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Warehouse processes improvement: The case of a pharmaceutical factory

Raquel Filipe Canastreiro de Almeida

Master in Management of Services and Technology

Supervisors:
PhD, Teresa Sofia Sardinha Cardoso de Gomes Grilo,
Assistant Professor,
Iscte-IUL

MSc, Susana Isabel dos Santos Ratinho,
Invited Assistant Professor,
Iscte-IUL

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BUSINESS
SCHOOL

Department of Marketing, Strategy and Operations

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Resumo

A indústria farmacêutica tem vindo a ganhar relevância ao longo do tempo, tendo já um peso considerável na economia portuguesa. Para garantir a excelência operacional, a conformidade com a regulamentação da indústria e uma gestão de custos eficiente, a gestão de armazéns revela-se crucial.

A Empresa A, localizada em Lisboa, procura uma gestão eficiente dos seus armazéns, porém enfrenta desafios relativamente à mesma. Existem duas Unidades nas instalações da empresa e ambas revelam problemas a nível de espaço disponível e arrumação, refletindo-se em elevadas taxas de ocupação. Esta tese tem como objetivo propor soluções para melhorar a capacidade de armazenamento e os constrangimentos de espaço nos armazéns, assegurando a correta utilização do espaço disponível e melhorando a eficiência operacional e a eficácia do processo de *picking* e armazenamento.

Este projeto segue uma metodologia de Caso de Estudo com uma abordagem mista – métodos quantitativos e qualitativos. As fases definidas resultam de uma adaptação dos modelos de Yin (2009) e Voss *et al*. (2002).

Dois cenários são propostos, sendo o primeiro a melhoria das instalações atuais e o segundo um plano de *layout* baseado numa combinação do *Systematic Layout Planning* de Muther (1973) com ferramentas *Lean* abordadas no estudo de Ramirez-Cruz *et al*. (2023). Os resultados obtidos mostram que o primeiro cenário é menos vantajoso quando comparado com o segundo, a nível de custo-benefício. O Cenário 2 registou ganhos de 17.09% na Unidade 1 e de 72.07% na Unidade 2, com um orçamento estimado de 3,000€, estando a sua implementação em curso.

Palavras-chave: espaço, arrumação, estudo de caso, melhoria de processos, *layout planning*
Classificação JEL: M11, L23

Abstract

The pharmaceutical industry has been gaining importance over time and already has a considerable impact on the Portuguese economy. To ensure operational excellence, compliance with industry regulations, and efficient cost management, warehouse management is crucial.

Company A, located in Lisbon, aims to manage its warehouses efficiently but faces challenges in achieving it. There are two Units on the company's facilities, and both have problems with available space and storage, resulting in high occupancy rates. This thesis aims to propose solutions to improve storage capacity and space constraints in warehouses, ensuring the correct use of available space and improving operational efficiency and the effectiveness of the picking and storage process.

This project follows a Case Study methodology with a mixed approach – quantitative and qualitative methods. The defined phases are adapted from the models of Yin (2009) and Voss *et al*. (2002).

Two scenarios are proposed, the first being the improvement of current facilities and the second a layout plan based on a combination of Muther's (1973) Systematic Layout Planning with Lean tools addressed in the study by Ramirez-Cruz *et al*. (2023). The results obtained show that the first scenario is less advantageous than the second in terms of cost-benefit. Scenario 2 recorded gains of 17.09% in Unit 1 and 72.07% in Unit 2, with an estimated budget of €3,000, and its implementation is currently in progress.

Keywords: space, storage, case study, process improvement, layout planning
JEL *Classification System*: M11, L23

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Glossary

3PL – Third-Party Logistics

API – Active Pharmaceutical Ingredient

APS – Analytical Problem-Solving

BPI – Business Process Improvement

DMAIC – Define, Measure, Analyse, Improve, Control

FEFO – First Expired First Out

FLP – Facility Layout Planning

GMP – Good Manufacturing Practices

IPS – Intuitive Problem-Solving

ISO – Organisation for Standardization

KPI – Key Performance Indicator

LIFO – Last In First Out

LM – Lean Manufacturing

LPS – Lean Production Systems

LR – Lean Readiness

LSS – Lean Six Sigma

PDCA – Plan, Do, Check, Act

PSC – Pharmaceutical Supply Chain

SAP – System Applications and Products in Data Processing

SKU – Stock Keeping Unit

SLP – Systematic Layout Planning

SS – Safety Stock

VLM – Vertical Lift Module

VSM – Value Stream Mapping

1. Introduction

This introductory chapter aims to provide context for the organisational challenge under the scope of this project, which is conducted in the pharmaceutical industry and oriented to warehouse management. This in-company project is performed in a German multinational, located in Lisbon, hereinafter denominated Company A. This section also describes the problem studied, the research question and objectives, the methodology and the structure of the work.

1.1. Context

The pharmaceutical industry plays an important role in improving global health, ensuring a better quality of life for people, as well as contributing to the extension of life expectancy. Nevertheless, the relevance of this industry to society goes beyond medicine, it also represents an important driver to economy. Characterised by high investments in research and development – around €55,000 million were spent in Europe in 2024 (EFPIA, 2025) – the pharmaceutical industry is responsible to inject into circulation good amounts of money, but also to employee several people, roughly 950,000 jobs in Europe in 2024 (EFPIA, 2025). Considering the Portuguese scenario, in 2024, the pharmaceutical industry contributed with exports of €3,453 million (Apifarma, 2025), 83.2% of total production for the same year, and the production accounted for 1.5% of Portuguese gross domestic product (Apifarma, n.d.).

According to Bekzhanova *et al*. (2021), storage and storage spaces, as well as the logistics of these locations, are very important in the pharmaceutical industry, including compliance with Good Manufacturing Practices (GMP). It is often the case that major changes are not necessary to improve the efficiency of operations in this industry, and Rebelo *et al*. (2021) proved this. According to the authors, adjustments to the layout and existing spaces can lead to an almost 10% increase in storage capacity, demonstrating that sometimes it is enough to make small changes to what already exists and, consequently, improve it without large investments. Derpich *et al*. (2022) also mentions that a study of the existing layout and Stock Keeping Units (SKUs) in a warehouse can appear as a less expensive solution when compared to major renovations.

However, the focus should not only be on operational efficiency. The concept of planning is also of great importance. Operations involving medicines must follow strict rules and comply with specific regulations, so a company's total control over them is essential. Friemann *et al*. (2014) studied the advantages of having control over the storage of pharmaceutical products and of this control being done by the companies themselves and not by third parties. There must be long-term, close monitoring of the storage of these products, highlighting the importance of

an adequate inventory, especially of the most important SKUs. Supply chain standards in the pharmaceutical industry are highly regulated compared to other sectors, as any decision has a major impact on the quality of the product that is delivered to the patient (Savage *et al*., 2006).

It becomes clear how important it is to plan and study a pharmaceutical company's existing warehouses, as well as the operational efficiency of each one. Company A is no exception and the company's facilities in Portugal, Lisbon, are currently facing challenges regarding their warehouses' operations. Its warehouses are essential to its business, as it is through the products stored and their quality that patients receive the medicines they need for their well-being. Nevertheless, the two warehouses of Company A, also known as Units, are currently facing difficulties handling the large volume of materials and products that need to be stored, more specifically packaging materials, due to space and storage limitations, which leads to saturated corridors and inefficiencies in the allocation and movement of materials.

There are specific storage difficulties in Unit 1, which is used to store packaging materials, room temperature materials from a client's Clinical Trials, raw materials and intermediate product, finished goods, and rejected products. This Unit is close to 90% occupancy rate, and several consequences result from that. For instance, the lack of available spaces for storage often results in the storage of products in locations that are not intended for those specific products, e.g., some packaging materials are in finished goods corridors. This also impacts the picking process: since some SKUs are located in the wrong locations, pickers often struggle to find the correct SKUs, which results in time wasted in this process and, sometimes, in errors in order preparation. Since there are no order preparation areas, on shipping days the corridors are blocked with materials and products, no areas for maneuvering and movements are limited.

Concerning Unit 2, which is used to store one finished good, raw materials, one Active Pharmaceutical Ingredient (API) and packaging materials, it is possible to find problems related to space limitations. The demanding storage conditions for the several product categories is an issue. Printed packaging materials represent the biggest concern: the volume of these items, and the conditions in which they must be stored – in an area with restricted access, with humidity and temperature control – represent a challenge, particularly when considering the current lack of space that characterises Unit 2. The lack of existing space and the impossibility of placing them elsewhere means that a solution is urgently needed. In fact, in November 2024, the area designated for the storage of these materials recorded an occupancy rate of 181.1%.

Limitations in terms of space and storage are evident, leading to efficiency and effectiveness problems. That's why, the company considers that it can not depend exclusively on these two Units. A study of existing facilities and the proposal of improvements is crucial to

contribute to operational efficiency and promote more effective storage. This study can serve as an example for other companies in the industry, since storage and inventory management are a challenge, or even for companies in different areas with the same challenges.

1.2. Research question and objectives

Considering what has already been mentioned, the research question that this project aims to answer is: "*How can Company A overcome the space limitations and storage constraints in its warehouses in order to make the picking and storage process more efficient and effective?*".

Given the research question, the main objective is to propose a solution to improve storage capacity and space constraints in the company's warehouses, ensuring the correct use of available space, aiming to improve operational efficiency and effectiveness in the picking and storage process. To achieve the general objective, the following specific objectives are defined:

- Diagnose the current state of the company's two Units along with their problems, underlining the root causes and assessing their impact.
- Propose solutions, suggesting a "to-be" plan to improve storage capacity and space constraints.
- Implement the proposed solution(s).
- Evaluate and monitor the results.

1.3. Methodology

This in-company project follows a Case Study methodology with a mixed methods approach, quantitative and qualitative research, to achieve the project objective. The methodology follows a structure based on five phases, adapted from the phases proposed by the authors Yin (2009) and Voss *et al*. (2002). The investigation is conducted systematically to ensure reliable results in line with the company's objectives. The five phases are: problem definition and scope, diagnosis of the current situation and data collection, analysis of the data and proposal of solutions, implementation of them, and evaluation and recommendations for future research. During these phases, Lean tools are also implemented to identify waste and inefficiencies. With the implementation of this structured methodology, the aim is to obtain a solution that improves the efficiency and overcome the space limitations and storage constraints of the company's warehouses, always considering the sustainability of the proposed solution in the future.

1.4. Scope

This project is carried out with the Logistics Department of Company A, in Lisbon, and is focused on the warehouse management process. Company A is a German multinational specialised in pharmaceutical manufacturing for the global market. The company's facility in Lisbon specialises in the manufacture of oral pharmaceutical forms and non-sterile liquid medicines, and its manufacturing services range from Clinical Trial production to commercial scale manufacturing, packaging, and pharmaceutical logistics. Although the focus is on warehouse management, the project considers links to other departments, namely the Production Department. The company has two Units in Lisbon, and the study is conducted in collaboration with both. Unit 1 is a warehouse which contains finished goods, packaging materials, raw materials and intermediate product, and rejected products. Unit 2 works with one finished good, two raw materials, one of which is an API, and packaging materials.

1.5. Structure of the project

An in-company project has a defined structure, which consists of five distinct chapters: introduction, literature review, methodology to be used, Case Study and, finally, conclusions. So, in detail, the structure used is as follows.

The first is an introductory chapter in which the pharmaceutical industry is framed and contextualised, as well as identifying the problem that gave origin to this project. The research question and objectives are defined. Reference is made to the methodology to be used, the scope of the project and, finally, the structure of the work.

The second chapter is the section that supports the study and provides the theoretical basis. It provides a framework for the themes and concepts used, the methodologies, and aims to show how other authors have dealt with the problem and what research there is into it.

The third chapter identifies the methodology used in the study, mentioning the various phases, as well as the methods and tools of data collection and the methods of data analysis.

Since the thesis is an in-company project, the fourth chapter concerns the Case Study. The company and the warehouses under study are presented, as well as the phases identified in the methodology.

The fifth chapter deals with the project's conclusions. There are a summary of the study and the answer to the research question, mentioning the limitations encountered during this project, as well as recommendations for future research.

2. Literature Review

This chapter contains the theory that supports this project. The platforms used for references' search were the ResearchGate, Google Scholar, ScienceDirect, and B-on. Since the main objective of this project is to propose a solution to improve storage capacity and space constraints in the company's warehouses, ensuring the correct use of available space, aiming to improve operational efficiency and effectiveness in the picking and storage process, keywords such as layout planning, resource allocation, space constraints, Lean, Six Sigma, warehousing, process improvement, and pharmaceutical were used to find the relevant literature. The search was narrowed to the period from 2000 to the present, although older articles and books were considered due to their significance for the topic. Studies' selection was made according to the rating given by the SCImago Journal & Country Rank platform. As it is a very specific industry and there are few studies applied to the pharmaceutical industry, occasionally articles with a lower classification (Q3) were considered, as well as some conference papers.

2.1. The role of warehouses and storage management

The warehouse is a place where incoming goods must be shipped in the quickest, most efficient and effective way and should therefore be seen as a transition point. They are crucial to ensuring that customer expectations are met, in terms of timely, complete and defect-free deliveries (Richards, 2018). According to Frazelle (2016), the fact that the warehousing process enables high inventory availability, reduces response times and generates value-added services, among many other aspects, means that it adds value to customer service. The author argues that warehousing, like inventory, also adds commercial value, as well as to the supply chain.

Živičnjak *et al*. (2022), says that warehouse management can be seen as a task whose importance is growing over time, and which can be considered a responsibility for employers who want to maximise the profitability of the business. Verma *et al*. (2022) state that for there to be a continuous flow of products in a supply chain, warehouse management is the essential factor. The authors also mention that storage capacity is crucial to the functioning of warehousing as a whole. Effectively and efficiently managing warehouses, which prove to be a challenge due to their complexity, has become a demanding task (Faber *et al*., 2013). Faber *et al*. (2013) defined the concept of warehouse management based on three elements: planning, decision rules and, finally, control. As a result of their study, the authors state that the more complex the warehouse task, the more extensive the planning and the more complex the decision rules.

Logistics has proved to be an area of increasing importance, as it is through logistics that customer satisfaction – in terms of money, time and quality – is ensured. Warehouses can be seen as a source of competitive advantage for companies and sometimes a critical analysis of existing available space can be seen as a less expensive solution and also generate capacity increases. Thus, with little investment and a critical approach to existing spaces, significant results can be achieved (Rebelo *et al*., 2021). Warehouses play a very important role when it comes to variations in productivity and demand, as they protect the company from these fluctuations and allow delivery times to be met. For products that have special storage conditions, the issue of available internal storage capacity is extremely important (Gamberini *et al*., 2008). The dimension of space required to store materials in order to satisfy a desired level of service, indicating the degree of availability of the storage space, can be the definition of warehouse storage capacity. When demand exceeds storage capacity, there is a lack of space and, consequently, external storage may be required when it is not supported internally, due to storage needs that exceed the internal service level (Lee & Elsayed, 2005).

After understanding the importance of efficient warehouse and storage management, and its crucial role in achieving operational efficiency, it is important to note that warehouses often face challenges that prevent them from achieving this, such as space constraints, and therefore the following section addresses this issue.

2.1.1. Space constraints and storage improvement

Several studies have been developed aiming at overcoming space constraints and storage difficulties outside the pharmaceutical industry.

There are often difficulties in warehouses when it comes to allocate classes of products in the corridors, more specifically, determining the optimum storage space used for a specific class. Storage areas should be planned towards the minimisation of travel distances. A class-based storage system is a possible strategic solution that allows this to be achieved and, consequently, enables the design of efficient layouts (Le-Duc & Koster, 2005).

There are, however, other types of systems for storing products. Roodbergen *et al*. (2015) developed a study in which they analyse how storage policies – namely random storage, ABC classification and class-based storage – influence the use of space and, consequently, the productivity of picking workers, in order to improve efficiency and operations. As for random storage, i.e. SKUs are allocated randomly, it is the most flexible method and allows space to be used to the maximum, but it increases picking times for pickers due to the longer distances they

travel because there is no order. In contrast, both ABC classification and class-based storage policies allow products to be allocated according to their importance and frequency, or according to product class based on criteria, ensuring a certain order. Both allow a better use of space and greater efficiency, improving the picking process, although the ABC method can lead to space being misused.

Another possible solution to storage problems which discusses the use of space with the picker productivity is presented in a study conducted by Foroughi *et al*. (2021): high-density storage. In this study, the authors analyse storage challenges, as well as the productivity of picking workers in high-density warehouses, focusing on mobile shelving systems. The authors demonstrate how the strategic allocation of products in this type of racking can be beneficial, especially when analysing the movements made and the use of space, contributing to warehouse efficiency. For example, fixed storage means that, in the case of mobile racking, more movements have to be made to reach the SKUs and, therefore, has not proved beneficial. To this end, mathematical models and computational tests were used to obtain the solutions.

Pharmaceutical Industry

A few authors have also developed research in this area considering the specific challenges faced in the pharmaceutical industries.

According to the study by Friemann *et al*. (2014), the need for reliable long-term capacity planning is extremely important due to constant developments in the pharmaceutical industry and increasingly stringent regulations. As such, these authors argue that the operations management of a company in the pharmaceutical industry should not be outsourced but should be the responsibility of the company. In this way, the risks associated with a lack of product control are reduced, since regulations are strict, and the quality of these products is essential for the well-being of patients. Bekzhanova *et al*. (2021) are proof of this and carried out a study on space planning in a pharmaceutical company, considering existing restrictions, in order to organise storage. Through this, they showed that the use of a correct storage system can prevent the expenditure of unnecessary costs associated with acquiring additional space in a warehouse, as well as manual work and minimising the time spent solving other tasks, proving the importance of warehouse management in this environment. The study led to the conclusion that the layout and rack configurations are directly linked to the use of space and safety, since a functional layout and an appropriate racking system contributed to better use of space and, consequently, greater safety. The authors mention that there should be specific storage areas for SKUs of greater importance and priority to respond efficiently to demand.

A study conducted as part of the reconstruction of an existing warehouse system in a pharmaceutical factory, as well as the design of a new material flow system, proved to have significant results in increasing storage capacity as well as safety and task efficiency (Petrovic *et al*., 2014). Foroughi *et al*. (2021) proposes the use of mobile racks installed on rails to slide sideways to improve storage in his study. A motor is in charge of moving blocks of racks in their entirety, forming a corridor and enabling access to a specific area rack. This type of mobile rack with a motor, accessed by vehicles handled by people or even unmanned vehicles, is used in refrigerated warehouses such as those in the pharmaceutical industry also.

As a way of overcoming these challenges related to space constraints, effective layout planning is essential for maximising storage capacity and, consequently, improving the efficiency of a warehouse. The following section explores this issue and what can be done to improve it.

2.1.2. Layout planning and improvement

Several studies have explored the importance of layout planning and its improvement, as a way of solving the constraints related to space and storage in warehouses. Many of these contributions come from sectors outside the pharmaceutical industry, providing methods and tools that can be applied to the industry.

Hosseini-Nasab *et al*. (2018) evidence that trends in the study of layouts and their evolution, as well as the characteristics of factories, mean that concepts associated with them are highly relevant. The concept of the facility layout planning (FLP) problem is one of them. The layout of facilities in a manufacturing context defines this problem and its purpose is to find the most effective layout, taking into account certain criteria as well as constraints – such as the size of the facilities, orientation and delivery and, consequently, collection points. The authors suggest an FLP classification system that considers several key factors, such as the type of problem, the planning approach, as well as the planning phase, the specifics of the production facilities, among others. According to the study carried out by Pérez-Gosende *et al*. (2021), the concept of FLP considers the various challenges associated with the design of these same facilities, such as the layout of the elements that make up industrial production systems. Over time, FLP has been the subject of study and research, as it has a major influence on operating costs, productivity and the efficiency of production systems, making it one of the operational decisions with the greatest impact. Thus, according to these authors, the planning of industrial

units is characterised as a process of physical organisation of the factors that make up the production system, with the aim of responding to the strategic objectives of the organisation.

An additional concept is related to layout and its improvement, namely, the Systematic Layout Planning (SLP). The SLP concept was developed by Richard Muther and, as the name suggests, consists of layout planning in phases, being a set of procedures as well as practices related to the components and areas that make up a layout. For smaller areas – such as offices, shops or, for example, small storage areas – Muther suggests a "short-form procedure", which consists of a simplified SLP. In short, this approach takes into account the three fundamental aspects of layout planning – relationships, space, and adjustment – and becomes a set of six steps: representing relationships, space requirements, schematising the relationships between activities, designing layouts of these relationships, analysing alternatives and detailing the chosen plan (Muther, 1973). Naqvi *et al*. (2016) conducted a study in which they used the SLP technique to improve the productivity of a manufacturing facility which will then be achieved through its redesign thanks to this technique. So SLP is used for layout development, as well as for improving material flows. The relevance of changing a layout in a warehouse context was demonstrated, since it is a place that is vulnerable to constraints in terms of space and capacity. Jasrotia and Sengottaiyan (2024) developed a study that aims to serve as a guide and map for companies who want to improve the layout of small and medium-sized warehouses and, consequently, their efficiency, using a systematic approach to implementing SLP and Lean tools. A layout that is suited to a company's activity and its needs is essential, as this can lead to an adequate workflow and higher levels of productivity. By combining this with Lean tools, waste is eliminated. Several Key Performance Indicators (KPIs) were defined in the study and the use of SLP proved to be beneficial for all of them, showing that significant improvements can be achieved when SLP is applied.

Pharmaceutical Industry

Due to the specific nature of the industry and the fact that it is highly regulated, not many studies were found on the application of these concepts. However, a recent study explored these challenges, showing the importance of studying the layout and use of these tools in order to meet the specific needs of this industry.

Ramirez-Cruz *et al*. (2023) carried out a study in a pharmaceutical warehouse, located in South America, where it is investigated aspects related to the layout of the warehouse, such as the current layout, the existing space, congestion in certain areas, among others. As a solution to the problems identified, the authors used an improvement model consisting of a combination

of Lean tools and SLP. In this way, SLP was used to organise areas of the warehouse that had been identified as problematic, in order to achieve a new layout. The cause of these problems was inaccurate orders and, through this combination of Lean tools and SLP, they managed to reduce the error rate by more than 4%. The authors have thus demonstrated that operational efficiency can be increased using these tools, as well as solving layout problems.

Many of these studies dealing with space and storage limitations, as well as layout challenges, aim to improve processes in order to enhance efficiency, space utilisation and, consequently, capacity.

To achieve these process improvements, there are philosophies and methodologies that are applied in a wide variety of industries.

2.2. Process Improvement

2.2.1. Business Process Improvement

There are several definitions of the Business Process Improvement (BPI) concept, however, one person who was very important to its development and dissemination was J. H. Harrington, who brought the concept to life in his book *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness* (1991). Thus, BPI can be defined as "a systematic methodology developed to help an organisation make significant advances in the way its business processes operate". Harrington (1991) also adds that BPI enables operations to be simplified and rationalised, thus promoting both internal and external customer satisfaction. There are five phases to this process: firstly, organising for improvement, then understanding the process in question, streamlining, carrying out measurements and controls and continuous improvement.

Yousfi *et al*. (2019) also represent outstanding researchers in terms of studying this concept, as they have contributed to its growth by incorporating ubiquitous decision-making mechanisms into processes, thus enabling processes to become more efficient and versatile, given the flexibility and the ability to respond to change of the new approach proposed.

Malinova *et al*. (2022) carried out an investigation into existing process improvement methods, where they studied the influence of organisational, procedural and environmental factors on their success and effectiveness. Thus, it is emphasised that process improvement must be aligned with the specifics of the context in which it will be applied.

2.2.2. Business Process Improvement philosophies and methodologies

When it comes to implementing BPI, there are philosophies and several methodologies for this purpose. They act as structured approaches that enable the desired improvements to be achieved, for example in operational efficiency and performance.

Lean

Regarding Lean philosophy, in the book *The Machine That Changed the World*, Womack *et al*. (1990) explain the origins of the concept, stating that all industries can adopt Lean principles. Lean production adopters will benefit from less inventory, and less maintenance of it, will have fewer defects and produce a greater variety of products. Lean producers have the ultimate goal of achieving perfection, which translates into lower costs, zero defects, no inventory and, ultimately, an endless variety of products. So is a philosophy that can be defined as the elimination of waste. The concept came with Toyota and the way it carried out its business, led by Taiichi Ohno. Shigeo Shingo, W. Edwards Deming, Henry Ford, also had influence. For Martin and Osterling (2014), Lean can have different meanings, depending on the context in which it is applied, leading to different results.

Lean thinking is based on five principles: value, value stream, flow, pull and perfection. Value is fundamental when it comes to Lean thinking, since it should start with a definition of value to meet what customers expect. Thus, the concept of the value stream can be defined as the set of specific actions that exemplify the journey of a product, from its conception to its delivery to the customer, and allows to identify where waste occurs (Womack & Jones, 2003). So, can be seen as a sequence of activities, that can occur sequentially or in parallel, containing flows of information and material. When the sequence is represented visually and consequently mapped, Value Stream Mapping (VSM) occurs. VSM came from a visual flow mapping technique used at Toyota Motor Company and provides a macro and holistic view, from the moment an order is placed to its fulfilment, allowing leadership to define strategic improvements (Martin & Osterling, 2014). Marin-Garcia *et al*. (2021), carried out a study on the implementation of VSM in healthcare services, highlighting the importance of this tool for identifying inefficiencies and improving processes in highly regulated environments.

Panwar *et al*. (2015), carried out a study on the adoption of Lean production in process industries, such as pharmaceutical, and developed a sequential process for applying Lean practices in a manufacturing industry context. Not all Lean practices are always applicable in contexts other than repetitive and high-volume production, which is why the authors studied

the possibility of applying Lean techniques, such as production in small batches or using pull production, in process industries. The authors demonstrated that the adoption of Lean practices depends on several factors, including the organisational culture of companies and their receptiveness, which can create obstacles and represent a barrier. However, it is showed that some tools and methodologies – such as VSM, 5S, among others – are increasingly being applied in process industries.

Also, a study carried out by Martins *et al*. (2020) in a manufacturing context applied 5S to working stations, resulting in increasing efficiency and lower processing times, while also helping to minimise errors and re-work needs.

Six Sigma

The Six Sigma concept emerged in 1980 at Motorola. The names behind this concept are Bill Smith (engineer at Motorola) and Mikel Harry (senior leader at Motorola), the former of whom created the concept and developed the Define, Measure, Analyse Improve, Control (DMAIC) approach and the latter of whom helped to spread the concept. Six Sigma is a systematic approach to process improvement. In other words, it is a set of statistical techniques that aim to continuously improve and enhance the quality of processes and that can help managers evaluate process performance. Quality control experts W. Edwards Deming and Joseph M. Juran also contributed to the development of this concept through, for example, the development of statistical process control and Plan-Do-Check-Act more commonly known as PDCA, which served as the basis for Six Sigma (Harmon, 2014).

Lean Six Sigma

Drohomeretski *et al*. (2014), mention that when the Lean manufacturing (LM) system is combined with the Six Sigma process improvement methodology, Lean Six Sigma (LSS) emerges. In the study carried out by the authors, they investigated what is prioritised – speed, quality, flexibility, reliability, cost and innovation – in each of these three approaches, and concluded that LSS performs identically to Six Sigma, although it is more complete and speed is highlighted, followed by quality, flexibility, reliability and cost. The organisation becomes faster, offers more quality and reliability while being more flexible and there is also a reduction in costs. Thus, the authors concluded that adopting LSS is more advantageous than adopting them individually.

Simulation

When a process or system is reproduced in a real-life situation, it means a simulation is being conducted. This process involves the creation of a fictitious scenario, and, through this, it will be possible to understand the functioning of the real system and draw conclusions. Thus, a change in a system can be simulated first and then the impact of the change and what changes in performance it will cause can be analysed. To design new production facilities, warehouses or even distribution centres, simulation has proven to be an essential tool, and it can also be used to analyse proposed improvements to existing systems (Banks *et al*., 1996).

Mehdouani *et al*. (2019), suggest a new approach to BPI based on simulation and integrates simulation models into Business Process Management. Thus, real-time performance evaluation and iterative improvements highlight the contribution of simulation to detecting inefficiencies, verifying alternative scenarios and ultimately optimising the implementation of a process.

Lian and Landeghem (2007), have developed a study linking the VSM with simulation. The authors show how the integration of simulation allows the VSM to be improved, since combine quantitative and qualitative tools to identify inefficiencies and see the effect of certain changes and the new scenarios that arise.

Optimisation

Optimisation is also becoming more important and nowadays many industries are using it, particularly manufacturing facilities. The evolution of technology has also contributed to this growth and adoption, especially when it comes to complex problems. In view of the aforementioned, optimisation can be defined as the process of achieving the best result. In other words, and mathematically, it can also be defined as the process of obtaining the maximum or minimum value of a given function with certain variables (Rao, 2009). Another way of looking at optimisation can be when, from a certain set of defined constraints, the best possible solution to a given problem is sought (Coello Coello, 2006). By optimising and continuously improving business processes, companies can maintain a secure position in a business world that is increasingly competitive and subject to change. To this end, the design and management of business processes are crucial (Vergidis *et al*., 2012).

Roodbergen *et al*. (2015), aimed to improve the performance of a warehouse and, using optimisation techniques, such as simulation, the authors developed a design methodology in a real-life context showing its practicality and, in this way, optimised the physical layout as well as the control policies. Some layout variables are presented, as well as control policies and, through simulation, the authors study several layout configurations to arrive at an optimal

layout. Raman (2011), has also developed a new integrated optimisation methodology for the manufacturing industry where it simultaneously addresses the issue of production variability and, consequently, considers the layout of the facilities and the material handling systems as a whole, which makes it possible to optimise the latter two and not just one individually. Many of the methodologies used to optimise these aspects do not address some critical points and focus on optimising just one of these aspects, and this is where the author differentiates himself.

2.2.3. Business Process Improvement philosophies and methodologies: the particular case of the pharmaceutical industry

This section explores applications of BPI philosophies and methodologies in the pharmaceutical industry.

Lean

A study concerning the presence of Lean principles in pharmaceutical manufacturing was carried out by Jaiganesh and Sudhahar (2013), more specifically the presence of Lean integration in a context of current GMP (referred to by the authors as cGMP) – such as Company A. The authors talk about the fact that the adoption of Lean in the pharmaceutical industry has been slower compared to others due to industry regulations, as well as the prioritisation of quality. However, a new perspective is given in the study: Lean and current GMP can be complementary, in that quality standards can be maintained while reducing waste, resources and enhancing operational efficiency. Finally, it is concluded that many companies in this industry have already implemented Lean principles, but these are hidden because they are ignored or incorrectly implemented. Garza-Reyes *et al*. (2018), in their study on Lean practices, in a context of pharmaceutical factories in Europe, sought to analyse the level of readiness of this industry regarding the adoption of LM, as well as its sustainability over time, assessing their quality practices. In other words, assessing the level of Lean readiness (LR) for the adoption of LM. To do this, it is used a set of six quality practices ranging from processes to human resources. However, the results of the investigation were not positive and show that the level of LR is insufficient, highlighting the difficulty in adopting Lean practices.

According to Sieckmann *et al*. (2018), in the pharmaceutical industry, Lean Production Systems (LPS) allow the requirements of this industry to be met. However, due to the specific characteristics of production processes and regulatory requirements, adopting certain models, and in the case of small and medium-sized enterprises, is a major challenge. In this way, the

authors suggest an LPS implementation process, consisting of five phases and 10 stages, based on the concept of “Industry 4.0” and focus on companies that produce their own medicines, such as Company A. The implementation process consists of four phases: planning, developing support systems, execution and sustainment. However, there is another phase that runs parallel to the last three phases, which consists of monitoring, control and documentation. The authors also mention that the special characteristics of this industry can also affect the proposed model and, consequently, will have different effects on the various stages of implementation. For example, the process of changing the layout of pharmaceutical facilities is much more complex than in other industries, and that this doesn't always prove beneficial.

Papalexi *et al*. (2015) carried out an investigation into the implementation of the Kanban system in the Pharmaceutical Supply Chain (PSC) to manage inventory and showed that by adopting this Lean technique, it is possible to have more structured delivery systems, shifting from ordering by impulse to a strategy, thus improving the quality of the services provided. Also, Argiyantari *et al*. (2020) performed an investigation into the PSC and showed that little importance is given to it and that all the recognition goes to the manufacturing industry. In this way, the authors have shown that PSC should be prioritised more and that, to this end, Lean principles are a very important tool for boosting good performance, since they allow costs to be reduced, waste to be eliminated and the quality of what they offer to be guaranteed. Thus, a Lean supply chain that complies with the requirements and regulations imposed on the industry in question is the key to innovation as well as good performance.

Six Sigma

The pharmaceutical industry has been adopting process improvement strategies, such as Six Sigma, to reduce costs and cycle times (Pokharkar *et al*., 2010).

Sharma *et al*. (2011), state that the use of Six Sigma is suitable for the pharmaceutical industry, as this industry has large amounts of documentation and data and, since this tool is based on statistics and therefore deals with a lot of data, it proves to be appropriate. Likewise, the fact that it takes into account the elimination of deviations and non-conformities is ideal for companies in this industry, as it is a highly regulated industry with high quality standards. Bell *et al*. (2023) also studied the effect of adopting Six Sigma in the pharmaceutical industry and the results were quality improvement, defect reduction and process improvement, thus contributing to cost reduction and operational excellence. On an ethical level, it has also been proven that the adoption of this tool is valid as long as the industry's regulations are complied with.

Lean Six Sigma

Elbermawy *et al*. (2014) define the concept of LSS by saying that Lean and Six Sigma can work as complementary methodologies, forming a single methodology. For the authors LSS can be defined as a methodology that aims to eliminate waste, as well as variation based on the DMAIC framework, in order to satisfy customers in terms of cost, delivery and quality. Stockouts, excess inventory, defects, transportation issues, among others, are some of the issues that affect the PSC, and, for this reason, this joint methodology is an asset for improving processes. Byrne *et al*. (2021) also proved the benefits of using LSS in the pharmaceutical industry, as they used it in their research to solve a problem related to order delays due to increased demand for a product in a pharmaceutical manufacturing facility. As a result, it was essential to analyse productivity and waste, and production line downtime was highlighted as a problem. To this end, the LSS was used to identify and eliminate waste and implement continuous improvement, resulting in an increase in quality and the satisfaction of customer needs.

Adeodu *et al*. (2023), by improving the efficiency of the process cycle, where they used the LSS (DMAIC) approach to do so, reducing waste, developed an improvement framework of warehouse processes. As a methodology for evaluating the processes in question, they applied Lean tools in the form of a Case Study at a third-party logistics (3PL). By using this approach, they were able to record improvements of up to 70% in terms of process cycle efficiency. Through this Case Study, it was possible to conclude that a Lean warehousing approach is highly effective and applicable in warehouse and logistics environments, helping to improve productivity.

Optimisation

In the study carried out by Rebelo *et al*. (2021), an approach that takes volume into account was suggested when it comes to analysing warehouse capacity and its optimisation, since the company was following an approach that consisted of assessing the number of pallets that could fit into a given box. However, it turned out that the same box had different capacities, depending on the type of material and how it was packaged, so it wasn't the most appropriate method. With this volume-based storage optimisation approach and the additional or different bins proposal, several improvements were achieved, in terms of costs, storage capacity, travel time and material damage, as well as safety.

Regarding storage optimisation, Bekzhanova *et al*. (2021) state that the most important task in a warehouse is the optimal arrangement of space. If the storage systems are suitable, it is possible to provide additional space and maximise and optimise warehouse space. Gamberini

et al. (2008) states that when it comes to companies that have warehouses with insufficient space for what they need, the optimal use of storage capacity is crucial. The authors carried out a study in which they suggest an approach to the arrangement and organisation of secondary packaging, pallets and storage racks, given that packaging sizes influence the design of the storage area. In this way, an approach that aims to optimise the use of space taking into account the existing storage area, avoiding the need for external storage is presented. With this research, the authors propose a methodology that consists of using the number of primary packages piled on each secondary box to define the height of that box and, consequently, the number of secondary packages piled on each pallet will define the height of the pallet load. The authors also highlight the fact that sometimes some products require specific storage conditions – for example, products in refrigerated warehouses – and the expansion of these spaces is not always possible due to their characteristics, so sometimes it is necessary to resort to external solutions.

To optimise the layout of facilities, there are tools and techniques to use. Benitez *et al*. (2019) carried out a study in which it mentioned some of them: SLP, mathematical programming, simulation, multicriteria decision analysis and, finally, LM.

2.3. Conclusion

This literature review is based on research related to the manufacturing and pharmaceutical industry and showed that most of the existing studies focus on warehouse improvement techniques, such as layout design/planning, as well as methodologies to improve processes, such as Lean and Six Sigma. However, some gaps are visible, namely the lack of an in-depth study of the practices and warehouses of this industry. There are several studies on warehouse management and storage in multiple sectors and industries, but the industry under study appears to be at a disadvantage, with few practical and real examples. For example, simulation is often used, with no real data on challenges experienced or results, as these are only expected results. On the other hand, existing studies in this industry focus more on specific aspects and processes, such as outsourcing decisions (Friemann *et al*. (2014)), racking equipment design (Bekzhanova *et al*. (2021) and Foroughi *et al*. (2021)), without taking a holistic view. As for Lean and SLP methodologies, there is a low applicability in this industry. Finally, the effects of layout changes in companies and factories in the industry under study are not explored in depth, making it a subject that has been poorly researched.

This literature review shows that space improvement is crucial in a warehouse and essential for achieving operational efficiency. This improvement can be done through layout design, or

even through strategic decisions and operational improvements to a company's existing processes and spaces. Using techniques such as SLP, Lean principles or in-house transformations can be seen as a more cost-effective alternative, without the need for outsourcing. To summarise pharmaceutical industry studies – in general, excluding the studies that focus exclusively on examples of BPI methodologies – Table 2.1 is presented.

Table 2.1: Literature review summary

Authors	Layout in warehouses	Space and storage	Case-Study approach
Savage *et al*. (2006)	×	×	×
Friemann *et al*. (2014)	✓	✓	×
Petrovic *et al*. (2014)	✓	✓	✓
Benitez *et al*. (2019)	✓	×	×
Bekzhanova *et al*. (2021)	×	✓	✓
Foroughi *et al*. (2021)	×	✓	×
Ramirez-Cruz *et al*. (2023)	✓	✓	✓

According to the table, the studies closer to this in-company project are the ones by Petrovic *et al*. (2014) and Ramirez-Cruz *et al*. (2023). Both deal with improving the layout of pharmaceutical warehouses and storage efficiency, showing the challenges of this industry which faces several regulations. Petrovic *et al*. (2014) presented a proposal to reconstruct the current storage system by reconfiguring the racks of a pharmaceutical plant, as well as designing a new material flow system through layout redesign to increase storage capacity, which leads to the idea of utilising vertical space. Ramirez-Cruz *et al*. (2023) also refers to the layout of a pharmaceutical warehouse and issues related to storage, combining Lean tools with SLP to improve the warehouse's processes, especially in terms of storage and replenishment. Both are case studies that follow a structured approach.

The present project differs from previous ones due to its holistic perspective and the several scenarios it presents, not focusing on just one aspect, as Ramirez-Cruz *et al*. (2023) focused only on reducing order errors. In turn, this study also integrates BPI tools, unlike Petrovic *et al*. (2014).

3. Methodology

This chapter identifies the methodology used in the study to answer the research question and meet the proposed objectives, mentioning the several phases, as well as the methods and tools of data collection and, consequently, the methods of data analysis. Therefore, a Case Study methodology is used in this project, where some Lean tools are employed.

3.1. Case Study methodology

The methodology used to develop this project and achieve the project objective is a Case Study with a mixed methods approach – quantitative and qualitative research. The Case Study methodology has been successfully applied in previous similar studies, such as it is the case of Petrovic *et al*. (2014) and Ramirez-Cruz *et al*. (2023). Both are studies developed in companies and, consequently, in real-life contexts. Each follows a logical and sequential structure, such as identifying the problem and diagnosing the current situation, analysing data, proposing improvements/solutions, and the respective implementation and analysis of results.

Since the research question relates to a "how", according to Yin (2009), case studies prove to be the most suitable approach. When questions of "why" or "how" arise, control of events does not depend on the researcher, and the focus of the research is a contemporary phenomenon in a real context, case studies are the most indicated. In turn, it allows researchers to preserve the significant characteristics of real events. Case studies can also be classified as exploratory, descriptive, and explanatory (Yin, 2009). This is a single Case Study, as it focuses on a detailed analysis of a single organisation, and descriptive as it describe the existing problems through qualitative primary data (gathered through semi-structured interviews and direct observations) and quantitative secondary data (collected through company records and documents), seeking to outline a solution, while at the same time having elements that make it explanatory, as it aims to explain why the solution chosen is more viable than other alternatives.

According to Mohaghegh and Größler (2019), there are two different behavioural ways of solving problems: IPS (Intuitive Problem-Solving) – which is characterised by quick decisions, resulting in short-term solutions – and APS (Analytical Problem-Solving), which represents structured, long-term solutions, focusing on the problem and its causes. In this project, APS have priority, as it is a structured Case Study, following several defined phases until the final decision is reached: problem definition, problem analysis, proposal of alternatives and design solution. However, as the authors' study advises, it is combined with IPS to prevent the situation from worsening and, in turn, achieve continuous improvement.

3.2. Case study stages

As Yin (2009) and Voss *et al*. (2002) explain, it is essential for case studies to follow a design.

I. According to Yin (2009), the phases to highlight are: plan, design of the case, prepare for data collection, collect the data, analyse, and report.

II. Voss *et al*. (2002), also describe the phases of a Case Study as follows: understand when to use case research, define the research framework, constructs and questions, select cases, then develop research instruments and protocols, conduct the field research (looking for reliability and validity in case research), data documentation and coding, and finally analysis, including hypothesis development, and testing.

This Case Study follows a structure and is organised into phases, which are an adaptation of those proposed by both authors and can be identified and described as follows (Table 3.1).

Table 3.1: Case Study stages

Yin (2009) stages	Voss *et al*. (2002) stages	Adapted Version
Plan: understand if the Case Study is suitable for the subject and the research question	When to use case research: understand if the Case Study is suitable for the context	Problem definition and scope
Design of the case: elaborate a research design (type of Case Study, unit of analysis and propositions), ensuring validity and reliability	Develop the research framework, constructs and questions: define the focus of the research and develop a theoretical basis Choosing cases: select cases that support the study	
Prepare for data collection: protocols and data collection methods and instruments	Develop research instruments and protocols: tools and protocols for data collection	Diagnosis and data collection
Collect the data: collect data from various sources	Conduct the field research: collect data from cases	
Analyse: analyse the data collected, relating it to the theoretical bases and identifying patterns	Data Documentation and Coding: document the data collected and use tools to analyse	Analysis and development of solutions/improvements
	Data Analysis Hypothesis Development, and Testing: analyse the data collected, develop or reformulate the hypotheses and test the theoretical foundations	
Report: present the findings and conclusions, discussing the contributions of the study		Implementation of the solutions/improvements; Evaluation of the proposal and recommendations for future research

In summary:

- *Problem definition and scope*: the research design is developed, identifying the research question, the objectives and the scope.
- *Diagnosis of the current situation and data collection*: understand the organisation and the current practices ("as-is situation"), as well as survey the difficulties and causes of the problem. Then, protocols and research instruments are used to collect the data.
- *Analysis of data and development of solutions/improvements*: the data collected in the previous phase is analysed using methods and tools and scenarios are proposed ("to-be scenario").
- *Implementation of the solutions/improvements*: according to the scenario(s) identified in the previous phase, implement the proposals if possible.
- *Evaluation of the proposal and recommendations for future research*: the results obtained are presented and the "as-is" scenario is compared with the "to-be" scenario.

The tools that are used, as well as the methods, are identified in the Figure 3.1.

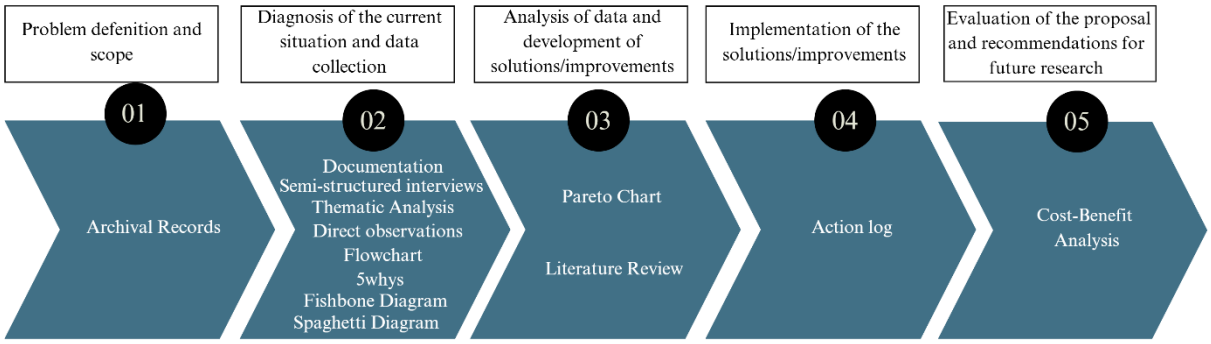


Figure 3.1: Project structure, tools, and methods

3.2.1. Problem definition and scope

Plan and define what is going to be done, i.e. the context, research question, as well as the objectives and scope of the project.

This stage is reflected in chapter 1.

3.2.2. Diagnosis and data collection

According to Yin (2009) and Voss *et al*. (2002), several sources of evidence should be used to make the data more reliable and accurate, in order to validate the information.

Semi-structured interviews are conducted face-to-face with the two managers, each responsible for one Unit. A list of questions is created to conduct the interviews and throughout the interviews, keywords are noted and audio recorded in order to transcribe them. Prior

authorisation was requested. Both interviews are conducted and answered in Portuguese and lasted about an hour and a half. The script used for the semi-structured interviews is divided into two groups: the first (Group 1) aims at understanding the organisation and current practices (Annexe A), and the second (Group 2) at diagnosing difficulties (Annexe B). In turn, the interviews are analysed using thematic analysis, following the method proposed by Braun and Clarke (2006). The phases proposed by Braun and Clarke (2006) are familiarisation with the data collected, generation of initial codes, the search for themes, reviewing and defining them and, finally, communication of the results obtained. It is therefore a qualitative method that is not very complex for analysing themes and patterns in the data collected. The fact that it is a flexible method allows the observations made by the participants to be systematically categorised and analysed, giving rise to evidence that supports the study. So, in sum, by transcribing the interviews, reading what is said and identifying what they have in common to form a pattern, the first phase is concluded – familiarisation with the data collected. Then, by highlighting certain points in the text and associating them with codes – in this case, short phrases – generation of initial codes occur, as well as themes and sub-themes.

Direct observations are also performed to understand the operation of the two Units – the space used, space limitations, inefficiencies, among others – where the contribution of the people involved in the activity of the two Units is valuable.

Some documentation, such as data from the inventories and floor plans of the respective Units, are also analysed to provide context and framing, serving as a complement and verification of the information that is collected. It is worth noting that collecting data from these different sources promoted data triangulation as shown in the figure below, allowing to verify the facts.

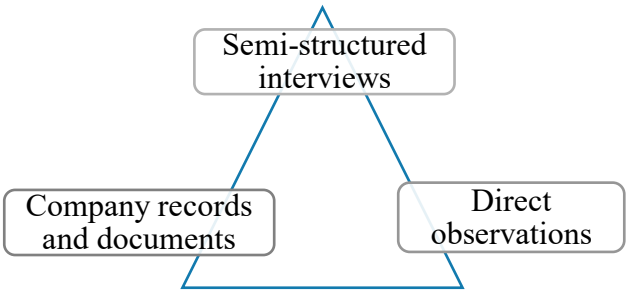


Figure 3.2: Data triangulation

Then, occupancy rates are evaluated in order to assess the initial performance and later compare it with the post-implementation performance of the proposals.

In short, semi-structured interviews and direct observation, as well as documentation are the source for data collection in this phase. Thematic analysis is made and tools such as the fishbone diagram, spaghetti diagram, flowchart, and 5Whys are used to summarise the problem

and its causes. Finally, all results and findings obtained at this phase (e.g., root causes identified with the fishbone diagram) should be validated with the Unit's managers and staff of both Units.

3.2.3. Analysis and development of solutions/improvements

The data obtained from the data collection is analysed and a solution(s) to the problems' root causes identified in the previous stage is proposed.

In this phase, regarding the analysis of data collected, the results obtained from the thematic analysis of the interviews must be presented. A Pareto Chart should be developed to identify the root causes of the problems and define which ones are the focus for proposed solutions.

As a complement, the literature review must be used to identify ideas for solutions and methods. So, after analysing the data collected, solutions and improvements are also proposed. As for the development of solutions/improvements, for one of the scenarios to be proposed, the study by Petrovic *et al*. (2014) on the redesign of existing warehouse systems, taking into account the vertical use of space and high-density storage systems is considered. Then, the simplified SLP by Muther (1973) is used for a second scenario with insights from Ramirez-Cruz *et al*. (2023) to adapt it to the context under study in this in-company project. Ramirez-Cruz *et al*. (2023) used SLP combined with Lean tools in their study, taking GMP into account due to the scope of the study. Both have identical phases, but Ramirez-Cruz *et al*. (2023) apply them to the industry under study. It is intended to be a structured methodology with the steps of Muther (1973), with the industry-specific practices, combined with Lean tools, of Ramirez-Cruz *et al*. (2023). The following table compares the authors, as well as the phases defined in each of the studies mentioned, showing that both are aligned (Table 3.2).

Table 3.2: Comparison of Muther's (1973) method with steps of Ramirez-Cruz et al. (2023)

Short-form procedure by Muther (1973)	Ramirez-Cruz *et al*. (2023) matching steps
Chart the relationships	Relational diagrams to map area proximities based on material flows and needs
Establish space requirements	5S and Standardised Work to establish the necessary use of space
Diagram activity relationships	Visual mapping of flows and procedures
Draw space relationships layouts	Layout proposal taking Lean principles into account
Evaluate alternative arrangements	Pilot test and simulation in a Software
Detail the selected layout plan	Selection of the most efficient layout and its details

3.2.4. Implementation of the solutions/improvements

Once a solution to the problem has been proposed, it should be implemented, and the actions monitored.

To this end, an action log should be used to monitor what is done, what action occurred, when it happened, what follow-up is done, and finally, the status of the action, i.e., whether it is complete, in progress, or to be done.

3.2.5. Evaluation of the proposal and recommendations for future research

The effects and impact of the proposal is evaluated, by comparing the new scenario with the current situation and the new results are measured and analysed. To this end, a cost-benefit analysis is carried out, comparing the gains in terms of positions for the materials and the respective quotes with those of the initial situation.

Finally, considering the results obtained, recommendations must be made for future improvements.

4. Case Study

In this chapter, the Case Study is developed in conformity with the steps defined earlier in the methodology, thus beginning the practical part of this research. The aim is to answer the research question and meet the objectives defined. It begins with a Case Study presentation, by doing a contextualisation and presentation of the company under study, as well as the warehouses and followed by the next phases to obtain a structured and sustained study: diagnosis and data collection, analysis and development of solutions/improvements, implementation, and evaluation of the proposal and recommendations for future research.

4.1. Case Study presentation

4.1.1. Company A

The Company A, a German multinational, was founded in 2006 and currently has 11 manufacturing facilities – located in Europe and North America, with the USA, France, Switzerland, Germany, Italy, and Portugal being the countries where they are located – and six technology platforms. Its mission is to support its global clients in the pharmaceutical industry and biotechnology, with the well-being of patients as its goal. Company A supplies various modalities – Peptides, Lipids, Oligonucleotides, Injectables, and Small Molecules – all of which are supported by the technology platforms. Therefore, Company A specialises in pharmaceutical manufacturing for the global market.

The Company A is located in an industrial area in Portugal, and the immediate environment is mainly warehouses, for instance the access is made by a principal road which provides access to the other principal roads of the country. The company's facility has two production Units (Unit 1 and Unit 2), and each Unit has its GMP certificate. So, in Portugal, Company A specialises in the manufacture of oral pharmaceutical forms and non-sterile liquid medicines, and its manufacturing services range from Clinical Trial production to commercial scale manufacturing, packaging, and pharmaceutical logistics.

Regarding the quality management system, the Company A follows international, regional and local standards and guidelines that are recognised in many countries such as International Organisation for Standardization (ISO), and Brazilian Health Regulatory Agency also known as ANVISA, for example. This system is complementary and encloses the specific rules of the pharmaceutical industry namely the European Union current GMP. Also has a Pharmaceutical Quality System based on GMPs. In turn, has an environment management system based in the ISO 14001 and ISO 50001 standards. This approach demonstrates the commitment with the

protection of the environment. The company is committed to ensure that the products manufactured, as well all the activities developed fulfil high standards of quality. Relevant standards are used like the National Law, European Commission Directives, and other scientific guidelines for human medicinal products. Exists an independent Quality Department, with the responsibility to maintaining, update and improve the current quality system in the organisational structure of the company. The environment management system is certified by ISO 14001. Company A also have GMP critical computerised systems for example, and an enterprise resource planning system and a Software for training management.

Regarding the suppliers and contractors, the company performs external audits to suppliers and contractors according to an established plan (annually approved). A risk management strategy is applied in areas, such as, maintenance of the industrial park, cleaning and Software validation, qualification of suppliers and global quality management for continuous improvement. The company only manufactures products for human use and has an active role for self-inspection with a significant effort in place to promote internal audits.

4.1.2. Company A warehouses

In Portugal, there are two Units at the company's facilities in Lisbon. The aim of both Units is to establish the correct way to store raw materials, packaging materials, intermediate products and finished goods, and this is a transversal objective for all employees in both warehouses.

Unit 1

Unit 1 has one production unit and administrative building. The type of products manufactured in this Unit are non-sterile products, as capsules, liquids for internal use, other solid dosage forms (multi dose powders and granules), semi-solids, and tablets. Biological medicinal products and transdermal patches packaging, also including labelling and secondary packaging of eye drops, are also part. Finally, no toxic or hazardous substances are handled. The warehouse area is 600 m^2. The Unit has a biometric system for access control to areas where GMP activities are in process.

The access from the exterior to unload goods is easy with a proper loading system and is made by a security airlock system to prevent fluctuations in the ambient conditions. The temperature and humidity of the warehouse is monitored. There are a few data loggers to record the ambient conditions properly located after a mapping work to detect the worst situation. There are several special areas as printed/unprinted packaging material areas and rejected

products which are closed areas inside the warehouse. The warehouse allows storing pallets in three, and sometimes on four and five levels, depending on the differentiation made by height.

Regarding material management and warehousing, the Unit 1 is equipped with temperature control and humidity control, designed for 20°C ± 5°C temperature. The relative humidity is only monitored with a maximum value of 70%. Inside the warehouse there are restricted areas for printed/unprinted packaging materials, flammable substances and rejected products. The Unit is secure, the access is restricted, and the doors kept closed. The system of storage is pallet racking in wood or plastic pallets (0.80 m x 1.20 m). The warehouse is divided in areas, and each zone has codification recognised by the computer system. For finished goods, after packaging the products go to the warehouse in the quarantine status. When the product comes inside the warehouse it goes to a location and the data from the product and the location are introduced in the computer system. Rejected products are stored in a specific area on the warehouse. Then, those products are destroyed by an outsourced company. In terms of layout, there are corridors where the products are organised according to their categories, and there is also access to the production area and the weighing/sampling room. There are also two offices.

Underneath Unit 1 is a basement which has also serves as support, also including a rejected area, a space for tertiary cardboard and pallets, as well as a flammables area.

Unit 2

Unit 2 is composed by a unique building with four levels in which it is located the finished good manufacturing and storage area, offices area, utilities areas and Quality Control laboratory. The type of products manufactured are Human Medicinal Products and Human Investigational Medicinal Products, and no toxic or hazardous substances are manufactured or handled.

Unit 2 is recent, being built in 2018 and consists of a four-level building with a total area of around 3,000 m^2. The ground area is dedicated to offices, technical rooms and access to production area. Level 1, the level being studied, is dedicated to reception/expedition area, warehousing, manufacturing, and packaging, including the following area distribution: excipient and packaging warehouse and reception expedition area with 270 m^2 and the cold warehouse area with 250 m^2. Unit 2 is equipped with a biometric system for access control to areas where GMP activities are in process to assure that only authorised personnel have access to those areas.

Regarding the type of products, it is a warehouse that only works with one finished good, a granulate for oral suspension. The Unit also work with two raw materials, one of which is an API and the other an excipient, and also does the manufacturing and primary packaging of

investigational medicinal products that use the API. Then, the packaging materials can be classified in two ways: primary packaging material, that which is in direct contact with the product, and secondary packaging material. There is also another relevant concept related to packaging materials: printed packaging materials. There are three types of printed materials in Unit 2: complex (in rolls), fold boxes and leaflets. In sum, Level 1 is divided into four main areas: manufacturing and primary packaging areas, secondary packaging area, which is contiguous to primary packaging area, loading docks/reception/expedition area, and finally a cold warehouse for the API and finished good.

Room temperature warehouse is designed to maintain a temperature between 20°C ± 5°C for the excipient and packaging warehouse and reception/expedition area. The cold warehouse for the finished good and API and some quality samples is designed to maintain a temperature range of 2ºC/8°C. No relative humidity is required in warehouses.

Regarding material management and warehousing, as Unit 1, the access to warehouse is restricted using biometric control system, and the doors are kept closed. Conventional racks in the excipient and packaging warehouse is the storage system used, and moviracks in the cold warehouse area – for Euro pallets in wood or plastic (0.80 m x 1.20 m) or US pallets (1.22 m by 1.02 m). The warehouse is divided in zones, and each zone has codification recognised by the computer system. Rejected products are stored in a specific area in Unit 1. It´s important to mention that the Unit has no direct connection to Unit 1 and the basement, mentioned above.

4.2. Diagnosis and data collection

Firstly, it is crucial to study the two Units in the company's facilities in Lisbon, to understand the current scenario and practices, i.e. their configurations and how they are organised.

Unit 1

Unit 1 is responsible for storing finished goods and four types of materials: raw material, intermediate product, intermediate product/bulk and, finally, packaging material, the latter comprising primary and secondary packaging material, which can be printed or unprinted. The warehouse is organised into areas according to the characteristics of the material to be stored and has a total of 911 positions, following a dedicated storage policy. It also counts with the support of a basement which has other specific areas, and which allows materials to be stored that have no place in the Unit in question. For moving materials in the corridors, a side loader forklift is used as lifting equipment. Their stock management policy follows expiry dates, that is First Expired First Out (FEFO) and consider certain factors and procedures, such as

positioning the heaviest materials (over 500kg) on level 1 (floor) of the racks whenever possible and mono-article by location, whenever possible. As for storage areas, there are several different areas for each type of material, some of which are closed areas with restricted access and the employees authorised to access closed areas are those from the Unit, the Unit Manager and the Supply Chain Manager. The existing flows of people, materials and products are shown below in Figure 4.1 which illustrates a spaghetti diagram.

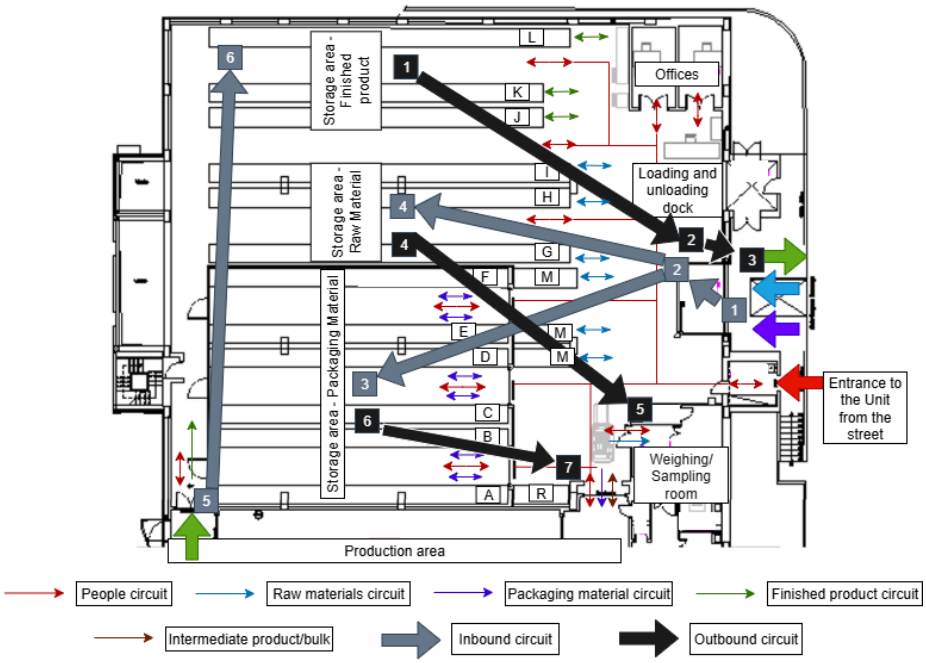


Figure 4.1: Unit 1 spaghetti diagram

The spaghetti diagram shows that, from a macro point of view, raw materials and packaging material enter the Unit by passing through the reception and inspection process (grey points 1 to 2) and are allocated to the respective corridors (grey points 2 to 3 and 2 to 4). Handling and storage of packaging materials, and raw materials is performed as described in the flowchart in Annexe C**.** Then, finished goods enter the Unit from Production (grey points 5 to 6). At the outbound level, finished goods are dispatched (black points 1 to 2 and 2 to 3) and some raw materials and packaging materials are sent to Production (black points 4 to 5 and 6 to 7). In terms of the people circuit, access to Unit 1 is from the outside or through the Production area and access to the weighing/sampling room is from inside the Unit. People can also walk through the storage corridors whenever necessary and there are also offices.

Now, from a more detailed point of view, regarding the materials circuit, the raw materials that need weighing leave the respective corridors and go to the weighing/sampling room, but there are specific cases that are not weighed, such as sucrose (for manufacture of liquids), icing sugar (for manufacture of tablets) and gelatine capsules (for filling capsules), and which are placed by the warehouse in the designated Production area, i.e. Unit 1 also do the picking for

Production, and the bulks can also be prepared by the warehouse to the Production. After manufacturing bulks of tablets and capsules, they must be labelled and duly accompanied by a warehouse movement sheet to be delivered to the warehouse. However, before these raw materials are used, they can be physically allocated, on a temporary basis, in the corridors of the factory, as long as there is no space in the respective warehouse or support room. Next, both primary and secondary packaging materials have a reserved storage area with biometric access, and the warehouse also do the picking of these materials for Production.

There are also areas marked out in yellow on the factory floor for pallets of finished goods, which are placed there on a temporary basis. In short, the materials circuit is U-shaped, since entry and exit take place on the same side of the warehouse, except for rejected products, which follow a different circuit. As for configurations, the Unit has conventional racks and light-duty racks, where there are vertical adjustments, i.e. differentiation by height, and it also has a pigeonhole system. The ceiling height of this Unit is around four metres. Annexe D illustrates the previously mentioned areas and their configurations.

The Table 4.1 completes the previous information:

Table 4.1: Materials, storage areas, and positions in Unit 1

Type of Material	Storage Areas	Positions
Printed/unprinted packaging material (0021 at SAP*)	Corridors A, B, C, D, E and F (Storage Packaging Material CBU) – closed area with biometric access	468
Room temperature materials (20°C ± 5°C) from a client's Clinical Trials	Corridors A and B – closed area with biometric access	Diverse (included in the 468)
Raw materials and intermediate product (0031 at SAP)	Corridors G, H, I and M area (Storage Raw Material CBU)	269
Finished goods (0011 at SAP)	Corridors J, K and L (Storage Finished Goods CBU)	174
Flammable material	Flammable room in the basement, which is a closed area with restricted access	1,600 litres capacity
Rejected products	Rejected area in the Unit and basement, both of which are closed areas with restricted access	4 at the Unit and 21 at the basement
Tertiary cardboard material	Basement, which is in a closed area with restricted access	Diverse
Pallets (plastic and aluminium)	Basement	Diverse

** System Applications and Products in Data Processing*

However, Unit 1 faces some difficulties and challenges, particularly high occupancy rates. Tompkins and Smith (1998), in the book *The Warehouse management handbook*, the authors talk about the need for space when a warehouse has occupancy rates above 80%, which is reflected in increased time wastage and, consequently, a decrease in productivity, making it less efficient. Furthermore, it is claimed that the more time spent searching for storage locations, the less accurate the classification of products becomes, meaning that the distinction between fast-moving and slow-moving items is lost. Therefore, what can be concluded from the previous observations is that, to have a healthy warehouse, a target of 80% is set, to be able to handle unforeseen events, shipments and production fluctuations and therefore have some free space. However, as can be seen in the following graphic (Figure 4.2) created by Company A, with a timeline from August 2024 to May 2025, this is far from the desired value.

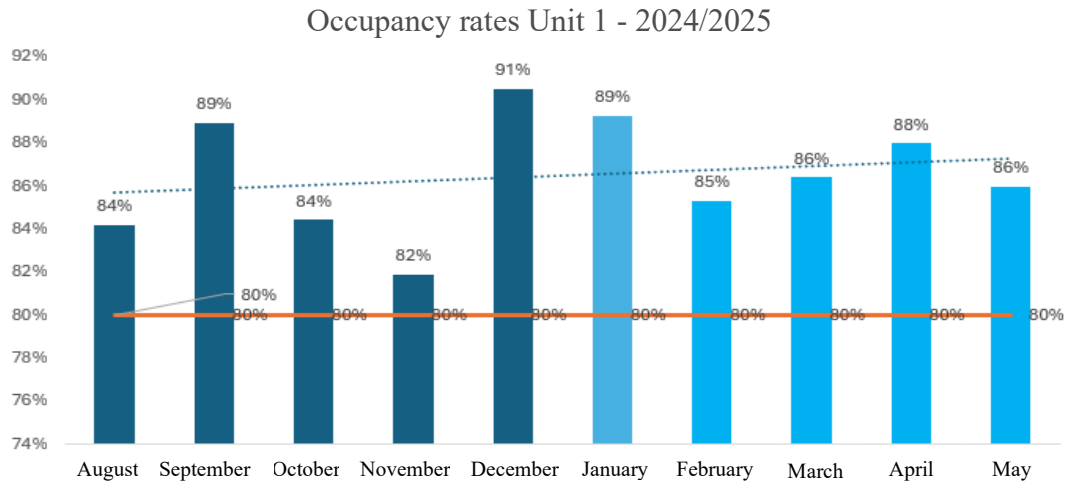


Figure 4.2: Unit 1 monthly occupancy rates

Occupancy rates are calculated considering the occupancy of each area of the warehouse per month, based on the total number of positions. In other words, of the 468 total positions in the packaging materials area, 269 in raw materials and 174 in finished goods are checked monthly to see the actual occupancy of each, taking into account the total of 911. Positions relating to rejected products, flammable, tertiary packaging materials and pallets do not count for this purpose because the rejected products area acts as a 'transition area', since the area designated for them is in the basement, like the others mentioned. The oscillations shown in the graphic are related to production peaks, i.e., whenever production stops, for example, for cleaning or vacations, or even produces large quantities, it influences warehouse occupancy, as there is less outflow of materials and products, or the opposite. The fact that it is necessary to buy materials in advance, due to the approvals they are subject to, means that the warehouse must also have space available for such cases.

A semi-structured interview is made to the Unit 1 Manager and based on the responses (Annexe E and Annexe F), a thematic analysis is performed on the respective interview in order to obtain results that help identify the causes of the problem. Separation and storage of materials by typology, lack of storage and space, high occupancy rates, FEFO and SAP, lack of calculation of safety stocks (SSs) considering service levels, overloaded storage systems, inefficiencies in the picking process, packaging materials are critical, and lack of designated areas are the initial codes identified. After obtaining these initial codes, a search for themes and sub-themes is made, reviewing and defining them, where related codes are grouped into themes and some even into sub-themes, while at the same time making the communication of the results obtained.

Thus, in Group 1 of the interviews, four themes and one subtheme are identified: structured and fixed layout – Unit 1 has products organised by typology and in specific areas, which can lead to a lack of positions for storage due to restrictions; FEFO policy for inventory management and the subtheme lack of SS calculation. As for the sub-theme, there is no formal policy for SSs, which are based on the Supply department's production plan; high occupancy rates and overcrowding – the Unit has high occupancy rates, which does not allow to be efficient; finally, storage systems need to be improved – there is a need to adapt the existing system or even consider expansion. As for Group 2, four themes and one sub-theme were also identified: storage problems that cause inefficiency and the sub-theme of overcrowding and material allocation problems – some materials are stored in incorrect areas or even outside the Units, such as in the basement, due to a lack of storage and there is also a lack of designated areas, such as the reception and expedition area; inefficiencies in the picking process – delays due to problems in the storage of materials, where there is stress due to the congestion of the Units; packaging materials – their storage and legal requirements make them of high importance; product growth – the Unit is forecasting an increase in products, which will increase the need for positions for certain materials, especially packaging materials. There are some suggestions for improvements, but they have not yet been implemented.

In order to understand the root causes of the problem, namely SKUs stored in the wrong corridors and the inefficient picking process, a 5Whys analysis is designed (Annexe G). Also, based on the thematic analysis, direct observations performed to understand the functioning of the Unit, as well as consultation of available documents – Procedures, Inbound, Outbound, and Stock – it was possible to make the following diagnosis.

Some packaging materials are not correctly located in the designated storage corridors, since there is a lack of available storage for them. Exists excessive orders of these materials,

since they are essential to the industry and without them the company can not continue its activity, and due to suppliers' constraints related to lead time. All this leads to high stock levels, high occupancy rates and, in extreme cases, can result in obsolete stock. These materials also have strict storage rules, namely temperature control and restricted access, which consequently limits their storage. So, there are mixed SKUs in the wrong corridors and designated areas are missing in the Unit, namely has no support or maneuvering areas – lack of an order preparation zone and an expedition area what leads to an inefficient picking process. Delays and changes in the production plan also mean that storage planning is not as effective as it could be. Due to lead times, overstocking is sometimes seen as a method. The dimensions of the Unit, i.e., physical limitations and temperature and humidity control, limit the usable storage space.

Workers face physical and mental stress, and overlapping tasks and processes are common. Congested corridors due to lack of storage cause stress and reduce efficiency, exacerbating material allocation problems. Resistance to change is also an obstacle. Problems with data recorded in SAP due to late implementation also has an influence on storage problems, because in some cases the data does not yet reflect reality. Sometimes Supply Chain planning faces problems due to delays and late changes in the demand plan and there is no inventory control system that considers the necessary order levels to avoid overstocking. Low-density storage systems like the pigeonhole system and light-duty racks limits the space for storage.

In order to represent the points that have been mentioned, a fishbone diagram is presented:

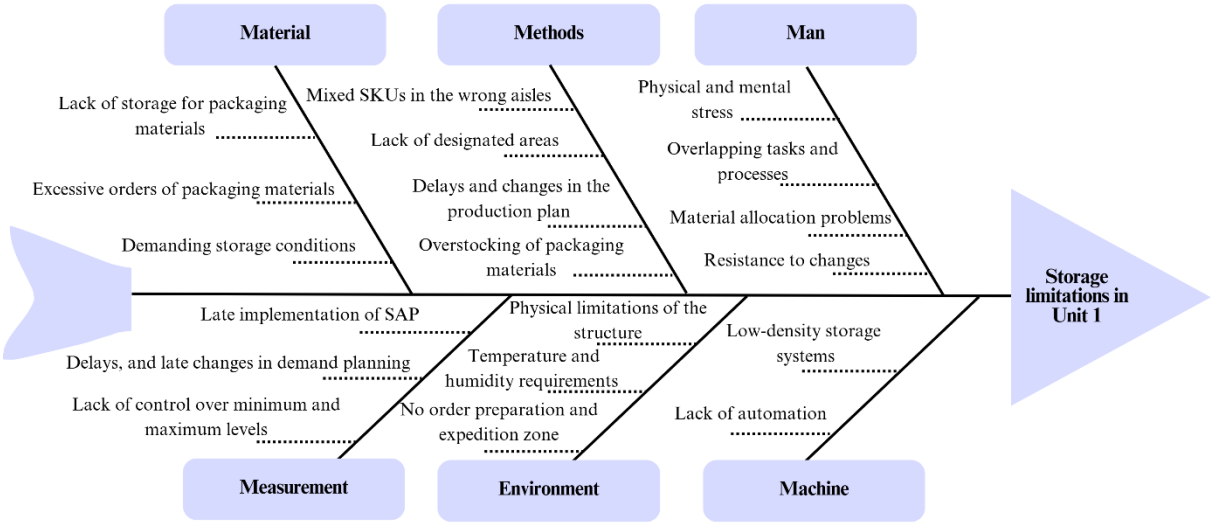


Figure 4.3: Unit 1 fishbone diagram

Unit 2

Unit 2 can be described as a filling line. It only works with one finished good, two raw materials, one is an API that is manufactured in another factory and the other a second non-active substance – natural xanthan gum – and three types of packaging material: complex rolls

(primary packaging material), fold boxes, and leaflets (secondary packaging materials). The Unit's function is to mix the API with the second excipient and then pack the final product. The Unit is also organised into areas that meet the requirements of the materials and products stored, these being an area for packaging materials and excipient storage with a temperature of 20°C ± 5°C, a cold storage area with a temperature of 2ºC/8ºC – which contains the finished good, the API and the Quality samples – and, finally, a sampling/weighing room and a loading and unloading dock. The first two areas are closed areas with restricted access, and the employees authorised to access them are those from the Unit, the Unit Manager and the Supply Chain Manager. This Unit also makes use of the basement to store some materials that don't have positions due to lack of space. Materials are moved using different handling equipment depending on the area of the warehouse and the material. Stock is also managed according to FEFO, and also practice single lot by location, as does Unit 1.

As for configurations, in the packaging materials and excipient storage area, the Unit has conventional racks and a light-duty rack, where there are vertical adjustments, i.e. differentiation by height. There are moviracks in the cold storage area, but this will not be explored in the project, as the focus of the study is on 20°C ± 5°C storage and the respective materials. The ceiling height of this unit is around 11 metres. The existing flows of people, materials and products are shown below in Figure 4.4 which illustrates a spaghetti diagram.

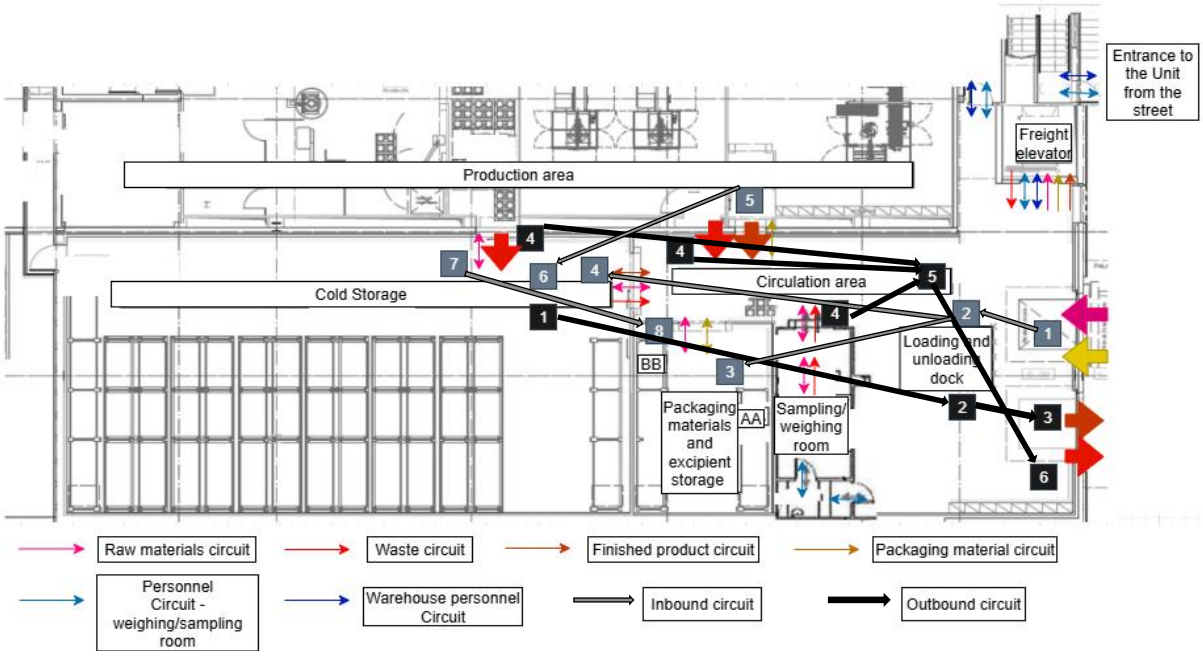


Figure 4.4: Unit 2 spaghetti diagram

This spaghetti diagram shows that the raw materials and packaging materials enter the Unit by passing through the reception and inspection process (grey points 1 to 2) and are allocated to the respective corridors (grey points 2 to 3 and 2 to 4), and handling and storage of packaging

materials and raw materials is performed as shown in the Annexe C, like Unit 1. The finished good enter the Unit from Production (grey points 5 to 6) as in Unit 1. There is also the case of returns of raw materials by Production area (grey points 7 to 8). At the outbound level, finished good are dispatched (black points 1 to 2 and 2 to 3), and all waste arising from production activities must be placed in the circulation corridor (black points 4 to 5) being removed through the warehouse and sent to the waste area outside the Unit (black points 5 to 6). In terms of people circuit, access is from the outside, which leads to stairs and an antechamber that ends up inside the Unit but there is also a lift.

In more detail, regarding materials circuit, the API must be stored in cold storage, and the remaining materials and the excipient must be stored in the packaging materials and excipient storage. So, the materials enter the Unit through the loading dock, being placed in reception area for checking. But when the API enters the loading dock, it is immediately placed in cold area, where it is checked. The excipient and API are sampled in sampling/weighing room and the entry and exit of materials from this area is through the warehouse. Next, after sampling, the remainder of the excipient is stored in packaging materials and excipient storage and the API in cold storage. The samples go via elevator to floor 2, entering Quality Control, i.e. after weighing, the excipient leaves packaging materials and excipient storage to circulation area and passes through cold storage, being placed in the Production area or, if there is a remaining quantity, returns to the packaging materials and excipient storage via the reverse circuit. Also, the API is sent directly from cold storage to Production.

All samples coming from Production and destined for Quality Control, for example finished good samples, leave the Production area entering the warehouse and taking elevator to floor 2, entering Quality Control. All raw materials sampled in the sampling/weighing room and all Unit 2 packaging materials, subject to approval, go via elevator for floor 2, entering Quality Control as well. Then, the primary and secondary packaging material is shipped from packaging materials and excipient storage and sent to Production area. The finished good, after leaving the Production area, is placed in cold storage. When shipped, it leaves the cold storage, passes through the circulation area and is shipped via the unloading dock. Similar to Unit 1, there are delimited areas on the factory floor for the placement of pallets of finished good, and for the placement of pallets of packaging material, which remain allocated in these areas on a provisional basis. Annexe H illustrates the previously mentioned areas and their configurations.

To illustrate the capacity and the real positions occupied, below is a record from November 2024 and September 2025 for the packaging materials and excipient storage area of Unit 2 (Figure 4.5).

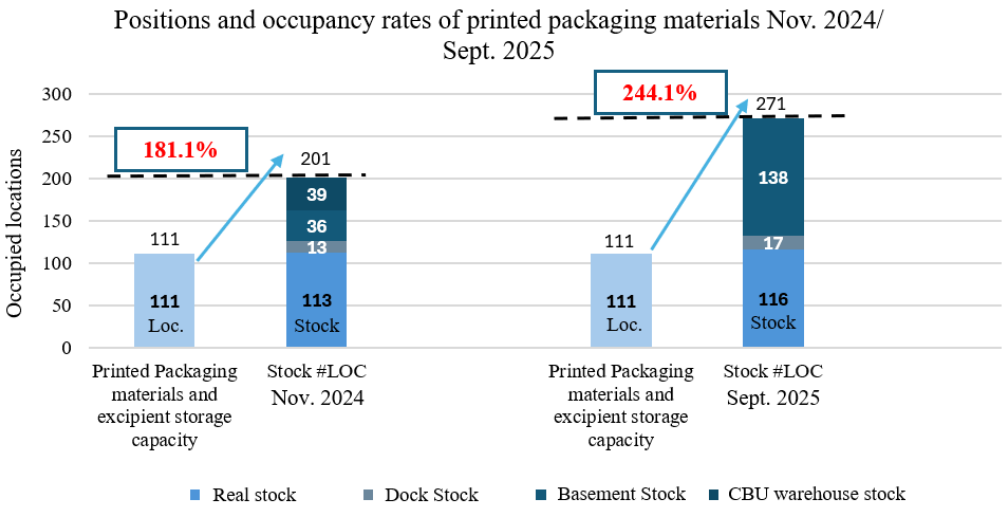


Figure 4.5: Unit 2 positions and occupancy rates of printed packaging materials

In terms of occupancy rates, the problem with printed packaging materials is evident. The stock of printed packaging materials is located in a specific area, as mentioned above, and comply with a series of regulations, for example, it is not allowed to stack this materials, which also reduces the available space. The storage area has a capacity of 111 positions, however, as can be seen in the graphic above (Figure 4.5) – where a comparison of the stock of these materials in November 2024 and September 2025 can be found – there is a stock of 113 in November, as well as additional stock in some operational areas. This means that the storage area for these items is full, and the dock, basement, and CBU warehouse areas are occupied with stock, which is not desirable. Adding up the total existing stock of printed packaging materials (201 materials) and comparing it with the capacity (111 materials) gives an occupancy rate of 181.1%. The same applies to the data recorded at the beginning of September and, in this case, it is possible to see that the stock of printed packaging materials is not tending to decrease, but rather to be a point of concern for the company. In this particular case, it was due to a production stoppage in August, which affected the entire use of stock and, consequently, the occupancy rate in the printed packaging materials warehouse is more than double the capacity. As a result, the API was not used, also registering an increase, and thus preventing the use of printed packaging materials and the finished good from being shipped. The occupancy rate of the cold area doesn't reveal any problems. It has a total capacity of 630 positions, with an occupancy rate of 49.8% in November 2024 and of 73.8% in September 2025 (Annexe I).

The total stock of printed packaging materials, 271 in September 2025, is equivalent to approximately 70 batches, so 14 batches per month. Each batch is assumed to consist of four pallets of printed materials. This amounts to a total of 56 pallets per month and dividing the total stock by the number of pallets per month shows that there is stock for approximately five

months of work. This analysis shows how inflated the stock is and that, according to suppliers, Just in Time should be practiced. In other words, this translates into low turnover and high inventory days, reinforcing the inflation of stock levels.

As in Unit 1, a semi-structured interview is made, following the same groups of questions (Annexe A and Annexe B) with the Unit 2 Manager, and based on the responses (Annexe E and Annexe F), a thematic analysis is conducted. The same codes, themes and sub-themes mentioned above and duly explained are identified. From direct observations and documents provided, as well as 5Whys (Annexe J) it is possible to make the following diagnosis.

Several points are identical to the causes in Unit 1, and therefore it is important to highlight other aspects. One of them is the relevance of the printed materials in Unit 2. As it is a warehouse with a high ceiling but limited horizontal space, there is a lack of space for printed materials, some of which have to be distributed across the Unit's dock, basement, or even Unit 1 to store all the stock. These materials are highly sensitive to storage conditions, which limits relocation options and reduces flexibility, and require temperature and humidity control, with complex rolls being the most sensitive. Access to all of them is also restricted. As previously seen in the stock records, there is a lack of a KPI to control material turnover and prevent overstocking. On the other hand, it is important to note that the storage system is limited due to the available space and, therefore, lacks high-density storage units. Finally, there are problems with the movement of materials, since due to the limited space available, the equipment has very short space to operate, and there are few areas for maneuvering. Associated with this, some of the movements have to be done physically because there is a lack of equipment to move some specific raw materials, which has already caused physical stress on workers.

In order to represent the root causes for the problem, a fishbone diagram is presented.

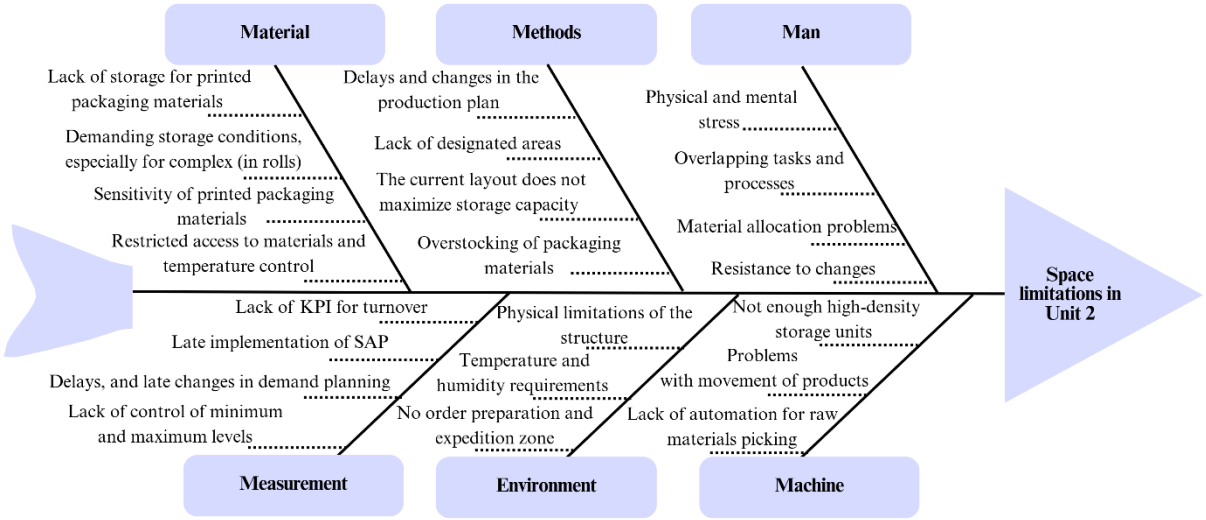


Figure 4.6: Unit 2 fishbone diagram

4.3. Analysis and development of solutions/improvements

4.3.1. Analysis of data collected

When the data about the "as-is" scenario has been collected, it is important to analyse it.

After identifying the codes, themes and sub-themes in the previous phase through thematic analysis of the semi-structured interviews, it is crucial to then analyse their meaning and impact. To do this, the qualitative data is transformed into quantitative data so that the weight and relevance of each can be identified. It was previously noted that the current layouts make it difficult to allocate materials, as they don't have the necessary positions, SSs also don't follow a formal policy for their calculation, both units operate under high occupancy rates, affecting efficiency and organisation, the picking process is inefficient which creates pressure on workers and is time-consuming, and packaging materials proved to be a critical point. However, it is necessary to analyse which problems are most relevant and which carry the most weight, in order to understand which ones most affect the company and require special attention.

For this purpose, a Pareto chart is constructed. But first, it is important to understand the criteria for drawing it. In this way, to obtain the frequency of each identified code, the number of times each appeared throughout each group of interviews (Group 1 referring to the diagnosis of the current situation and Group 2 relating to the difficulties experienced) and the responses from both Unit Managers were added together. In this case, the frequencies are the total number of times the codes appear, rather than the number per group or the number per response from each Unit Manager. In other words, for each question in each group and each response from both managers, the occurrence of codes is recorded simultaneously, so that all occurrences are counted in total. The Table 4.2 shows the codes and frequencies used to construct the chart.

Table 4.2: Codes and frequencies from thematic analysis

Code	Frequency
Separation by typology	3
Lack of space and storage	13
High occupancy rates	5
FEFO and SAP	2
Lack of Safety Stock policy	2
Overloaded systems	13
Inefficient picking process	4
Packaging materials	15
Lack of designated areas	4
Total	61

Using these codes and frequencies, the Pareto chart depicted in Figure 4.7 is obtained.

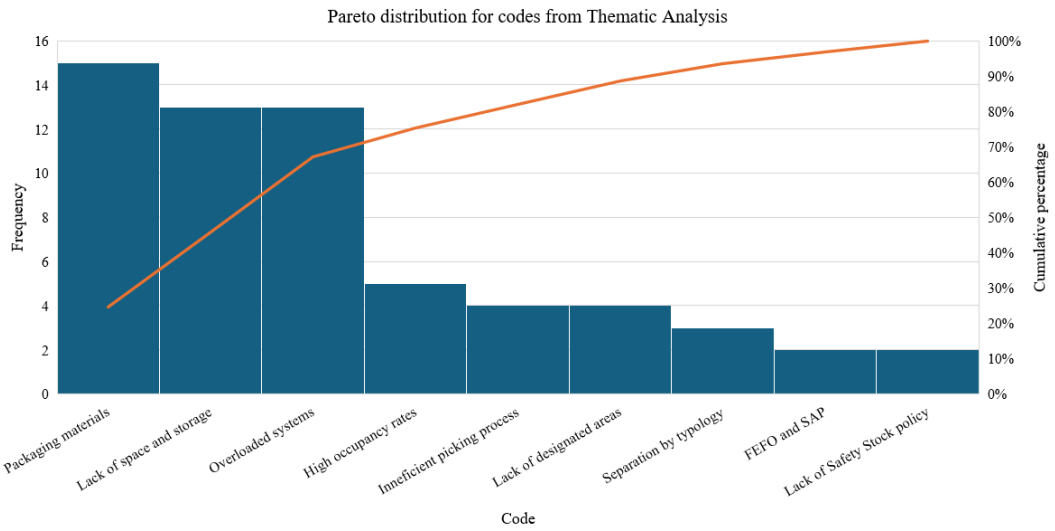


Figure 4.7: Pareto chart of the company's challenges

Firstly, the codes are organised in decreasing order, i.e. from highest frequency to lowest. Next, it is important to understand three concepts: absolute frequency, cumulative frequency and cumulative percentage. Packaging materials have a frequency of 15, a cumulative frequency of 15, and a cumulative percentage of 24.6%, as the cumulative frequency is divided by the total number of frequencies (61). Lack of space and storage has a frequency of 13, but a cumulative frequency of 28, since the previous cumulative frequency (in this case, 15) must be added to the absolute frequency of the current code (13), giving a cumulative percentage of 45.9%, since the cumulative frequency (28) is divided by the total (61), as seen previously. Several conclusions can be drawn from the diagram above. Packaging materials alone explain approximately 25% of all problems. If these are added to the lack of space and overloaded systems, approximately 67% of problems are explained. Considering the high occupancy rates and inefficiencies of the picking process, approximately 82% of the problems are addressed. In conclusion, if the focus is on these categories, most of the current challenges can be solved.

4.3.2. Solutions/improvements

4.3.2.1. *Scenario 1* – Improvement of current Units

Sometimes improving existing spaces and, consequently, their layout is enough to achieve significant results, such as more efficiency and storage capacity. Thus, making adjustments to what already exists can be a viable solution with controlled investments (Rebelo *et al*., 2021).

Unit 1

Starting with Unit 1, based on the configurations shown above, it is possible to notice that there are 17 different configurations, three of which are light-duty racks. The light-duty racks are

located at the warehouse pillars in order to maximise space and one of them occupies the space of a conventional 16 module rack. They all hold small boxes and have between five and eight levels, ranging from five to 25 modules, so there are 12 light-duty racks in total. On the other hand, one of the conventional rack configurations includes a pigeonhole system, with reduced compartments for storing small boxes, which occupies five modules of the rack.

In view of the above, in spaces with limited storage space and when there is not enough flexibility to make major changes to the existing structure, leveraging vertical space in a warehouse can be a solution. So, a Vertical Lift Module (VLM) is proposed for this Unit to replace the several light-duty racks and the pigeonhole system for storing small items. A VLM is an automatic system which, as the name suggests, serves to store small items vertically and, via a lift, delivers trays of items directly to the user. It is characterised as a dense storage system and, as Foroughi *et al*. (2021) stated in their study on the importance of dense systems, it is suitable for locations with lack of space for storage, since it maximises the capacity. It is important to note that it also complies with GMP and can have temperature control, which is crucial in the industry under study. Access is also conditioned and controlled, making it a viable solution for this industry, taking into account existing requirements and regulations. Since it is automated, it also makes picking easier, more efficient and reduces errors. The fact that it can be linked to SAP is also an advantage of implementing this system.

Currently, according to the company's stock file, the light-duty racks have a total of 74 positions occupied. The pigeonhole system has 13 positions utilised. By using a VLM, it is possible to allocate all the items in the same place and thus free up storage in the Unit allowing more positions in the VLM for future needs. Although, the suggested location for installation must take several physical factors into account: the Unit has a ceiling height of approximately four meters, and conventional racks are typically approximately 1.10 meters deep. These measures show that it will not be possible to place the VLM between corridors, as it would block the passage, since a lift normally has a depth of more than three metres. The Modula company has some options and has a more suitable solution for limited spaces (Modula, n.d.):

- *Modula Lift*: there are several models, such as the ML50D, MC25D, MC50D and MC75D, for example, but the depths of these models start at three metres and can reach great heights.
- *Modula Slim*: A compact model, ideal for limited spaces and budgets. There also different models and sizes, however all have a depth of 1.6 metres, and their height can vary between 2.4 metres and seven metres.

The suggested locations for both are illustrated in the Annexe K, and according to the current layout and respective configurations previously indicated, could be at the beginning of

corridor L, near the offices. If Company A opts for Modula Lift, it should reduce the capacity of the racks identified with Configuration III in corridors K and J, to allow the circulation and movement of equipment, people and materials. If it opts for Modula Slim, since it can have a minimum depth of 1.6 metres, no major changes to the current structure will be necessary. On the other hand, when installing VLM, light-duty racks can be replaced by another type of system to gain space for more storage, as already mentioned, and therefore Configuration 1 in corridor A can be replaced by Configuration IV in both cases, consistent with the organisation of the corridor in question. And Configuration VI in corridor B could eliminate the pigeonhole system and give place to five positions for reduced pallets, as it has in level one of its configuration.

It is expected that with the implementation of the VLM, the Unit will achieve improvements in terms of storage, make picking more efficient due to its automatic system and, consequently, facilitate accessibility to SKUs, thereby reducing the distances travelled by the picker. The fact that it can be connected to SAP also allows for precise inventory control. Two possible partners for implementing this system in Company A's Unit 1 could be Modula, as already mentioned, or Kardex. The purchase and installation of a VLM can vary, depending on height and width, between €45,000 and €65,000.

Unit 2

Unit 2 is divided into two areas: packaging materials and excipient storage and cold storage. The packaging materials and excipient storage area faces major problems in terms of occupancy and, consequently, available space. This area has a ceiling height of around 11 metres, but it is quite narrow, with the corridor between the racks being less than three metres, which even makes it difficult to manoeuvre the class 300A forklift, i.e. a forklift for material handling suitable for narrow aisles with a considerable height, being driven manually. According to the data previously presented, it has an occupancy rate of over 100%. Based on the configurations of the Unit (Annexe H), it can be seen that there are one light-duty rack, four conventional racks and four different configurations, with two racks having seven levels and the other two eight levels. Two rack modules are 3.6 metres long and the other two are 2.7 metres long.

Due to the limitations of horizontal space, and similar to Petrovic *et al*. (2014) who study the hypothesis of reconstructing the pallet rack system used in a pharmaceutical warehouse to increase storage capacity, it is suggested that the existing system be adjusted, improving the differentiation by height and making changes to the levels of the rack beams, thus improving the utilisation of vertical space. One of the themes addressed in the article by Bekzhanova *et al*. (2021) is the influence of racking systems on the use of space and how they can contribute to

improving it. It is therefore proposed that they be improved in order to make the most of the height of the racks, since the current system has positions that are occupied to half their capacity and there are empty spaces from one level to the next. In short, it is suggested that the levels of the existing racks be changed and new beams added, with the 3.6 metres long modules having eight levels of beams instead of six and, in turn, the 2.7 metres long modules also having eight levels instead of seven. The issue of weight is also taken into account, and the heaviest materials (500 kg) will be moved to level 1 (floor), and the smallest will be positioned on the levels above. It is estimated that this new system will have capacity for 20 more positions. The supply of the new beams and delivery, as well as the assembly and alteration of the shelves will cost around €2,000, according to a quote requested from Mecalux. Attached is an illustration of the proposed improvements (Annexe L).

To make full use of this limited area, there are also other possible solutions, such as Drive-in or Drive-Through racking and a Pallet Shuttle. However, the limitations of the area, as well as the load it stores, and the FEFO stock management system must be considered in order to make the right decision. The area in question is five metres wide, less than 6.7 metres long and 11 metres high and the load is on Euro pallets, i.e. 800 mm by 1,200 mm, and the height of the load can be 750 mm or 1,300 mm. Therefore, the possibility of a Drive-in was studied, but it is not recommended as it is limited to Last In First Out, commonly known as LIFO. Unlike this, a Drive-Through can work with FEFO, but the fact that a forklift must enter the corridors and their width must be adapted to it makes its installation unfeasible.

Therefore, a Pallet Shuttle is a possible alternative since, if configured or having separate loading and unloading areas, it can operate according to FEFO and has the capacity to have several references for each storage channel, making it more versatile than the first ones mentioned. In turn, the fact that a forklift does not need to enter the corridors makes it a more viable solution. As Euro pallets are used, each set of racks can have a depth of 1,300 mm, i.e. 1,200 mm for the pallet and an additional 100 mm for the structure's clearances. As for the front, since there are five metres available in width and FEFO is used, it is advisable to have two fronts of 800 mm c/c plus 100 mm of clearance. However, an access corridor is required on the opposite side for the forklift to move and remove the load that expires first, thus practising FEFO. The channels can be organised according to expiry dates and batches, so that the first to be removed is the one with the earliest expiry date. Finally, since the load is between 750 mm and 1,300 mm high, the Pallet Shuttle structure can have height levels of, for example, 1,500 mm for each level (1,300 mm maximum load height plus 200 mm clearance).

An estimate for investment in this system is €30,000 to €50,000, but the actual price is available upon consultation with suppliers such as Mecalux or Dexion Portugal, for example. However, it involves a high initial investment, unlike the first improvement proposed.

4.3.2.2. *Scenario 2* – Proposal for basement layout using SLP

For the second scenario, it is proposed to reorganise Company A's existing basement – located below Unit 1, and which both Units use – and redesign it to better suit their needs. The aim is to suggest a layout plan that will provide greater support for the Units and their space and storage problems, helping to reduce their occupancy rates by utilising the available space in the basement. To this end, the Simplified SLP methodology (Muther, 1973) is applied, since the space under study is limited and there is low flexibility for changes, the flows are not complex and the scope of the project is also small, and some of the areas are fixed and can not be changed. The models and forms provided in Muther's book are used and, in addition, some suggestions from the model proposed by Ramirez-Cruz *et al*. (2023) are followed. As Ramirez-Cruz *et al*. (2023), Naqvi *et al*. (2016) and Jasrotia and Sengottaiyan (2024) state and show in their studies, the implementation of SLP allows for improvements in operational efficiency and combining it with Lean tools can produce great results.

Thus, the six steps of the simplified SLP approach – chart the relationships, establish space requirements, diagram activity relationships, draw space relationships layouts, evaluate alternative arrangements, and detail the selected layout plan – are applied in this scenario, as well as some Lean tools, namely 5S as in Ramirez-Cruz *et al*. (2023) and Kanban.

Phase I – chart the relationships – serves to represent the relationships between the areas, activities or characteristics and their proximity needs, as well as the justification. Thus, it combines letters that establish the importance of the relationships with numbers that establish the justification and, in this way, allows for thoughtful planning regarding the location of the areas to obtain the most suitable structure, as well as understanding the existing flows. In the case of this study, there are 11 different areas, and their relationships have been studied.

First, there are separate areas in the basement and the Units under study share the space with the Maintenance and Clinical Trials, who own the cold chamber. Exists a reserved area divided into two parts, both with racks, and the second area is currently used to store the Units' consumables – which can vary from overalls, gowns, gloves, caps, foot covers, masks, adhesive tape, angle brackets and so on. Then there is a central storage area with racks available and positions on the floor marked out in yellow for tertiary packaging material: four types of pallets (Euro plastic pallets, aluminium pallets, Euro fumigated wood pallets and US fumigated wood

pallets) and five types of cardboard boxes, and a frontal forklift is used for handling material. Flammables have an area with a capacity of 1,600 litres and these can vary between Ethyl Alcohol and Ethanol. In addition, another reserved area is available with an area for rejected products and an area for sorting waste from the activity. Finally, the production support equipment is also in the basement. The relationship chart has been drawn up (Figure 4.8) and the relationships between the areas described have been represented (Annexe M).

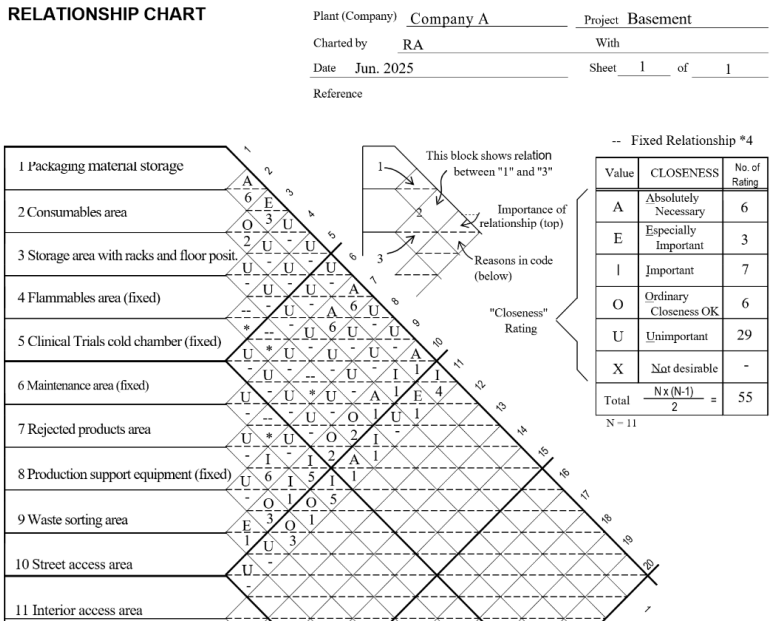


Figure 4.8: SLP phase I

It is important to emphasise that four of the areas mentioned are fixed and can not be altered in their layout and will therefore not be the subject of changes or of the study, these being the flammables area, the Clinical Trials cold chamber, the Maintenance area, and the production support equipment. The basement can be accessed in two ways: from inside the company or from outside. It is important to note that is a basement, and it is a very limited space with a ceiling height of three metres, however, due to ceiling pipes, it is not possible to take full advantage of it, so has around 2.80 metres available. For example, it is only possible to have between two and three levels of racks, depending on the height of the load to be stored. The equipment used in the basement for material handling are a forklift and a stacker.

Moving on to Phase II – establish space requirements – the space needed for each area is studied, as well as its specific characteristics. Thus, for the areas identified in the previous phase, the measurements of the areas are placed, the desired physical characteristics in terms of structure and, finally, the desired characteristics in terms of services and requirements. However, services and requirements – such as water and drains, compressed air, among others – are classified similarly to the relationship chart, i.e. with letters that establish the degree of importance (A, E, I, O, -). Figure 4.9 illustrates what has been mentioned.

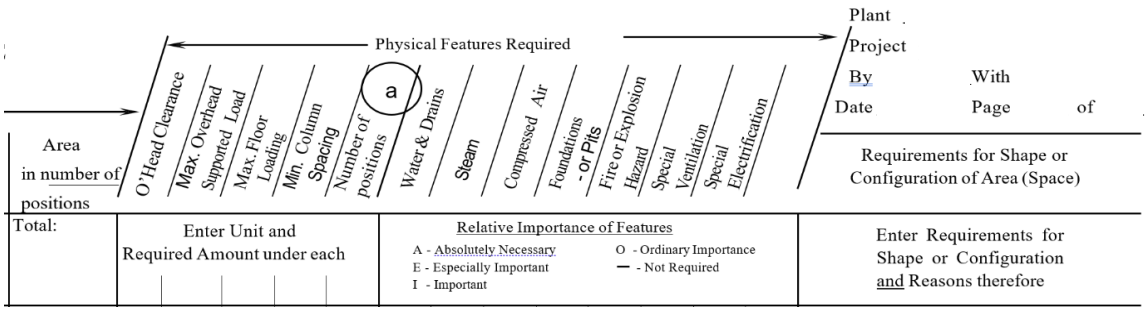


Figure 4.9: Fields of the annexe to be fulfilled in phase II of the SLP

For this project, since there are no records of the dimensions of the basement areas, the model has been adapted: as a measure for the "Area in" shown in the Figure 4.9, the requirements relating to the number of positions for materials stored in each area are used, i.e. the number of pallet spaces. Normally, in this model, the area is in square feet or square metres, but as the measurements of the respective areas of the basement are not available, the number of positions required was used to define the space requirements. First, the section where the areas for each activity are entered is filled in (according to the study, a total of 440 positions will be required), then the desired physical characteristics of the building structure and their respective units and quantities are selected. In this case, since the measurements of the space are unknown as already mentioned, the desired positions are repeated. Then the desired characteristics of auxiliaries or utilities and, finally, specific aspects relating to the shape and configuration of specific areas. It should be noted that there is additional space at the end of the document for notes necessary to understand the document and its respective explanation. In this case, there is a note represented by the letter “a” (the full model is available at Annexe N).

Like Ramirez-Cruz *et al*. (2023), the desired position values were assigned after the application of a Lean tool, 5S. In order to reorganise the space mentioned in the study, the authors used 5S to eliminate materials that were not needed and to clean the space, to apply SLP in an organised space that was ready to receive the changes, while also promoting this method to the workers so that it would become common practice. The project therefore took this aspect into consideration, and the basement was cleaned using 5S so that the space available to implement SLP would have all the necessary conditions and reflect the real space available. With the application of this tool, old materials, expired projects and studies were removed, and a gain of 20 positions was generated. So, the number of positions desired in each area was obtained by studying the space and positions currently available, after cleaning and eliminating unnecessary materials. It should also be noted that for consumables, Company A currently works with a Lean tool, Kanban, in order to have a history. In this way, it is possible to know the quantity to be purchased based on usage and delivery time, allowing for more controlled

and conscious stocks and thus avoiding high occupancy rates in the area. In short, by recording inventory, the Company A study consumption, organise quantities and avoid waste.

Moving on to Phase III – diagram activity relationships – this results in a combination of the first two data collection phases mentioned above. Here, the areas identified are transformed into circles and the relationships between them are established using lines, considering the classification assigned in Phase I. Firstly, the relationships between the A's and E's are established, using four lines to represent the A's and three lines to represent the E's. Then the I's, two lines, and O's, one line, are adjusted and added. Finally, the diagram is redrawn again and the relationships adjusted, always making a distinction between what should be closer or slightly further away according to the classification of the relationships. Finally, the necessary space defined in Phase II is added to the final diagram, next to each circle of the corresponding activity. The diagram for this project can be found in Annexe O.

In Phase IV – draw space relationships layouts – the diagram drawn up in the previous phase is adapted to a plan, i.e. the diagram is overlaid on a plant of the area under study and possible layout alternatives are studied. For this study, there are two layout alternatives that differ in the following ways: the first consists of having a storage area with racks in the middle and floor positions around, and a waste sorting area inside the basement; the other, has a storage area with floor positions in the middle and racks around and the waste sorting area is outside the basement, leaving the reserved area where it was free. Annexe P contains the alternatives.

Phase V – evaluate alternative arrangements – compare the layout alternatives and evaluate them. Each plan is identified with a brief description, the factors and considerations to be evaluated and a weight is assigned, depending on the degree of importance from “1” to “10”. Finally, the results achieved are categorised again using letters and converted into numbers in order to multiply by the defined weight and obtain a score. Figure 4.10 illustrates what has been described, and this phase is full available in the Annexe Q.

EVALUATING ALTERNATIVES

Weights set by RA Tally by RA

Ratings by R A Approved by

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Plant Company A

Project Basement Date Jun. 2025

Description of Alternatives:

Enter a brief phrase identifying each alternative.

A. Storage area with racks in the middle and floor positions around; waste sorting area inside

B. Storage area with floor positions in the middle and racks around; waste sorting area outside

D.

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E
1 Workflow	5	O 5	E 15			
2 Space utilization	10	I 20	A 40			
3 Cost of installation	9	E 27	E 27			
4 Storage density	8	I 16	A 32			
5 Convenience for personnel	7	I 14	E 21			

Figure 4.10: SLP phase V

In this project, the alternative with the highest score is Alternative B, having scored 135 and Alternative A only 82. So, the Alternative B is selected for the next phase.

Finally, Phase VI – detail the selected layout plan – concludes this short-form procedure and consists of detailing the alternative chosen in the previous phase. Thus, the specific characteristics of each area, as well as the equipment used, are detailed and the plan can be found in Annexe R. In the case of this project, firstly, the different areas will be labelled with the number "1" whenever they are Unit 1 materials, the number "2" whenever they are Unit 2 materials and, finally, a number "3" whenever they belong to Maintenance, so that it is easier to identify those responsible and to solve problems whenever necessary. Starting with the packaging materials area, it is currently just an area with racks, but it will be adapted to receive these materials, i.e. it will have the necessary temperature control (20°C ± 5°C) in order to fulfil the requirements for storing them and, as it is a restricted access area, it also fulfils one of the requirements for storing these materials. Half of this area will be used for Unit 1 packaging materials and the other half for Unit 2 packaging materials. Positions will be defined and available in SAP and the equipment used will be a stacker. The area reserved for consumables will remain the same, with only more positions available on the existing racks due to the cleaning carried out through 5S. The flammables, Maintenance, Clinical Trials cold chamber, and the production support equipment areas will remain the same, without any kind of modification, as they are fixed structures that can not be changed. The rejected products area, although small for the company's needs, will also remain unchanged due to its limited space and requirements (fenced area with restricted access).

However, special emphasis should be placed on the basement storage area outside the reserved areas, as this is the one that will experience the most transformation. Currently there are sets of racks that form a corridor, but this is not practical as they are not large enough for the forklift to operate and the materials stored there do not need to be on shelves but can be stacked on the floor. Therefore, in order to increase the utilisation of space, it is suggested that these same racks be transferred to the sides of the area under analysis, with one set being transferred in its entirety and the other set being split up and having new racks supplied to complete the missing blocks – two more 1,825 mm racks and one 2,700 mm rack will be purchased, as illustrated in Annexe R and Annexe S. All the sets have racks with a height of 2,500 mm and two load levels (the load to be stored being 300 kg and 800 mm x 1,200 mm x 1,800 mm). The existing sets of racks will also be divided between the Units. In this area under analysis, there will be a central island with access and traffic corridors. Between the pallet corridors there will be passageways for people to circulate, in order to conduct inspections, for

example, delimited with yellow lines to mark the circuits and storage spaces for the tertiary packaging materials stacked on the floor, i.e. the four types of pallets and the different cardboard boxes. The entry and exit of materials in this area will also follow the FEFO system and the flow will be U-shaped, as in the Units. Materials will be transported with the forklift to the basement and material movements in this area will be carried out with a stacker. All the new positions, as well as inventories, will be standardised and recorded in SAP.

Finally, the waste area also has the potential to change. It is located in a fenced area of the basement that connects to the rejected products area, but there is no need for this as it is not required. As the reserved areas are of great importance due to the high occupancy rates at the Units, partly due to storage requirements, the area could be utilised for more storage of materials that actually need to be in these restricted access conditions. There is a car park with an awning next to the outside access to the basement, but it is advised not to use it due to its location and consequent lack of security. Being on a narrow street and in a key location for loading and unloading materials into the basement, the car park is unsafe due to the passage of trucks, forklifts with loads and the risk of accidents, for example. Therefore, since the waste is chemical but not toxic and can therefore be stored outside, it is suggested that the car park be eliminated and replaced by a waste sorting area. With this change, the reserved area would increase and could support the insufficient area for rejected products and also serve to store other materials that need these conditions. No shelving would be needed, and the logic would be the same as outside the reserved area: short pallet lanes with a stacker. Since the outside area already exists, the investment would be minimal, and it might only be necessary to increase the coverage of the space. The same goes for the inside of the basement, as the reserved area already exists and there is no need to install a fence to delimit the space.

4.4. Implementation of the solutions/improvements

One of the scenarios presented is currently being implemented, Scenario 2: Proposal for basement layout using SLP.

Firstly, the space was studied and a 5S was carried out in order to clean the basement and release space, as mentioned in the previous chapter Phase II of the SLP implementation. Then the proposal and its layout were designed and then submitted for approval. Next, Mecalux was asked to quote for the alteration and modification of the existing structure, as well as the height levels of the new shelving to be supplied, totalling approximately €3,000. Then, the purchase order for approval was awaited before starting implementation. At the same time, air monitoring

began in the reserved area with dataloggers to assess the air and the possibility of storing the packaging materials, which are required to be stored at a controlled temperature of 20°C ± 5°C. The Annexe T shows the actions over the time.

The material and the new set of racks arrived at the company on 28 August. The assembly of the racks and the alteration of the existing structures for the new locations is scheduled to begin in early November.

4.5. Evaluation of the proposals and recommendations for future research

This project proposes two scenarios, and both are evaluated according to a cost-benefit analysis.

For the first scenario, for Unit 1 it is suggested to implement a VLM to replace the light-duty racks, and the pigeonhole system, freeing up space and gaining some positions. The quote may vary between €45,000 and €65,000. Considering the 468 initial positions of packaging materials the gain can be 16 more positions if Configuration 1 in corridor A is replaced by Configuration IV and five positions with the replacement of the pigeonhole system by reduced pallets in corridor B. For Unit 2, an improvement is proposed to the existing storage systems in the packaging and excipient storage area, specifically a change to the existing beams and an increase in the respective levels, to improve differentiation by height. According to a quote requested from Mecalux, this will cost the company approximately €2,000, and it is estimated that there will be a gain of 20 positions. So, the area would increase from a capacity of 111 positions to 131 positions. The Pallet Shuttle suggestion will not be evaluated, as it is not cost-effective compared to the first suggestion due to the investment and changes required.

As for the second scenario, a redesign of the company's existing basement is proposed using the SLP method proposed by Muther (1973) and complemented by Ramirez-Cruz *et al*. (2023) with the addition of Lean tools. It is estimated that distances travelled, and movements will be reduced, since positions assigned to materials will be properly identified and marked and standardised and recorded in SAP, as well as inventories. With the adaptation of the area reserved for storing packaging materials, a gain of approximately 160 positions is expected, which translates into 80 positions for Unit 1 and 80 for Unit 2. In turn, the basement's central storage area is currently made up of racks with a capacity of between 70 and 75 positions. With the proposed change to this area, i.e. new locations for the existing racks and corridors of stacked pallets, it is estimated that there will be a total of 200 positions, i.e. 100 positions for each Unit. For this change, according to the quote requested from Mecalux, the company will incur a cost of approximately €3,000. Table 4.3 summarises what has been described.

Table 4.3: Expected results of the proposed solutions for packaging materials

	Scenario 1		Scenario 2	
Unit	*Unit 1*	*Unit 2*	*Unit 1*	*Unit 2*
Initial positions	468	111	468	111
New total positions	+21 → 489	+20 → 131	548	191
Gain (%) (new positions minus initial positions divided by initial positions)	4.49%	18.02%	17.09%	+80 → 72.07%
Quote	Between €45,000 and €65,000	€2,000	€3,000	

Regarding storage gains, the most notable results are in Scenario 2. Its implementation cost, when compared to the first scenario, also proves to be the lowest, since the company will only be using what already exists and making changes with a low monetary impact. In terms of space utilisation, the second scenario also appears to be more beneficial because, despite the low ceiling height, there is room for horizontal expansion. The implementation of a VLM in Unit 1, prove to be more complex and require more effort and investment, when compared to the changes in the basement and consequent gains. However, changes to the facilities at Unit 1 and Unit 2 could represent significant improvements to the picking process at the Units.

For future research, it is advisable to study and analyse the results experienced in the picking process to ascertain more concrete results. Studying other scenarios would also be beneficial, namely the possibility of Company A resorting to outsourcing (3PL). There are two possibilities that are relevant to the project: outsourcing for the packaging materials or outsourcing for the Maintenance materials. Since packaging materials have a significant influence on this problem, it would be advantageous to study the effect of outsourcing them. In turn, since the basement is shared with Maintenance, seeing the effects of outsourcing in the basement would be relevant. Assuming a charge of around 15 cents a day per pallet location and €1.20 for each pallet in and out, it is advisable to study the effects on space utilisation and storage gains. However, since the flow and movement of packaging materials is high, the results may not be favourable, and it may be more worthwhile to outsource Maintenance materials and have all the space in the basement for the Units under analysis. It is also advisable to study the impact of different metrics on packaging material inventory turnover in order to reduce stock levels. In other words, since delivery times for these materials vary, with some being delivered in weeks when suppliers are local and others in months, but they are ordered at the same time, considering criteria such as distance, minimum delivery lead time and supplier origin can be beneficial in reducing excess materials and controlling stock more effectively. For more generic materials, Kanban can be used.

5. Conclusion

This study departed from the notorious problems of space and storage limitations and, consequently, high occupancy rates at Company A's facilities, located in Lisbon and belonging to the pharmaceutical industry. Certain SKUs were stored in areas not intended for storage, and the corridors were congested, especially on shipping days. All of this resulted in inefficiencies and an ineffective picking process.

To meet this challenge, this in-company project sought to answer the research question "*How can Company A overcome the space limitations and storage constraints in its warehouses in order to make the picking and storage process more efficient and effective?*", aiming to propose a solution(s) to improve storage capacity and space constraints. According to the scientific literature in the area, Case Study methodology has been the most widely applied for similar purposes (e.g., Petrovic *et al*. (2014) and Ramirez-Cruz *et al*. (2023)). Accordingly, a Case Study methodology was selected for this study, but an adaptation of the phases proposed by Yin (2009) and Voss *et al*. (2002) was developed, consisting of five stages and using a mixed methods approach. Semi-structured interviews, direct observations, and company records and documents were the methods used to collect information, and Lean tools – such as 5S, fishbone diagram, flowchart and spaghetti diagram – were used in the development of the Case Study, as well as the SLP method proposed by Muther (1973).

The Case Study gave rise to two possible scenarios. Scenario 1 consisted of smaller-scale improvements of the current Units without the need for major modifications or outsourcing. For Unit 1, the acquisition of a VLM, with Modula Slim appearing to be the most suitable due to its reduced depth, to store the materials found in the light-duty racks and pigeonhole system, giving way to possible new storage systems, such as rack configurations for packaging materials that do not go to the VLM and require more positions. This proposal has a cost that can vary between €45,000 and €65,000 and represents a gain in terms of positions of 4.49%. For Unit 2, an improvement in height differentiation in the storage systems for printed packaging materials was proposed to reduce empty spaces. To do this, new beams will be needed to increase the levels of the racks and adjust the existing ones. According to Mecalux will cost €2,000 and will represent a capacity gain of 18.02%. Both proposed improvements consider the use of vertical space, as explored by Petrovic *et al*. (2014) in their study.

Considering Scenario 2, it was based on a proposal to redesign the layout of an existing area of the company – the basement. The method proposed by Muther (1973) was used and complemented using Lean tools, as exemplified in the study by Ramirez-Cruz *et al*. (2023). As

it is a limited area with low flexibility for changes and with relatively simple flows, the simplified SLP methodology was chosen, consisting of a set of six steps. Several areas were studied, and it is estimated that this redesign will yield a 17.09% gain for packaging materials for Unit 1 and a 72.07% gain for Unit 2. The implementation of this scenario is currently ongoing, with an estimated cost of €3,000 for the alteration of one of the basement areas.

Both scenarios answer the research question, as they represent solutions that will have a positive impact on the occupancy rate of the Units, which will reduce congestion of the corridors, improve the picking process and increase storage capacity. When comparing both scenarios, Scenario 2 shows to be the most favourable option in terms of cost-benefit.

However, some limitations were encountered in this project. Some difficulties were encountered in accessing information and there were some delays in receiving it, which led to delays in data collection. Finally, it was not possible to observe the full implementation of Scenario 2, since the project was interrupted due to Maintenance work in the basement, which led to its postponement. Finally, it was not always easy to gather and contact workers and managers whenever necessary, which made it difficult to meet certain deadlines.

Although positive results have been observed with the proposed improvements, there is always something missing that can be enhanced. Therefore, for future research, it is recommended to study the impact of these measures on the picking process through productivity KPIs. The possibility of outsourcing can also be explored, both for packaging materials and for the basement Maintenance staff's materials. Finally, studying the effect of differentiated inventory turnover metrics may also be beneficial to reduce excess inventory and adapt it to the respective delivery time and location of suppliers, for example.

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7. Annexes

Annexe A – Group 1 semi-structured interview script

The following table shows the semi-structured interview script regarding Group 1.

Annexe A.1. Group 1 semi-structured interview script

Group 1 Organisation and current practices	
Portuguese	English
"Que materiais/SKUs são armazenados na Unidade? As disposições incluem zonas ou áreas específicas para cada categoria de produto/SKU, ou os artigos estão misturados no espaço?"	What materials/SKUs are stored in the Unit? Do the arrangements include specific zones or areas for each product/SKU category, or are items mixed together in the space?
"Como fazem a arrumação dos materiais atualmente? Que política de arrumação têm? Aplicam algum tipo de regra para a arrumação dos SKU (arrumação dedicada, aleatória, …)? Existem políticas para diferentes categorias de SKU? Por exemplo, aplicam uma classificação ABC?"	How do you currently store materials? What storage policy do you have? Do you apply any kind of rule for SKU storage (dedicated storage, random storage, ...)? Are there policies for different SKU categories? For example, do you apply an ABC classification?
"Que políticas de Gestão de Stocks aplicam? As políticas diferem entre categorias de SKU (existem diferenças entre diferentes categorias de SKU)? E como calculam os SS e com que níveis de serviço?"	What Stock Management policies do you apply? Do the policies differ between SKU categories (are there differences between different SKU categories)? And how do you calculate SS and with what service levels?
"Qual é a disposição/*layout* atual da Unidade?"	What is the current layout of the Unit?
"Que sistemas de armazenamento existem atualmente? O sistema de arrumação é específico? Consideram que estes sistemas são adequados para os tipos de SKU armazenados?"	What storage systems currently exist? Is the storage system specific? Do you think these systems are suitable for the types of SKUs stored?
"Como está estruturado o *picking process*?"	How is the picking process structured?
"Qual é a capacidade total de armazenamento da Unidade e como é que essa capacidade é atualmente utilizada?"	What is the total storage capacity of the Unit and how is this capacity currently used?

Annexe B – Group 2 semi-structured interview script

The following table shows the semi-structured interview script regarding Group 2.

Annexe A.2. Group 2 semi-structured interview scrip

Group 2 Diagnosing difficulties	
Portuguese	English
"Que desafios ou dificuldades encontram com as práticas de armazenamento atuais?"	What challenges or difficulties do you encounter with current storage practices?
"Os SKUs ou categorias de produtos específicas apresentam desafios? A alocação dos SKUs, pode ser alterada na Unidade para ser mais eficiente?"	Do specific SKUs or product categories present challenges? Can the allocation of SKUs be changed in the Unit to be more efficient?
"Sentem que existe algum problema com as matérias-primas ou relacionado com outros materiais armazenados? Por exemplo, em termos de espaço disponível ou acessibilidade, ou outro fator?"	Do you feel there are any problems with the raw materials or related to other stored materials? For example, in terms of available space or accessibility, or some other factor?
"Existem fatores de disposição, questões organizacionais ou outros elementos que dificultam o picking process? Consideram o processo eficiente? Ou acham que têm dificuldades devido à disposição dos espaços por exemplo, ou até mesmo devido a outros fatores?"	Are there disposition factors, organisational issues or other elements that hinder the picking process? Do you find the process efficient? Or do you find it difficult because of the layout of spaces, for example, or even because of other factors?
"Estão a prever um aumento no vosso volume de produtos ou novas linhas de produtos?"	Do you foresee an increase in your product volume or new product lines?

Annexe C – Packaging materials and raw materials handling and storage flowchart



Annexe A.3. Packaging materials and raw materials handling and storage flowchart

Annexe D – Unit 1 configurations



Annexe A.4. Unit 1 configurations

Annexe E – Answers from semi-structured interviews for Group 1

The following table shows the answers of both managers of each Unit regarding the first groups of questions of the semi-structured interviews.

Annexe A.5. Answers from semi-structured interviews for Group 1

Topic	Group 1 Organisation and current practices	
	Manager Unit 1	Manager Unit 2
Materials/SKUs and how they are organised	"Os nossos SKUs estão divididos por corredores. Os corredores J, K e L têm produto acabado, os materiais de embalagem (impressos e não impressos) estão no corredor A até ao F e as matérias-primas nos corredores G, H, I e zona M. Os inflamáveis estão numa área própria na cave e temos uma área aqui na Unidade para produtos rejeitados. Por isso sim, existem áreas específicas e não estão misturados no espaço. Só a situação do corredor J não cumpre com a política atualmente. Está com material que não deviam estar, porque não temos posições disponíveis para colocar certos produtos nas áreas dos mesmos."	"Trabalhamos apenas com um produto acabado, discriminado por países, e tem dois tipos de acabamento. Funcionamos como uma linha de enchimento. Pegamos no API que é fabricado noutra fábrica e o nosso trabalho é misturá-lo com um segundo acompanhante, mas que não é ativo. Portanto trabalhamos com duas matérias-primas, mas só uma delas é API. Depois embalamos e temos materiais de embalagem que podemos classificar de várias formas: material de embalagem primário e secundário. Aqui dentro da Unidade temos uma zona para os materiais de embalagem, também chamados de impressos nesta indústria e outra para os restantes SKUs, tendo a primeira uma temperatura controlada de 15ºC/25º e a segunda de 2ºC/8ºC.
Storage of materials and policies	"Atualmente está por corredores, ou seja vamos seguir essa configuração e cada um tem a sua zona destinada. Não temos nenhuma classificação ABC."	"Nós tentamos sempre quando podemos agrupar os produtos, dentro do possível tentamos juntar produtos homogéneos numa zona específica dentro do mesmo armazém. Tentar trabalhar da forma mais sequencial possível. Aqui a lógica não é ABC. Aqui o que manda são os materiais de embalagem impressos, que têm prioridade devido às condições de armazenagem."
Stock management policy and safety stocks	"O SAP bloqueia os vencidos na data, então a política é verificar as validades, que se vê na listra trimestral – o FEFO. O *safety* stock é com a *Supply*. Não existe política, porque os materiais são encomendados em função do	"Aplicamos o FEFO e utilizamos o SAP. Temos o Sistema de Kanban. Não existe política de *safety* stocks, porque os materiais são encomendados em função do plano de produção. Está implícito na quantidade associada a cada lote. Em quantidades superiores

	plano de produção. Está implícito na quantidade associada a cada lote.”	ao consumo esperado. De certa forma está incluído nas *order quantities*, porque é um cenário pessimista. Se a linha correr mal, o consumo dispara.”
Layout	“Entrando na Unidade temos uma visão da área de armazenamento em frente, do lado esquerdo temos acesso à zona de produção e de pesagem e do lado direito temos uma zona de receção/expedição e dois escritórios. Falta-nos uma área de preparação de encomendas e de expedição, uma vez que a receção é feita pelo mesmo sítio da expedição”	“Assim que entramos estamos num cais com uma temperatura 15ºC/25ºC e depois temos uma zona para os materiais de embalagem impressos também com a temperatura anterior e uma zona de frio com temperatura 2ºC/8ºC. Não temos propriamente uma área designada para preparação de encomendas, por exemplo.”
Storage systems	“Temos estantes para paletes, sistema de colmeia e estantes ligeiras. São adequados, pois trabalhamos com o planeamento e vamos dimensionando. No entanto, devemos considerar alternativas, como adaptar a cave, uma vez que se encontra por baixo do nosso armazém e iria facilitar a arrumação. É adequada, mas necessita de alterações de forma a melhorar e a ter mais arrumação pois estão sobrelotadas.”	“Temos estantes para paletes, estantes ligeiras e *moviracks*. Se são adequados? Estamos em modo de sobrevivência e estamos a ir aprendendo. Falta-nos espaço e os sistemas estão sobrelotados. Temos melhorias em mente, mas implicam custos.”
Picking process	“É um processo que apresenta dificuldades. Não temos a quantidade de posições e arrumação suficientes e os corredores estão cheios. Não temos também áreas de apoio nem de manobra. Falta a área de receção e a área de exportação. Ou seja, não temos nenhuma área de preparação, nem de exportação.”	“O *picking* demora porque temos de juntar muita coisa de várias zonas, pois aqui não temos espaço para tudo. Transportamos materiais da cave ou materiais de embalagens primários do armazém de cima também (Unidade 1), mas resolvemos nunca deixando o *picking* para o último momento. O volume de trabalho é sempre igual e é em função do ritmo de produção.”
Total capacity and how it is being used	“Então nós temos 911 posições e estamos com 765 ocupadas. No mês de outubro registámos uma ocupação de 84%, sendo que definimos uma meta de 80%. Por isso estamos acima da capacidade e a falta de arrumação tem aumentado.”	“A capacidade da zona dos materiais de embalagem impressos é de 111 posições e está atualmente com uma taxa de ocupação de 180%, a do armazém de frio é de 630 e está com uma taxa de ocupação de 41%. Os materiais impressos são a grande preocupação devido à falta de espaço.”

Annexe F – Answers from semi-structured interviews for Group 2

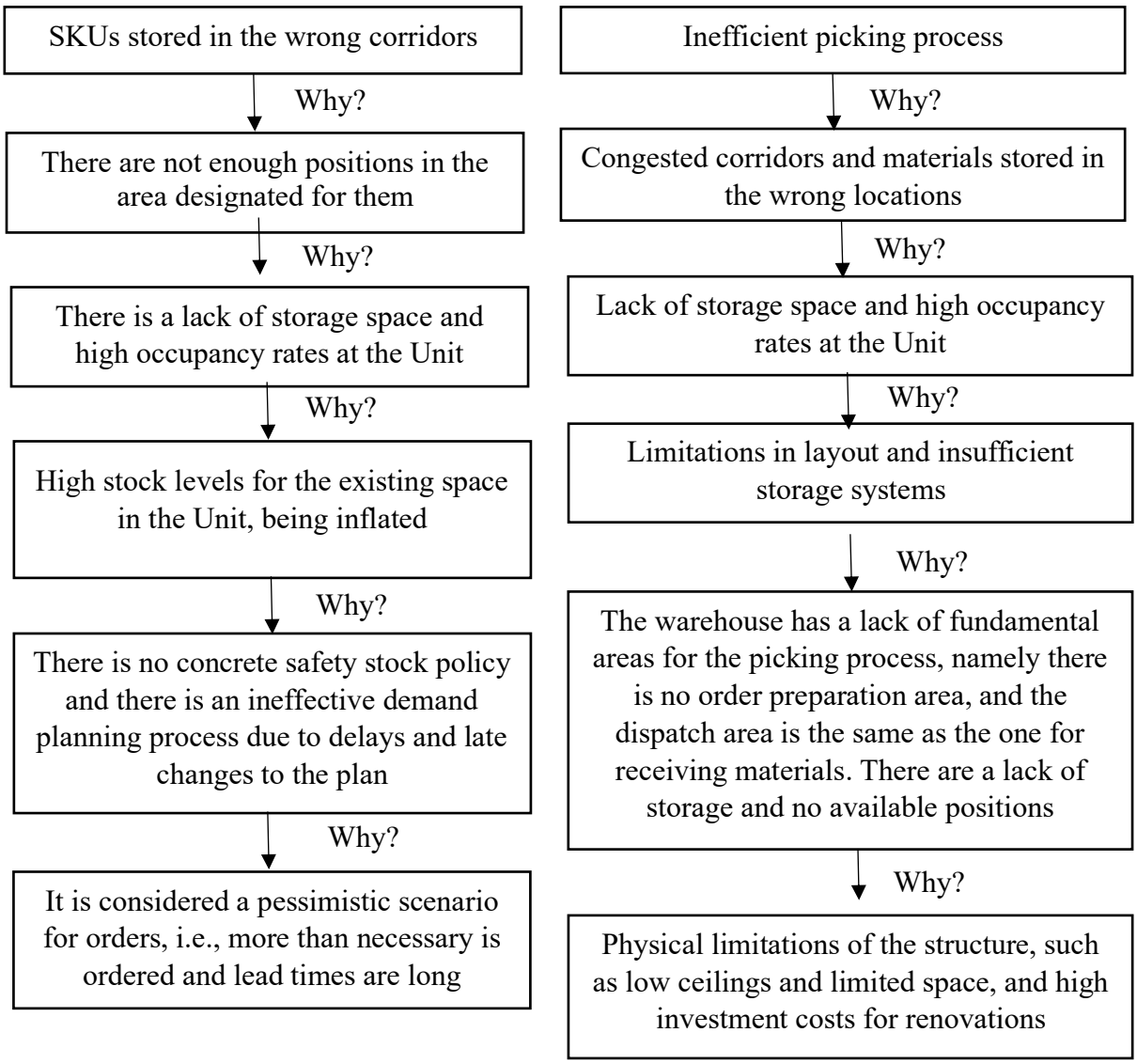
The following table shows the responses of both managers of each Unit regarding the second group of questions of the semi-structured interviews.

Annexe A.6. Answers from semi-structured interviews for Group 2

Topic	Group 2 Diagnosing difficulties	
	Manager Unit 1	Manager Unit 2
Current difficulties and challenges	"Temos dificuldade a nível de arrumação. Temos produtos em corredores que não deviam estar, como por exemplo os materiais de embalagem que só deviam se encontrar na área reservada destinada aos mesmos e estão em corredores de produto acabado. Só que não temos posições disponíveis para colocar na área respetiva. Estamos com quase 90% de ocupação e atualmente até usamos zonas da cave também."	"Há três materiais de embalagem impressos aqui e são nestes três que nós temos problemas e esta é mesmo a parte mais difícil. Temos outra razão que é, como estes materiais entram na linha são mais sensíveis às condições de armazenamento. E terceiro, sobre o porquê destes materiais serem tão impactantes, existem leis para os armazenar e temos de os guardar em zonas de acesso reservado, com controlo de humidade e de temperatura o que nos reduz ainda mais o espaço para os mesmos."
SKUs allocation challenges	"Sim e vejo oportunidade para tornar a alocação de SKUs mais eficiente. Eu até comecei a trabalhar nisso. A primeira coisa que fiz quando cheguei a esta empresa foi trabalhar com Kanban."	"Sim. É ajustar os espaços aqui e criar um armazém noutra área da empresa, ou pensar em Outsourcing."
Problems of available space and accessibility with stored materials	"Sim. Por exemplo os materiais de embalagem encontram-se em corredores onde não é suposto devido à falta de arrumação, quando apenas se deviam encontrar na área reservada destinada aos mesmos. Os inflamáveis encontram-se fora da Unidade, na cave. O mesmo acontece com alguns rejeitados."	"Os materiais de embalagem impressos são mesmo o maior problema. Não temos tudo aqui na Unidade. Temos materiais na cave e materiais de embalagens primários na Unidade 1 e para estes sítios o acesso é feito só pelo exterior. Temos problemas a nível de espaço e acessibilidade."
Picking process	"Não é um processo eficiente. Gera muito stress, porque nós não temos a quantidade de posições suficientes e então os corredores estão cheios. Vamos imaginar que cai um picking e eu tenho de ir buscar o material. Mas tenho de tirar todo o material do corredor A e colocar no B. Mas depois	"Temos problemas e foi falado numa auditoria. É uma situação para resolver. Quando transportamos materiais da cave ou materiais de embalagens primários da Unidade 1, o produto fica exposto às condições climatéricas, porque o acesso é

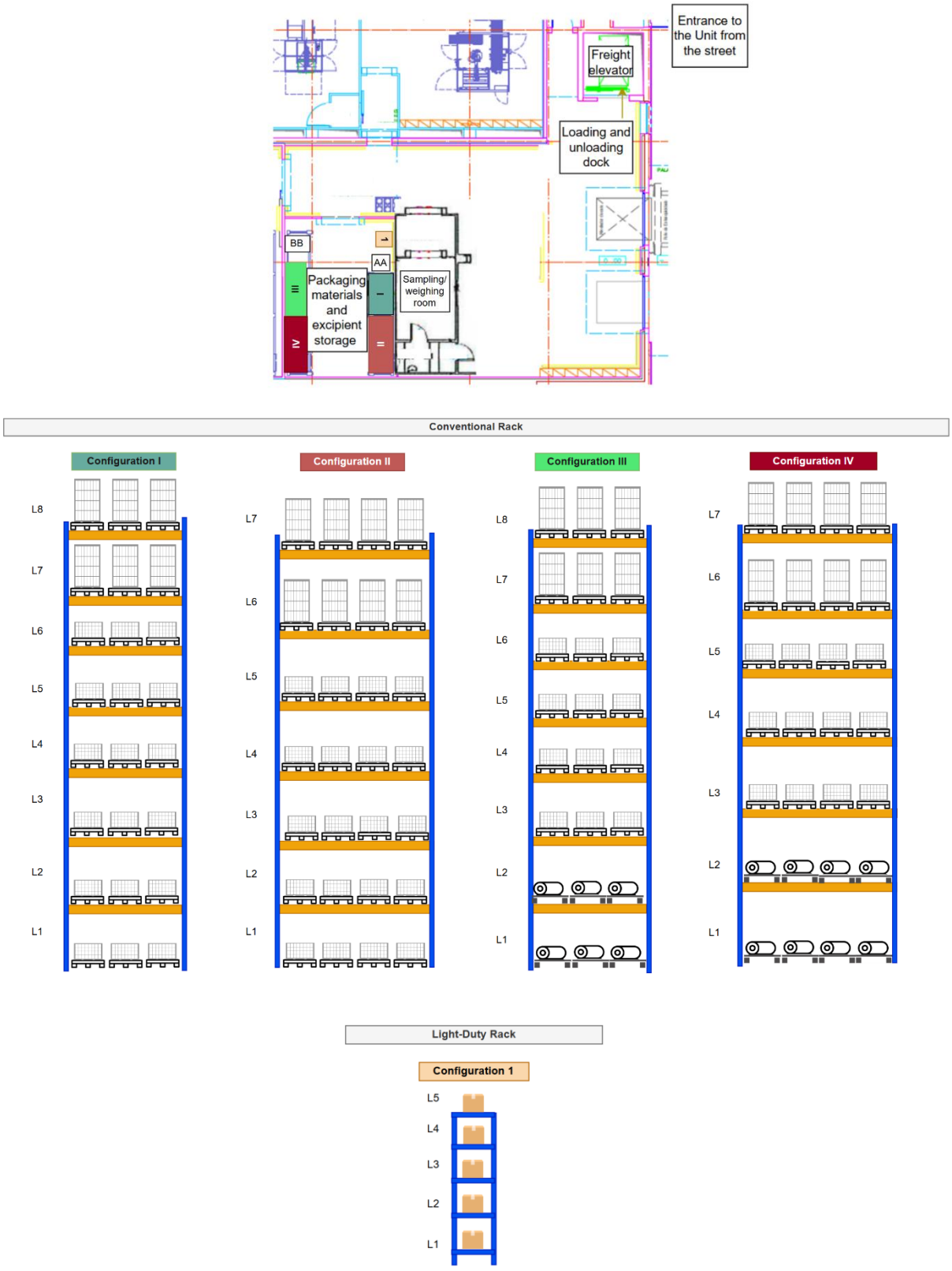
	preciso de ir buscar ao B e colocar no A. E também não tenho um armazém "saudável" – para ele ser saudável preciso de ter um máximo de 80% de ocupação e ter as áreas de apoio ou de manobra e nós não temos. Não temos a receção e também a questão de exportação, porque nós não temos a área para preparar a exportação e expedir."	feito pelo exterior. E as equipas têm de parar para me dar os materiais, colocar no cais e a passagem não é fácil. Não é eficiente, mas não há solução. O picking demora porque temos de juntar muita coisa de várias zonas, pois aqui não temos espaço."
Products and product ranges	"Estamos a prever talvez um aumento no volume de produtos, o que vai aumentar o número de materiais de embalagem e por aí sucessivamente."	"O produto acabado fisicamente tem maior volume. Em termos financeiros é o que dá o lucro da empresa. Estamos a falar de uns 15/20 países e a gama está a crescer. A empresa está a abrir mais mercados. Daqui a um ano a minha projeção é a empresa precisar de aproximadamente 300 posições para materiais impressos."
The most challenging material to store	"Existem alguns, mas eu acho que o mais crítico hoje está a ser o material de embalagem. Os inflamáveis também, porque temos capacidade para 1400 litros e estamos com 2700 – 180% de ocupação. Mas por ser uma área específica e muito controlada, tendo alarme, controlo de temperatura, etc. não se pode fazer muito. Por isso diria estes dois, mas com mais ênfase nos materiais de embalagem."	"Sim. Todos os materiais de embalagem impressos, sendo que há um mais crítico... os rolos de complexo. É mais sensível às condições e dependemos muito dos fornecedores e o tempo de encomendas é grande. Mais o problema das devoluções. É mais eficiente pedir grandes quantidades."

Annexe G – Unit 1 5whys for storage limitations and inefficient picking process



Annexe A.7. Unit 1 5whys for storage limitations and inefficient picking process

Annexe H – Unit 2 configurations



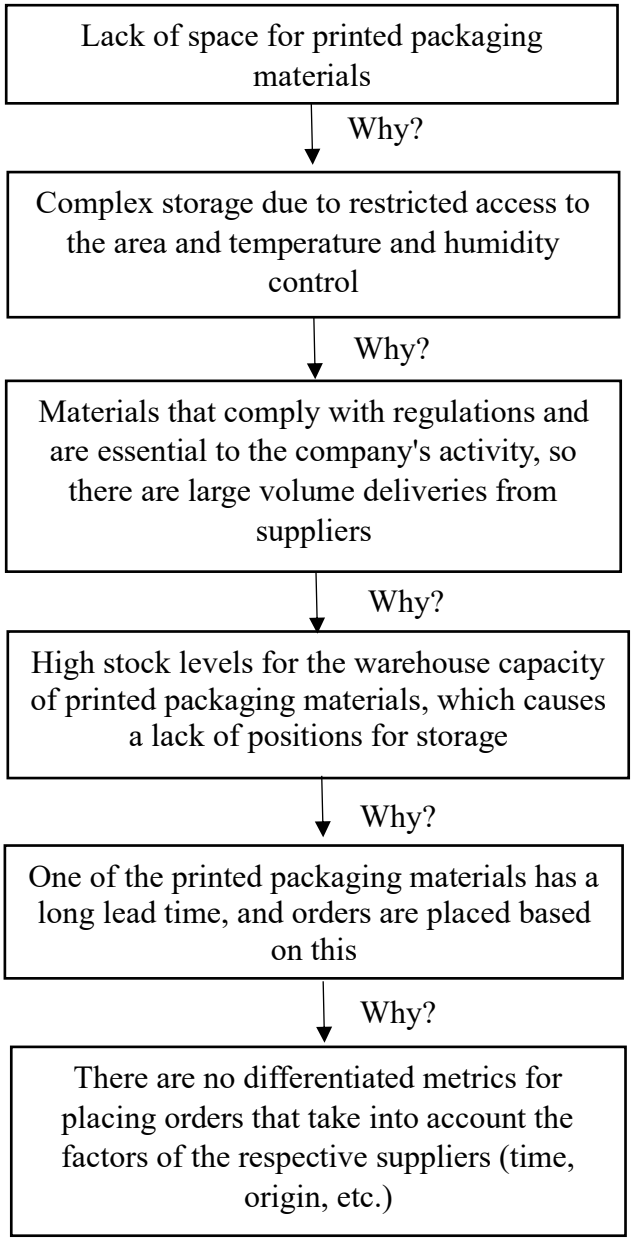
Annexe A.8. Unit 2 configurations

Annexe I – Unit 2 cold storage occupancy rates for Nov. 2024/Sept. 2025

Annexe A.9. Unit 2 cold storage occupancy rates for Nov. 2024/Sept. 2025

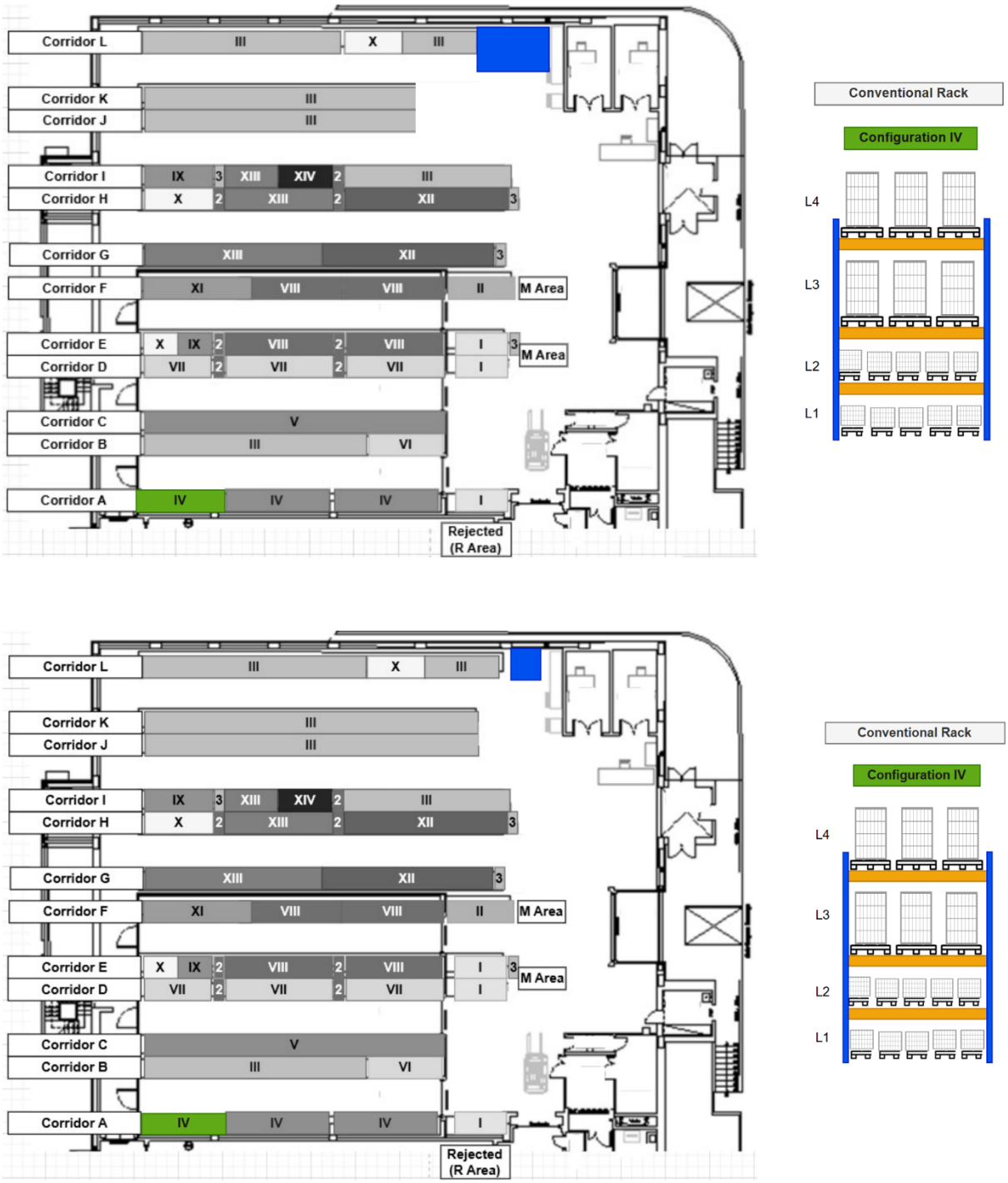
Cold Storage area (2ºC/8ºC) Nov. 2024				
	Total	Finished good	API	Quality Samples
Capacity (positions)	630	224	343	63
Real stock (positions)	314	167	86	61
Occupancy rate (%)	49.8%	74.6%	25.1%	96.8%
Cold Storage area (2ºC/8ºC) Sept. 2025				
	Total	Finished good	API	Quality Samples
Capacity (positions)	630	224	343	63
Real stock (positions)	465	180	223	62
Occupancy rate (%)	73.8%	80.4%	65.0%	98.4%

Annexe J – Unit 2 5whys for space limitations



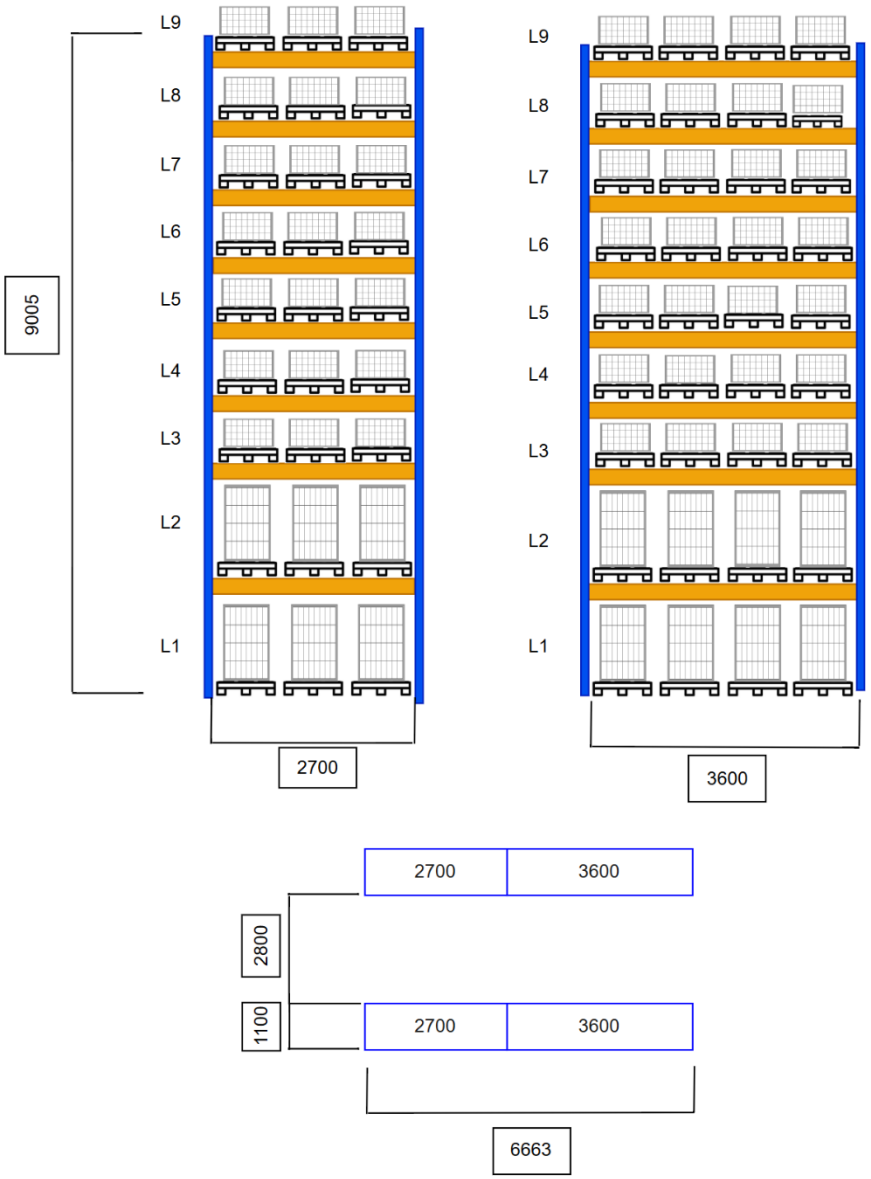
Annexe A.10. Unit 2 5whys for space limitations

Annexe K – Unit 1 VLM suggested locations



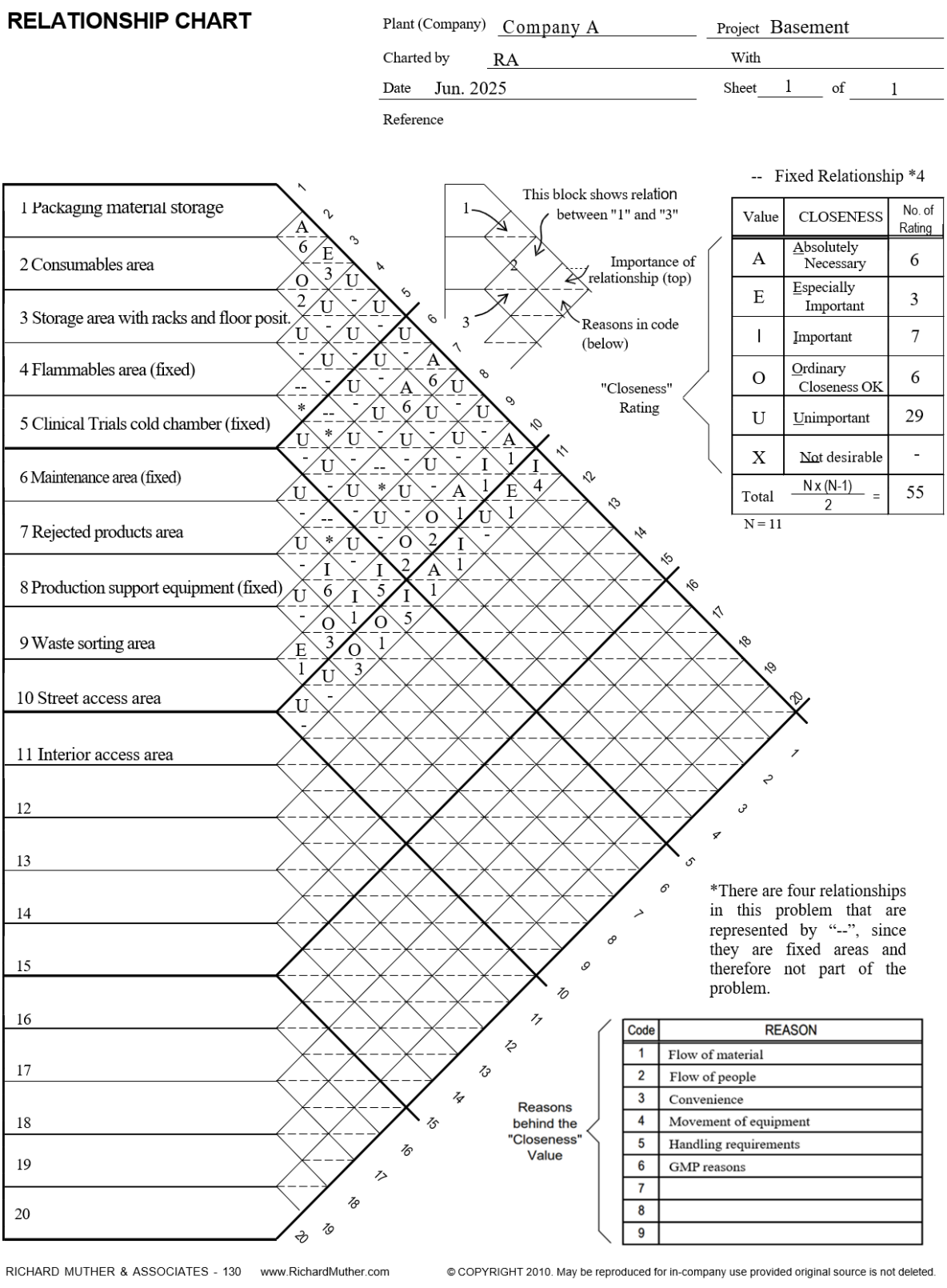
Annexe A.11. Unit 1 VLM suggested locations

Annexe L – Proposed modifications for Unit 2 configurations



Annexe A.12. Proposed modifications for Unit 2 configurations

Annexe M – SLP phase I: relationship chart



Annexe A.13. SLP phase I: relationship chart

Annexe N – SLP phase II: activities area and features sheet

ACTIVITIES AREA & FEATURES SHEET

Plant Company A
Project ~~Basement~~
By ~~RA~~ With
Date Jun. 2025 Page 1 of 1

Activity → | Physical Features Required →

No.	Name	Area in number of positions	O'Head Clearance	Max. Overhead Supported Load	Max. Floor Loading	Min. Column Spacing	Number of positions	Water & Drains	Steam	Compressed Air	Foundations - or Pits	Fire or Explosion Hazard	Special Ventilation	Special Electrification	Requirements for Shape or Configuration of Area (Space)
	Basement	Total: 440	Enter Unit and Required Amount under each					Relative Importance of Features: A - Absolutely Necessary; E - Especially Important; I - Important; O - Ordinary Importance; — - Not Required							Enter Requirements for Shape or Configuration and Reasons therefore
1.	Packaging material storage	160	-	-	-	-	160	-	-	-	-	-	A	-	Reserved area with restricted access and temperature control (15ºC-25ºC)
2.	Consumables area	50	-	-	-	-	50	-	-	-	-	-	O	-	Reserved area with restricted access
3.	Storage area with racks and floor positions	200 (75 racks + 108 floor positions)	-	-	-	-	200	-	-	-	-	-	O	-	
4.	Flammables area	b -	-	-	-	-	-	-	-	-	-	A	E	E	Alarm, smoke detectors and armored door for security
5.	Clinical Trials cold chamber	b -	-	-	-	-	-	-	-	-	I	-	A	E	Restricted access and temperature control (2ºC-8ºC)
6.	Maintenance area	b -	-	-	-	-	-	-	-	I	-	-	-	O	
7.	Rejected Products area	30	-	-	-	-	30	-	-	-	-	-	O	-	Reserved area with restricted access
8.	Production support equipment	b -	-	-	-	-	-	-	-	E	-	-	-	E	
9.	Waste sorting area	c -	-	-	-	-	-	-	-	-	-	-	-	-	
10.	Street access area	c -	-	-	-	-	-	-	-	-	-	-	-	-	
11.	Interior access area	c -	-	-	-	-	-	-	-	-	-	-	-	-	
12.															
13.															
14.															
15.															

Sub-Activities or Areas

Notation References

a There is no data in meters for the areas. There are only the number of positions required for pallets in each area
b Are fixed areas that will not be subject to layout changes – no space requirement
c Only relevant areas for understanding the proximity of the others and the reasons - no space requirement

No. _____ Activity _____ Sheet _____ of _____

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Annexe A.14. SLP phase II: activities area and features sheet

Annexe O – SLP phase III: activity relationship diagram

Diagram the relationship:

Company A

Basement

RA Jun. 2025

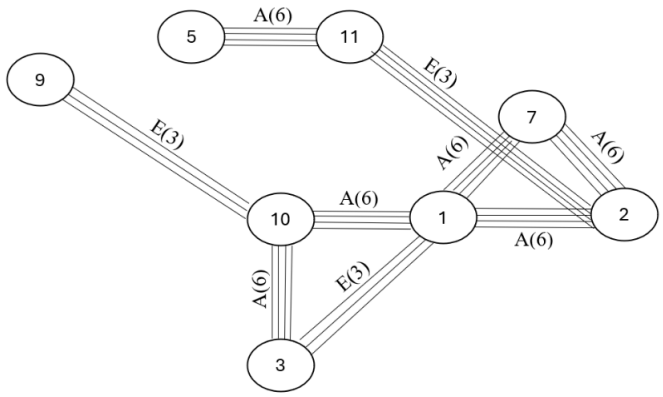
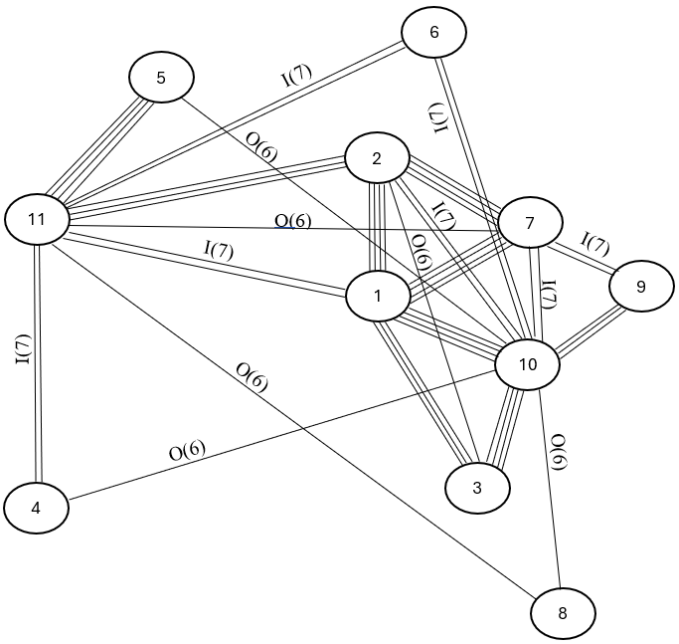


Diagram A's (4 lines) 6

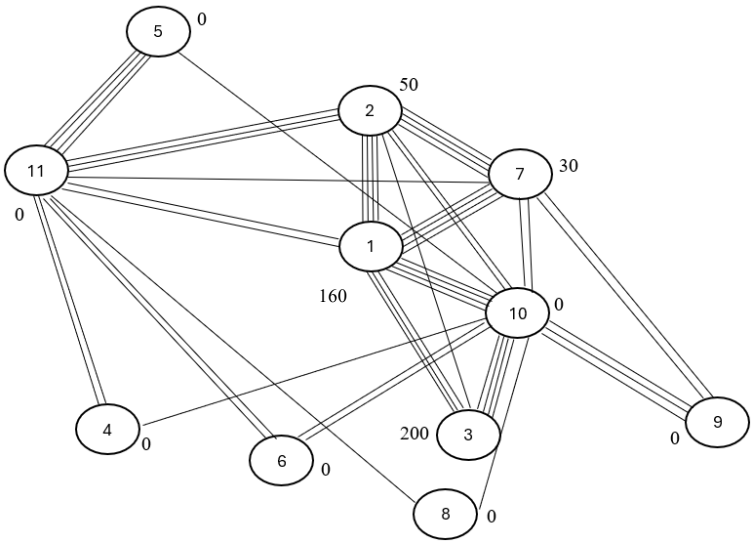
And add E's (3 lines) 3



Redraw

Add I's (2 lines) 7

Add O's (1 lines) 6



Redraw

Check

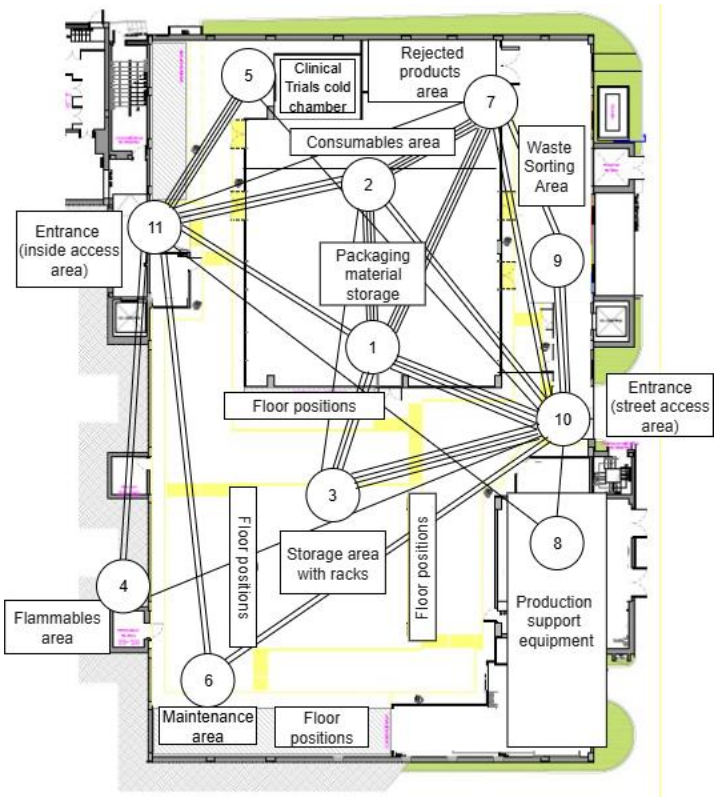
Add space for each activity

Final diagram

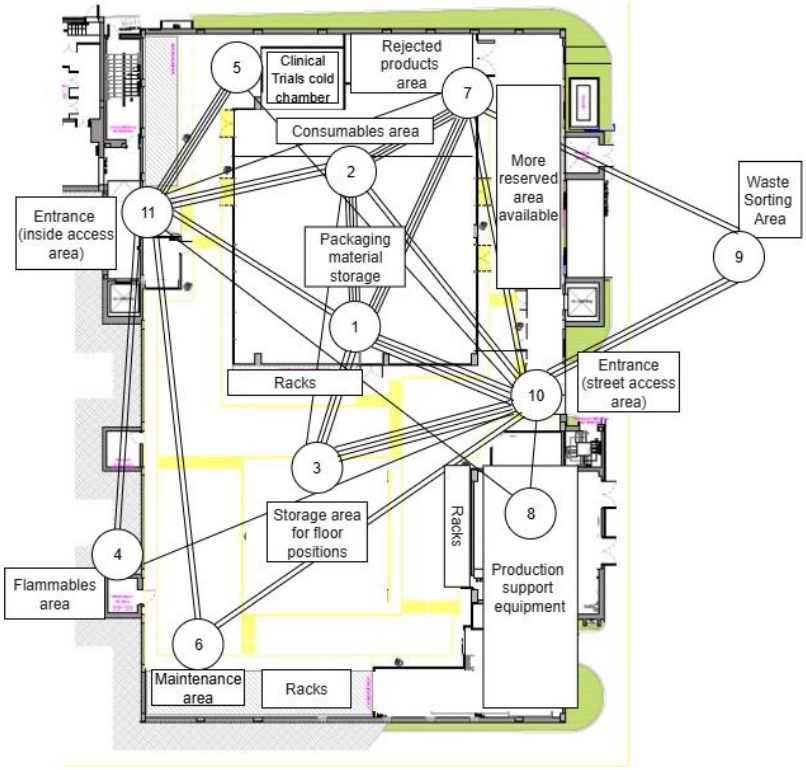
Annexe A.15. SLP phase III: activity relationship diagram

Annexe P – SLP phase IV: spatial relationship layouts design

Alternative A:



Alternative B:



Annexe A.16. SLP phase IV: spatial relationship layouts design

Annexe Q – SLP phase V: alternative arrangements evaluation

EVALUATING ALTERNATIVES

Weights set by RA Tally by RA

Ratings by R A Approved by

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Plant Company A

Project Basement Date Jun. 2025

Description of Alternatives:

Enter a brief phrase identifying each alternative.

A. Storage area with racks in the middle and floor positions around; waste sorting area inside

B. Storage area with floor positions in the middle and racks around; waste sorting area outside

D.

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E
1 Workflow	5	O 5	E 15			
2 Space utilization	10	I 20	A 40			
3 Cost of installation	9	E 27	E 27			
4 Storage density	8	I 16	A 32			
5 Convenience for personnel	7	I 14	E 21			
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16 Rating values:						
17 A = 4 points						
18 E = 3 points						
19 I = 2 points						
20 O = 1 point						
Totals (rating values x WT)		82	135			

Reference Notes:

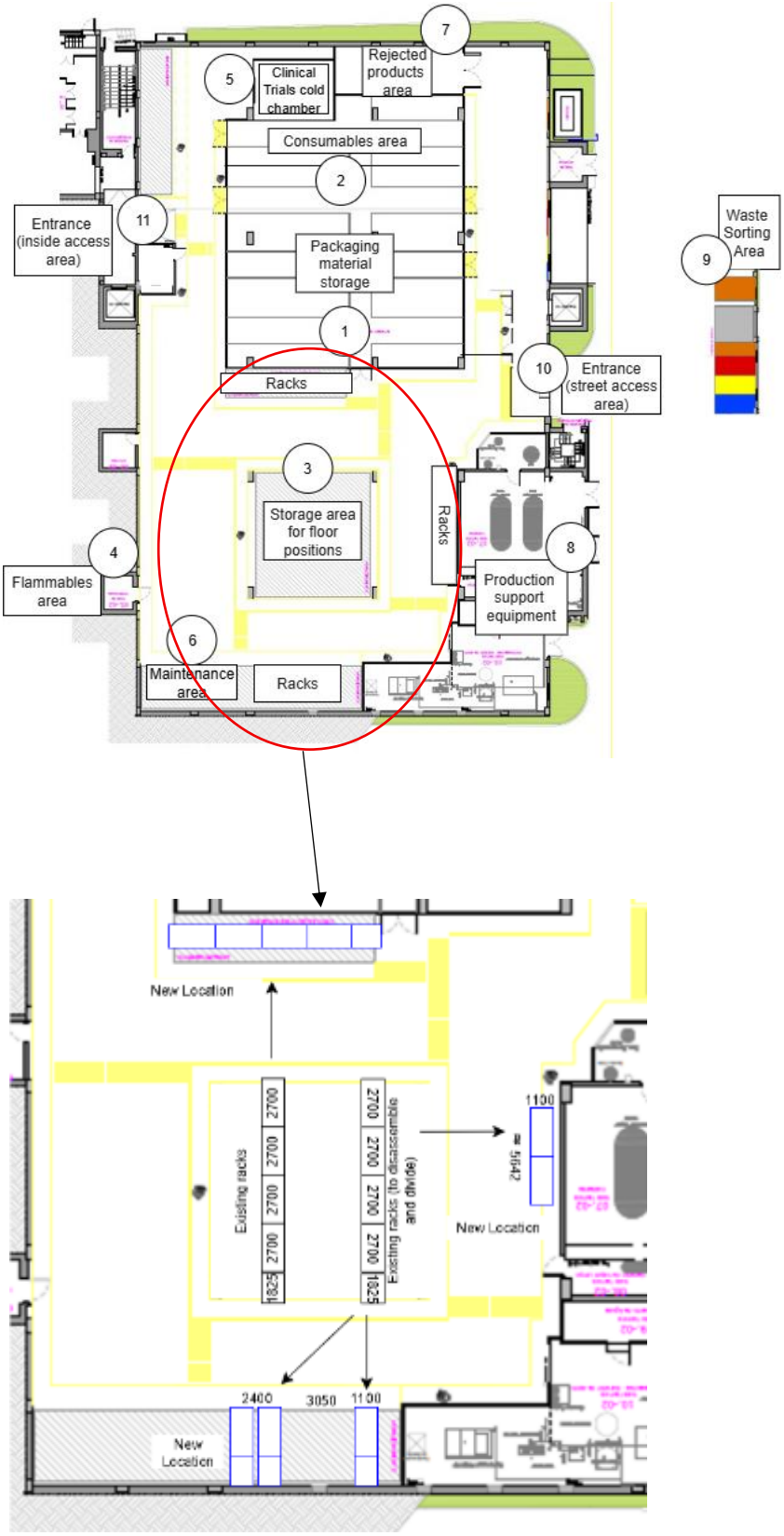
a.
b.
c.
d.
e.
f.

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Annexe A.17. SLP phase V: alternative arrangements evaluation

Annexe R – SLP phase VI: detailed selected layout plan

Detailed plan:



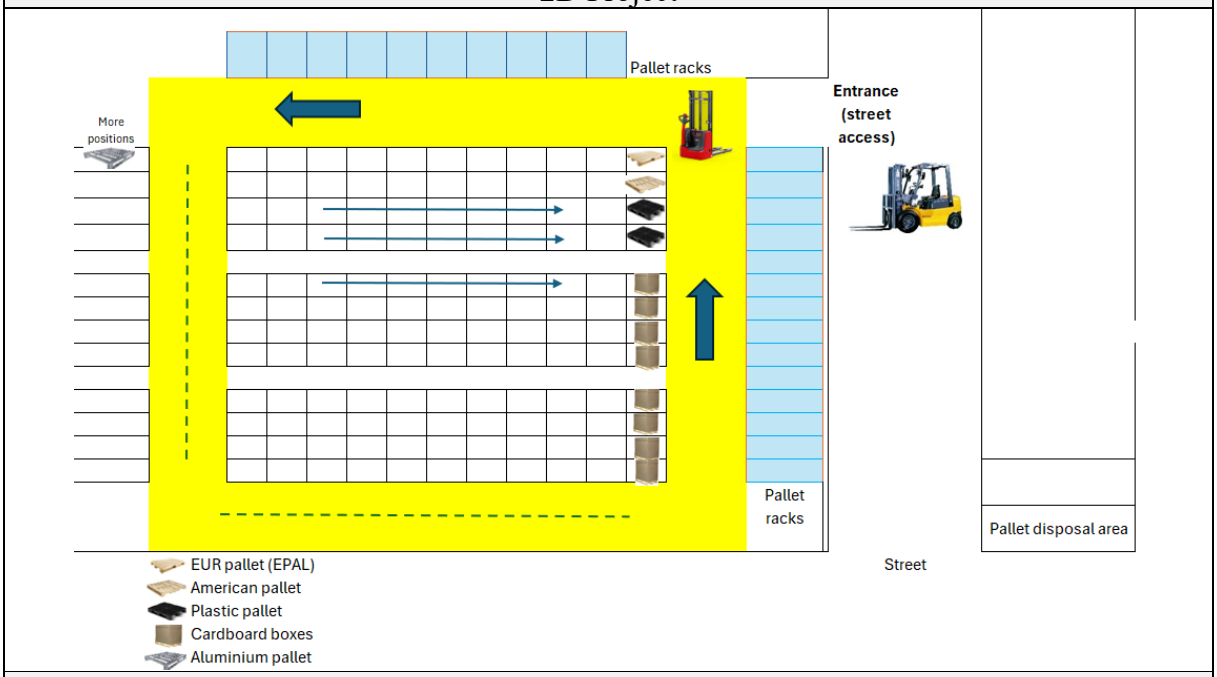
Annexe A.18. SLP phase VI: detailed selected layout plan

Annexe S – Visual plan of the central area of the basement

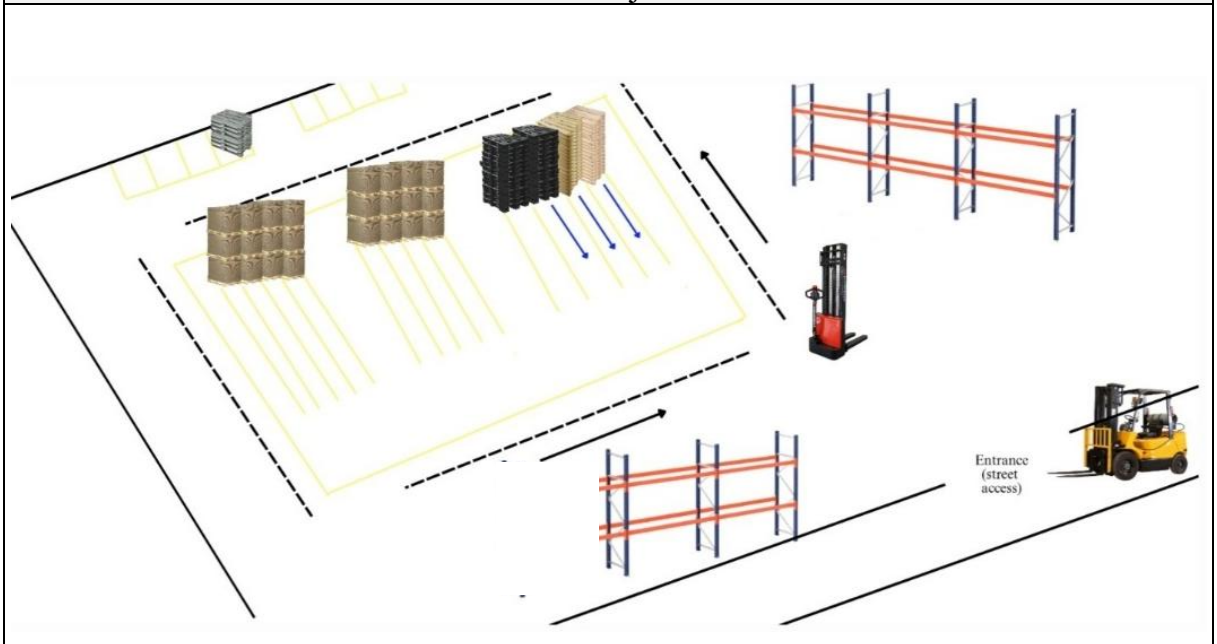
Annexe A.19. Visual plan of the central area of the basement

Detailed Storage area for floor positions

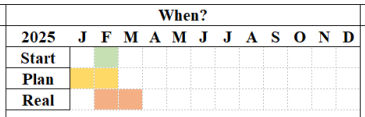
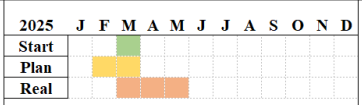
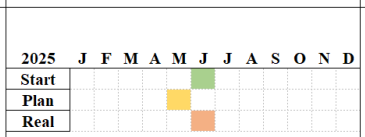
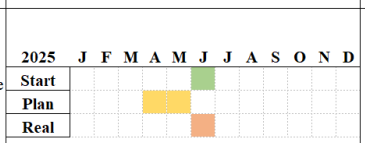
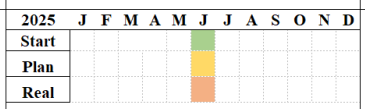
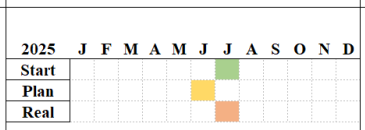
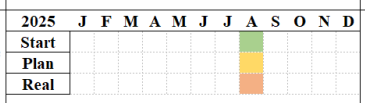
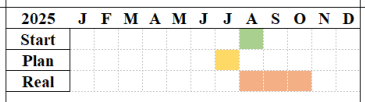
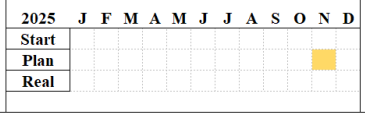
2D Project



3D Project



Annexe T – Action log

Company A	***Action Management***			
What?	**Action**	**When?**	**Follow-up**	**Situation**
5S methodology	Perform 5S to clean the basement and release space		*Verify the space and see layout options*	Completed
Layout proposal for the Basement	Redesign the basement layout using SLP		*Review with the project team*	Completed
Submit layout proposal for approval	Present the improvements to the person in charge of the project		*Formal approval*	Completed
Request a quote	Contact the chosen company to give a quote		*Check costs and times*	Completed
Purchase Order	Internal request for Purchase Order approval		*Keep in touch with the responsible department*	Completed
Ask the selected company to proceed with the change	Contact the company and clarify deadlines		*Keep track of set dates and deadlines*	Completed
Materials Delivered	Delivery of materials and new racks for the new layout		*Inspect the material and confirm quantities*	Completed
Monitoring the air conditions in the basement	Installation of dataloggers to evaluate and control temperature		*Analyse the recorded data*	In progress
Implement the layout proposal	Reorganisation and changes according to the proposed layout; assemble racks		*Monitor implementation and make changes*	To-do

Annexe A.20. Action log