

Warehouse Automation in a Luxury Fashion Platform

Bárbara Domingues dos Santos Freitas Souto

Master's Dissertation

FEUP Supervisor: Professor Bernardo Almada Lobo

Farfetch Supervisor: Francisco Cunha



Master in Mechanical Engineering

2023-06-26

Abstract

This dissertation work was motivated by a project at Farfetch within the Fulfillment Design team, and involves designing possible automation solutions for a manually operated warehouse.

In the world of e-commerce and retail, order fulfillment is a fundamental process that involves the entire course of an order, beginning with the moment a client places it and ending with the successful delivery of the products.

The increase in e-commerce sales volume, coupled with the need to reduce time to market and meet current levels of service to ensure customer satisfaction, are currently the biggest challenges for supply chains. Fashion e-commerce faces them profoundly, particularly due to seasonality and product diversity, as well as to the diverse preferences of customers. For this reason, companies are pressured to streamline operations, optimize inventory management, and improve logistical capabilities. Within this context warehouses play a critical role.

Manual warehouses, in general, have difficulties to adapt to these changes, leading to bottlenecks and inefficiencies. Therefore, warehouse automation appears as one of the solutions to enhance performance, accuracy, and speed in order fulfillment processes. In the fashion sector, process automation offers advantages such as flexibility, scalability, and increased response times to meet such varied demands.

Based on the described situation, this dissertation explores and identifies the main opportunities for automation at a fashion e-commerce warehouse. The main areas explored here are Packaging and Storage, with potential direct and indirect savings.

Initially, the automation potential was explored, identifying specific opportunities within each area that stood out. Subsequently, the current AS-IS situation of each area was studied, enabling a better understanding of the processes. A market study was then conducted to identify the key suppliers in each area that meet the required needs. Finally, the TO-BE process was mapped for each identified area. The methodology used throughout this project also serves as a guide for future projects.

Implementing automation solutions is a complex task due to the level of detail and alignment it requires, as well as the impact it has on operations. For this reason, the presented solutions have not yet been implemented. However, their implementation plan was also an outcome of this thesis.

This study estimates savings of approximately €2M and €57K for the packaging and for the storage areas, respectively.

Resumo

Este trabalho de dissertação foi realizado no âmbito de um projeto da Farfetch, na equipa de Fulfilment Design e envolve o desenho de possíveis soluções de automação para um armazém operado manualmente.

No mundo do *e-commerce* e do retalho, é fundamental o cumprimento do processo de *fulfilment*, que envolve todo o percurso de uma encomenda, começando no momento em que o cliente a coloca e terminando com a entrega dos produtos.

O aumento do volume de vendas de *e-commerce*, aliado à necessidade de reduzir o tempo para o mercado e atender aos atuais níveis de serviço, a fim de garantir a satisfação do cliente, são agora os maiores desafios das cadeias de abastecimento. O *fashion e-commerce* enfrenta-os de forma profunda, especialmente devido à sazonalidade e diversidade dos produtos, bem como à diversidade de preferências dos clientes. Por esta razão, as empresas são pressionadas a racionalizar as operações, otimizar a gestão de inventários e a melhorar as capacidades logísticas. Neste contexto, os armazéns desempenham um papel fundamental.

Os armazéns manuais, de forma geral, enfrentam sérias dificuldades em adaptar-se de forma eficiente a essas mudanças, o que leva ao aparecimento de gargalos e ineficiências. Desta forma, a automação de armazéns é apresentada como uma das soluções para aumentar a *performance*, a precisão e a rapidez nos processos de *fulfilment*. No que toca ao setor *fashion*, a automação de processos oferece vantagens, tais como a flexibilidade, a escalabilidade e o aumento dos tempos de resposta para atender à tão diversificada procura.

Baseada na situação descrita, esta dissertação explora e identifica as principais oportunidades de automação num armazém de *fashion e-commerce*.

As principais áreas exploradas neste estudo são o *Packaging* e o *Storage*, com oportunidades de poupanças diretas e indiretas significativas. Numa primeira instância, foi explorado o potencial de automação, identificando dentro de cada uma das áreas oportunidades específicas. Em seguida, foi detalhada a situação *AS-IS* de cada uma das áreas, o que permitiu uma melhor compreensão dos processos. Posteriormente, um estudo de mercado identificou os principais fornecedores em cada área que satisfazem as necessidades requeridas. Por fim, mapeou-se o processo *TO-BE* para cada uma das áreas identificadas. A metodologia usada no decorrer deste projeto, servirá como guia para projetos futuros.

A implementação de soluções de automação é um trabalho complexo pelo nível de detalhe e alinhamento que exige e pelo impacto que detém no decorrer das operações. Por este motivo, as soluções apresentadas ainda não foram implementadas. Contudo, o seu plano de implementação foi também um resultado desta dissertação. Os resultados deste estudo preveem savings de cerca de 2M€ e 57K€ para as áreas de *Packaging* e de *Storage*, respetivamente.

Acknowledgments

The past five years, which have now come to an end, have made me more humane and happier. If that is the case, I owe it, especially to those who experienced these years alongside me.

Firstly, I want to thank to my parents, for their dedication and constant commitment to my education, and for their love, and guidance. My sense of responsibility and perseverance are a result of their unwavering support. To my mother, in particular, who never tires of listening to me when I'm concerned about something. She continues to be the best comforter in the world. To my brother and father, thank you for your love and support, and for always being there for me.

Next, I am grateful to my dear friends. To Maria Cacho, Teresa, Cati, Maria Pinto, Bárbara, Sara, Juls and Inês, thank you for every moment we shared. My academic life began with you, and my personal life has only improved since you appeared. Thank you for always supporting me. For teasing me whenever you can, and even when you can't. For always being ready to listen to me. For the best "Queima das Fitas" I have ever experienced and for our "barraquinha", which was also our home. My academic journey began with you, and it ended with you. You are the ones who will never end.

To Inês Ferrari and Kiko for being here since the first day.

To NEEM, for being an association that has given me so much and allowed me to grow and learn new things. To Kiko Silva, Inês and Manel, for their constant support and affection. To Pedro, for being a brother. To the team of Coordinators who accompanied me this year, and to my team, thank you for being a second family!

A huge word of appreciation for those who have been with me from the beginning, thank you for listening to me, for being a shoulder to lean on, and for being my home. To my grandparents and my godmother, Xica, for supporting me and always caring about my future. To Xica, in particular, for sharing with me the "Sofazinho de dois lugares." To Gui and Matilde, for being the support and embrace I can always turn to, and for being much more than friends or cousins, but sisters to me. To the Spicy group, lifelong friends. To my family, the craziest I know, but also the most special and wonderful.

I want to acknowledge those who closely accompanied me during this internship. To Maria Morais, who has been the older sister I never had. For all the support she has always given me, for all the times she listened to me and offered advice. To Luís Fragoso, who made a tremendous contribution in helping me understand the complexities of warehouse processes and who was always available for whatever was needed. To Daniel, André and Tiago for welcoming me so warmly and celebrating my achievements. To Luís Guerra, for being so approachable and ready to help, and for the challenges he presented. To FxFF and Farfetch, for allowing me to undertake this project and for showing me a whole new world.

Lastly, and certainly not least, my sincerest thanks go to my supervisors, Professor Bernardo Almada Lobo and Francisco Cunha, for their wise advice, support, and all the assistance they provided me with.

To all of you, a heartfelt thank you from the bottom of my heart.

"Posso estar longe de ser perfeito, mas estou cada vez mais perto de ser quem sou."

Manuel Clemente

Contents

1	Introduction	1
1.1	The Company	1
1.2	Project Background	2
1.3	Project Goals and Motivation	2
1.4	Methodology	3
1.5	Dissertation structure	4
2	State of the Art	5
2.1	History of Automation	5
2.2	Automation Purposes	6
2.3	E-commerce	7
2.4	Warehouse Automation in the Fashion Industry E-commerce	8
2.5	Warehouse Processes and Automation Technologies	9
2.5.1	Processes	9
2.5.2	Technologies	9
2.6	Main Considerations	10
3	Current Situation Analysis and Identification of Automation Opportunities	13
3.1	Analysis of the Current Operational Framework (AS-IS)	13
3.1.1	Process Mapping	14
3.1.2	Find Major Opportunities	16
3.1.3	Identification of Opportunity Areas	17
4	Methodology	21
4.1	Packing	21
4.1.1	Opportunities	21
4.1.2	AS-IS Process	22
4.1.3	Suppliers and Possible Solutions	26
4.1.4	TO-BE Process	28
4.2	Storage	31
4.2.1	Opportunities	31
4.2.2	AS-IS Process	32
4.2.3	Suppliers and Possible Solutions	33
4.2.4	TO-BE Process	34
5	Results	37
5.1	Packaging	37
5.1.1	Operational Savings	38
5.1.2	Delivery Savings	41

5.2	Storage	42
6	Conclusions and Future Work	45
6.1	Conclusions	45
6.2	Future Work	46
6.2.1	Packing	46
6.2.2	Storage	47
6.2.3	New Opportunities	48
A	Gantt Chart	55
B	Business Case Packaging	57
C	Business Case Storage	61

Acronyms and Symbols

3PL	Third Party Logistics
AGV	Automated Guided Vehicles
AMR	Autonomous Mobile Robot
AS/RS	Automated Storage and Retrieval System
AWB	Air Waybill
B2B	Business-to-Business
B2C	Business-to-Consumer
C2C	Consumer-to-Consumer
CAGR	Compound Annual Growth Rate
DC	Distribution Center
DCs	Distribution Centers
ERP	Enterprise Resource Planning
FPS	FARFETCH Platform Solutions
FTE's	Full Time Equivalents
NGG	New Guards Group
RMFS	Robotic Mobile Fulfillment System
SKU	Stock Keeping Unit
WMS	Warehouse Management System

List of Figures

3.1	Warehouse A - Value Stream Mapping.	16
3.2	Inbound and Outbound Process	16
3.3	Direct Costs Distribution.	18
3.4	Outbound Waterfall Chart.	18
3.5	DC2 Warehouse Layout	19
3.6	Storage AS-IS for Beauty Category	20
4.1	Methodology Framework	21
4.2	Packaging Process Map AS-IS.	23
4.3	European Union Process Matrix AS-IS.	24
4.4	Non European Union Process Matrix AS-IS.	24
4.5	Current Operation at the warehouse	26
4.6	Study on Packaging Suppliers	27
4.7	Packaging Process Map TO-BE.	29
4.8	EU Process Matrix TO-BE.	30
4.9	NON EU Process Matrix TO-BE.	30
4.10	Future Operation at the warehouse	31
4.11	Study on Storage Suppliers.	33
4.12	Layout Areas TO-BE.	34
4.13	Cross Picking and Packaging Operations.	35
5.1	Manual Cycle Time AS-IS.	38
5.2	Manual Cycle Time TO-BE.	39
5.3	Monthly Forecast EU.	39
5.4	Monthly Forecast NON EU.	39
5.5	Operational Savings.	40
5.6	Delivery Savings.	41
5.7	Total Savings.	41
5.8	Payback Period - Packaging.	42
5.9	Study on Storage Suppliers.	42
5.10	Monthly Cost AS-IS.	43
5.11	Monthly Cost TO-BE.	43
5.12	Savings on Area for each Scenario and Supplier.	44
5.13	Payback Period - Storage.	44
5.14	Costs of DC1.	44
6.1	Implementation Plan for packaging Machine.	46
6.2	Implementation Plan for Vertical Storage.	48

A.1	Gantt Chart	56
B.1	Packaging Business Case - EU Calculation	58
B.2	Packaging Business Case - Non EU Calculation	59
B.3	Packaging Business Case - Payback period	60
C.1	Storage Business Case	61

List of Tables

3.1	Warehouse Metrics Comparison	14
3.2	Pros and Cons of Automation	17
4.1	Assumptions on AS-IS Packaging Process	22
4.2	Process Steps AS-IS	23
4.3	Processes In Scope For Automation	28
4.4	Process Steps TO-BE	29
4.5	Summary of Product Categories, Stock Quantities, and Storage Requirements . .	32
5.1	Forecasted Orders In Scope	38
5.2	Productive Hours per Operator	40

Chapter 1

Introduction

1.1 The Company

FARFETCH is a global online platform that connects consumers with a curated selection of luxury fashion items from boutiques and brands around the world. It was founded in 2007 and launched in 2008 by the Portuguese entrepreneur José Neves due to his passion for fashion. José had this idea during a trip to Paris Fashion Week, where he became aware that independent high-fashion boutiques needed a presence in the online marketplace. FARFETCH acts as a connection between customers and luxury boutiques around the world, and provides in its digital marketplace an astounding variety of products that users can explore. The company serves more than 190 countries and has merchandise from over 1400 of the world's greatest brands, boutiques, and department stores.

One key characteristic that distinguishes FARFETCH is its focus on providing a unique and customized shopping experience. The platform uses cutting-edge technology and data analytics to deliver personalized suggestions based on individual tastes and interests, allowing customers to discover new designers, trends and special pieces. Ensuring a delightful experience to its customers is, as previously mentioned, one of the company main goals. For this reason, FARFETCH has broadened its services beyond its online marketplace and included same-day delivery in strategically selected cities, allowing consumers to receive their purchases quickly. In 2017, it expanded on this offering by creating F90, a special 90-minute delivery service in exclusive collaboration with Gucci.

FARFETCH platform agglomerates four additional business units - FARFETCH Platform Solutions (FPS), Browns, Stadium Goods and New Guards Group (NGG). It started as a marketplace for boutiques, and today it serves boutiques and brands.

In fact, the acquisition of Browns in 2015 allowed FARFETCH to enter the retail sector, whereas the acquisition of NGG in 2019 to start controlling the whole supply chain and design of brands, with a vertical integration.

1.2 Project Background

Fulfilment by FARFETCH (FxFF) arose at the Operations Department initially as an opportunity to sell the service to its marketplace partners. However, it ended up being the election service of its Business Units.

The service initially started with a warehouse in Italy, so that marketplace partners could have their stock there without having to worry about fulfilment management. However, once acquired Browns, its operation in the UK started being managed by FxFF, as later with B2B (Business to Business) stock from NGG.

With the network continuously growing, FARFETCH saw the need to centralize its brands and partners' stock and installed a warehouse in the Netherlands. The Browns stock was gradually transferred there. This warehouse is one of the largest FARFETCH network and its operation is the basis of this study.

1.3 Project Goals and Motivation

As FARFETCH is a digital company, advanced technology is not only intended for its platform but for its entire network. The warehouse just mentioned in the last section, started its operations in 2021 and is until now running under manual operations. This means all the processes in inbound and outbound namely putaway, picking and packing are all performed by humans. Human work can cause numerous problems, such as:

- **Inefficiency:** operations are slower and prone to errors which can result in delays, increased labor costs and reduced productivity.
- **Human Errors:** operations are more susceptible to human errors. Inaccurate inventory counts, picking mistakes, incorrect data entry are some examples. This can lead to inventory discrepancies, fulfilment issues, financial losses and customer dissatisfaction.
- **Limited Scalability:** with business growth, manual operations struggle to scale efficiently. Scaling a manual warehouse implies additional labor, space and buildings, which highly increases investments.
- **Lack of Data-Driven Insights and Real Time Visibility:** manual operations generate limited data and incomprehensible or insufficient analytics. Also, these operations do not allow for real-time visibility of inventory levels, order status, and warehouse performance, jeopardizing continuous improvement and growth.
- **Cost Implications:** manual works in a warehouse usually require a larger workforce and extensive training. In addition, labor costs vary from country to country but tend to be expensive in some areas. All these costs impact the profitability in a warehouse.
- **Safety Risks:** exposure of workers to many risks and injuries. Maintaining a safe environment becomes challenging with human work.

- **Difficulty in Meeting Customers' Expectations:** the goal of offering to customers the best possible shopping experience is challenging when operating under manual work. The competitive market and today's expectation for speed and accuracy becomes limited and struggling with such a rudimentary operation.

All the above reasons lead to the need to automatize processes and motivated the scope of this thesis. Its main goals expected to be achieved are as follows:

1. **Analyze opportunity areas for automation:** aims to prioritize automation initiatives within the company's current situation. It involves justifying the selection of both the warehouse and the specific areas within the warehouse for automation.
2. **Explore viable solutions for implementation:** entails examining potential suppliers and their offerings, and identifying optimal solutions.
3. **Quantify the impact of the selected solutions:** involves building business cases to evaluate both the expenses and benefits associated with the chosen solutions, enabling the estimation of the payback period.
4. **Provide recommendations for the implementation of the selected solutions:** encompasses offering well-informed guidance and actionable suggestions regarding the practical adoption and integration of the identified solutions.
5. **Establish a robust methodology as a foundation for exploring future automation opportunities:** aims to develop a comprehensive framework that serves as a guiding principle for the exploration and assessment of potential automation endeavors in the future.

1.4 Methodology

Due to the project's intricacy and in order to guarantee coherency, a comprehensive plan was delineated at the beginning of this dissertation. This plan, presented in Appendix A and described below, encompasses all the tasks to be completed.

The first task involved was Contextualization in which the main goal was to understand the expected project output..

The second task involved developing the State of the Art on the Automation topics considered for this project.

Tasks three to six constitute the core of this work, encompassing the principal analyses. These analyses explored and verified the opportunities and benefits of automation by creating and presenting business cases for each area considered for automation.

The seventh task involved defining and creating an implementation plan for each business case and highlighting future work that should be established.

Finally, the eighth task includes Dissertation Writing, which is done in parallel with all of the above tasks.

1.5 Dissertation structure

This dissertation is organized into six chapters outlined as follows:

Chapter 1- Introduction of the present work starting with the company's presentation, going through project background, motivation, goals, and underlying methodology.

Chapter 2- State of the Art to scientifically understand and support decisions or assumptions made during this work.

Chapter 3- Problem's Description which defines the current situation and allows to identify the opportunities with the greatest potential for automation.

Chapter 4- Methodology followed in the development of this work. This chapter offers a detailed description of how each business case of automation inside a different warehouse area was developed. Each area is analysed in 4 dimensions: opportunities, as-is process, suppliers and possible solutions and to-be process.

Chapter 5- Final Results, presented in the form of business cases reflect the work carried out and allow to draw conclusions from the analysis executed.

Chapter 6- Conclusions and Future Work where the main knowledge and improvements achieved on the current dissertation are summarised and future projects presented.

Chapter 2

State of the Art

Never before has there been such intense competition for warehouse and fulfillment logistics ((Company, 2021)). The just-in-time philosophy is creating market changes going from massive orders of an identical product to small orders of a variety of products which translates into small volumes of stock with a big range of products in a warehouse. Productivity, agility and customization are key drivers determined by market conditions. The current growth of e-commerce and omni-channel distributions, combined with the requirement to minimize time-to-market are causing the need to automatize logistics processes and therefore to automatize warehouses (Custodio and Machado, 2020). This is especially challenging in the fashion industry due to low inventory stability and seasonality.

2.1 History of Automation

Automation is mainly known as the technology that allows a process to run without human assistance or interference ((Groover, 2016)). By using a set of programmed instructions and a control system to carry out tasks, the ability to execute and operate a system through automation means becomes possible, eliminating the need for human intervention in what was previously a manual process (Custodio and Machado, 2020).

Automation can be classified in three different types: fixed automation, soft automation and flexible automation. The first one is inflexible and made for a specific function and cannot handle product variety. Some examples include automated assembly machines, chemical manufacturing processes and material handling conveyor systems (see (Custodio and Machado, 2020) (Groover, 2016)). Soft automation allows some adaptability to change, it still requires equipment reconfiguration which affects production, but it raises lower production rates and more flexibility than fixed automation. Computer numerical control and industrial robotics represent two examples of soft or programmable automation. Finally, flexible automation is a development of programmable automation facilitating uninterrupted operations and seamless processes (MacDuffie and Pil, 1996).

It responds effectively to changes in volume requirements, product-mix requirements and processing capabilities that will allow for product variety and shorter product life cycles. As it might be obvious it implies several costs to assure the high customization needed (Groover, 2020).

Automation may also be seen in another two perspectives. The first is described as mechanization and is more traditional. A more recent perspective emerged combining both mechanization and computerization. In this context, mechanization is often seen as the process of replacing human tasks by machines, while computerization relates with the ability of handling and controlling information by using automation (Sjøbakk et al., 2014).

2.2 Automation Purposes

Automation is a necessity that has become evident in the last decades for keeping the production processes alive and at optimal conditions to fulfil the business goals in short, medium and long term (Wiktorsson et al., 2017). The main goal of automation is to reach efficiency, speed and error avoidance by shortening lead times, making processes more systematized and reducing human errors. Therefore, automation can be used in different businesses, and it has been explored to improve them as much as possible. In warehouses businesses, the main purposes of automation are to reduce labor and operational costs, better utilize resources, improve customer service, enhance data accuracy and analysis, optimize warehouse space, enhance inventory control, improve workplace space, enhance material handling coordination and improve order fulfillment accuracy, among others (Jenkins, Abby, 2020).

Warehousing is the interim storage of items between two successive stages of a supply chain (Bartholdi and Hackman, 2016). Receiving, storing, sorting, stocking, order picking, and shipping are the core activities of warehousing, which are crucial elements in every supply chain (Boysen et al., 2019).

In recent decades, the boom in e-commerce made warehouse to face more orders than ever before. The "Double 11" online shopping festival's express delivery volume surpassed 3.9 billion parcels in 2019, while the total volume of express delivery in 2020 exceeded 70 billion shipments. Technology behemoths are making significant investments in smart warehouses to handle the rising e-commerce logistics demand quickly and affordably (Zhen and Li, 2022). For instance, in 2018, Amazon opened a fulfillment facility at Sparrows Point with a robotic mobile fulfillment system (RMFS), which uses Amazon robotic technology and cutting-edge procedures to empower the employees to go above and beyond for customers. This incorporates hundreds of "drives" that sit at the bottom of pod units carrying goods and transport the unit to an employee when necessary. Instead of rows of shelves, these pods move, make right-angle twists, and glide across the floor (Babcock, 2019).

Additionally, according to (Company, 2021), investments in automation are anticipated to drive significant industry growth – “the warehouse-automation market is forecast to reach \$51 billion with a CAGR (compound annual growth rate) of 23 percent.” In the last five years and thanks

to venture capital funding, which has helped companies to address some challenges, the automation industry has witnessed a significant increase in the availability of new warehouse-automation innovations. Also, crucial companies have benefited greatly from private equity. SoftBank, for instance, invested \$2.8 billion in AutoStore that is a supplier for grocery and e-commerce sectors. Numerous of these technologies such as automated guided vehicles (AGVs) and AMRs have demonstrated their efficacy in addressing the challenges of conventional e-commerce warehouses, such as labor shortages, and the growth of SKU complexity and service expectations.

2.3 E-commerce

E-commerce is the process of buying and selling products online. E-commerce has emerged in the 1990s and introduced a new concept called online sales. A great amount of new businesses emerged since that, (Khosrowpour, 2006).

With e-commerce, anyone may buy anything without leaving their home and has access to a wide variety of items. Furthermore, there is a 24-hour availability as there is no closing time with online purchasing, which enables flexibility for clients who do not have the time or choose not to visit actual stores. Another advantage that e-commerce provides is the international reach offered to brands or stores. On the other hand, completing online shopping forces the shopper to buy before actually handling the things, which can be a significant disadvantage, aside from the fact that they must wait for the products. These are two of the main challenges that are currently being addressed, (Zanzalari, 2022).

E-commerce is divided in three different types that are: Business to Business (B2B), Business to Consumer (B2C) and Consumer to Consumer (C2C). B2B is the transition between two parties which are businesses. B2C is the online sale to the end consumer and C2C is for example what happens in eBay, where a private client can sell products to another third-party consumer. According to (Giannikas et al., 2017), 4 key aspects distinguish B2B from B2C in logistics.

1. Products: although a big number of products may be ordered by end-customers nowadays, certain items may only be used by some businesses (for example, a turbine blade).
2. Orders: contrarily to B2B, orders from B2C customers are expected to be of a smaller quantity and value. B2C orders tend to satisfy their personal demand whereas B2B orders tend to satisfy the demand of their own customers.
3. Client: here client is referred to as the organization that is providing the products or services to a logistic center. In B2B it may vary significantly as clients can be factories, distributors, wholesalers, retailers or corporations. In contrast, B2C clients are usually retailers.
4. Receiver: In B2C, the order is received by an individual end-customer, while in B2B commerce receivers are typically companies.

The online luxury market is one segment of e-commerce that is slowly moving to this type of sales approach. Not only are major brands developing their own websites, but online platforms

such as Farfetch, Net-a-Porter, and Mytheresa are emerging in this market, with their platforms selling a very diverse range of products from brands and, in the case of Farfetch, boutiques located all over the world ((Schmidt et al., 2015)).

2.4 Warehouse Automation in the Fashion Industry E-commerce

The Fashion industry is one of the most challenging markets nowadays. Allied with the fast expansion of e-commerce, fashion products are particularly hard to manage efficiently in a warehouse due to low inventory stability and seasonality.

When it comes to fashion e-commerce companies, products are usually kept in large warehouses to meet service requirements in terms of delivery times and to serve as an inventory buffer to ensure availability. Hence, a company would greatly benefit from the effective management of such a warehouse in supply, order picking, and storage areas. Aside from that, special traits in fashion items are presented such as a volatile and unexpected demand in terms of volume and value connected with seasonal trends, and rarely refilled items that instead are replaced with new collections due to consumers' needs of always having the latest products. Furthermore, customers are now more understanding and aware of markets and therefore require a more discerning shopping experience both in terms of purchase and return.

All the points mentioned above gather a set of unique challenging characteristics for fashion warehousing. The consequences are the increased necessity for shorter lead times, the need for rigorous training for operators and the increased pressure to manage rising operational expenses associated with a specialized labor shortage. Throughout the luxury market, erratic demand, cyclical trends and a significant number of returns come up with the need of immediate answers for customer demands and provide ideal solutions at the ideal moment (Pedrielli et al., 2016).

Customer experience is a vital aspect of fashion warehouse *e-commerce* since it serves as the foundation for building brand loyalty, encouraging repeat purchases, and encouraging favorable referrals, all of which lead to long-term business growth and success (Smith and Wheeler, 2002). The fashion industry is investing heavily in Artificial Intelligence (AI). Due to the high importance of customers' impression and needs in this market, this investment is going to sentiment analysis which is a system that collects information about customers feedback through language processing, websites and phone calls. After processing all this information, the system can help finding what is positive and negative about some product attributes and help to understand if the brand is being mentioned.

All in all, it is important to understand how to answer the system conclusions regarding products. And for this, the warehousing aspect of the supply chain is a crucial step in the route of goods since the traditional ones might act as a bottleneck, slowing down distribution. Yet a solution provided by robotics and AI might turn around most warehouses' paradigm. It is now possible to hire small autonomous mobile robots that can complete the task instead of investing in a costly fixed big infrastructure such namely conveyors and massive grid-like automated storage and retrieval systems. Autonomous mobile robots show many benefits such as turning a completely

empty warehouse today into a fully operational and highly efficient and productive warehouse in a couple weeks. (Company, 2023)

2.5 Warehouse Processes and Automation Technologies

2.5.1 Processes

In order to better understand the different automation technologies that can be applied in a warehouse, it is first needed to clarify the main processes that occur there, namely the Inbound, Storage and Outbound.

The Inbound or receiving process deals with the reception of goods and is the start of the operation where few sub-processes occur, such as the inspection of goods. (Rouwenhorst et al., 2000) (Williams, BR, 2018). The Storage procedure is primarily concerned with the product's later use in the Outbound procedure. Within a warehouse, there are fundamentally two types of storage: bulk storage and pick storage (Clements et al., 2016). Bulk storage is mainly used as the reserve area and usually does not foresee frequently access from warehouse staff (Rouwenhorst et al., 2000). On the other hand, pick storage is commonly replenished by bulk storage and is supposed to be easily accessed by the warehouse staff. Typically, this area accommodates less quantity of products. (Calzavara et al., 2017). The last process, called Outbound, is responsible for fulfilling customer orders. The main sub-processes highlighted here are order picking, packing and shipment. Picking operation is responsible for the sorting and consolidation of the orders. After this, products must be packed, which means accommodate them inside a box. Some extras, such as labels, must be added before shipping to guarantee that orders are delivered correctly and to the right customer (Rouwenhorst et al., 2000). All of these processes are connected to a warehouse management system (WMS), that allows the operations teams to keep track and control them (Ross et al., 2010).

2.5.2 Technologies

The degree of automation of each of the aforementioned processes can vary significantly. The Inbound process has a high level of human involvement and a low level of automation. Looking at its sub-processes, inspection of goods, quality control repacking and labeling, only the last two may include technologies. The remaining always requires human involvement (Zhou, Chen, 2008).

Nonetheless, there are technical automation solutions in the Inbound process, usually concerned with the tracking of goods and the prior communication of the company about incoming goods in advance. This technology is called advanced shipping notification (ASN). ASN offers suppliers the possibility to notify their consumers in a structured way about individual orders and expected arrival periods. Regulating the Inbound process allows for the reduction of costs and avoids random shipments, which causes delays for both companies (Nilsson and Elmar Merkle, 2018).

Regarding the Storage process the use of automated storage and retrieval systems (AS/RS) in companies' storage processes has been the most significant advancement in recent years. An AS/RS system pretends to automatically store goods at the determined position and afterwards retrieve the items from the storage area according to the requested order. As a result, this system is not only in charge of the storage area, but also of Outbound process duties such as product picking. Companies that use such systems can save up to 40% of their storage space while also increasing picking efficiency, reducing human effort, and increasing accuracy (Marchet et al., 2012)(MaterialHandling, 2021).

In a completely different level of automation is the Outbound process. Picking is one of the top operations when it comes to automation technologies in warehouses. There are two types of different systems, Person-to-Goods and Goods-to-person. In the first one, the operators in the warehouse move to the storage location of the item and pick it while in the second the goods are brought to the operator (Nilsson and Elmar Merkle, 2018).

Person-to-Goods include technologies such as: pick-to-light, in which lights are integrated with pick location media and when an item is scanned a light shows up the location of the item; the voice-directed and radio frequency (RF)-directed picking that work in the same way as the previous one; RF-technology identifies the item, the voice-directed program sends the picker to the item's final position (Forte, 2014).

In turn, Goods-to-Person features the following technologies: Automated Guided Vehicles (AGVs) that are robots mainly used to the horizontal movement of goods. These robots are integrated with the WMS and controlled by it. The WMS assigns orders to each AGV and the robot must follow a route in order to move the goods to the picker according to (Oleari et al., 2014); automated forklifts which is another solution for the movements of goods and it is part of the AGVs. This technology in addition to the possibility of moving goods horizontally, also allows vertical movement and works as a normal forklift (Jacobus et al., 2015); automated conveyor system which is also used to transport goods to the picker is defined as 'length of a shelf fashioned into a closed loop that is rotatable (under computer control) in either direction (...) the benefits of a carousel is that rather than have a picker, human or robot, travel to retrieve an item, the item can travel to the picker' (Bartholdi III and Platzman, 1986).

Another sub-process of the Outbound process is the packing of goods. Some of the technologies associated are wrapping robots and automatic packaging machines. However, the latter is not quite explored being considered with a low level of automation (Rose, 2023).

2.6 Main Considerations

After this literature review chapter, the next one will provide a description of the problem at hand, followed by the outline of the methodology used to address it and the corresponding results. For the study in question, two automation solutions will be presented for two of the just mentioned processes in subsection 2.5.2.: Packing in Outbound and Storage processes.

Although there is not much development and technological demand for the packing operation when compared to picking, it was considered an opportunity for automation, for the reasons explained in the following chapter. In what concerns to the technology applied to the Storage process, it will be a specific case of the AS/RS (Automated Storage and Retrieval System).

Chapter 3

Current Situation Analysis and Identification of Automation Opportunities

Note: Please bear in mind that all the data presented in this study, here or in any other chapter directly related to the company's activity corresponds to fictitious and modified values in order to ensure company confidentiality.

The present study strives to identify areas within a fashion warehouse where the implementation of automation technologies may generate value. An 'area' encompasses a discrete section or zone within the facility that is dedicated to the execution of specific tasks or functions.

As previously mentioned, the warehouses under consideration do not currently employ any form of automation in their operations. However, they do utilize software for data storage purposes and may have conveyors that support specific manual operations. A conveyor is a mechanical apparatus used to transport goods from one location to the other.

At the start of this project, a warehouse had already been chosen. The rationale for selecting this particular warehouse will be presented in the following section where an analysis of the existing situation (AS-IS) will be conducted. Subsequently, in Chapter 4, the methodology employed is described offering a detailed description of how to address the operational problems identified in the AS-IS section.

3.1 Analysis of the Current Operational Framework (AS-IS)

To initiate an automation study, the first step entails analyzing the operational environment. The selection of the warehouse in scope was based on four key factors, including volume, stock on hand, area, and operational costs, as outlined in Table 3.1.

Table 3.1: Warehouse Metrics Comparison

Warehouses	Volumes [%] (Inbound, Outbound, Returns)	Stock on hand [%]	Area [%]	Cost of operations [%]
A	80%	73%	70%	67%
B	13%	16%	12%	9%
C	4%	4%	6%	8%
Others	4%	7%	12%	16%

The table shows warehouses A, B, C, and other warehouses from the company clustered as Others. Clearly, warehouse A shows the highest volumes, stock on hand, area, and cost of Operations in the company, and therefore is the selected one. This warehouse is located in Central Europe.

However, other reasons reinforce this choice. In addition to leading volumes and inventories, warehouse A has its business already well-established and stable, in operation for some time. Furthermore, while warehouses B, C and Others are spokes, A is a hub, and therefore more standardized operations occur. A 'hub' is a central or primary distribution center (DC) or warehouse serving as a central point where goods are consolidated, sorted and shipped. 'Spoke' on the other hand, refers to smaller distribution centers (DCs) or warehouses that are located closer to customers. Without loss of generality, this fact led warehouse A to become the main focus of this study and therefore the one under which this study in automation was performed.

3.1.1 Process Mapping

In order to grasp the key issues of the AS-IS, the value stream mapping was conducted as shown in Figure 3.1.

The warehouse in study operates mainly for a single business unit. Since this is a fashion business, it contains different categories of products, such as: Apparel, Footwear, Beauty Products, Hazmat Products and High Value Products. The layout is divided into zones, with each zone corresponding to one or more categories. Both the categories and the layout will be presented later in Chapter 4.

The operation of this warehouse is managed by a Third-Party Logistics (3PL) provider. Suppliers request a time slot for delivery of the products they need to ship, and the 3PL verifies the information in that request against the products that are in the Warehouse Management System (WMS). The product information contained in the WMS is sent via integration from the Enterprise Resource Planning (ERP) software. This is managed by the commercial team, which inserts the information when the order is created. Goods arrive at the warehouse either through shipment arranged by suppliers or through shipment arranged by the company. Upon arrival, the products are unloaded to the waiting area. The operator will then verify if the quantities of products align with the expected quantities to be received. The products are then registered in the WMS and

placed on trolleys. Once the trolley reaches full capacity, it is then taken by an operator, also referred to as a runner, and transported to the Putaway zone.

The designated team proceeds to the Putaway zone and transfers the trolleys to the storage area. The storage area is divided into different zones based on category distinctions, which are indicated through a visual management system. The operators place the items in the respective zones based on the available space. Prior to storage, the products are not assigned to a specific location. This allocation occurs only when products are stored through a scan of the product and the respective storage location. This initial stage is generally referred to as Inbound.

Customers use the platform to place orders, which are then communicated to the WMS. The WMS processes these orders and organizes them into picking waves. Each picking wave is defined using optimized routes generated by a specific module of the WMS. The assigned picking waves are then provided to operators who collect several items, also known as batch picking, from various categories present in the particular picking wave. Each picking wave is composed of a set of orders which may be single or multi item orders. Multi-item orders refer to those where a single customer purchases more than one item in a single platform order. On the other hand, single-item orders occur when a customer purchases only one item on a platform.

Once the Picking operation is completed, the operators transport the collected products on trolleys to the Packaging area, where they are properly packed.

Finally, the packed orders are arranged on different pallets based on the carrier. The carriers are then responsible to transport the orders from the warehouse to the customers. Customers can be either the end consumer or, within the scope of this business, studios, stores, or other warehouses. The former situation is also known as a Business to Consumer (B2C) service, while the latter is referred to as a Business to Business (B2B) service.

It is worth noting that the Outbound phase encompasses the period from the beginning of Picking until the commencement of the pick up process by the carriers, which occurs after the completion of the Packaging operation. Similarly, the Inbound procedure takes place until the Putaway process is finished. Figure 3.2 provides a visual representation that illustrates this concept clearly.

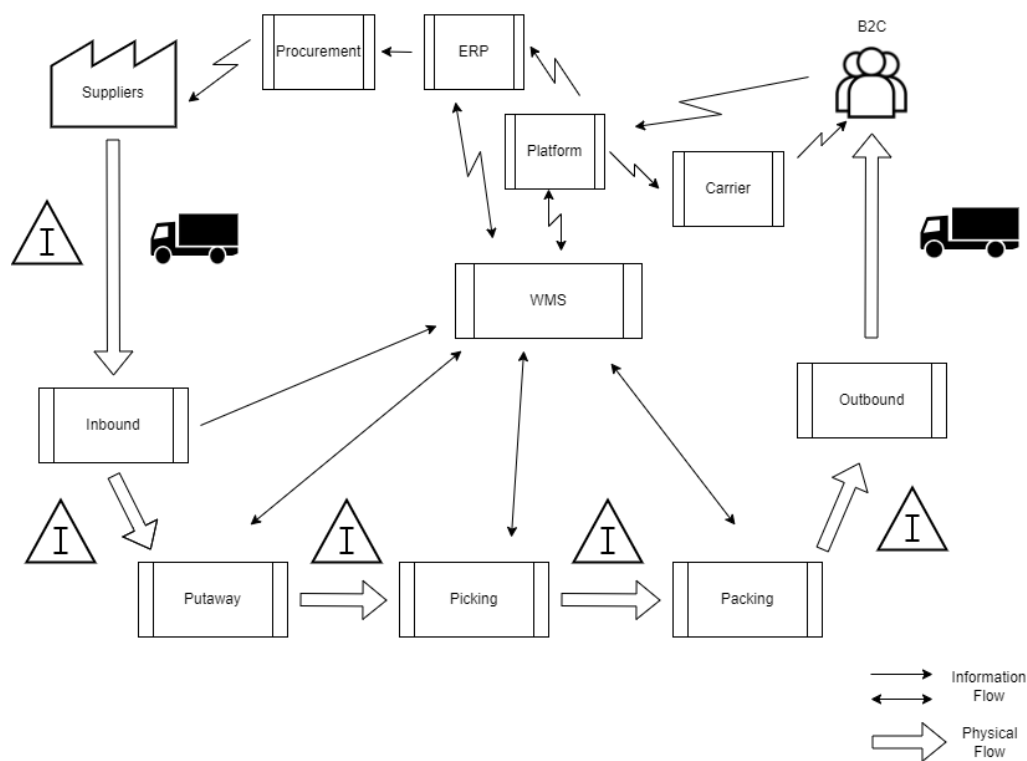


Figure 3.1: Warehouse A - Value Stream Mapping.



Figure 3.2: Inbound and Outbound Process

3.1.2 Find Major Opportunities

After mapping the AS-IS process, a brainstorming session was conducted to generally list the advantages and disadvantages of automating the warehouse under study. Table 3.2 summarises the result of this study.

Table 3.2: Pros and Cons of Automation

Pros	Cons
Storage Capability Improvement	High Initial Investment
Less Area With More Storage Capacity	Maintenance
Possibility To Grow In Height	Requires Tech Skills and Training
Better Use Of Space	Depreciation
Increase Safety	Less Flexibility and Lack Of Adaptability
Reduce The Labour Cost	
Operator Walking Reduction	
Increased Accuracy, Productivity and Efficiency	
Reduce Shipping Costs	

3.1.3 Identification of Opportunity Areas

The initial step in analyzing Warehouse A involves identifying the areas that show potential for automation.

Through a thorough analysis of the profit and loss (P&L) statement, it was possible to determine the specific areas within Warehouse A that incur higher costs and, as a result, present significant opportunities for improvement and, therefore, automation. For direct costs, the three lines considered were inbound, outbound, and returns. Returns is the designation given to the process of managing goods or products that are taken back by customers due to damage reasons, since the wrong product was shipped, or for any other reason that should be thoroughly investigated. Due to the complexity involved, and also because it does not impact greatly the costs, it was not considered for this study. The standout area was outbound, which accounted for more than half of the total direct costs (53%) as may be observed in Figure 3.3. These costs are scrutinized in Figure 3.4 which highlights its distinction between operations such as Picking, Packing, Administrative (Admin), Loading, and others.

Inbound, Outbound and Returns Distribution

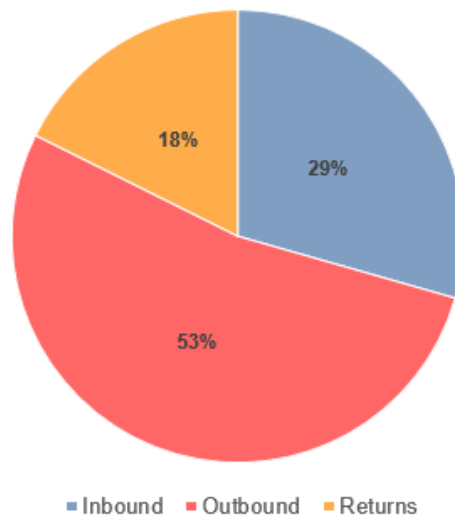


Figure 3.3: Direct Costs Distribution.

Going deeply into the Outbound it is possible to verify that the operation with higher expenses is essentially the Packaging with 55% of the Outbound costs as shown in Figure 3.4

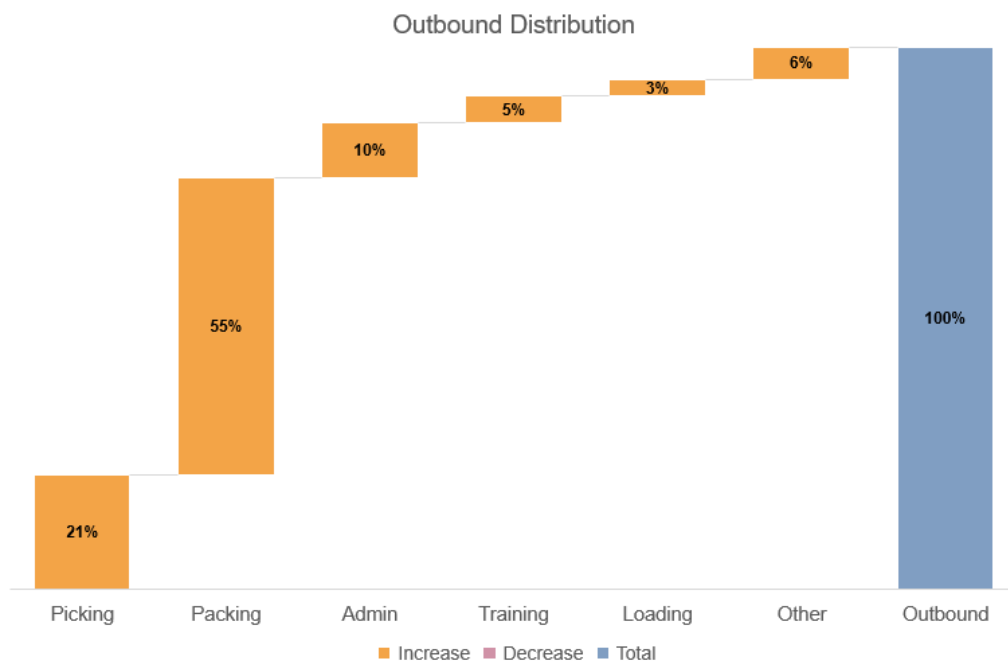


Figure 3.4: Outbound Waterfall Chart.

In addition, another opportunity area emerged. Two distribution centers (DCs) that are joined by two access doors make up the layout of warehouse A. Since a significant increase in the company's stock and sales was anticipated at the time this warehouse was established, there are now two DCs, both rented.

Due to previous space optimizations, one of the DCs, DC1, is only being used for a small portion of the stock. In turn, DC2 is home to the majority of the current stock and is separated into zones.

As mentioned at the beginning of this section, there is a variety of product categories, and it is through these categories that DC2 divides its zones as presented in Figure 3.5.

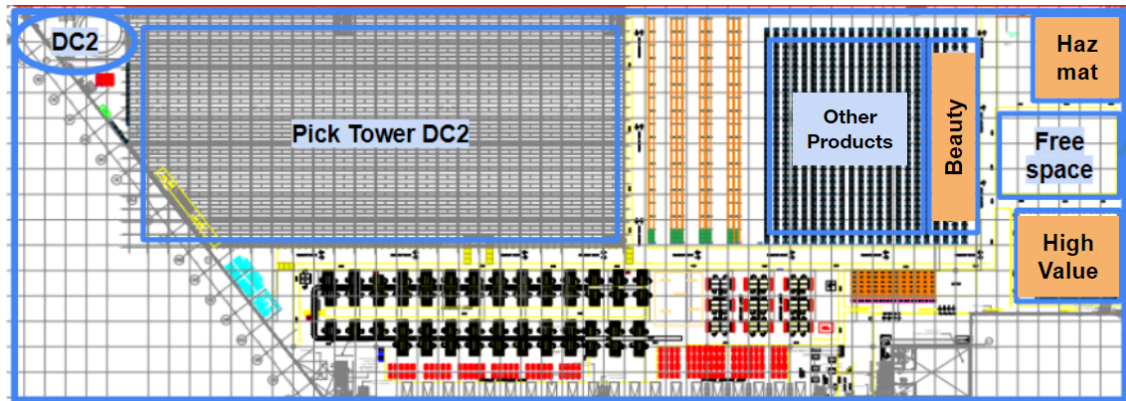


Figure 3.5: DC2 Warehouse Layout

Site visits were conducted by some team members and it was revealed that the storage area allocated to certain categories was excessively large. Furthermore, an evaluation of the forecast volumes for 2024 combined with past experience, suggests that these particular categories are not anticipated to undergo significant increases. This has made the storage area stand out as an opportunity for automation. The categories are: Beauty, Hazmat and High Value highlighted in Figure 3.5. Consequently, the Pick Tower and Other Products, also illustrated, are out of consideration in this study. The Beauty category is currently kept in two aisles. Similarly, Hazmat and High Value, two other categories presented, are kept in enlarged zones that take up more room than is required in DC2. It is important to point out that Hazmat products are stored in a separate container due to the special storage conditions they require because they are, for instance, flammable products. This means that temperature control and fire protection are highly necessary to safeguard these products. In turn, High Value products are kept in a cage to prevent theft since, as their name indicates, they are exclusive and expensive products. The use of the Beauty storage, as illustrated in Figure 3.6, served as an example to elucidate the storage-related issue.



Figure 3.6: Storage AS-IS for Beauty Category

Chapter 4

Methodology

The present chapter aims to describe the methodology (see Figure 4.1) followed for the analysis of the areas identified in the previous Chapter.

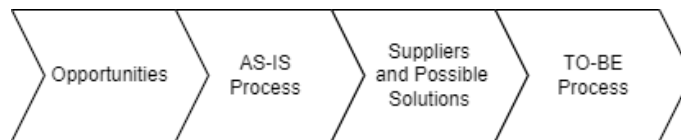


Figure 4.1: Methodology Framework

The same methodology was conducted for each area. Firstly, the opportunities inside each area were outlined. Subsequently, the AS-IS process was mapped. Then, the suppliers and possible solutions were compared and identified. And finally, the TO-BE process was mapped, incorporating the identified solutions.

4.1 Packing

4.1.1 Opportunities

Apart from the higher costs just mentioned in the last section, the Packing area has the potential for bigger savings that will impact the value chain in a wider range.

In 2021, the company was looking for solutions to reduce the shipping costs of its B2C deliveries. In addition, there was the process of rationalizing its transport boxes, as there were 12 different models at the time.

Those boxes were not always of the appropriate size to accommodate the products, resulting in empty space inside them. This empty space, referred to as "transport air", incurs unnecessary costs and contributes to an increased carbon footprint. Since freight charges are calculated based on weight and volume, using bigger boxes than needed leads to additional costs and excessive resource utilization, including extra fuel consumption and paper usage.

As a final motivator, there was a goal to increase the productivity of Warehouse A, and Packaging is clearly a labor-intensive activity, whether it be assembling the boxes, placing the products,

closing the packaging, labeling, or other processes. With fewer full time equivalent's (FTE's), the 3PL cost would also reduce.

4.1.2 AS-IS Process

After analysing the opportunities in Packaging, the process AS-IS was mapped. Table 4.1 will first present the assumptions made at the outset of this study. The manual inefficiency here presented considers general human inefficiencies, such as breaks or distractions, and is an existent estimated value for this process.

Table 4.1: Assumptions on AS-IS Packaging Process

# Shifts Per Day	2
# Working Hours Per Shift	8
# Working Days / Week	5
# Weeks / Year	52
Break Time Per Shift (h)	0.5
% Manual Inefficiency	20%

The team's visit to the warehouse, along with video observations of the Packaging operation and meetings conducted with the operations team facilitated the identification of the following processes: regular process without folding, regular process with folding, fragile items, big multi orders with more than one box and beauty items. Upon closer scrutiny, the different processes may be subdivided by combining the type of pack with the destination. This is important as it can influence how shipment documents are added. If a product is sent to European Union, a thermal label should be placed on the box. However, if the product will be sent outside European Union, the documents added must be sent in a Plastic Pouch attached to the box. The existing types of packs are as follows: regular boxes, pop-up boxes and envelopes, all of different sizes.

So, the general processes will now be subdivided as shown in the following process map presented in Figure 4.2. The various processes listed will be executed through a series of manual steps done by the operators.

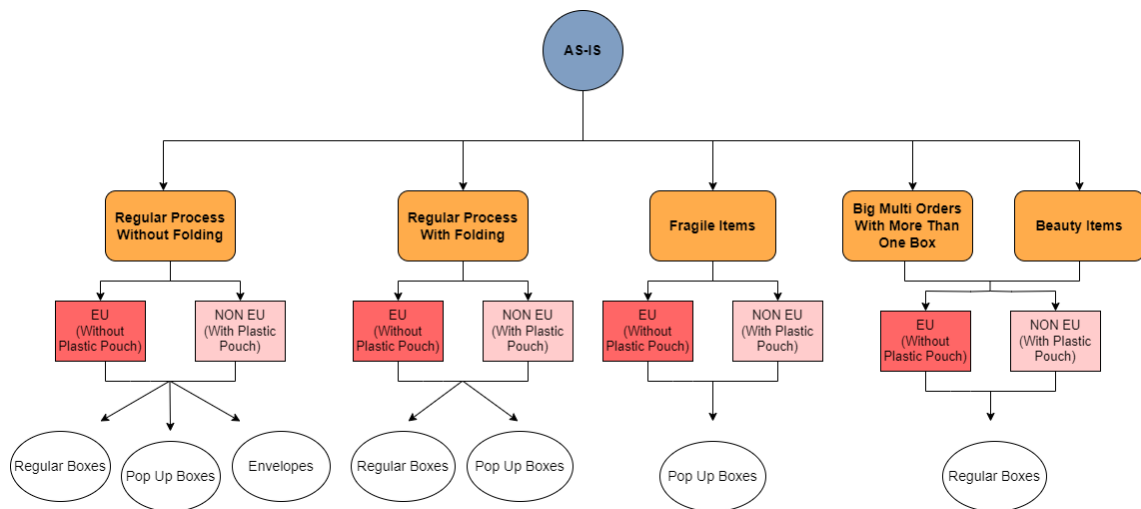


Figure 4.2: Packaging Process Map AS-IS.

Table 4.2 describes all the steps that can occur during these procedures. Following that, in Figures 4.3 and 4.4, two matrices are provided, depending on whether the products are transported to European Union or outside European Union. These matrices outline the individual steps involved in each process, along with their respective time duration.

Table 4.2: Process Steps AS-IS

Steps	Description
1	Scan SKU
2	Check Tag ID
3	Check Label Info (Size/Colour)
4	Unwrap Item(s)
5	Fold Item(s)
6	Rewrap Item in Polybag
7	Wrap Item with Bubble Plastic
8	Choose and Scan the Box(es)
9	Set the Box(es)
10	Insert Fulfill Paper
11	Print AWB and Shipping Documents
12	Separate AWB and Documents (Int /Ext)
13	Stuff Box With Protective Padding
14	Close Box(es)
15	Add Fragile Stickers
16	Add External Docs
17	Place Order in the Conveyor

EU (Without Plastic Pouch)		Average Time (s) of each Step																
		Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17
Processes	Regular Process without folding with regular boxes	6	5	5	-	-	-	-	15	21	-	36	3	-	10	-	7	4
	Regular Process without folding with pop up boxes	6	5	5	-	-	-	-	15	4	-	36	3	-	10	-	7	4
	Regular Process without folding with envelope	6	5	5	-	-	-	-	15	-	-	36	3	-	10	-	7	4
	Regular Process with folding with regular boxes	6	5	5	22	40	46	-	15	21	-	36	3	-	10	-	7	4
	Regular Process with folding with pop up boxes	6	5	5	22	40	46	-	15	4	-	36	3	-	10	-	7	4
	Fragile Items	6	5	5	-	-	-	88	15	21	-	36	3	50	10	14	10	4
	Big multi orders with more than 1 box	17	16	16	52	80	-	-	46	63	-	36	3	-	40	-	7	6
	Beauty	6	5	5	-	-	-	-	15	21	89	36	3	-	10	4	7	4

Figure 4.3: European Union Process Matrix AS-IS.

NON EU (With Plastic Pouch)		Average Time (s) of each Step																
		Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12	Step 13	Step 14	Step 15	Step 16	Step 17
Processes	Regular Process without folding with regular boxes	6	5	5	-	-	-	-	15	21	-	36	10	-	10	-	29	4
	Regular Process without folding with pop up boxes	6	5	5	-	-	-	-	15	4	-	36	10	-	10	-	29	4
	Regular Process without folding with envelope	6	5	5	-	-	-	-	15	-	-	36	10	-	10	-	29	4
	Regular Process with folding with regular boxes	6	5	5	22	40	46	-	15	21	-	36	10	-	10	-	29	4
	Regular Process with folding with pop up boxes	6	5	5	22	40	46	-	15	4	-	36	10	-	10	-	29	4
	Fragile Items	6	5	5	-	-	-	88	15	21	-	36	10	50	10	14	29	4
	Big multi orders with more than 1 box	17	16	16	52	80	-	-	46	63	-	36	30	-	40	-	52	6
	Beauty	6	5	5	-	-	-	-	15	21	89	36	10	-	10	4	29	4

Figure 4.4: Non European Union Process Matrix AS-IS.

In order to give more context, a brief description of each process will now be done. Please note that this analysis is focused on B2C service since it corresponds to the majority of processes. The regular process without folding is the most generic process, where the operator identifies the item and checks if everything is correct (steps 1 to 3). Afterwards, he will choose and scan the box being used for packaging the order (step 8), setting up systematically which box will be used (step 9). After this the shipping label (Air Waybill) is printed (step 11). The Air Waybill is a document that is sent with products by an international air courier in order to provide comprehensive information about the shipment and enable tracking for the customer and the customer service teams. Once the Air Waybill is printed, the operator will separate it from other documents and will close the box (steps 12 and 14). Then, the external documents are added (step 16). Finally, the operator places the order in the conveyor (step 17) which will be subsequently sorted to the pallet of the respective carrier.

This process (regular process without folding) will be separated into six different processes. Please see Figure 4.2 to better understand this division. The first three, presented along the first three lines of Figure 4.3 are all regular processes without folding without plastic pouches, which

means they will all be sent to an European Union location, as already mentioned. They are three due to the three types of boxes - regular box, pop up box and envelope. The last three processes, first three lines in Figure 4.4 are also regular processes without folding, but now, with plastic pouches, so they will be sent to outside European Union. As it will be possible to understand by analysing these last two figures, the main differences in all these six processes relay on the following: the need to add a plastic pouch (step 16). The separation of documents (step 12) and their subsequent addition to the box (step 16) take more time since the operator needs to put all the documents inside a plastic pouch and add it to the box while the thermal label is only a sticker placed directly on the outer carton; when the product is inserted into a regular box the set up of the box (step 9) takes more time than when it is a pop up box that assembles by itself. Envelopes are being considered as boxes for simplification purposes, however, they do not need to be assembled and therefore step 9 does not exist for this case. In terms of the regular process with folding, the key distinction from the previously mentioned method is that the folding of products now becomes a necessary step. For this reason, three new steps are now mentioned, they are - unwrap item (step 4), fold item (step 5), and rewrap item in polybag (step 6). Step 4 occurs because the products are delivered to the operator on hangers and wrapped in plastic. As previously stated, they must be removed, folded, and placed in the polybag in this manner. Additionally, there are no envelopes for this process (the fraction of envelopes is residual and has been ignored). The rest of the process is identical to the preceding one and occurs under the same circumstances, i.e., a plastic pouch may or may not be included, and the products may be supplied in standard or pop-up boxes. Inevitably these three extra phases lengthen the process relative to the prior one.

Regarding fragile items, the mapping was done separately from the others since these are products that must be handled with greater care and present subtle changes in their procedure. Although most of its steps (steps 1, 2, 3, 8, 9, 11, 12, 14, 16, and 17) are identical to the previous ones, there are some differences. The primary differences are discovered immediately after inspecting the product (step 3), where the item will be wrapped in bubble plastic (step 7). Upon selecting, scanning, and setting the boxes (steps 8 and 9), and preparing all shipping documentation (steps 11 and 12), the operator must stuff the boxes with protective padding (step 13). To guarantee proper handling, the box will be closed (step 14) and a sticker stating that it is a sensitive item will be attached (step 15). Steps 16 and 17 involve the addition of external documents and the placement of the order.

For big multi-orders with more than one box, since this is a large multi-order process with many goods and thus multiple boxes, the procedure is practically the same as the standard procedure with folded items, the difference is in the time required. This process will only use regular boxes.

Lastly, when it comes to beauty items, special attention must be given to their delicate nature, requiring them to incorporate specific care measures. Once the first five stages, which in this case are steps 1, 2, 3, 8, and 9, have been completed, the box is ready to accept the contents. After inserting the contents, the operator must cover the sides and top with a protective paper (step 10). The box is then closed when all of the documents have been printed and correctly separated (steps

12, 13 and 14). The delicate stickers and other paperwork must also be attached to the package for these products (steps 15 and 16). Finally, the box can be shipped and is placed in the conveyor (step 17).

The following scheme presented in Figure 4.5 pretends to illustrate part of the operation in the warehouse to make it more comprehensible for the reader.

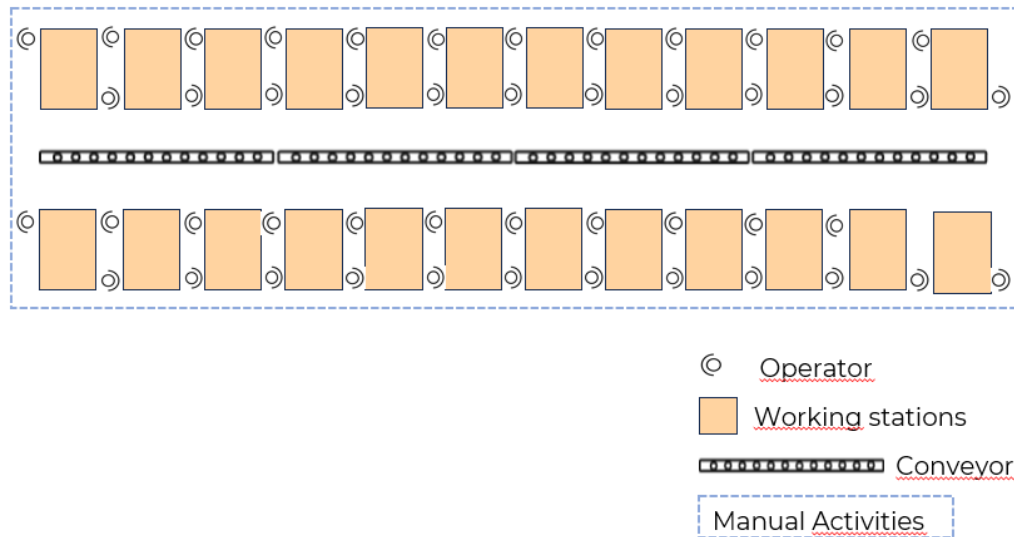


Figure 4.5: Current Operation at the warehouse

4.1.3 Suppliers and Possible Solutions

Considering the three incentives listed in the 'Opportunities' section (4.1.1), the substantial costs this action entails (55% on direct costs), and also taking into account the AS-IS process, a benchmark analysis was performed on the suppliers that offer automatic Packaging machine solutions. The results are presented in Figure 4.6.

Machine Attributes	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Output (boxes / hour)	900	720	1100	1020
Box with easy open and return	Yes	No	Easy opening, customer must use tape for returns	Only tearstrip
Box min and max dimensions (mm)	230 x 140 x 35 810 x 640 x 340	210 x 155 x 55 620 x 510 x 460	250 x 190 x 60 620 x 610 x 270	320 x 155 x 40 620 x 360 x 215
Weight and Dimensional Records	Yes, optional	Yes, included	Yes, optional	Yes
Maintenance plan	Yes, several levels, see commercial proposal	Yes, see proposal	To be shared by the supplier	Yes
Sorter by carrier	Yes, 3-way sorter	Yes, included	No	Yes, not integrated (outsourced)
Number of Fan Fold supplies	2 (standard) 4 (optional)	2 (standard)	up to 6	4
Cost	970.000 €	1.200.000 €	1.300.000 €	1.100.500€

Figure 4.6: Study on Packaging Suppliers

The required hourly output to meet customer demand was set at 750 boxes per hour, and the cost for the specified requirements should be as low as possible. The table analysis revealed that the only supplier that does not fulfill the output requirements is Supplier 2, and for this reason, it will not be considered as a feasible supplier.

Regarding the second row of the table, which indicates the ease of opening and closing boxes - a crucial factor to ensure a positive customer experience - it was determined to confirm that all providers offer, at the very least, a part of the pretended solution. However, Suppliers 3 and 4 do not provide optimal choices because they do not allow the box to be closed easy and practically.

With regard to the box sizes, there is a parallelism in the intended criteria for the maximum and minimum dimensions supplied. On the one hand, the amount of air inside the box is supposed to be as minimal as possible, hence smaller boxes accommodate less air volume. On the other hand, because it is a fashion warehouse, the products vary greatly, both in terms of seasonality and size, which often become unpredictable. As a result, the size range was claimed to be as broad as possible in order to fit larger-sized products if they arose. This proved that Supplier 1 is the greatest fit for this need, with the highest and smallest potential box volumes - 1127 cm³ and 176 256 cm³, respectively. When it comes to the next two factors, weight and dimensional records, and maintenance plans, all providers appear to be on an equal footing. However, Supplier 1 has some flexibility in its maintenance plans, which provides it another advantage over the others.

After these two, the sorter by carrier is presented. There are currently four carriers transferring

products from the warehouse to the end client, with a tendency to increase due to cost optimization initiatives. Regarding this feature, we can confirm that Supplier 3 does not support carrier sorting and Supplier 4 does, but it is not integrated, thus it will incur additional charges. As we can see, Supplier 1 is once again the most adaptable supplier.

Regarding the "Fan Fold supplies" it is a continuous sheet of cardboard that is folded in a regular pattern and is used to feed the machine in this example. Because the company sells not only in one channel, that requires at least two different types of packaging, as the box branding is different. Each box branding can be associated to one type of packaging which means that at least, two Fan Fold are needed to feed the machine, something that all suppliers allow. Finally, the investment costs to acquire each machine are presented, and we can determine that, once again, Supplier 1 has the best proposal, which is slightly less than 1M€, a value that all other providers exceed.

The aforementioned considerations led to the decision that Supplier 1 would be the ideal source to advance with the discussion.

4.1.4 TO-BE Process

Once Supplier 1 was selected, it was necessary to study the impact of implementing its technology, through process redesign. The expected future packaging process will be named "TO-BE process". All the existing manual processes were presented to the supplier and after careful examination, it was concluded that due to their complexity, certain processes could not be incorporated in the Packaging machine. We note that this issue was verified across all suppliers. The processes are presented in the Table 4.3 along with an analysis of the percentage of sales of each one.

Table 4.3: Processes In Scope For Automation

Process	% Sales	In Scope for Automated Line?
Regular Process with folding with pop up boxes	13.6%	Yes
Regular Process with folding with regular boxes	13.2%	Yes
Regular Process without folding with pop up boxes	30.4%	Yes
Regular Process without folding with regular boxes	19.4%	Yes
Regular Process without folding with envelope	16.9%	No
Fragile Items	1.9%	No
Big multi orders with more than 1 box	4.0%	No
Beauty	0.7%	No

The first four processes, encompassing packaging regular products in regular packaging, are in scope of the automation, whereas specific products such as Beauty and Fragile items, as well as orders packed in more than 1 box were left out of scope of automation. Since the products will now enter the Packaging machine, the distinction of processes variations based on box type loses its sense, since the auto-packer will assemble its own boxes, as stated in Figure 4.6. As a result,

the TO-BE process will be more streamlined, when compared to the AS-IS as depicted in Figure 4.7

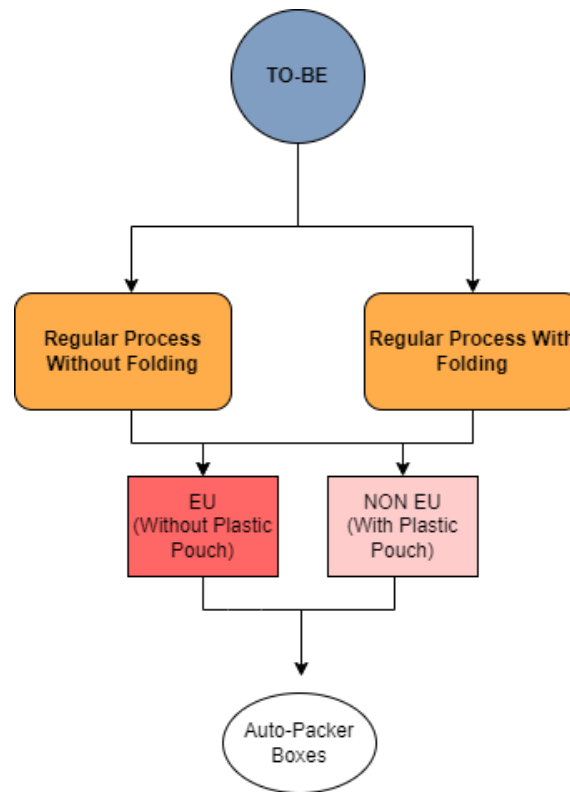


Figure 4.7: Packaging Process Map TO-BE.

The main benefit expected with the implementation of the auto-packer is the reduction of manual steps and the labour costs associated to them. This reduction can be clearly identified in Table 4.4, when compared with the AS-IS process Table 4.2. The table present the steps that will remain in the TO-BE process.

Table 4.4: Process Steps TO-BE

Steps	Description
1	Scan SKU
2	Check Tag ID
3	Check label info (size/colour)
4	Unwrap item
5	Fold Item
6	Rewrap Item in Polybag
7	Place order in the conveyor
8	Scan AWB
9	Add external docs
10	Place order in the conveyor

The average time of each step is presented in Figures 4.8 and 4.9 that correspond to products that will be sent inside European Union or outside European Union respectively.

EU (Without Plastic Pouch)		Average Time (s) of each Step									
Processes		Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10
	Regular Process with folding	6	5	5	22	40	46	-	-	-	4
	Regular Process without folding	6	5	5	-	-	-	-	-	-	4

Figure 4.8: EU Process Matrix TO-BE.

NON EU (With Plastic Pouch)		Average Time (s) of each Step									
Processes		Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10
	Regular Process with folding	6	5	5	22	40	46	4	6	29	4
	Regular Process without folding	6	5	5	-	-	-	4	6	29	4

Figure 4.9: NON EU Process Matrix TO-BE.

By analysing the Time and Method study above and comparing them to the ones presented in the AS-IS process in Table 4.2, it may be observed that the stages requiring product Packaging have been suppressed, as just mentioned. They were as follows: "Choose and scan the box" (step 8); "Print AWB and Shipping Documents"(step 11); "Separate AWB and Documents (Int / Ext)" (step 12); and "Close box" (step 14). The elimination of these steps results in an expected decrease in manual operation time, implying a reduction in the number of operators required to ensure product packaging. The expected positive results, as well as the total savings from this study, will be revealed later in chapter 5.

The following scheme presented in Figure ?? pretends to illustrate the future operation in the warehouse with the packing machine implementation, to make it more comprehensible for the reader.

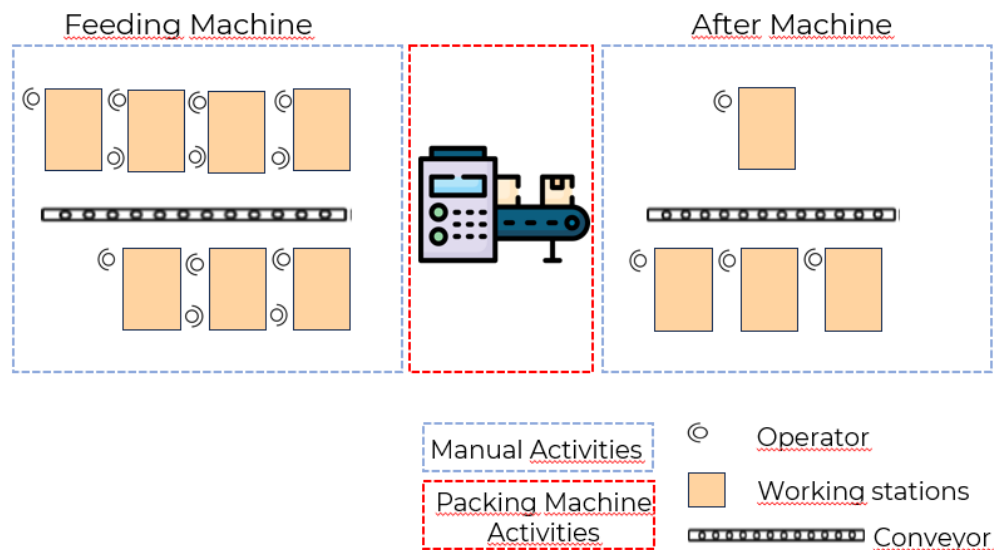


Figure 4.10: Future Operation at the warehouse

4.2 Storage

Storage is another area identified with potential for automation. Thus, this section will present the methodology followed to address the main issues highlighted in Chapter 3.

4.2.1 Opportunities

As previously mentioned and illustrated in the preceding section, the storage of the Beauty, Hazmat and High Value categories is non-optimized and excessive in size, contrasting with the small average size of these product categories. Considering this and upon closer examination of possible automation solutions, it was identified that the storage of these categories presents opportunity for vertical storage, with the main goal of releasing floor space, which could be used for other purposes (storage, processing) or even reducing rental costs.

The change in storage methods presents a significant opportunity for space reduction, whereas indirectly, as the warehouse under consideration is leased. This indirect area saving implies that releasing space within either DC1 or DC2 does not directly translate into cost savings, as the distribution center itself remains in operation.

Nevertheless, there are other possible use cases unlocked from the implementation of this automation, such as increased storage capacity, which can be utilized for storing other products or accommodating temporary storage and new processing areas. Additionally, an increase in productivity is expected, as even with optimized routes in the Putaway and Picking processes, there is still time wasted due to operators' movement along the aisles with the current storage layout.

Furthermore, despite the aforementioned considerations regarding cost savings, this resizing opportunity may lead to direct reductions in expenses. As outlined in the problem description chapter, DC1 currently works as a distribution center with very limited stock. Therefore, freeing

up space in DC2 also presents a storage opportunity for the existing products in DC1. If such liberation becomes feasible, the cost reduction would be significant.

Summing up, the main opportunities this automation can contribute to are:

- Release Space for other products or for other logistic purposes, such as processing areas
- Reduce Rental Costs, as it can be a contributor to release DC1, since it currently stores a minor portion of the inventory.
- Increase Productivity, since the rearrangement of space can lead to easier accessibility and avoid unnecessary dislocations to get products.
- Achieve costs savings that can be a consequence of increasing productivity but have its major opportunity if there is a possibility of releasing DC1.

4.2.2 AS-IS Process

With the liberation of space being the main highlighted opportunity for this area, the layout presented in the previous chapter was analyzed to quantify the current context. Additional data was accessed and is summarized in Table 4.5.

Table 4.5: Summary of Product Categories, Stock Quantities, and Storage Requirements

Category	Average Size of Product in cm^3	Stock on Hand in Units	Volume to be Stored in m^3	Area Occupancy in m^2
High Value	545	11000	6	600
Hazmat	667	3000	2	300
Beauty	800	35000	28	170

Regarding DC1, considered as an opportunity for releasing the whole rental, the registered area occupancy is 36 000 m^2 . It is known that the current price paid per square meter per month is €4.50.

Regarding productivity analysis, the products categories in the warehouse were analysed according to their demand and the products within the Beauty, Hazmat, and High Value Categories are classified as C products, indicating a low turnover. Therefore, the impact of the productivity increase is expected to be low in importance, when compared to the potential space savings, and though it will not be quantified.

The costs of the current AS-IS situation will be presented later in Chapter 5 in order to compare them with the costs of the proposed TO-BE solution.

4.2.3 Suppliers and Possible Solutions

In order to be able to choose a solution for the automation area in question the following specifications were listed:

- Maximum Storage Space Optimization.
- Store in Height (until 15 metres).
- Fire Protection and Temperature Control for Hazmat Products.
- High Security due to High Value Products.
- Low Training and Maintenance Costs.

A market analysis of the main vertical storage solutions was conducted, and two suppliers emerged as top players in the market with whom discussions were initiated. Henceforth, they will be referred to as Supplier 5 and Supplier 6. The desired requirements were communicated to the suppliers, and the necessary data for the study was shared.

Both suppliers presented automated storage and retrieval system (AS-RS) as solutions for the business needs, specifically a Vertical Lift Module. The summarized information about their solutions is presented in Figure 4.11 presented below:

	Supplier 5		Supplier 6	
	Model A	Model B	Model C	Model D
Area	3.5	9	9	10
Height	7	10	7	10
Machine total volume (m^3)	24.5	90	63	100
#Drawers	78	123	60	120
Storage Volume Capacity (m^3)	8	40	20	45
Safety & Security	Hazmat Fire Protection &		Hazmat Fire Protection &	
Maintenance & Training	Basic - Own Company provides support Training: 2/3 days (including maintenance)		Basic - Own Company provides support Training: 2/3 days (including maintenance)	
Cost	€ 30,000.00	€ 50,000.00	€ 45,000.00	€ 65,000.00

Figure 4.11: Study on Storage Suppliers.

In what concerns to the considered area occupancy of each machine and since for Beauty, Hazmat and High Value the actual occupancy rounds 1000 m^2 as presented in Table 4.5, all the machines present good opportunities of space reduction.

Regarding the volume capacity and once more by observing Table 4.5 the actual volume to be stored totals approximately 39 m^3 which is feasible in Model B or Model D presented by the suppliers. Model A and C emerged after considering the possibility of separating High Value from the other categories, due to questions raised by insurance. Even though machines offer the

possibility of having a restricted area for this category, it might be a problem still to combine these categories, since High-Value products present exorbitant costs.

For the 'Safety & Security' parameter which considered the points just mentioned as well as for the 'Maintenance & Training' parameter, both suppliers presented the same conditions and capability.

Finally, the cost range is between €30 000 and €65 000 which was considered acceptable. There is a stipulated budget for this case study that cannot be revealed. However, this budget may be variable and reassessed depending on the results presented by the calculations developed for this business case.

Based on the presented reasons, it was decided to proceed with the study considering both suppliers. The results of this study will be presented in Chapter 5.

4.2.4 TO-BE Process

The main change and benefit that will be evident in the TO-BE process, as previously discussed, is the release of floor space. In this regard, since a supplier has not been chosen yet, one possible scenario in terms of area requirement is presented in Figure 4.12. The scheme represents an adapted layout from the current configuration, as presented in Figure 3.5 in Chapter 3, and it only illustrates the in-scope zones. It is important to note that the placement of the modules in the figure is arbitrary, as the intention is solely to compare areas.

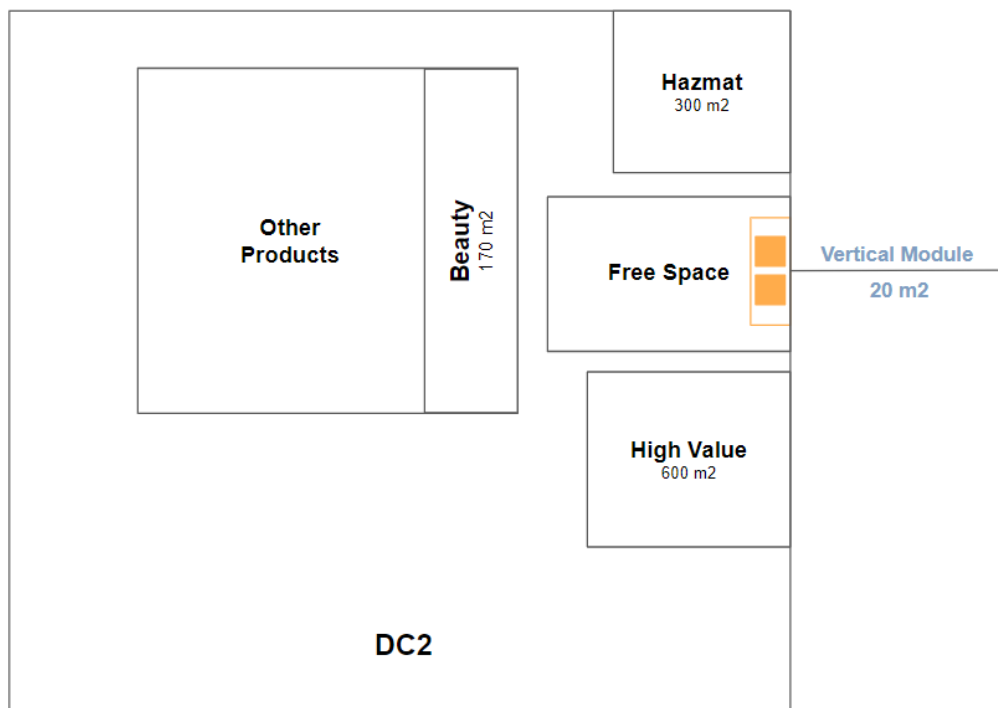


Figure 4.12: Layout Areas TO-BE.

Based on this, it was decided to proceed with the study considering both suppliers. The results of this study will be presented in Chapter 5.

In addition to space savings, although not one of the primary benefits in this case, an increase in productivity is expected. This increase will result from the reduction in movements during put-away and picking, as only one zone (in orange on Figure 4.12) will need to be accessed to retrieve products from the three categories. In the current process, apart from having to access three different zones, the operator needs to move along the aisles for picking or putaway of products from the same category.

It is expected that the operator would have idle time whilst waiting for the machine to present the drawer to store or retrieve the product from. Considering it is expected to have more than one vertical module, which may be necessary due to the existing stock volumes and storage requirements, it is relevant to divide the operator's work between the number of existing machines and also consider the inclusion of a Packaging station, to reduce idle time and integrate operations, improving process flow. This scenario is illustrated in Figure 4.13.

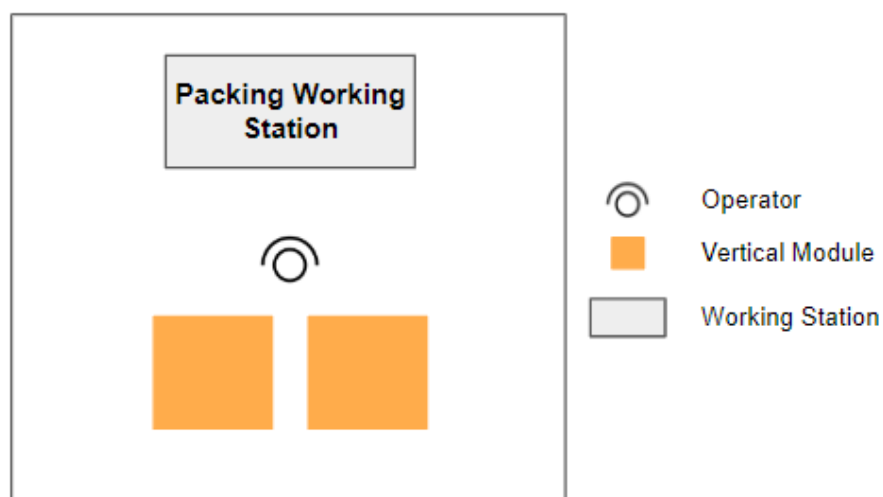


Figure 4.13: Cross Picking and Packaging Operations.

Chapter 5

Results

The results presented for this project are based on a simple Excel model and are presented in order similar to Chapter 4. Firstly, the results for the Packaging operation are depicted, followed by the Storage solution and the associated opportunities. The costs and benefits of the considered solutions for each case are finally given. Each model represents a business cases.

5.1 Packaging

For this section, the business case aims to determine the impact of implementing the Packaging machine, also known as auto packer. The desired outcomes, as discussed in the Opportunities section (4.1.1) are: achieving operational savings and reducing freight rates to obtain delivery savings.

The operational savings result from the reduction of the number of operators required in the process. The implementation of the automatic packaging machine will allow, as can be inferred, the automatic packaging of products, replacing the manual steps involved in this task for the processes in scope. These steps include "Choose and Scan the Box(es)" (Step 8), "Set the Boxes" (Step 9), "Print AWB and Shipping Documents" (Step 11), "Separate AWB and Documents (Int/Ext)" (Step 12) and "Close Box(es)" (step 14), as presented in Table 4.2.

Certain carriers charge for each shipment based on the volumetric weight, The currently existing standard boxes do not allow for the maximum reduction of these costs. Thus, the delivery savings will be obtained since the machine produces each box based on the size of each product. This feature allows for the reduction of empty space between the box and the product inside it, resulting in lower volume and consequently lower associated costs.

As mentioned in Chapter 3, the implementation of a Packaging machine encompasses the following processes: regular process with folding and regular process without folding, both for European Union and outside European Union. Consequently, the results presented in this business case will solely consider these processes.

5.1.1 Operational Savings

Regarding the order profile, it is known the distribution of orders forecasted for the next year, for both European Union and outside European Union is (see Table 5.1).

Table 5.1: Forecasted Orders In Scope

Processes	EU [orders]	NON EU [orders]	EU [%]	NON EU [%]
Regular Process with folding with pop up boxes	86754	184323	4.34%	9.22%
Regular Process with folding with regular boxes	84352	179219	4.22%	8.96%
Regular Process without folding with pop up boxes	194764	413806	9.74%	20.69%
Regular Process without folding with regular boxes	123941	263333	6.20%	13.17%

The obtained results were calculated and will be presented based on the aforementioned distribution.

Firstly, the total time for each process was determined through the process matrices of the current AS-IS process, Figures 4.3 and 4.4 presented in Chapter 4. This time represents the manual cycle time per process of one operator and was measured in seconds. In these calculations and as shown in Figure 5.1 this time is presented in minutes.

	Manual Cycle Time AS-IS (min)	
	EU	NON EU
Regular Process with folding with pop up boxes	3.4	3.9
Regular Process with folding with regular boxes	3.7	4.1
Regular Process without folding with pop up boxes	1.6	2.1
Regular Process without folding with regular boxes	1.9	2.3

Figure 5.1: Manual Cycle Time AS-IS.

Afterwards, the same approach was applied to the TO-BE process by following figures 4.7 and 4.9. The times will be expressed in Figure 5.2. Please bear in mind that for the TO-BE process no

distinctions are being considered between boxes since the Packaging machine will have its own boxes.

	Manual Cycle Time TO-BE (min)	
	EU	NON EU
Regular Process with folding	2.1	2.8
Regular Process without folding	0.3	1.0

Figure 5.2: Manual Cycle Time TO-BE.

As it was concluded this supplier fulfills the necessary output which means that only one machine is needed. Using the monthly order forecast available, the number of monthly orders for each process was calculated using the distribution presented in Table 5.1. The results of these calculations are presented in Figures 5.3 and 5.4.

EU												
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Net working days	21	21	22	20	22	21	20	22	20	20	21	22
Forecasted orders 2023 [orders]	177501	150165	175309	120536	165888	299391	183785	140643	101573	107416	113730	264062
Regular Process with folding with pop up boxes	7699	6514	7604	5228	7196	12987	7972	6101	4406	4659	4933	11454
Regular Process with folding with regular boxes	7486	6333	7394	5084	6997	12627	7751	5932	4284	4530	4797	11137
Regular Process without folding with pop up boxes	17285	14623	17072	11738	16155	29155	17897	13696	9891	10460	11075	25715
Regular Process without folding with regular boxes	11000	9306	10864	7470	10280	18553	11389	8716	6295	6657	7048	16364

Figure 5.3: Monthly Forecast EU.

NON EU												
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Net working days	21	21	22	20	22	21	20	22	20	20	21	22
Forecasted orders 2023 [orders]	177501	150165	175309	120536	165888	299391	183785	140643	101573	107416	113730	264062
Regular Process with folding with pop up boxes	16359	13839	16157	11109	15289	27592	16938	12962	9361	9900	10482	24336
Regular Process with folding with regular boxes	15906	13456	15709	10801	14865	26828	16469	12603	9102	9626	10191	23663
Regular Process without folding with pop up boxes	36725	31070	36272	24939	34323	61945	38026	29099	21016	22225	23531	54635
Regular Process without folding with regular boxes	23371	19772	23082	15871	21842	39420	24198	18518	13374	14143	14974	34768

Figure 5.4: Monthly Forecast NON EU.

The number of monthly orders just calculated above was used to calculate the monthly times per process for one operator for both situations AS-IS and TO-BE.

In the situation AS-IS, the monthly time of each process was calculated by multiplying the number of monthly orders of each process presented in figures 5.3 and 5.4 by the respective execution time of that process shown in Figure 5.1. The same approach was taken for the TO-BE

situation. The number of monthly orders presented in figures 5.3 and 5.4 was multiplied by the respective execution time of each process that, in this case, is presented in Figure 5.2.

Recalling the assumptions made in Table 4.1, in Chapter 4 it was possible to calculate the number of productive hours for one operator, as shown in Table 5.2.

Table 5.2: Productive Hours per Operator

# Working Hours Per Shift	8
Break Time Per Shift (h)	0.5
% Manual Inefficiency	20%
Productive Hours per Operator(h)	6

For each month the processes' time was summed obtaining the total time. This time divided by the number of days per month times the productive minutes per operator and allows for the calculation of the number of operators per month NO_m as shown in Equation (5.1).

$$\frac{TT_m}{ND_m \cdot 6 \cdot 60} = NO_m, \quad (5.1)$$

where TT_m denotes Total Time per month, ND_m refers to the Number of Days in that month, and NO_m the Number of Operators needed in one month.

Assuming that an operator costs €20/hour and is paid for 8 service hours per day, and given the number of days and operators for each month, ND_m and NO_m , the total monthly cost TC_m can be calculated, as shown in Equation (5.2).

$$20 \cdot 8 \cdot ND_m \cdot NO_m = TC_m \quad (5.2)$$

These calculations were performed for the AS-IS process without the automatic packer, and for the TO-BE process with the automatic packer, and they are divided into the EU and NON EU processes, based on the order profile distribution presented in Table 5.1. The operational savings were calculated by the difference between the costs of AS-IS and the costs of TO-BE, as shows Figure 5.5

AS-IS	EU Total Costs	NON EU Total Costs	Total Costs
	€ 529,600	€ 1,344,907	€ 1,874,507
TO-BE	EU Total Costs	NON EU Total Costs	Total Costs
	€ 229,280	€ 474,933	€ 704,213
OPERATIONAL SAVINGS			€ 1,170,293

Figure 5.5: Operational Savings.

The detailed monthly results are listed in Appendix B and can be viewed for further information.

5.1.2 Delivery Savings

A study previously conducted by the Fulfilment Packaging team showed that, due to the fact that the chosen auto packer optimizes the box dimensions to the products, orders are expected to be shipped with less volume, obtaining an estimated shipping cost saving per order of €1.19.

To analyse the orders eligible for the delivery saving benefit, the percentage of orders in scope charged by the courier based on volumetric weight (where the auto packer brings benefit) was determined as 80.3%. Recalling Table 4.3 presented in Chapter 4, it is possible to calculate the percentage of orders out of scope which total 23.5%.

The weighted delivery saving per order WDS_o was then calculated using the considered percentages, the cost saving per order CS_o , and taking into account a safety margin SM for size variability, 25%, determined by the packaging team. The used formula is presented in equation 5.3 as shown above. The percentage of volumetric weight orders is represented by VW and the percentage of orders out of scope is represented by OS .

$$VW \cdot (1 - OS) \cdot CS_o \cdot (1 - SM) = WDS_o \quad (5.3)$$

Since all the variables are known, weighted delivery saving per order was estimated and the result was €0.55. Taking into account a forecasted order volume of 2,000,000 for the upcoming year, it was possible to calculate the total delivery savings for the next year, as shown in Figure 5.6.

Weighted Delivery Saving	€ 0.55
Forecasted Order Volume	2,000,000.00
Delivery Savings	€ 1,100,000.00

Figure 5.6: Delivery Savings.

The total savings achieved by using the Packaging machine, considering both operational and delivery savings, are presented in Figure 5.7 below.

DELIVERY SAVINGS	€ 1,100,000
OPERATIONAL SAVINGS	€ 1,170,293
TOTAL SAVINGS	€ 2,270,293

Figure 5.7: Total Savings.

Considering both savings and the investment, it was possible to the payback period presented in Figure 5.8.

Payback Period (years)	0.43
------------------------	------

Figure 5.8: Payback Period - Packaging.

All these results are included in Appendix B.

5.2 Storage

For this case, the four machine models presented by the two shortlisted suppliers were taken into account, as mentioned in Chapter 4.

Based on the Table 4.5 presented in that chapter, the volume occupied by the Stock on Hand of each category is as follows:

- Beauty: $28 m^3$
- Hazmat: $2 m^3$
- High Value: $6 m^3$

These volumes add up to $36 m^3$.

Supplier comparison presented in Figure 4.11 will be shown once again here in Figure 5.9 presented bellow so that the reader can better follow the explanation.

	Supplier 5		Supplier 6	
	Model A	Model B	Model C	Model D
Area	3.5	9	9	10
Height	7	10	7	10
Machine total volume (m^3)	24.5	90	63	100
#Drawers	78	123	60	120
Storage Volume Capacity (m^3)	8	40	20	45
Safety & Security	Hazmat Fire Protection &		Hazmat Fire Protection &	
Maintenance & Training	Basic - Own Company provides support Training: 2/3 days (including maintenance)		Basic - Own Company provides support Training: 2/3 days (including maintenance)	
Cost	€ 30,000.00	€ 50,000.00	€ 45,000.00	€ 65,000.00

Figure 5.9: Study on Storage Suppliers.

Based on the analysis of this figure, it was verified that only models B and D allow for the combination of all the categories in scope. However, if the warehouse insurance provider specifies that the High-Value category must be separated from the others, both supplier 5 and supplier 6

must employ two modules. This is because the total capacity of Model A or Model C allows the total volume of this category to be accommodated.

Thus, two scenarios were created for each provider:

- Scenario 1: Combining the Beauty, Hazmat, and High-Value categories into a single module - Model B for Supplier 5 and Model D for Supplier 6.
- Scenario 2: Splitting the categories into two modules, one for Beauty and Hazmat and another for High Value. Model B or Model A for Supplier 5 and Model D or Model C

Since the chosen scenario was not initially determined, the results for each supplier were given for both scenarios.

The average 'monthly cost' of the space occupied by each category was calculated by multiplying the space occupied by each category, by the monthly price per square meter of €4.5, as mentioned in Chapter 4. The results of these calculations are summarized in the following table.

	Area Occupancy (m2)
Beauty	170
Hazmat	300
High Value	600

Total Costs AS-IS (per month)	€ 4,815.00
--------------------------------------	------------

Figure 5.10: Monthly Cost AS-IS.

Next, the 'monthly cost' for the TO-BE process of each provider in the two possible scenarios was calculated using the same logic as presented above. The values are shown in the following Figure 5.11.

	Supplier 5	Supplier 6
Scenario 1	Model B	Model D
Scenario 2	Model B + Model A	Model D + Model C

Total Cost of Area TO-BE/month (Scenario 1)	€ 40.50	€ 40.50
Total Cost of Area TO-BE/month (Scenario 2)	€ 56.25	€ 85.50

Figure 5.11: Monthly Cost TO-BE.

This allowed for the calculation of "monthly savings" for each provider and scenario by taking the difference between the "monthly cost" of the AS-IS process and the "monthly cost" of the TO-BE process. These savings were then converted into annual savings by multiplying them by 12 months, considering that the rental costs and the space occupied by each category do not suffer

considerable deviations between months. The results of these calculations are summarized in Figure 5.12.

	Supplier 5	Supplier 6
Savings on Area/month (Scenario 1)	€ 4,774.50	€ 4,774.50
Savings on Area/month (Scenario 2)	€ 4,758.75	€ 4,729.50
Savings on Area/year (Scenario 1)	€ 57,294.00	€ 57,294.00
Savings on Area/year (Scenario 2)	€ 57,105.00	€ 56,754.00

Figure 5.12: Savings on Area for each Scenario and Supplier.

Based on these results, the automation payback period was calculated and is shown on Figure 5.13.

	Supplier 5	Supplier 6
Investment (Scenario 1)	€ 50,000.00	€ 65,000.00
Investment (Scenario 2)	€ 80,000.00	€ 110,000.00
Savings on Area/year (Scenario 1)	€ 57,294.00	€ 57,294.00
Savings on Area/year (Scenario 2)	€ 57,105.00	€ 56,754.00
Payback Period (years - Scenario 1)	0.87	1.13
Payback Period (years - Scenario 2)	1.40	1.94

Figure 5.13: Payback Period - Storage.

After this study was completed, there was already a response from the insurance team indicating that the products in the High-Value category should be separated from the others due to the risks involved. This means that the considered solutions should be confined to the assessment of scenario two, which assumes this separation. Considering the results presented above, it was concluded that Supplier 5 best met the required conditions by providing lower investment costs and higher returns.

One final consideration was made in the case of the opportunity to free up DC1, with the results expressed in Figure 5.14. The cost of DC1 per year will be converted into annual savings, representing a significant opportunity.

Area Occupancy - DC1- (m2)	36000
COST AS-IS per month	€ 162,000.00
COST AS-IS per year	€ 1,944,000.00

Figure 5.14: Costs of DC1.

The results of this business case are summarized in Appendix C

Chapter 6

Conclusions and Future Work

6.1 Conclusions

Throughout this project, the main areas of automation opportunity were analyzed, and potential suppliers and their respective solutions that provided the highest possible benefit were identified. Additionally, a methodology was created that aims to become the framework for future automation projects.

Regarding the packaging area, the identified benefits mainly stem from two major areas: operational and delivery. The first area is directly related to the costs of manual labor and its high intensity in this activity, while the second area is based on previously conducted studies that assume a high cost associated with the volumetric weight charged by carriers.

In terms of operational aspects, the process mapping stands out as a crucial part of this study. Understanding the complexity of operations, the different types of processes and existing products, and the details of each step not only facilitated the development of this study but also, as will be seen next, the identification of future opportunities. Through mapping, it was also possible to anticipate the possible steps that could be automated and thus incorporated from a TO-BE process perspective. This process was designed after conducting a market study in search of a supplier that met the required needs.

The implementation of the automatic packer machine presents, as observed in the results, significant opportunities for both operational and delivery savings. The TO-BE process significantly reduces the number of operators, resulting in a benefit of €1,170,293. Furthermore, the reduction of empty space in the boxes, made possible by adapting to the size of the products with this technology, leads to a delivery saving of €1,100,000. With this benefit, the return on investment is estimated to be less than a year, which is promising.

Regarding the storage area, the analysis conducted identified different opportunities that are initially not explored from such a process-oriented perspective but rather from a space optimization viewpoint. The analysis of certain categories revealed that the space currently occupied by them has significant potential for reduction due to previous optimizations in the warehouse. Thus, the search for Vertical Storage solutions becomes the perfect solution in terms of minimizing occupied

space and increasing storage capacity, transitioning from floor areas of around 1000 m^2 to areas ten times smaller.

The savings resulting from this case study manifest in the form of indirect savings since this space is freed up but still incurs costs. However, apart from enhancing the increase in existing capacity, it also boosts productivity. These cases will be further explained in the following section.

The project developed here serves as an introduction and exploration of a new area for the company, which is warehouse automation. As seen, it presents immense potential and therefore aims to expand and be part of future developments within the company, not concluding here.

6.2 Future Work

An implementation plan was developed in order to align the following steps to implement the chosen solutions in each area identified as an opportunity for automation. These recommendations were included in this section even though they are a consequence of this dissertation since they require future work. Also, an introduction to possible new areas to extend automation is made in this section.

6.2.1 Packing

For this area, the implementation plan is detailed in Figure 6.1.

Task		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Scoping	Business Go/No Go												
	Workshop to align scope and timeline of the developments needed												
	Workshop to define detailed operational TO BE scenarios												
	Go/No Go decision												
	Final supplier selection + sign off												
	Project submission and prioritization												
Design	Warehouse design Process Flow Design & Sign-Off												
Development	Machine production												
	3PL Developments (WMS)												
	Company Developments (Platform)												
	Company Developments (Integrations)												
Testing	SOP review & design Training												
	Warehouse Physical setup & Warehouse IT setup												
	Testing (Integrations & User Acceptance Testing)												
Implementation													

Figure 6.1: Implementation Plan for packaging Machine.

Once the project is submitted and approved, technological scoping and developments are required in the Warehouse Management System (WMS) and Platform, as well as the integrations connecting both systems. The integration aspect is particularly important as the implementation of the automatic packer will introduce new packaging types of packaging that need to be recognized and interpreted by the systems.

Five phases comprise these initiatives: Scoping, Design, Development, Testing and Implementation, which for this initiative are expected to run in parallel with the production/delivery period of the machine (approximately 6 to 8 months).

With regard to the packaging process, the following future opportunities for improvement should also be highlighted:

- As the manual cycle times in Figures 5.1 and 5.2, Chapter 5, orders shipped within European Union have a shorter turnaround time than orders where external documents are added. This time saving is largely connected to the fact that a thermal label is used for these products instead of a plastic pouch. See in more detail Step 16 in Figures 4.3 and 4.4, and Steps 7,8 and 9 in Figures 4.8 and 4.9.
- The percentage of out-of-scope processes remains significant at around 30%.

In the interest of simplification, in-scope processes were considered for processes that did not require extensive analysis due to the time constraints of the study. However, the above points are already taken into account.

Regarding the first point, the possibility of converting documents sent in a plastic pouch into a thermal label is currently being studied. This solution can only be implemented with the approval of the carriers, as there are certain regulations that must be followed. However, this solution has already been implemented with one of the existing carriers.

Concerning the second point, discussions are currently underway with the supplier in question with respect to the possibility of integrating a new technology that would include the production of envelopes in the machine. The prospect of packaging fragile items is also being investigated, assuming they have already been protected before entering the machine.

In this context, there is an ongoing perspective, taking into account the highlighted improvements and the implementation plan mentioned above.

6.2.2 Storage

For the vertical storage area, the implementation plan is illustrated in Figure 6.2.

Task		M1	M2	M3	M4	M5	M6	M7	M8
Scoping	Business Go/No Go								
	Workshop to align scope and timeline of the developments needed								
	Workshop to define detailed operational TO BE scenarios								
	Go/No Go decision								
	Final supplier selection + sign off								
	Project submission and prioritization								
Design	Warehouse design								
	Process Flow Design & Sign-Off								
Development	3PL Developments (WMS)								
	Machine production								
	Testing (Integrations & User Acceptance Testing)								
Testing	Warehouse Physical setup & Warehouse IT setup								
	SOP review & design Training								
	Implementation								

Figure 6.2: Implementation Plan for Vertical Storage.

The initial steps of this plan are similar to those previously described until the project is internally approved and submitted. However, the expected complexity in terms of technological development is lower than in the previous case. This is because there are no major changes to affected processes such as picking and putaway, and no platform implementation or new integrations are expected. This emphasizes the simplicity and speed associated with the expected benefits of this case study.

As mentioned earlier, regarding future works, the improvements identified here are aimed at increasing productivity. Performing cross-operational picking and putaway with more than one machine, as well as the ability to set up a packaging workstation near these machines, will result in a significant increase in productivity.

6.2.3 New Opportunities

6.2.3.1 Picking

The analysis of the warehouse Profit and Loss statement shown in Figure 3.4 in Chapter 3, reveals that picking has the highest direct costs, after packaging. Therefore, it is considered a potential area for future automation initiatives.

Due to the short duration of this project, it was not possible to conduct an in-depth study in this area. In addition, some obstacles were identified, such as the current aisle width in the warehouse, which prevents the application of the solutions presented by the suppliers. Changing the aisles in

a warehouse requires careful study by the design team, as it affects various warehouse operations and involves costs and time. However, the possibility of such a change is currently being studied.

6.2.3.2 New warehouse:

The company has recently acquired a new business, whose operational footprint includes two new warehouses. The sales volume associated with this new business is expected to represent more than half of the the network's existing outbound volume. It is known that there is full control over the supply chain of this operation. In addition, unlike other business units of the corporate group, there is not a wide variety of products categories. The higher supply chain control combined with a narrower product range and a higher stock depth per product result in an higher standardization of operations, with less need for manual processes. This lower process variability, together with the high volume, justifies the investment in future automation initiatives.

Bibliography

- Babcock, S. (2019). Amazon fulfillment center brings robotics to sparrows point.
- Bartholdi, J. and Hackman, S. (2016). Warehouse & distribution science: Release 0.97. the supply chain and logistics institute. georgia institute of technology, atlanta, ga.
- Bartholdi III, J. J. and Platzman, L. K. (1986). Retrieval strategies for a carousel conveyor. *IIE transactions*, 18(2):166–173.
- Boysen, N., De Koster, R., and Weidinger, F. (2019). Warehousing in the e-commerce era: A survey. *European Journal of Operational Research*, 277(2):396–411.
- Calzavara, M., Glock, C. H., Grosse, E. H., Persona, A., and Sgarbossa, F. (2017). Analysis of economic and ergonomic performance measures of different rack layouts in an order picking warehouse. *Computers & Industrial Engineering*, 111:527–536.
- Clements, K., Sweeney, K., Tremont, A., Muralidhara, V., and Kuhl, M. E. (2016). Evaluation of warehouse bulk storage lane depth and abc space allocation using simulation. In *2016 Winter Simulation Conference (WSC)*, pages 2239–2249. IEEE.
- Company, M. . (2021). Automation has reached its tipping point for omnichannel. *McKinsey & Company*.
- Company, M. . (2023). Generative ai: Unlocking the future of fashion. *McKinsey & Company*.
- Custodio, L. and Machado, R. (2020). Flexible automated warehouse: a literature review and an innovative framework. *The International Journal of Advanced Manufacturing Technology*, 106:533–558.
- Forte, K. (2014). Picking methods and technologies: Making sense of the strategy and technology options. *Modern Materials Handling*.
- Giannikas, V., Woodall, P., McFarlane, D., and Lu, W. (2017). The impact of b2c commerce on traditional b2b warehousing. In *ISL 2017: 22nd International Symposium on Logistics*, pages 375–383.
- Groover, M. P. (2016). *Automation, production systems, and computer-integrated manufacturing*. Pearson Education India.
- Groover, M. P. (2020). *Fundamentals of modern manufacturing: materials, processes, and systems*. John Wiley & Sons.
- Jacobus, C. J., Beach, G. J., and Rowe, S. (2015). Automated warehousing using robotic forklifts. US Patent 8,965,561.

- Jenkins, Abby (2020). Warehouse automation explained: Types, benefits & best practices. <https://www.netsuite.com/portal/resource/articles/inventory-management/warehouse-automation.shtml>. Accessed in March 23, 2023.
- Khosrowpour, M. (2006). *Encyclopedia of e-commerce, e-government, and Mobile Commerce*. Idea Group Reference.
- MacDuffie, J. P. and Pil, F. K. (1996). From fixed to flexible: Automation and work organization trends from the international assembly plant survey.
- Marchet, G., Melacini, M., Perotti, S., and Tappia, E. (2012). Analytical model to estimate performances of autonomous vehicle storage and retrieval systems for product totes. *International Journal of Production Research*, 50(24):7134–7148.
- MaterialHandling, U. (2021). As/rs system - automated storage & retrieval systems details. Accessed in March 21, 2023.
- Nilsson, A. and Elmar Merkle, D. (2018). Technical solutions for automation of warehouse operations and their implementation challenges.
- Oleari, F., Magnani, M., Ronzoni, D., and Sabattini, L. (2014). Industrial agvs: Toward a pervasive diffusion in modern factory warehouses. In *2014 IEEE 10th International Conference on Intelligent Computer Communication and Processing (ICCP)*, pages 233–238. IEEE.
- Pedrielli, G., Vinsensius, A., Chew, E. P., Lee, L. H., Duri, A., and Li, H. (2016). Hybrid order picking strategies for fashion e-commerce warehouse systems. In *2016 winter simulation conference (WSC)*, pages 2250–2261. IEEE.
- Rose, M. (2023). How automated roll wrapping could benefit your company.
- Ross, D. F., Weston, F. S., and Stephen, W. (2010). *Introduction to supply chain management technologies*. Crc Press.
- Rouwenhorst, B., Reuter, B., Stockrahm, V., van Houtum, G.-J., Mantel, R., and Zijm, W. H. (2000). Warehouse design and control: Framework and literature review. *European journal of operational research*, 122(3):515–533.
- Schmidt, J., Dörner, K., Berg, A., Schumacher, T., and Bockholdt, K. (2015). The opportunity in online luxury fashion. *McKinsey & Company*.
- Sjøbakk, B., Thomassen, M. K., and Alfnes, E. (2014). Implications of automation in engineer-to-order production: a case study. *Advances in Manufacturing*, 2:141–149.
- Smith, S. and Wheeler, J. (2002). *Managing the customer experience: Turning customers into advocates*. Pearson Education.
- Wiktorsson, M., Granlund, A., Lundin, M., and Södergren, B. (2017). Automation and flexibility: An apparent or real dilemma? *Innovative Quality Improvements in Operations: Introducing Emergent Quality Management*, pages 35–48.
- Williams, BR (2018). A complete guide on how to have an effective inbound. <https://www.brwilliams.com/blog/logistics-services-key-successful-inbound-outbound-process/>. Accessed in April 5, 2023.

Zanzalari, D. (2022). Advantages of e-commerce.

Zhen, L. and Li, H. (2022). A literature review of smart warehouse operations management. *Frontiers of Engineering Management*, 9(1):31–55.

Zhou, Chen (2008). Warehouse Inbound and Storage. <https://www2.isye.gatech.edu/~pinar/teaching/isy3104-fall2008/WarehouseOperationsHandout2.pdf>. Accessed in April 20, 2023.

Appendix A

Gantt Chart

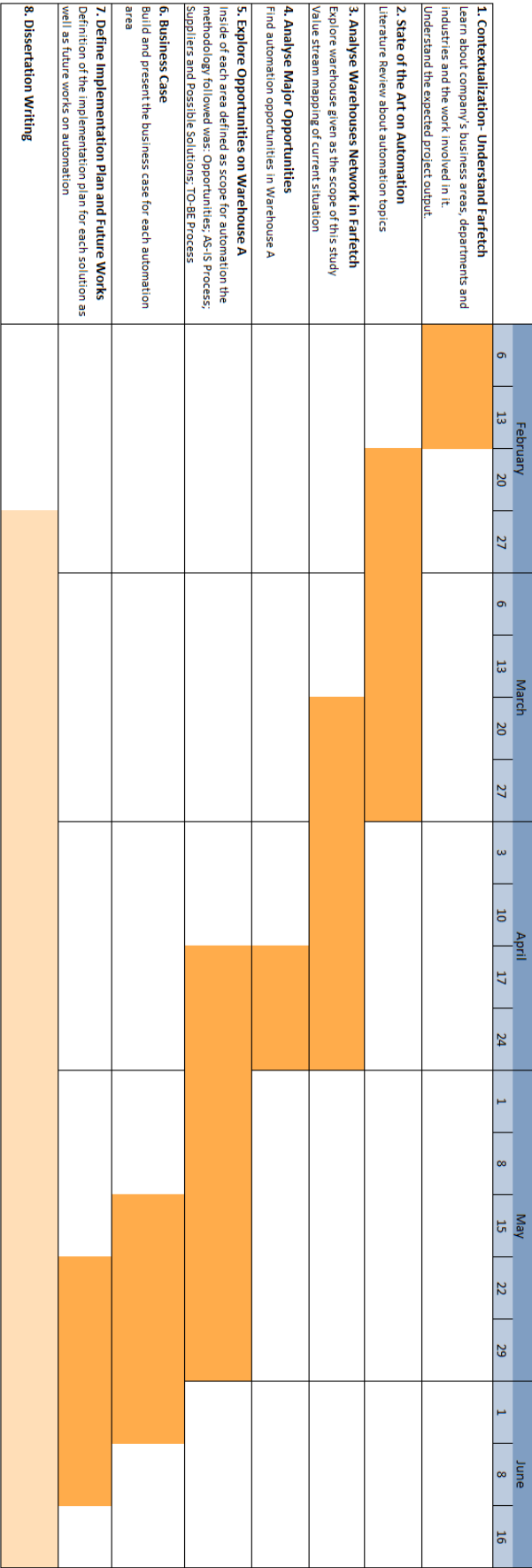


Figure A.1: Gantt Chart

Appendix B

Business Case Packaging

EU																																																																																																																																											
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May																																																																																																																															
Net working days	21	21	22	20	22	21	20	22	20	20	21	22																																																																																																																															
<table> <tr> <th colspan="14">EU</th></tr> <tr> <th colspan="14">Needed operator working time [min]</th></tr> <tr> <td>Regular Process with folding with pop up boxes</td><td>26076</td><td>22060</td><td>25754</td><td>17707</td><td>24370</td><td>43982</td><td>26999</td><td>20661</td><td>14922</td><td>15780</td><td>16707</td><td>38792</td><td></td></tr> <tr> <td>Regular Process with folding with regular boxes</td><td>27450</td><td>23222</td><td>27111</td><td>18640</td><td>25654</td><td>46299</td><td>28422</td><td>21750</td><td>15708</td><td>16611</td><td>17588</td><td>40836</td><td></td></tr> <tr> <td>Regular Process without folding with pop up boxes</td><td>27426</td><td>23202</td><td>27087</td><td>18624</td><td>25632</td><td>46260</td><td>28397</td><td>21731</td><td>15694</td><td>16597</td><td>17573</td><td>40801</td><td></td></tr> <tr> <td>Regular Process without folding with regular boxes</td><td>20533</td><td>17371</td><td>20280</td><td>13943</td><td>19190</td><td>34633</td><td>21260</td><td>16269</td><td>11750</td><td>12426</td><td>13156</td><td>30546</td><td></td></tr> <tr> <td>Total [min]</td><td>101484,2</td><td>85855,5</td><td>100231,4</td><td>68915,2</td><td>94845,0</td><td>171174,0</td><td>105077,3</td><td>80411,0</td><td>58073,5</td><td>61414,1</td><td>65024,0</td><td>150975,1</td><td></td></tr> <tr> <td>Number of Operators per month</td><td>14</td><td>12</td><td>13</td><td>10</td><td>12</td><td>23</td><td>15</td><td>11</td><td>9</td><td>9</td><td>9</td><td>20</td><td></td></tr> <tr> <td>Costs with operators</td><td>€ 47,040</td><td>€ 40,320</td><td>€ 45,760</td><td>€ 32,000</td><td>€ 42,240</td><td>€ 77,280</td><td>€ 48,000</td><td>€ 38,720</td><td>€ 28,800</td><td>€ 28,800</td><td>€ 30,240</td><td>€ 70,400</td><td>529,600</td></tr> </table>														EU														Needed operator working time [min]														Regular Process with folding with pop up boxes	26076	22060	25754	17707	24370	43982	26999	20661	14922	15780	16707	38792		Regular Process with folding with regular boxes	27450	23222	27111	18640	25654	46299	28422	21750	15708	16611	17588	40836		Regular Process without folding with pop up boxes	27426	23202	27087	18624	25632	46260	28397	21731	15694	16597	17573	40801		Regular Process without folding with regular boxes	20533	17371	20280	13943	19190	34633	21260	16269	11750	12426	13156	30546		Total [min]	101484,2	85855,5	100231,4	68915,2	94845,0	171174,0	105077,3	80411,0	58073,5	61414,1	65024,0	150975,1		Number of Operators per month	14	12	13	10	12	23	15	11	9	9	9	20		Costs with operators	€ 47,040	€ 40,320	€ 45,760	€ 32,000	€ 42,240	€ 77,280	€ 48,000	€ 38,720	€ 28,800	€ 28,800	€ 30,240	€ 70,400	529,600
EU																																																																																																																																											
Needed operator working time [min]																																																																																																																																											
Regular Process with folding with pop up boxes	26076	22060	25754	17707	24370	43982	26999	20661	14922	15780	16707	38792																																																																																																																															
Regular Process with folding with regular boxes	27450	23222	27111	18640	25654	46299	28422	21750	15708	16611	17588	40836																																																																																																																															
Regular Process without folding with pop up boxes	27426	23202	27087	18624	25632	46260	28397	21731	15694	16597	17573	40801																																																																																																																															
Regular Process without folding with regular boxes	20533	17371	20280	13943	19190	34633	21260	16269	11750	12426	13156	30546																																																																																																																															
Total [min]	101484,2	85855,5	100231,4	68915,2	94845,0	171174,0	105077,3	80411,0	58073,5	61414,1	65024,0	150975,1																																																																																																																															
Number of Operators per month	14	12	13	10	12	23	15	11	9	9	9	20																																																																																																																															
Costs with operators	€ 47,040	€ 40,320	€ 45,760	€ 32,000	€ 42,240	€ 77,280	€ 48,000	€ 38,720	€ 28,800	€ 28,800	€ 30,240	€ 70,400	529,600																																																																																																																														
<table> <tr> <th colspan="14">EU</th></tr> <tr> <th colspan="14">Needed operator working time [min]</th></tr> <tr> <td>Regular Process with folding with pop up boxes</td><td>16426</td><td>13896</td><td>16223</td><td>11154</td><td>15351</td><td>27705</td><td>17007</td><td>13015</td><td>9399</td><td>9940</td><td>10524</td><td>24436</td><td></td></tr> <tr> <td>Regular Process with folding with regular boxes</td><td>15971</td><td>13511</td><td>15774</td><td>10845</td><td>14926</td><td>26938</td><td>16536</td><td>12654</td><td>9139</td><td>9665</td><td>10233</td><td>23759</td><td></td></tr> <tr> <td>Regular Process without folding with pop up boxes</td><td>5762</td><td>4874</td><td>5691</td><td>3913</td><td>5385</td><td>9718</td><td>5966</td><td>4565</td><td>3297</td><td>3487</td><td>3692</td><td>8572</td><td></td></tr> <tr> <td>Regular Process without folding with regular boxes</td><td>3667</td><td>3102</td><td>3621</td><td>2490</td><td>3427</td><td>6184</td><td>3796</td><td>2905</td><td>2098</td><td>2219</td><td>2349</td><td>5455</td><td></td></tr> <tr> <td>Total [min]</td><td>41824,6</td><td>35383,6</td><td>41308,3</td><td>28402,0</td><td>39088,4</td><td>70545,8</td><td>43305,4</td><td>33139,7</td><td>23933,8</td><td>25310,6</td><td>26798,3</td><td>62221,3</td><td></td></tr> <tr> <td>Number of Operators per month</td><td>6</td><td>5</td><td>6</td><td>4</td><td>5</td><td>10</td><td>7</td><td>5</td><td>4</td><td>4</td><td>4</td><td>8</td><td></td></tr> <tr> <td>Costs with operators</td><td>€ 20,160</td><td>€ 16,800</td><td>€ 21,120</td><td>€ 12,800</td><td>€ 17,600</td><td>€ 33,600</td><td>€ 22,400</td><td>€ 17,600</td><td>€ 12,800</td><td>€ 12,800</td><td>€ 13,440</td><td>€ 28,160</td><td>229,280</td></tr> </table>														EU														Needed operator working time [min]														Regular Process with folding with pop up boxes	16426	13896	16223	11154	15351	27705	17007	13015	9399	9940	10524	24436		Regular Process with folding with regular boxes	15971	13511	15774	10845	14926	26938	16536	12654	9139	9665	10233	23759		Regular Process without folding with pop up boxes	5762	4874	5691	3913	5385	9718	5966	4565	3297	3487	3692	8572		Regular Process without folding with regular boxes	3667	3102	3621	2490	3427	6184	3796	2905	2098	2219	2349	5455		Total [min]	41824,6	35383,6	41308,3	28402,0	39088,4	70545,8	43305,4	33139,7	23933,8	25310,6	26798,3	62221,3		Number of Operators per month	6	5	6	4	5	10	7	5	4	4	4	8		Costs with operators	€ 20,160	€ 16,800	€ 21,120	€ 12,800	€ 17,600	€ 33,600	€ 22,400	€ 17,600	€ 12,800	€ 12,800	€ 13,440	€ 28,160	229,280
EU																																																																																																																																											
Needed operator working time [min]																																																																																																																																											
Regular Process with folding with pop up boxes	16426	13896	16223	11154	15351	27705	17007	13015	9399	9940	10524	24436																																																																																																																															
Regular Process with folding with regular boxes	15971	13511	15774	10845	14926	26938	16536	12654	9139	9665	10233	23759																																																																																																																															
Regular Process without folding with pop up boxes	5762	4874	5691	3913	5385	9718	5966	4565	3297	3487	3692	8572																																																																																																																															
Regular Process without folding with regular boxes	3667	3102	3621	2490	3427	6184	3796	2905	2098	2219	2349	5455																																																																																																																															
Total [min]	41824,6	35383,6	41308,3	28402,0	39088,4	70545,8	43305,4	33139,7	23933,8	25310,6	26798,3	62221,3																																																																																																																															
Number of Operators per month	6	5	6	4	5	10	7	5	4	4	4	8																																																																																																																															
Costs with operators	€ 20,160	€ 16,800	€ 21,120	€ 12,800	€ 17,600	€ 33,600	€ 22,400	€ 17,600	€ 12,800	€ 12,800	€ 13,440	€ 28,160	229,280																																																																																																																														
<table> <tr> <th colspan="14">EU</th></tr> <tr> <th colspan="14">EU Total Costs AS-IS</th></tr> <tr> <td>EU Total Costs AS-IS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table>														EU														EU Total Costs AS-IS														EU Total Costs AS-IS																																																																																																	
EU																																																																																																																																											
EU Total Costs AS-IS																																																																																																																																											
EU Total Costs AS-IS																																																																																																																																											
<table> <tr> <th colspan="14">EU</th></tr> <tr> <th colspan="14">EU Total Costs TO-BE</th></tr> <tr> <td>EU Total Costs TO-BE</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table>														EU														EU Total Costs TO-BE														EU Total Costs TO-BE																																																																																																	
EU																																																																																																																																											
EU Total Costs TO-BE																																																																																																																																											
EU Total Costs TO-BE																																																																																																																																											

Figure B.1: Packaging Business Case - EU Calculation

NON EU													
Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
Net working days	21	21	22	20	22	21	20	22	20	20	21	22	
AS-IS Without Automatic Packer	Needed operator working time [min]												
	Regular Process with folding with pop up boxes	63254	53513	62473	42954	59116	106691	65493	50119	36196	38279	40529	94101
	Regular Process with folding with regular boxes	67834	57388	65142	44789	61641	111248	68291	52260	37743	39914	42260	98121
	Regular Process without folding with pop up boxes	32872	27810	74962	51541	70934	128020	78586	60139	43433	45391	48631	112913
	Regular Process without folding with regular boxes	86182	72910	54167	37243	51256	92505	56785	43455	31384	33189	35140	81589
	Total [min]	250142,3	211620,0	256743,5	176526,7	242946,1	438463,5	269156,2	205973,5	148755,7	157312,7	166559,5	386723,9
	Number of Operators per month	34	28	33	25	31	58	38	27	21	22	23	49
	Costs with operators	€ 114,240	€ 97,067	€ 114,400	€ 86,667	€ 107,467	€ 201,067	€ 131,733	€ 93,600	€ 72,800	€ 76,267	€ 79,733	€ 169,867
	NON EU Total Costs AS-IS												
													1,344,907
													€
TO-BE With Automatic Packer	Needed operator working time [min]												
	Regular Process with folding with pop up boxes	34899	23524	34468	23699	32616	58864	36134	27652	19970	21119	22361	51918
	Regular Process with folding with regular boxes	33932	28707	33513	23043	31712	57234	35134	26886	19417	20534	21741	50480
	Regular Process without folding with pop up boxes	12242	10357	12091	8313	11441	20648	12675	9700	7005	7408	7844	18212
	Regular Process without folding with regular boxes	7790	6591	7694	5290	7281	13140	8066	6173	4458	4714	4991	11589
	Total [min]	88863,0	75178,0	87766,1	60344,5	83049,5	149885,8	92009,3	70410,7	50851,2	53776,3	56937,2	132199,0
	Number of Operators per month	12	10	12	9	11	20	13	9	8	8	8	17
	Costs with operators	€ 41,600	€ 34,667	€ 41,600	€ 31,200	€ 38,133	€ 69,333	€ 45,067	€ 31,200	€ 27,733	€ 27,733	€ 27,733	€ 56,933
	NON EU Total Costs TO-BE												
													474,933
													€

Figure B.2: Packaging Business Case - Non EU Calculation

AS-IS	EU Total Costs	NON EU Total Costs	Total Costs
	€ 529,600	€ 1,344,907	€ 1,874,507
TO-BE	EU Total Costs	NON EU Total Costs	Total Costs
	€ 229,280	€ 474,933	€ 704,213
			OPERATIONAL SAVINGS
			€ 1,170,293
Weighted Delivery Saving		€	0.55
Forecasted Order Volume			2,000,000
DELIVERY SAVINGS		€	1,100,000
DELIVERY SAVINGS		€	1,100,000
OPERATIONAL SAVINGS		€	1,170,293
TOTAL SAVINGS		€	2,270,293
INVESTMENT		€	970,000
TOTAL SAVINGS		€	2,270,293
Payback Period (years)			0.43

Figure B.3: Packaging Business Case - Payback period

Appendix C

Business Case Storage

	Area Occupancy (m2)
Beauty	170
Hazmat	300
High Value	600

Total Costs AS-IS (per month)	€ 4,815.00
--	------------

	Supplier 5	Supplier 6
Scenario 1	Model B	Model D
Scenario 2	Model B + Model A	Model D + Model C
<i>Total Cost of Area TO-BE/month (Scenario 1)</i>	€ 40.50	€ 40.50
<i>Total Cost of Area TO-BE/month (Scenario 2)</i>	€ 56.25	€ 85.50

	Supplier 5	Supplier 6
Savings on Area/month (Scenario 1)	€ 4,774.50	€ 4,774.50
Savings on Area/month (Scenario 2)	€ 4,758.75	€ 4,729.50
Savings on Area/year (Scenario 1)	€ 57,294.00	€ 57,294.00
Savings on Area/year (Scenario 2)	€ 57,105.00	€ 56,754.00

	Supplier 5	Supplier 6
Investment (Scenario 1)	€ 50,000.00	€ 65,000.00
Investment (Scenario 2)	€ 80,000.00	€ 110,000.00
Savings on Area/year (Scenario 1)	€ 57,294.00	€ 57,294.00
Savings on Area/year (Scenario 2)	€ 57,105.00	€ 56,754.00
Payback Period (years - Scenario 1)	0.87	1.13
Payback Period (years - Scenario 2)	1.40	1.94

Figure C.1: Storage Business Case