S-shape routing algorithm was put in place to allow the pickers to return to the packing area in the same aisle that they were in. The code for this scenario that was then adapted for other scenarios is in Appendix A

4.4.2 Scenario 1

The first suggestion was the improvement of the locations of the SKUs. For this scenario, new locations were created based on a class-based storage system. This class-based system would create fixed locations based on their ABCs classifications. The first draft of the distribution of the SKUs in the warehouse is shown in Figure 4.4. However, after some consideration, it was decided that the bottom rack would be the location of SKUs with lower classification because of the lack of accessibility in this rack.

Because of the different dimensions of the SKUs and the fact that they were stored in their arrival boxes, the decision was made to separate the items into zones. This zone separation also optimized the packing process considering that items with similar dimensions would be grouped. The make-up family remained in their containers. The Hair category was reorganized, and for this category, a standard location with 25cm of width was created. The rotation of the products needed to be crossed with how much stock could be kept in each of these locations. To examine this new constraint the average quantity sold for each product in 4 weeks was checked and for this category of products the following decisions were followed:

- Items from the color line that belongs to the subfamilies No Ammonia, Demi-Permanent, Permanent would only be attributed to one location that would be able to hold 108 units;
- Hair products that did not fall in the subfamilies described above would have two different treatments:
  - Products with classification T, A, or B would be given three locations. As these items are liquid bottles, their dimensions meant that more locations were needed in order to avoid constant restocking. A single location would hold 24 units of 1 liter bottles, 32 units of 300ml, and 192 units of 200ml and 150ml bottles.
  - Products with classification C had two locations.

The U category was divided into three groups:

- Nail polishes like products that would normally be stored in boxes of 6 units, these products would also be divided based on their classifications. The T, A, and B SKUs would have a location of 30 cm that stored 864 units and the C SKUs had a location of 20 cm that stored 576 units.
- The equipment line remained in floor-level storage attributed to their dimensions.
- The limited collections that were launched throughout the year were in floor-level storage in pallets due to their high production quantity.
- Other lines of U were treated with a different thought process as in addition to their dimensions, there was needed to be space available to store the produced product. With these restrictions, the location's width was set at 45 cm. SKUs with C classification would be stored in only one location and the SKUs with other classifications had two locations.

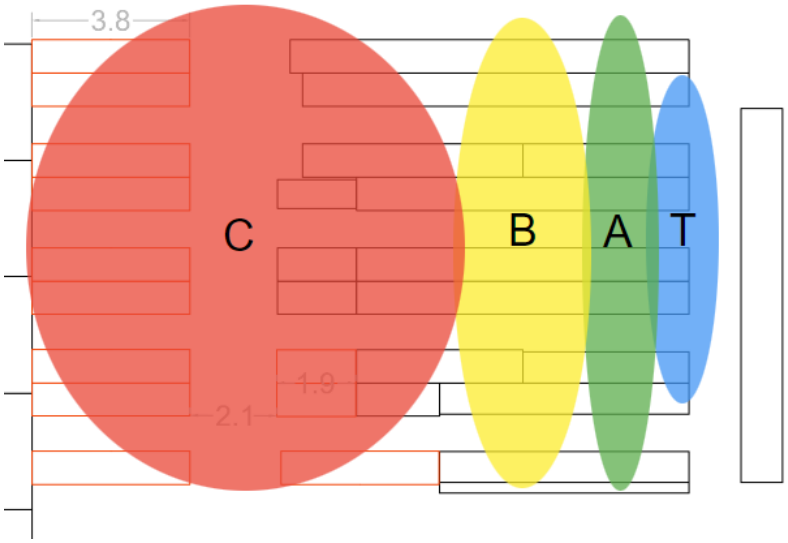


Figure 4.4: Distribution of the Classifications of the Products

To attribute the SKUs to their respective location the number of locations of a rack was calculated and a code was created to give each SKU the number of necessary locations. The code used the racks as matrices that had 4 lines and the number of columns was calculated by dividing the length of a rack by the width of the location. The number of lines was diminished to 3 because of the accessibility concern, and the bottom shelf would be filled by lines of the matrices with worse classifications.

4.4.3 Scenario 2

Another solution that was presented after the observation of the picking difficulties was the implementation of a picking cart. This implementation would limit the number of times that the picker would need to return the picked items to the packing area. An example of a picking cart that was proposed can be observed in Figure 4.5. In this scenario some assumptions had to be changed:

- The picking capacity of the picker was increased to 300 items, this change being the main factor for the utilization of a cart.
- The routing of the aisles had to be changed because of dimensions constraints. The width of the cart which was 45 cm and the width of the corridors 80cm, did not allow two carts to pass in the same aisle in different directions. A limitation was created to limit the direction of the aisle to only one way;

Unlike the previous scenario where the cost of implementations would be negligible, this scenario would have the cost of acquiring the carts. After discussing the cost of a cart with suppliers and with 3 pickers needing to have a cart, the cost of this scenario would be 1000€.



Figure 4.5: Example of a Picking Cart

4.4.4 Scenario 3

For the third scenario, a mix of scenarios one and two was created, where the locations followed a class-based storage and the pickers carried the items in carts as well. This scenario combined the efficiency of being able to carry more items in a trip and the new locations of the SKUs with more rotation closer to the packing area. This scenario has the same limitations as Scenario 2 where the aisle can only be traversed in one way, which can make the choice of locations of the new SKUs irrelevant. Both Scenarios 2 and 3 had the possibility of creating congestion in the aisles making the solutions not optimal.

4.4.5 Scenario 4

To solve the problem of congestion in the aisle using the carts, the layout of the warehouse was changed to increase the width of the aisle to a value that allowed two carts to pass simultaneously, Figure 4.6 shows a sketch of the new layout. To achieve this condition, two sets of racks were removed from the layout, however, this reduces the number of locations available. To solve this new issue, the packing area, shown in figure 4.7 was taken out and replaced by a process where the sorting of the picking and the packing would be done simultaneously. A single table would be left in a different location for the international orders that needed extra steps to be concluded. To accomplish the process of packing while picking, an investment in equipment needed to be made. Four Personal digital assistants (PDAs) were considered and in addition to this equipment, a warehouse management system (WMS) had to be acquired to work with the PDAs.

With the implementation of the PDAs, the picking process would suffer some changes. The pickers would receive information on their equipment of the location of the next item, move to said location, and, at the location, they would scan the bar code that marked the location of the

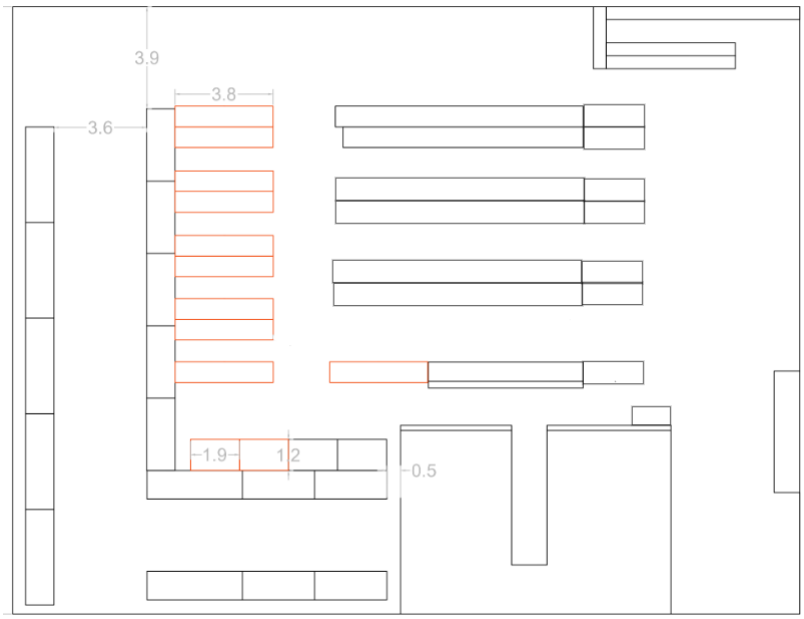


Figure 4.6: Sketch of the New Proposal Layout

product, scan the product and scan the box where they would place the item. This process would diminish the possible errors made in the picking, and keep the information of what box the item picked was stored.

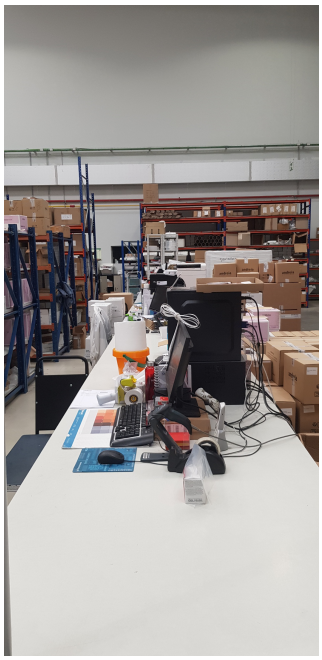


Figure 4.7: Packing Area

Besides the possible picking time improvements, the implementation of a WMS would allow a better information record of the number of items in each SKU location, leading to an improved

stocking process and an easier way to access the location of the SKUs. With this system the pickers would have to rely less on the previous knowledge of the location of the products and would only need to follow the indications of the PDAs, making it easier for newcomers to understand the process. Some budgets for the implementation of this system were gathered and the cost of implementation would be around 6000€ for the acquisition of the PDAs, in (Figure 4.8) and 8000€ for the implementation of the WMS. The WMS would lead not only to improvements in the efficiency of the picking but also to a better flow of information on the SKUs locations in the warehouse as well as the stock available in each one. With this new scenario, besides the changes to the layout of the warehouse in the code, the picking time was changed to 15 seconds, and the routing was improved to an optimal routing system where the program would calculate the shortest travel time to each location.



Figure 4.8: Example of the PDA considered for the Budget

4.4.6 Scenario 5

Higicol's orders have a great variance in quantity and lines of reference. In Table 4.5 the values for the standard deviation and average of the quantities of items and lines of reference for the orders of the first five months of 2023 are shown. These results indicate that the size of orders varies greatly from order to order and while some orders would be to large to be carried in a single trip, some orders would not make use of the ability of the cart to carry more orders. With this problem, a new scenario was created, where the orders that, using the data of the dimensionalization of the products, would fill two standard boxes or less would be batched together and be picked and packed together. The system would allow the picker to, using the bar codes capabilities of the PDAs, read the code of the article, which would indicate the box in which the picker needed to

pack the product. The batch-picking strategy would optimize the picker travel time as no more than three orders would be batched together, and the batching program would prioritize orders that had SKUs in common.

Table 4.5: Average and Standard Deviation of the Orders in the First Five Months of 2023 in Higicol

	Average	Standard Deviation
Quantity of items	272	1240
Lines of SKUs	40	55

4.4.7 Comparison of Picking Times of the Scenarios

With the scenarios created a group of representative orders was chosen with the intention of being able to test if the scenarios brought improvements to the process. Table 4.6 shows a list of examples of these representative orders with the lines of references and quantities of each order. In Table 4.7, the time of picking time for each order in each scenario is shown, Scenario 5 shows grouped orders, those being orders 1,2, and 3 together, and orders 4, 5, and 6 were also batched.

In figure 4.9, it is possible to observe the percentage of time improvement in each scenario. The percentage improvement of the location changes, utilizing pick-by-hand is 33% compared to the original scenario. Scenario 1 proves to be a better improvement of the picking time than the utilization of carts, which have improvements of 19% with current locations and 25% with new locations. This stems from the lack of ability that the scenarios with the carts have to transversing the aisles in both directions. The limitation of not having the ability to transversing the aisles in both directions proves to be a factor that greatly enhances the picking time, as pickers would have to cover greater distances to either complete their orders picking list and would not be able to use the best route to go to the packing area to drop the items that were already picked. However, this limitation is solved in Scenarios 4 and 5, where pickers can use both directions of an aisle. These scenarios bring an improvement to the picking time despite having the packing happening at the same time as the sorting. The improvement can also be attributed to the routing system searching for the optimal path to every location instead of focusing on an S-shape routing. As this time picking results were obtained using simulation, they do not account for the human component of the pickers therefore the real gains of the different scenarios can be lower.

4.4.8 Cost and Return on Investments of the Scenarios

Within the scope of only improving the picking time of the analysis the scenario where the lay-out of the warehouse is changed and a WMS and PDAs are installed and utilized are the optimal scenarios. However, these scenarios have a higher cost than the others, combining the cost of acquiring PDAs, a WMS, and carts. An estimate of 15000€ would have to be spent. By utilizing

Table 4.6: Sample of the Orders used

Orders	Lines of reference	Quantidade
order 1	44	115
order 2	33	90
order 3	22	85
order 4	39	83
order 5	22	72
order 6	23	145
order 7	45	1201
order 8	49	240
order 9	41	471
order 10	22	508
order 11	25	509
order 12	20	1029
order 13	22	1091
order 14	49	150
order 15	63	582
order 16	66	3665

Table 4.7: Times of the Scenarios for Sample Orders

	Original Scenario	**Scenario1**	**Scenario2**	**Scenario3**	**Scenario4**	**Scenario5**
order 1	1545.8	1115.1	2501.6	1604.8	1694.0	2729.9
order 2	1380.6	1038.4	2135.8	1050.2	1462.8	-
order 3	997.1	831.9	1410.1	649.0	703.6	-
order 4	1498.6	855.5	1988.3	2607.8	998.0	1714.3
order 5	1044.3	749.3	1327.5	696.2	727.4	-
order 6	973.5	702.1	1445.5	772.9	741.3	-
order 7	3823.2	1905.7	2330.5	3062.1	1206.2	1206.2
order 8	2070.9	1044.3	2649.1	2873.3	1185.3	1185.3
order 9	2218.4	1174.1	2306.9	2660.9	1108.1	1108.1
order 10	2000.1	896.8	1256.7	743.4	867.5	867.5
order 11	1911.6	1475.0	1480.9	932.2	825.5	825.5
order 12	3840.9	2867.4	1339.3	955.8	1210.5	1210.5
order 13	3239.1	1628.4	1492.7	1073.8	820.5	820.5
order 14	1799.5	961.7	2755.3	3091.6	1100.0	1100.0
order 15	2430.8	1575.3	2879.2	3292.2	1321.3	1321.3
order 16	10260.1	5286.4	3835.0	4737.7	1861.0	1861.0

a work day of eight hours and an average of 20 orders a day for the original scenario, the improvement in the time of the orders can be used to estimate how many orders would be possible to complete in a day. With this information, it is possible to calculate the Full Time Equivalent (FTE) for a day of work. Scenarios 4 and 5 make use of four pickers doing the sorting and packing simultaneously, while the final one would be supporting the international orders, in the current system,

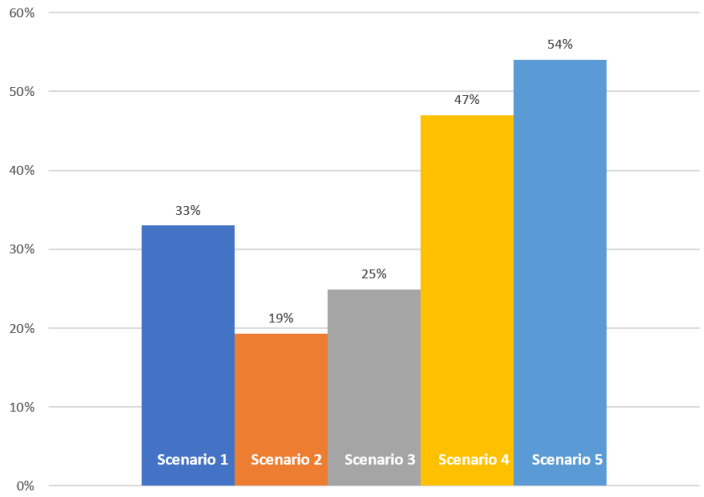


Figure 4.9: Graph of % Improvement in each Scenario

only three pickers are responsible for the sorting. In Table 4.8 the number of pickers needed to achieve the same daily orders as the current situation is shown. In most of the scenarios only three pickers are needed, meaning in the first three scenarios, a picker could be reallocated to another function in the warehouse or in the production area, while in the last two scenarios, two pickers could be reallocated. Calculating the pickers' yearly wage as 10000€, it is possible to calculate the gain of each scenario in terms of human resources. Scenarios 4 and 5 which have a decrease in pickers, would save twenty thousand euros in human resources, making it possible to pay for the upgrade in just one year. The installation of the WMS would also lead to returns in terms of information that would help the company, improving the speed of the workers when locating items and the restockers' information of what SKUs need to restock.

Table 4.8: FTE of the New Scenarios

Scenario	FTE	Number of pickers	cost of scenario(€)
1	2.01	3	100
2	2.4	3	1000
3	2.25	3	1100
4	1.62	2	15000
5	1.38	2	15000

4.5 Medium to Long Term Picking

Despite having found a short-term solution that would greatly improve the picking operation, it would come at the cost of losing rack spaces, as at least three racks would have to be removed, this measure would be counter-productive to one of the initial problems that were identified by Higicol related to the growth of the company. With the focus of this new solution being one with a higher temporal length, it allowed the solutions to focus on some additional problems,

for example, the fact of the pickers not respecting the batches of products and the indication of picking the oldest batch, to prevent products from staying in stock too long and surpassing their expiration date. Another problem that was analyzed in this new time scope was the fact of the picking area coexisted in the same warehouse as the production area. This was a concern because of the fire hazard safety levels of the production area and the inability to grow the picking area in that warehouse.

Solutions like the implementation of RFIDs tags for the products were studied, however at a cost of ten cents per tag, without looking at the implementation cost of the machines needed for reading those tags, it was considered too expensive for the benefits it would bring. Automation solutions like a miniload warehouse were also considered but with budget implementation costs of 1 million euros, other solutions had to be devised. To solve these problems a solution was created where the picking area was moved to the third warehouse. The third warehouse's dimensions were smaller than the one with the production in it, having 460 m^2 and it had the drawbacks of having inside racks with outsourced products that would have to be moved to create space for the picking area as it is observable in Figure 4.10.



Figure 4.10: Original Layout of Warehouse 3

The solution encountered for this problem was to move the racks present in the third warehouse to the area that would be freed in the first warehouse with the removal of the picking area, increasing the stock area that the warehouse already had. In order to keep the quality management working area and keep the original number of racks, while increasing the width of the aisles to still enable the carts to go back and forth a new layout for the warehouse was established. This

new layout is presented in Figure 4.11. To maintain the seventy-two racks present in the current picking layout, a mezzanine platform on top of the picking area was designed. This mezzanine would have $15 * 10m^2$ and would have the same racks as the ground level in the same design. With this system it is possible to, in the set of racks that are placed in the limits of the picking area, add one rack, to have a set of racks with seven racks. After a solution for the problem of the possible lack of space in the best scenario of the short-term problems was developed, the focus of the project went to the problem of product batches. The solution to this problem is derived from the location of the SKUs in the optimal scenario for short-term improvement. While the SKUs would continue to be stored following a class-based policy, inside of the space reserved for each class the items would follow a dynamic storage policy, where each location would only have one batch of SKU, and when the number of items reaches a threshold, an order to fill a new location with that SKU would be filled. The cost of this new operation would be the cost of Scenario 5, adding the construction of a mezzanine structure and the reallocation of the racks and products from one warehouse to the other. The cost of the mezzanine implementation would be 27000€ thousand euros and the reallocation of the racks would lead to a cost of 2000€, moreover, there is an optional cost of 4000€ related to the option of buying four new racks to increase the space available for the SKUs. The picking time would be 47% for batch picking and 41% for single order picking, providing a gain similar to the short-term picking options. With a cumulative cost of 50000€ and the same reallocation of the two pickers, this new scenario would start to be profitable in two and a half years, only looking to gains in human resources and not considering the gains in information due to the WMS implementation and the better batch information.

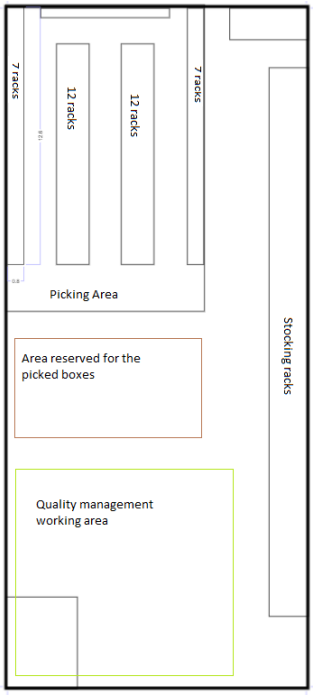


Figure 4.11: New Layout of the Third Warehouse

4.6 Key Performance Indicators

In order to keep track of the improvement of the scenarios that can be implemented, a system of KPIs should be implemented for the responsible of the logistic department to keep track of the performance of the process and some areas that could be improved with the gaining of experience of the pickers in the new system. Some of the picking KPIs that were suggested are:

- Picking cycle time (order completion time): the simplest KPI for the picking process, it keeps track of the time that the pickers take to complete an order.
- Accuracy of the picking: This KPI will keep track of the errors that are incurred in the picking process. These errors can be system-based or human-based. With this KPI, the supervisors can observe if the process leads the pickers to human error or if there is a problem with the system itself.
- Time to pick: This KPI allows to observe if the routing system is optimal or if the pickers are taking too long to find their next item.
- Pick density: with the goal of studying if the location of the items in the warehouse is optimal, this KPI allows to check what areas of the warehouse have more picks.
- Pick productivity: A continuation of the first KPI, this allows to better understand how many SKUs are being picked in a time frame chosen by the company. This KPI is an important complement to the first one has a order can be much bigger than another order and skewed the results.

Chapter 5

Conclusions and future work

In the current day and age, the optimization of factory work is a major concern in the industry, as every second saved is money that can be gained.

This project consisted of analyzing the picking process in Higicol and developing new solutions to improve the picking. The continuous growth of the company and the increase in orders and order size created a major concern in the capacity of the company to provide services to new customers. A concern with the ability of pickers to deal with this increase was also noted as the workload would pose health risks to them. The use of new technological products was also low at Higicol and the information was more on the workers' side than in the system. This made the process heavily dependent on the workers and those workers became hard to replace.

To better understand the industry and some picking technologies, visits to other warehouses in the same branch of operations and to warehouses that used a similar ERP as Higicol but with an integrated WMS were made. These visits brought valuable insights into how the picking process was performed in similar warehouses and the policies and technologies they used and how different WMS systems interacted with the ERP used by Higicol.

Solutions to the picking inefficiencies were encountered in the form of different scenarios with different temporal scopes. These scenarios tackled the problems and inefficiencies that were observed in the process as the SKUs with heavy rotation not being close to the packing area, or the distance traveled by the pickers due to the inability to carry more items.

All the new scenarios were studied and time gains were found that would allow either reallocating some pickers available to the process or tackling more orders. The installation of a WMS poses a great gain of information to the company with a mapped-out plan of the locations, both in the picking area and in the stocking area, and information on the quantity of SKUs in each location. This last information would be instrumental to an improved restocking of the picking area.

One of the major adversities of this project was the time constraint in which it was inserted as it was not feasible to do any major changes in the time dedicated to the project and no implementation of the scenarios was applied to the process due to the inability to disrupt the picking operations to do the necessary changes to the process. A proposed solution to this problem was

the vacation period in August were the company closes and the changes could be made to the warehouses and to the picking area.

Future problems that this project envisions are related to the pickers and their inertia to change the way they work, which means the project will have to have a smooth transition so they have time to get used to some of the changes that were proposed. As a plan of action, this year Scenario 5 should be implemented for the pickers to get used to the PDAs systems and to better study the improvements in the system, In the following year the solution with the change of the warehouse can be used depending on the results of the latest implementation.

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Appendix A

Code example for the original scenario

Listing A.1: Python example

```
import random
import pandas as pd
import heapq

# Define the warehouse layout
num_aisles = 4
num_racks_per_aisle = 10
rack_length = 1.80  # Length of each rack in meters
routing_speed = 2  # Speed of movement in meters per second
pick_time = 5  # Time in seconds to pick an item
return_speed = 1  # Speed of movement during return in meters per second

# Create a warehouse graph
warehouse_graph = {}
for aisle in range(num_aisles):
    for rack in range(num_racks_per_aisle):
        current_rack = f"A{aisle+1}R{rack+1}"
        warehouse_graph[current_rack] = []

        # Connect to adjacent racks in the same aisle (forward direction)
        if rack < num_racks_per_aisle - 1:
            next_rack = f"A{aisle+1}R{rack+2}"
            warehouse_graph[current_rack].append((next_rack, rack_length /
            routing_speed + pick_time))

        # Connect to adjacent racks in the same aisle (backward direction)
        if rack > 0:
            prev_rack = f"A{aisle+1}R{rack}"
            warehouse_graph[current_rack].append((prev_rack, rack_length
            / routing_speed + pick_time))
```

```
        # Connect to racks in adjacent aisles (forward direction)
        if aisle < num_aisles - 1:
            lower_rack = f"A{aisle+2}R{rack+1}"
            warehouse_graph[current_rack].append((lower_rack, rack_length
            / routing_speed + pick_time))

        # Connect to racks in adjacent aisles (backward direction)
        if aisle > 0:
            upper_rack = f"A{aisle}R{rack+1}"
            warehouse_graph[current_rack].append((upper_rack, rack_length
            / routing_speed + pick_time))


def s_shape_distance(node, goal):
    node_aisle, node_rack = map(int, node[1:].split('R'))
    goal_aisle, goal_rack = map(int, goal[1:].split('R'))

    # Calculate the S-shape distance
    if node_aisle % 2 == 0:  # Even-numbered aisle
        return abs(node_rack - goal_rack) + abs(node_aisle - goal_aisle)
    else:  # Odd-numbered aisle
        return abs(node_rack - goal_rack) + abs(node_aisle - goal_aisle) + 1


def a_star(graph, start, end, heuristic_fn):
    # Initialize distances and visited nodes
    distances = {node: float('inf') for node in graph}
    distances[start] = 0
    visited = set()
    queue = [(0, start)]

    while queue:
        # Get the node with the shortest distance from the start
        current_distance, current_node = heapq.heappop(queue)

        # Skip if already visited
        if current_node in visited:
            continue

        # Mark the current node as visited
        visited.add(current_node)

        # Check if we reached the destination
        if current_node == end:
            return distances[end]

        # Explore neighbors of the current node
        for neighbor, weight in graph[current_node]:
```

```
            distance = current_distance + weight

            # Update the distance if it's shorter than the current
            distance
            if distance < distances[neighbor]:
                distances[neighbor] = distance
                heapq.heappush(queue, (distance, neighbor))

    # If no path found
    return float('inf')


def read_sku_data(file_path):
    df = pd.read_excel(file_path)
    sku_positions = {}
    sku_quantities = {}

    for _, row in df.iterrows():
        sku = row['SKU']
        aisle = row['Aisle']
        rack = row['Rack']
        position = f"A{aisle}R{rack}"
        quantity = row['Quantity']


        sku_positions[sku] = position
        sku_quantities[sku] = quantity

    return sku_positions, sku_quantities


def estimate_total_time(orders, starting_point, sku_positions,
sku_quantities):
    total_time = 0
    quantity_picked = 0
    current_rack = starting_point

    for i in range(len(orders) - 1):
        start_sku = orders[i]
        end_sku = orders[i + 1]

        # Get the positions of start and end SKUs
        start_rack = sku_positions.get(start_sku)
        end_rack = sku_positions.get(end_sku)

        if not start_rack or not end_rack:
            print(f"SKU positions not found for start SKU:
            {start_sku} or end SKU: {end_sku}")
```

```
            continue

        # Find the routing time for the current order
        routing_time = a_star(warehouse_graph, start_rack,
        end_rack, s_shape_distance)
        total_time += routing_time

        # Update the current rack to the end rack for the next iteration
        current_rack = end_rack

        # Increment the quantity picked
        quantity_picked += sku_quantities.get(start_sku, 0)

        # Check if the picker needs to return due to quantity exceeding 15
        if quantity_picked > 15:
            # Calculate the return time based on the distance
            between current position and starting point
            return_time = a_star(warehouse_graph, current_rack,
            starting_point, s_shape_distance)
            total_time += return_time

            # Reset the quantity picked and update the current rack
            to the starting point
            quantity_picked = 0
            current_rack = starting_point

        # Check if the quantity of the current SKU is larger than 15
        sku_quantity = sku_quantities.get(end_sku, 0)
        if sku_quantity > 15:
            # Calculate the number of times the picker needs to pick
            the entire quantity of the SKU
            num_picks = sku_quantity // 15

            # Calculate the additional routing time for picking the
            SKU multiple times
            multiple_pick_time = num_picks * a_star(warehouse_graph,
            current_rack, end_rack, s_shape_distance)

            # Update the total time
            total_time += multiple_pick_time

            # Update the quantity picked by subtracting the multiple
            of 15 from the SKU quantity
            quantity_picked += sku_quantity - (num_picks * 15)

    # Calculate the return time based on the distance between
    the current rack and the starting point
    return_time = a_star(warehouse_graph, current_rack,
```

```
    starting_point, s_shape_distance)
    total_time += return_time

    return total_time
# Load SKU positions, quantities, and order sequence from Excel file
sku_positions, sku_quantities = read_sku_data('sku_data.xlsx')
order_sequence = SKU_list



# Define the starting point
starting_point = 'A1R1'

# Calculate the estimated total time
total_time = estimate_total_time(order_sequence, starting_point,
sku_positions, sku_quantities)

# Print the order sequence and total time
print("Order Sequence:", order_sequence)
print("Estimated Total Time:", total_time, "seconds")
```