



WAREHOUSING: A COMPARATIVE METHODOLOGY APPROACH

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Undoubtedly, people change lives.

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ABSTRACT

The aim of this study is to find ways to increase an agile flow of materials in a warehouse while comparing different methodologies. In order to achieve this goal, an analysis of the current status of a warehouse of raw material and packaging is carried out and some situations that lack improvements are highlighted. Afterwards enhancements are suggested in several dimensions: the analysis of the capacity, the allocation method and the layout. To analyse the current situation, two different tools are created in Excel, all from the beginning, taking into consideration the company's point of view and the new one, proposed by the author. Regarding the capacity, a volume approach is suggested so as to understand the warehouse capacity. Thus, a change in the storage assignment policy is proposed which results in a different layout. Evidence leads to the conclusion that with the proposed methodology it is possible to see a warehouse with a more balanced occupation, a decrease in costs, in material damages, and in the travelling distance and time (29,96 km/year, approximately 32,52 hours). An increase in the warehouse capacity (9,77%) and in terms of safety can also be identified, leading to the conclusion that the suggested methodology could be implemented.

KEYWORDS

Storage assignment problem, warehouse storage policies, supply network, warehouse layout, material flow, warehouse storage methodologies

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RESUMO

O objetivo da presente dissertação é encontrar formas de fomentar um fluxo ágil de materiais num armazém, comparando diferentes metodologias. Para atingir este objetivo, é feita uma análise do estado atual de um armazém de matérias primas e produtos de embalagem. Após investigar e compreender o funcionamento do mesmo, algumas situações que carecem de melhoria são destacadas. Posteriormente, são sugeridos alguns aprimoramentos em várias dimensões: na análise da capacidade, no método de alocação e no *layout*. Para examinar a situação atual, são criadas duas ferramentas distintas em Excel, tendo em consideração o ponto de vista da empresa e o da nova proposta apresentada pela autora. Relativamente à capacidade, é sugerida uma abordagem que tem em consideração o volume por forma a identificar a verdadeira capacidade do armazém. Assim, é apresentada a possibilidade de uma mudança na política de armazenamento, que resulta num *layout* diferente. Os resultados levam à conclusão de que, com a metodologia da autora, é possível observar um armazém com ocupação mais balanceada, uma diminuição nos custos, nos danos dos materiais, na distância e no tempo de deslocação (29,96 km/ano, aproximadamente 32,52 horas). Também se consegue identificar um aumento de 9,77% na capacidade do armazém e um acréscimo de segurança, levando à conclusão de que a metodologia sugerida poderia ser implementada.

PALAVRAS-CHAVE

Problema de alocação de materiais, políticas de armazenamento de materiais, rede de abastecimento, *layout* do armazém, fluxo de materiais, metodologias de armazenamento

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LIST OF ABBREVIATIONS

List of Abbreviations

DGEG	Direção Geral de Energia e Geologia
ID	Identify
ISEP	Instituto Superior de Engenharia do Porto
No.	Number
P. Porto	Instituto Politécnico do Porto
RFID	Radio Frequency Identification
SAP	Systemanalyse Programmentwicklung
SKU	Stock Keeping Unit
ST	Storage strategy
U.S. Dollar	United States dollar

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1. INTRODUCTION

In this chapter the relevance of the study for society is highlighted. Then a clear description of the question under investigation is provided. Later, the methodologies that were followed in order to develop the thesis are explored. The company, which is the object of study, is later introduced, and an overall structure of the dissertation is presented.

1.1. Framework and relevance

Before the industrial revolution, business took place on a local scale with small transactions between individuals and organizations (Battista et al., 2014), (Duvut, 2008). However, with the revolution, large-scale industrial processes began to emerge, which introduced new challenges. More recently, and in the same trend, rapid globalization has brought about several transformations, fostering competitiveness (Erixon, n.d.) and increasing customer requirements (Hyken, 2016). The high service level which companies have presented their customers with, has made them more demanding than ever (Hyken, 2016). Therefore, organizations need to keep identifying their weaknesses and to think about ways to convert them into opportunities.

Although enterprises are often able to quantify the amount they spend, and even admit that they need to reduce costs, most are unable to identify what their true expenses should be, or define their potential minimum possible spending amount (Herrmann et al., 2019). According to these authors, such is because companies do not have a clear methodology for determining costs. This lack of knowledge is one of the first issues that makes it difficult to identify how and in what aspects more gains can be obtained, in order to increase efficiency as well as to reduce costs (Herrmann et al., 2019).

The lean thinking philosophy has been largely spread all over the world being applied to enterprises and even to daily personal life (Earley, 2016). The simplicity of the different strategies and the associated cost reduction, has made this way of manufacturing and living very popular, as several tools introduce small and easy tasks which boost efficiency (Smart, 2013), (Palevich, 2013). One problem is that companies started using these tools because they wanted to improve something, but the starting point did not always have a quantified prediction of the outcomes. Therefore, firms would just change things to make them better than they were, and then, quantify the improvements. Another issue is that managers would implement measures without understanding the true problem, and without involving the shop floor, so the outcomes were not always as good as expected (Das, 2020). In this dissertation the starting point is to consider the overall picture and target the aspects that cause more entropies making a point of involving the close participation of the workers. Then, a structured analysis is conducted, and new solutions are suggested based on quantified results.

One aspect that has, for long, been critical is warehousing (Fumi et al., 2013a), (Morton, 1974), (Kämäräinen et al., 2001), (Frazelle, 2002), (Richards, 2014), (Pettersson & Segerstedt, 2013), (Falsini et al., 2012). Data reveal that 39% of the logistics costs in Europe are due to activities regarding the warehouse (Fumi et al., 2013a). In fact, all over the world warehouse activities represent around €300 billion every year, with more than 85% involving operating costs - such as space, picking, storage, sorting, labour, equipment, packaging and dispatching (Herrmann et al.,

2018). This value tends to increase, as there is a growth and prevalence of e-commerce and global supply networks, which add even more complexity to the processes (Herrmann et al., 2019).

Despite all the costs, this activity is crucial. Warehouses are vital for any institution as they boost the usefulness of goods by increasing the time they are available to potential customers (Ramanathan, 2006). This is the basic and primordial function of warehouses - saving goods for them to be available when needed.

However, in operational terms, a warehouse seems to be much more than a place to store things: it can be an opportunity for competitive advantage (Farahani et al., 2011). Adequate management can lead to a great minimization of the total cost of the operations of the warehouse and help meet the expectations of the service level for the business, thus optimizing the warehouse and acquiring a competitive advantage (Zenieris, 2014). Bearing in mind the increased velocity with which customers demand their goods to be available, the faster the retrieval of goods a company can present, the quicker these products will be made available for customers. This helps outperforming its competitors and boosting the success of the company by making it easier to deliver the right products to the right clients, in the right place, at the right time, and under the right price (Fontana et al., 2013), (Jiang et al., 2009).

As warehouse activities are numerous and done on a daily basis, small changes can lead to great improvements and enable major savings (M. C. Chen et al., 2005), (Fontana et al., 2013). Indeed, the time that warehouse activities require, is an important aspect to be taken into consideration (Fontana et al., 2013). One of the functions that requires extreme care is that of order picking because it represents a considerable part of the total time spent on the request cycle (Fontana et al., 2013). On the one hand, this activity is relevant for the production system (for the furnishing of kits to the assembly stations), and, on the other, for the physical distribution activities by helping to meet customer's demand (Petersen & Aase, 2004), (Fontana et al., 2013), (Dallari et al., 2009).

A major feature enabling the efficiency of an order picking process is the storage policy adopted (Le-Duc & Koster, 2005), (Fontana et al., 2013).

The storage location assignment problem was first identified as an issue of great relevance to operations management and research in 1976 (Hausman et al., 1976a), (Fumi et al., 2013a). This problem deals with the allocation of goods in the space they can be stored in, with the greatest possible reduction of handling costs, and with the best use of storage space (Reyes et al., 2018). There are several features that acutely affect this issue: the storage area design, the storage space availability, the warehouse storage capacity, the physical characteristics of the products, their arrival times, and their demand behaviour (Reyes et al., 2018).

Several scientific studies (Fumi et al., 2013a), (R.D. Meller & Gau, 1996), (Russell D. Meller, 1997), (James A. Tompkins & Smith, 1998), (J.A Tompkins et al., 2011) have been held in order to find ways to increase the efficiency of warehousing, focusing on the management of inventory storage. Yet, these researches have not managed to combine ease of use with the guarantee of tangible results and imply high implementation costs and great deals of resources (Pessotto, 2009), (Fumi et al., 2013a), (Rowley & Institute of Logistics and Transport, 2000) such as money and time, compelling companies to continuously keep allocating great amounts of funds, to be able to stay competitive and on the leading edge.

On a positive line, the adoption of lean procedures may bring about possible savings of up to €35 billion (Herrmann et al., 2018). Moreover, the layout of warehouses is of extreme importance as it affects the strategy of management of the supply network and its costs and service level (Zhang, 2017), (Bowlby et al., 1984), (Grant & Fernie, 2008), (Cagliano et al., 2011), (Bottani et al., 2012), (Battista et al., 2014).

1.2. Issues and objectives of the study

The goal of this study is to find ways to increase an agile flow of materials in a warehouse while comparing different methodologies.

The proposed dissertation, intends to, firstly, highlight how customers are more demanding than ever, and how they are compelling companies to be faster every day. Another aspect under study is the importance of the existence of a harmonious supply network and management, much more than of a simple supply chain. A further aim is to pinpoint the importance of the role of warehouses as they are responsible for a considerable part of costs and are a possible source of competitive advantage (Herrmann et al., 2019). High focus should be given to one of the logistic challenges in this reality - the problem of the allocation of materials - as it can represent a considerable cost reduction. Several storage policies ought to be explored. The study intends to analyse a first storage policy, used in the company that was the object of study, following an action-research methodology. This analysis and diagnosis should lead to a set of possible results, bearing in mind the proposed goal. It is important to examine a second storage policy, chosen by the author as an improvement of the first one. Despite changes in the storage policy other improvements are suggested in terms of determining the true capacity of the warehouse. A last objective of this study is to carry out a comparative approach for the possible solutions to the problem, assessing the most beneficial one. This project aims to highlight that critical thinking, and the introduction of simple changes, may lead to great cost reductions and increase the capacity and flexibility of enterprises.

In order to achieve the main goal of this study, several steps are considered essential:

- Highlighting the importance of lean management
- Featuring the role of warehouses and stocks
- Exploring of storage policies
- Analysis of the storage policy used in the company
- Viewing the warehouse capacity critically
- Assessment of a different storage policy
- Comparison of both strategies
- Proposal of minor-cost improvements
- Suggestions for further developments

It is not enough to say that there is a need to reduce costs and try out solutions without a concrete improvement plan. It is necessary to firstly ask what the impact of the changes would be, and only then choose the areas that may have more impact, based on factual analysis. In this project it is considered that the adoption of a different perspective in terms of the layout capacity and change in the allocation method will achieve savings in traveling distances. This should also bring about other savings such as cost of manpower and a reduction in the costs related to the need for an external warehouse and an increase in safety.

1.3. Methodological options

An investigation methodology can be understood as a systematic way to solve research problems, or as the science that studies the way that research is carried out scientifically (Kothari, 2008).

A descriptive methodology was adopted to understand the status of the situation: for example data such as the number of products, their dimensions, the dimensions of the bins, the percentage of occupation among others, were collected and calculated (Rajendra Kumar, 2008). In order to study the motives that led to those results, the analytic method was applied (Thomas et al., 2015).

During the development of the project, a combination of theoretical knowledge and practical observation was carried out, in order to create and verify the description of procedures, therefore a hypothetical-deductive methodology was followed (Lawson, 2015). The literature review was a useful tool to understand the storage policy used by the company and to formulate the hypothesis: that critical thinking and the adoption of a different perspective in terms of the layout capacity and change in the allocation method, could achieve savings in traveling distances, as well as other savings such as cost of manpower and costs related to the need for an external warehouse and an increase in safety.

Finally, the type of investigation followed was action-research, which allowed a systematic approach that made it possible to find effective solutions to everyday problems, addressing the complex dynamics in a concrete social environment (Stringer, 2013), in this case, the daily interactions of the warehouse of "N" Company. The analysis and diagnosis resulted in a set of possible actions taking into account the proposed objective – to help the company to improve the flow of materials in the warehouse.

All historical data were extracted from SAP version ECC 007, and then processed in Excel Office 365. All measures of depth, width and height were registered in millimetres, but the final results are shown in meters for an easier perception. The layout of the plants was manipulated using Solid Works version 2018 and all flowcharts were deployed with Bizagi Modeler version 3.7. Although a scale was not provided, a scale of 1:600 cm was assumed from the field experience. For confidential purposes the name of the company is given as "N".

1.4. Introduction to the company

"N" Company is a food and beverage enterprise with a unique global presence in 190 countries worldwide ("N" Company, 2019), standing out not only for its economic results and capacity for innovation, but also for its social and environmental concerns.

In an economic perspective, "N" Company's dividends have been growing for 24 consecutive years ("N" Company Global, n.d.), with a 42% increase in profit in 2018, compared to the previous year (Sorvino, 2019). Based on that year's sales, "N" Company was named the largest food and beverage company in the world (Clere, 2018), having managed to keep this title in 2019 (Food Engineering, 2019). Even this year (2020), taking into consideration the COVID impact, until August, the firm had an organic growth of 2,8%, a trend that is expected to continue ("N" Company, 2020). In Portugal, "N" Company has also shown solid growth (total sales of 500 million euros, with an organic growth of 3,2% in 2018 (Barroso, 2019)). One of the contributions to this growth is the belief that, as the

CEO says, “leadership in innovation is essential to conquer the market” (Askew, 2018). With this mindset, “N” Company constantly innovates in several areas (Watrous, 2019).

The firm is also concerned with social aspects, such as gender equality, hunger and the environment, having been recognized this year (2020) on the Bloomberg Gender Equality Index (Spur, 2020). In addition, environmental goals have been set and achieved. In 2018, one of the Portuguese plants was recognized by DGEG as the unit with the largest reduction in primary energy at a national level between 2009 and 2014 (TerraNova, 2018).

In this study, closer attention will be given to a plant located in the centre of Portugal, more exactly to the warehouse of raw material and packaging.

This project attempts to analyse and understand the procedures that annually lead to the success of the enterprise, without neglecting other pertinent aspects already mentioned. This leads to the belief that “N” Company is a suitable and relevant company for this case of study.

1.5. Structure of the thesis

The thesis is organised as follows: Chapter 1 provides a global presentation of the thesis. In Chapter 2 it is possible to see a literature review on relevant topics of the dissertation. Chapter 3 explains the methodologies under discussion and shows the methods used in order to conduct a theoretical application. The results are provided and discussed in Chapter 4. Lastly, Chapter 5 makes some concluding remarks, recognises some limitations, and suggests further research.

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2. LITERATURE REVIEW

An increase of importance is being given to the supply network as customers are increasingly more demanding, making entities lower their costs and delivery times. In this line of thought warehouses require an increasingly higher amount of attention as they have a considerable role both in terms of timing and costs.

This chapter intends to provide a literature review on relevant topics of the thesis. Firstly, the importance of a strategic warehouse management is shown, as it may be a significant competitive advantage (Faber et al., 2002) and because it is the foundation of this research. Then, the concept of a supply network is highlighted. The subsequent need for lean warehouses in the supply network is emphasised, as these structures are responsible for a considerable portion of costs (Herrmann et al., 2019), and are the core of the project. Afterwards the role of inventory is underlined. Then, a simple approach is introduced, in order to quantify costs. After this, one of the problems that warehouse managers face – inventory storage assignment - is addressed. Subsequently, a theoretical approach to possible solutions for this problem is carried out, being the base for the solutions presented.

2.1. Strategic warehouse management in the supply network

Supply chain management can be defined as the effort to ensure the right product in the right place, to the right customer, at the desired time, in the right quantity and condition, while guaranteeing the adequate quality, balancing everything with controlled costs (“Seven ‘Rights’ of Logistics,” 2006), (Alglawe et al., 2019), (Feigin & Business Expert Press., 2011), (Batra et al., 2018). This management has seen rapid developments (Shi et al., 2016).

The concept of supply chain is gradually being replaced by the idea of a supply network, a concept that goes beyond the first one. This approach, that is connecting more suppliers, is based on three major foundations. The first is allowing every player to be modelled more easily. The second is considering the inter-dependence of different factors that affect the whole network in order to calculate them more easily and to identify bottlenecks (so as to reduce overall costs and lead-times). The third one is to enhance the overall efficiency and to involve solutions that can be potentially computerized (Wu & O’Grady, 2005), working more as a connected network rather than a chain.

With the global market, it is even more important to optimize resources, which involves eliminating waste, making the best use of time, looking for continuous improvement and using technologies in order to achieve cost savings (Caunhye et al., 2012). Thus, it is preponderant to overcome obsolete costing methods, to be able to respond to the competitive reality. In an increasingly demanding society (Hyken, 2016), where efficiency and effectiveness are key concepts, it is vital to understand the best resources to explore (Zelga, 2017). To this end, it is very important to ensure that companies are able to truly identify and understand their costs which is not always the case (Anderson & Narus, 1998), (Miller, 2017).

Several tools have been developed to help companies understand the environment in which they operate, namely regarding the competition, their customers and, mainly, themselves, in order to

survive and be successful (Dyson, 2004), (Amatulli et al., 2011). The challenge is quite dynamic in a constantly changing reality. For example, the most recent workforce (Millennium generation) values considerably different aspects from other generations. It is crucial to ensure that they are motivated and involved in the dynamics of the company, given that they constantly seek to feel that they are part of something and perform diverse tasks. This group of people are not only looking for a job, but for challenging careers, with responsibilities, where they can exceed themselves daily. All of these imply a different management (Deal et al., 2010). But many other factors can be pointed out, which go beyond the traditional assessment of the financial impact of decisions, and which involve costs that are not always direct. For example, it is necessary to detect the amounts spent on the resources consumed to carry out the activities, determine efficiency and effectiveness rates, constantly look for new activities that increase performance and be aware of the technological evolution that accompanies the entire process (Quesado & Maria Carlos da Silva Pinto Lopes, 2015).

2.1.1. The supply network

According to Rushton et al., distribution has been a fundamental aspect of industrial and economic life for many years, but it was not only until recently that it was attributed its due importance as a major function in itself. One of the reasons for this lack of recognition may be that distribution is a function which is composed of many sub-functions and many sub-systems and these were treated as individual management operations. Nowadays, the need to consider how these different operations are interrelated and interact with one another has been recognised by academics and in business. This has resulted in the adoption of a more scientific approach towards the subject and led to a more holistic view of the logistics function and of the individual sub-systems. The real need for and manner of planning distribution and logistics has been studied together with some of the essential operational issues. As the importance of distribution and logistics grew, so did the number of names and definitions that were given. A few of these are (Rushton et al., 2006):

- physical distribution
- logistics
- business logistics
- materials management
- procurement and supply
- demand chain management

Considering the attempts to produce a precise definition of logistics, several of these have been elaborated.

Logistics can be defined as “those activities that relate to receiving the right product or service in the right quantity, in the right quality, in the right place, at the right time, delivering to the right customer, and doing this at the right cost” (Shapiro, 1985). It can also be seen as the efficient transfer of goods from the source of supply through the place of manufacture to the point of consumption in a cost-effective way whilst providing an acceptable service to the customer (Rushton et al., 2006). Another definition can be “the business of transporting and delivering goods” (Oxford dictionaries, n.d.). For other authors, logistics is the management of all activities which facilitate movement and the co-ordination of supply and demand in the creation of time and place utility (Ballou, 2006).

Physical and information flows, and storage from raw materials to the distribution of the finished project are all part and parcel of logistics. It could then be said that supply and materials management are the storage and flows in the production process, whereas distribution is the storage and flows from the last production phase to the client. Nowadays, great importance has been attributed to both information and to physical flows and storage. Reverse logistics has also gained relevance – this is concerned with the path of used products and returnable packaging going back through the system (Rushton et al., 2006).

It may be seen that there are functions and sub-functions which require systematic planning in the specific environment, as well as in the distribution system (Rutner & Langley, 2000).

It must be said that there is no exact name or definition since products, companies and systems are all different to each other. Logistics is not a single, static function so it must necessarily be flexible, adjusting to the conditions and demands of the specific business environment it is applied to (Rushton et al., 2006). Thus, according to the authors, the various names are used and accepted in the academic and business world and there has been quite general acceptance of the following relationship described in Equation 1:

$$\textit{Logistics} = \textit{Supply} + \textit{Material Management} + \textit{Distribution} \quad \text{Equation 1}$$

Having considered the defining components of logistics it is relevant to take into consideration the importance that has gradually been attributed to this area. Many business organisations have witnessed how changes in their logistics have led to greater improvements. These companies have come to realise that logistics can offer a positive “value added” contribution, contrary to the traditional stance that the different functions of logistics are simply an additional cost (Rushton et al., 2006), (Rutner & Langley, 2000).

Considering the impact of logistics on business and on the economy, several studies have shown its relevance (Chapman et al., 2003), (Tracey, 1998).

The fact that logistics requires great use of human and material resources implies that it will have a huge effect on the national economy of a country. A study showed that in 2004, approximately 30% of the working population in the United Kingdom was associated with work which was related to logistics. These findings draw attention to the need to better understand logistic costs and to work out the means to reduce these costs as far as possible (Rushton et al., 2006).

Another source states that the European cold chain logistics market was worth over 75 billion U.S. dollars in 2019 and is expected to reach 112,8 billion U.S. dollars by 2025. According to these data, cold chain logistics involves the “transportation of temperature-controlled products along a supply chain using refrigerated packaging solutions to preserve the quality of products such as fresh agricultural goods, seafood, frozen food or pharmaceutical products” (Statista, 2020).

In 2019, in Portugal, the gross value added of the sector of transports and warehousing, activity of information and communication has shown an increase of 4,1% (2,0% on the previous year), leading to a contribution of 0,3 percentual points (INE, 2020).

2020 has not been such a good year. The Corona virus has caused global damages and logistics is not an exception. The impact was firstly seen in China. However, by the end of February of the current year, about 70% of large industry had already restarted operations. The pandemic has

spread worldwide causing lockdowns and border closures that limited the movement of goods, leading to stock piling. In fact, the full effect of the pandemic on the overall supply network is not yet known but changes are already being felt. Other forms of demand are increasing, namely the e-commerce. On a brighter side, there have been some records in low fuel prices that have given some leverage to this sector. Logistics is also adapting to the circumstances, with different safety protocols, new modes of transport and contributing to this humanitarian fight, providing transportation free of charge and the material flow of goods, namely both medicine and food (International Finance Corporation, 2020). Indeed, the world should work as a global network with constant interaction and dependence.

The interrelationships of the different logistic elements are interpreted in a planned manner as being part of a whole, so as to carefully identify and determine cost trade-offs. These trade-offs are positive benefits of the logistics system as a whole. At times, a certain trade-off may imply an additional cost in one function but will lead to larger cost-saving in another. The system, as a whole, will benefit. As the authors defend, these trade-offs are the core of the total logistic concept. In planning the distribution and logistics, this view of the system as a whole and its costs should be taken into consideration. Complementarily, there is the service level that is required by the customer that must be dealt with and is of extreme importance. Successful logistics may in fact be considered as the balance of total logistic cost and customer service level (Rushton et al., 2006).

2.1.2. Lean warehousing

A warehouse can be seen as the place where goods are stored (Woubshet, 2017) or the place where the raw material and/or final products are kept (Juneja, n.d.). Warehousing refers to the set of activities that involves storing goods on a large scale in a systematic and orderly manner and making them available as soon as they are needed (Woubshet, 2017). At first glance, the management of this type of infrastructure may seem an easy task to manage and even a place where the factory work is simple. Nevertheless, this can prove to be an extremely complex activity when considering the need to minimize the amount of existing goods but, at the same time, ensure that there are enough products when needed. Also, when considering the possible locations of the products, the type of material to be stored, the life of the products and other restrictions such as the typology and size of the pallets and lots, among others.

In this sense, in operational terms, a warehouse seems to be much more than a place to store things, it can be an opportunity for competitive advantage. It has some benefits, namely (Farahani et al., 2011):

- It allows storage of goods - basic and essential function of warehouses (saving goods for them to be available when needed).
- It is an integral part of the production process - sometimes the manufacturing process may require a period of time to complete a given product (even without any type of operations) as is the case with wine production. These goods can be stored until they are needed again.
- It enables reception and possession of returned products - In reverse logistics the movement of returned goods is important, so that warehouses can act as a place to accumulate and make decisions about returned goods.

- It allows for consolidation - When consumers order products from different locations and want them to be shipped together, the warehouse has the ability to receive products from different locations and then deliver them as requested.
- It permits rebulking - large quantities of merchandise are divided into smaller quantities (less than truckload) and sent to customers.
- It also makes postponement possible – Some warehouses are able to postpone production processes. These warehouses have autonomy and the capacity to perform some small productive tasks such as packaging and labelling. In-process goods are kept in the warehouse and when a special order is received (for example promotional campaigns) these activities begin to be carried out and the warehouse turns the goods into final products according to the requirements of the customers.
- It allows cross docking – Sometimes the inventory does not stay in the warehouse for more than 12 hours. The warehouse receives the inventory, transfers it to vehicles and delivers it to dealers. This decreases inventory costs and lead times by decreasing storage times.
- It permits transshipment – Transferring goods from one vehicle to another when needed
- It makes product-fulfilment centres possible– Warehouses that deal directly with the end customer.
- It increases the usefulness of time assets, extending their time availability to potential customers.
- It ensures the continuous production of goods - Some authors argue that the continuous production of goods in factories requires an adequate supply of raw materials, which implies the existence of sufficient stock/storage.

Thus, the schools of thought that promote the flow of materials gain importance. The lean concept can be defined as a philosophical way of working that emphasizes the elimination of waste throughout the processes (Gauci, 2010) . This means that using resources for something other than creating what the consumer recognizes as value is wasteful and, as such, should be eliminated. The concept of value is defined as any action or process that the consumer would be willing to pay. The lean process thus seeks to preserve and create value at a lower cost, leveraging efficiencies, which results in more agile and faster process flows (Gauci, 2010). So there is no need to have such high inventory volumes or to rely on long-term predictions. Instead, processes become so fast and agile and lead times so short that it is possible to establish a closer relationship with consumers and do what they want, when they want to.

Although in vogue, this philosophy has been fostered for many years. In fact, in 1911 Frederick Taylor, in his work “The Principles of Scientific Management”, evidenced a set of losses related to inefficiency in general and to human waste. He argued that the elimination of this type of inefficiency depends on the application of principles of systematic management and not on an extraordinary capacity of employees. In this way, success depends on a management which is capable of perceiving problems, synthesizing them and drawing up plans that all employees - not only the most knowledgeable - can perceive (Taylor, 2007).

After Taylor (1856 - 1915) (Sniderman, 2012) the world saw the first and second world wars. At the end of the second war it was necessary to restructure countries in several areas. The American automobile industry was booming, and Japan had to respond competitively within three years to survive. Americans produced large quantities of a small variety of automobiles. The Japanese idea

was to produce several models in reduced volume. Taiichi Ohno worked as a production engineer on the Toyota Motor Corporation series and knew that he could not fully copy the American production system. Taiichi looked closely at American supermarkets. At the time, a large number of people travelled by train and then walked home. Thus, they could not carry large shopping volumes and so were forced to go to the supermarkets (almost) daily, buying small volumes of various products for dinner. When analysing the products that were sold, the supermarkets knew what they needed to replenish for the next day. This just-in-time system allowed supermarkets to make several products available, including competitive brands, in a user-friendly way (Stobbs, 2012)

Inspired by his observations of the American supermarkets, Taiichi began to analyse the various forms of waste at Toyota and challenged all employees of the company to help him. By doing so, Taiichi made Toyota the first company to introduce the “Lean Manufacturing” concept. Taiichi identified a set of factors of waste, which became known as the list of seven types of waste in production (Womack & Jones, 1996):

People:

- Movement - Unnecessary movements of people while they are working on the products
- Over-Processing - Using unnecessary steps to finish a product
- Waiting - Waiting times for people to start the next task and which are unnecessary

Quality:

- Defects - Products that do not fulfil the expected quality

Material:

- Over-Production – Producing goods that are not needed
- Transport - Unnecessary transport of parts for production
- Inventory - Products in the pipeline waiting to be finished or finished products waiting to be shipped

Lean Warehousing is a set of principles to be applied to the functioning of a warehouse. Thus, a lean warehouse is one in which the five Womack & Jones principles and several Lean tools are applied that are characterized by a set of aspects (Womack & Jones, 1996), (Lean Australia, n.d.):

- Perception of value: what is the real value perceived by the consumer (not only what a particular company strives to provide, but the added value that the consumer values).
- Understanding the value chain: understanding all activities from the conceptual stage to the moment the product reaches consumers. The key issue is to identify which steps add value to the consumer. Then, it is important to think about how to eliminate the steps that do not add value, keeping only those that do.
- Continuous flow: with the previous steps ensured, the conditions that permit one to identify the design that allows a continuous flow of orders and production are facilitated. Although it will always be possible to distinguish the stages that take the longest, high quality is ensured at a reduced cost price.
- Pull strategy: the aforementioned conditions mean that it is not necessary to rely on short-term forecasts, but rather to be highly capable of responding to the needs of consumers because the response time and the lead time have been so compressed that it is possible to do what the consumer wants, when he wants. When these phases are completed, it is possible to think of perfection.

- Perfection: after ensuring all others, management has time to worry about improving processes, which is extremely important. Although the state of complete perfection (where all stages of the process create perceived value for the final consumer) is totally theoretical, it must always be the objective of managers.

In this context, the management of the amounts involved is a key factor in warehouses. After identifying the costs, it is necessary to be able to use this information and apply it in order to boost results. In this perspective, the ABC analysis is a popular approach which is chosen because it is easy for any user to understand, regardless of their qualifications

2.1.3. Inventory

It is extremely useful to understand what drives companies to store goods (Woubshet, 2017).

Several factors make the existence of stocks expensive, namely the cost of capital, or the cost of all the activities necessary for the stored products (human resources, stock management systems, receipt of material and its allocation to the appropriate location), the need to protect the material, the risk of deterioration and loss and the need for packaging and management. However, the existence of an inventory is necessary due to some aspects (Juneja, n.d.):

- Protect the company against unexpected changes in consumer demand, against changes in lead time and to improve customer service.
- Make the most of economies of scale when buying, transporting and producing in high volumes, reducing the cost per unit.
- Be able to cope with different levels of demand and supply when it is possible to foresee that they will not be equivalent at the same time (for instance the production of sugar that only occurs in a specific period, but that is in demand all year).
- Have a contingency plan for atypical situations, such as strikes, floods, fires or attacks.
- Eliminate entropy, insofar as products in the process of being manufactured are stored in order to eliminate entropy points and promote productivity.
- Precaution against price changes where changes are unexpected (and which, most of the times, imply increased costs) keeping raw materials at an economical price.

2.1.4. ABC analysis

The ABC analysis (also known as Pareto analysis) is a categorization technique which has been successfully applied to inventory management to determine the priority of goods, based on the Pareto Principle. According to this principle, the majority of the inventory (about 80%) comes from a minority of items (about 20%) (Viswanathan & Bhatnagar, 2005). The ABC analysis can be applied in diverse aspects such as demand or costs. Taking expenses as an example, the ABC classification should reflect the highest cost items, which must be carefully managed and the low cost items, which are of less importance (Ravinder & Misra, 2016). Therefore, it is recommended to place larger orders for items at low cost, reducing the time spent placing and planning orders (Lyles, 2018). As Lyles says, based on this analysis, needs can be balanced and patterns identified to determine the feasibility of stocking the most expensive products, making it easier to ensure that funds are channelled as cheaply as possible and improve accuracy regarding purchase quantities according to the time available (Lyles, 2018).

Traditionally, the ABC analysis was based on only one criterion - dollar volume- for performing categorization. Over the last thirty years, however, there has been increasing questioning of this sole criterion. It has been argued that modern businesses and supply chains need to be able to deliver the right products swiftly to very specific clients in order to survive. Since suppliers, intermediaries and customers are spread all over the world and product lives are rapidly decreasing, other criteria have been put forward as extremely relevant and useful in order to achieve better financial results. Among these are: demand, lead time, item criticality, durability, scarcity, reparability, stockability, commonality, substitutability, the number of suppliers, mode and cost of transportation, the likelihood of obsolescence or spoilage, and batch quantities imposed by suppliers and sales (Ramanathan, 2006), (Ravinder & Misra, 2016).

2.2. Storage location assignment problem

Managing warehouses can prove to be an extremely complex activity when one takes into account the need to minimize the amount of existing goods, also known as stock, but, at the same time, guarantee the existence of sufficient products when necessary, when thinking about the possible locations of the products, the types of materials to be stored, the lifetime of the products and other restrictions such as the typology and size of the pallets and lots (Woubshet, 2017).

For a harmonious flow of materials, several steps must be followed (Berg & Zijm, 1999):

- Receipt of goods - Goods are removed from vehicles and delivered to warehouse employees
- Inspection and quality control - Operators make sure that they receive the correct quantity of the correct products
- Preparation to transport to the area where the products will be stored
- Storage - Goods are transported to storage areas
- Order picking – Goods are removed when orders arrive
- Preparation for transport in the shipping area (for example packaging)
- Transportation of goods to the shipping area - Goods are available to be shipped

An efficient warehouse should take into account, principally, the reduction in costs, space used, and distance travelled. Therefore, the objective of finding solutions for the stock allocation problem is to reduce the requirement for space and to minimize the total distance travelled or travel time throughout the warehousing process (Fontana et al., 2013)

The storage location assignment problem has for long been studied by several specialists, who have elaborated warehouse storage models and policies, in order to enhance overall financial benefits.

2.3. Warehouse storage policies

Storage systems are fundamental elements of supply chains as products need to be put into storage locations before they can be picked to fulfil customer orders. Storage policies are a set of rules which can be used to assign products to storage locations. Before such an assignment can be made, decisions must be taken as to which pick activities will take place in which storage system (Koster et al., 2007).

It is possible to distinguish between a storage model and a storage policy. According to Manzini, both have the same goal: to determine in which storage location the loads are to be held, in order

to minimize the material handling effort, and the cost of put-away and retrieval (2012). However, whereas a storage model is a mathematical optimization model, the storage policy is a management rule. As the author states, though a storage policy may not generate the optimal storage plan, it is easier to implement because it does not require the solution of an optimization model (Manzini & Goetschalckx, 2012). The first mathematical models were elaborated to study the performance of storage systems in dual command cycles. Here, first a storage and then a retrieval operation are performed on each trip of the material handling truck. Hausman et al., (1976) and Mallette & Francis (1972) proved that for single command cycles, product turnover-based dedicated storage minimizes the total travel time necessary to perform all the tasks. These results were later extended to dual command cycles by Malmborg and several co-authors (Manzini & Goetschalckx, 2012).

Several storage policies have been elaborated as management policies that define where best to place items in the warehouse. Some of the most common ones (Manzini & Goetschalckx, 2012) will be presented further on.

2.3.1. Random storage

In this storage policy, all incoming goods, are gathered in a location that is selected at random, in the warehouse. Therefore, as long as there is a vacant space, every bin has the same probability of being selected (Hausman et al., 1976b), (Lerher et al., 2010), (L. Chen et al., 2011), (Popović et al., 2014), (Fumi et al., 2013b). This is the simplest storage policy because it does not use any information about the unit load. Neither the characteristics of the SKU to which the unit load belongs, nor the residence time characteristics of the unit load are taken into account.

The main advantage is a high space utilization, which is due to the fact that no internal structure or partitioning of the storage locations is required. It is, in fact, the storage policy which requires the smallest possible warehouse size. This smaller storage size in turn reduces the travel cost to a specific location. On the other hand, in this option, the location of unit loads belonging to different SKUs is constantly altering in the warehouse which may imply that the put-away or retrieval operations have to search for the unit load belonging to a particular SKU, thus increasing travel distance. (Kyung & Sharp, 1991). Therefore it is extremely important to have an accurate inventory map that is accessible in real time to the material handling operators for the storage system to operate efficiently (Manzini & Goetschalckx, 2012).

This storage policy only works as a computerized solution, otherwise the order-pickers would probably select the nearest available location resulting in another storage policy entitled closest open location storage policy (Manzini & Goetschalckx, 2012).

2.3.2. Closest open location storage policy

In this type of storage policy, the employee will store the products in the first vacant place which is found. As Hausman et al., (1976) defends, if goods are transported in full pallets, both random and closest open location storage policies have like performances. As in the case of the random storage policy, the Cube per-order Index requires the smallest storage size and is likewise negatively affected by the constant changes in the location of the unit loads. The existence of an exact inventory map which is accessible in real time to the material handling operators is, thus, also of ultimate importance (Manzini & Goetschalckx, 2012).

2.3.3. Dedicated storage

Product-dedicated storage policies establish the storage location of goods according to the characteristics of the product or SKUs that the unit load holds. Some of the product characteristics that are commonly used are the demand rate, the maximum inventory over the planning horizon, or the turnover ratio. These policies also divide the storage locations into several sections, each of which is reserved to hold the unit loads of a group of SKUs. Most often, two, three, or the number of products when each section holds unit loads belonging to one single SKU is the number of sections used (Manzini & Goetschalckx, 2012).

In this case, each product is kept in a fixed place. This is a human-friendly storage policy as it helps order pickers to remember the location of the goods. Frequently the whole layout is designed to match the product-to-location assignment (Koster et al., 2007). As the products are gathered in a logical way, it is possible to save work. Another interesting aspect is that because this storage policy allows one to take into consideration the specific characteristics like the weight of the products, it allows the allocation of the heavier ones to the bottom, reserving the top space for the lighter ones. When this is done, together with routing the order pickers appropriately, a good stacking sequence is efficiently guaranteed (Manzini & Goetschalckx, 2012).

The main drawback, however, is that even if there is no stock of the assigned goods, as the location is reserved for that specific item, the shelf remains unoccupied. Besides this, if there is a high increase in the demand, enough space has to be assured, resulting in the lowest space utilization of all storage policies (Manzini & Goetschalckx, 2012).

2.3.4. Class-based storage

Another possibility is to combine several of the methods previously mentioned which is found in the concept of class-based storage. The required warehouse size can be reduced if the storage policy allows sharing of the storage locations among the different SKUs. Although this implies an increase in travel times because the unit loads are no longer in perfect order, the reduction in size of the warehouse may be more significant. This issue has been studied by several authors (Hausman et al., 1976a), (Bahrami et al., n.d.), (Manzini & Goetschalckx, 2012).

In this storage policy, the warehouse is divided into several sections which are dedicated to a group of SKUs. Each section is called a storage zone. The group of SKUs attributed to a specific zone is called a product class. Inside a storage zone, the unit loads of the different SKUs that belong to this class are randomly stored. The classes may be defined according to several criteria such as demand, cost, Cube per order Index or pick volume. Although more than three classes can be stipulated, typically goods are divided into three (Manzini & Goetschalckx, 2012).

The ABC analysis previously mentioned is a simple way to divide items into classes based on their popularity. For instance, if products are grouped into classes according to their demand, then the class with the highest demand has approximately 20% of the goods but is responsible for about 80% of the turnover (Viswanathan & Bhatnagar, 2005).

One of the basic problems in this storage policy is to determine the size of each zone according to the products that will be stored in this zone. If the SKUs are replenished in a similar manner, then sharing of the storage space may produce only a small reduction of the required warehouse size. It

is usually assumed that the replenishment behaviour of the SKUs is independent among them. In this case, sharing the storage locations can take advantage of the fact that during a particular time some SKUs will have a high inventory while other SKUs will have a low inventory. If the replenishment patterns are independent, statistical analysis may be used to calculate the probability that the storage zone size will be large enough to hold the unit loads of the product class. When the unit loads of product class to be stored do not fit in the corresponding storage zone, it is assumed that these will be stored in the next storage zone (Manzini & Goetschalckx, 2012). As the authors defend, with the class-based method, fast-moving products are closer to the depo and, at the same time, the low storage space and flexibility of the random storage still holds. Hausman et al. adds that the class-based storage might require more space than randomised storage because goods can only be stored in a certain class region. This implies that the space requirement increases with the number of classes (1976b).

2.3.5. Family grouping

In some cases, it may be interesting to detect patterns in demand as some products may be typically, ordered together with others. If such a relation is identified, it is useful to allocate these products next to each other, which has been termed family grouping. This storage policy can be combined with others, for instance, class based, however, this must be carefully undertaken, as the specific characteristics of each product must be considered (Manzini & Goetschalckx, 2012). The authors argue that the group storage policy leads to greater space requirements as compared to random assignment. In order to apply family grouping, it is essential to know or to be able to predict the statistical correlation between the goods. There are two types of family grouping to be found in the literature: the complementary-based and the contact-based method.

The complementary-based method takes into account the degree to which items are complementary. Firstly, the items are gathered into groups according to the degree to which they are ordered together (complementary). In the second phase, they are allocated the closest possible together, in order to avoid extra traveling time (Manzini & Goetschalckx, 2012). In the contact-based method, contact frequencies are used to group goods into clusters. Contact-frequencies are based on the frequency with which items are picked in sequence, one directly after the other, so as to place them together in the same cluster. In this case, the high level of interdependence between the location of the items and their routing is highlighted. According to the authors, as both sides cannot be realistically completely solved, it is necessary to establish priorities in solving the problem.

As can be concluded from the above, at times, more than one storage policy may be applied together. For instance, dedicated storage may be used in the pick sections, and the random storage can be an option for the bulk area for replenishment. Thus, the potential advantages of each option may be enhanced, and the disadvantages lessened (Manzini & Goetschalckx, 2012).

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3. DESCRIPTION OF APPLIED METHODS

In this chapter the different approaches under investigation are described. Firstly, the way “N” Company tries to think about ways to increase the efficiency of the flow of the warehouse is shown. Therefore, the layout of the warehouse of raw material and packaging is analysed so as to reveal the dynamics of “N” Company. Afterwards, the process of analysing the available capacity of the warehouse is defined as this is a starting point for the decision process of allocating goods that is then explained. In a natural sequence to this description, a new proposed methodology emerges based on a critical thinking analysis. A different way of analysing the capacity of the warehouse is next suggested, resulting in a consequent change in the layout and in the allocation of goods. Lastly, the methodology used to compare the analysed perspectives is presented.

3.1. “N” Company’s approach

As seen before, in order to find a better storage strategy, several methodologies can be conducted. “N” Company uses a dedicated storage policy in which there is a dedicated location for each part number. Therefore, it is important to be familiar with the layout of the warehouse in order to understand the flow of materials and the overall dynamics of the company. It is also essential to know how “N” Company evaluates its storage capacity and to be familiar with the procedure which is followed in allocating goods.

3.1.1. The layout and flow of the warehouse

The first step in “N” Company’s methodology is to look at the overall plant and understand how it is organised. The layout of the warehouse is in accordance with the way they store goods. Therefore, it is relevant to understand the division of materials.

At “N” Company, the allocation of goods is divided into three main groups. While analysing the products, one needs to take into considerations if the materials have special characteristics (for instance, if they need to be stored under reduced temperature or if they have allergenics). Another aspect that needs to be analysed is if goods can be separated according to the way they are packed. Sometimes, both criteria are taken into consideration. Therefore, goods can be stored according to:

- The specific characteristics of the goods: for instance BLQ for products blocked for production; CAC for cocoa products; CMF and FRU for products that need to be kept cold; RES for leftovers (goods that were not fully used by production)
- The way they are packed: for example LIQ for liquid containers; CORES for big bags that are considered very high; TPF for bottles and lids, DOS for items that do not need a full pallet; ROT for boxes of labels that do not need a full pallet; CPL for wrapping products; CXP for big boxes; CXS for small boxes; EST for flattened boxes
- And, sometimes, for both: namely, LBB for big bags with gluten; BBH for Big Bags with lactose; NEU and NPQ for food products that can be next to all the others, and are not packed in containers

Therefore, the type of constraints that goods have must be evaluated.

If goods have restrictions only related to packaging, the type of packaging should be identified and then goods should be allocated to that bin. If the constraints are solely related to the product, the type of restriction should be identified, and goods should be allocated to the bins reserved for that constraint. Otherwise the combination of characteristics and type of packaging should be analysed, and goods should be allocated to the corresponding special products and packaging bins.

Schematically the process can be shown in the flowchart of Figure 1:

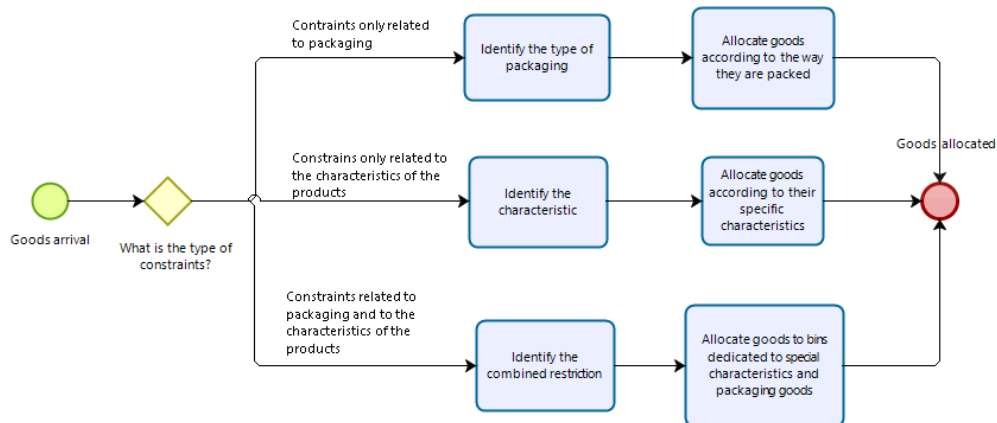


Figure 1 – Flowchart of N'' Company's overall decision process of allocating goods

In this line of thought, the layout is conceived so that there is a bin for each type of packaging, for each relevant characteristic of the goods (that requires closer attention) and for the relevant combination of both.

3.1.2. Determining the available space in the warehouse

Following the same line of thought, it is important to understand what type of materials were consumed during the previous year, by using historical data, extracted from SAP. Then each material should be categorized by groups (for instance, products with gluten, products that need low temperature, etc). In order to do this, the support of the warehouse team is needed.

The division of these materials can be seen in two main factions: the first one with restrictions that cannot be modified and the other with less strict constraints.

The first group consists of products with allergens (gluten, lactose, soy), organic products, materials that require controlled temperature (such as fruit and vitamins), goods that need controlled temperature and have reduced size; liquid containers and chicory. These groups require special attention as they have unique restrictions:

- Allergens, and organic products cannot be stored near each other
- Materials that need low temperature must be stored under controlled temperature zones
- Liquid containers have a defined manner of storage due to security reasons
- Chicory also needs special attention due to the height of the packages

From now on, these products will be mentioned as special products or products with heavy restrictions. The other group includes products which have lesser constraints. The latter incorporates oval caps, big bags, wrapping products, cocoa, flattened boxes, cardboard covers and

Table 1 - Safety distance of the bin, adapted from Expopal Comércio de Paletes (2019)

For levels between	$X_{3,4,5}$	Y_3
0/3.000 mm	75	75
3.000 / 6.000 mm	75	100
6.000 / 9.000 mm	75	125

In order to understand the real available area, the depth and length of each bin must be measured. From this, the dimension of the bars (both lateral and longitudinal), and the safety distance (in accordance with the above information) ought to be deducted.

This information is then sorted by storage strategies. For each strategy, the number of modules that exists, the quantity of pallets that fit in that strategy, the amount of pallets per module, the m^2 available for the strategy and, lastly, the m^2 per number of pallets are calculated.

For a clear understanding, each location is composed of a set of bins and each bin has several modules. Taking into consideration the example of Figure 2, this would be 1 bin with 3 modules and a part of one location.

In parallel, all goods and their respective constraints should be gathered and listed with the appropriate storage strategies and possible locations.

3.1.3. Allocation of goods

The compilation of the information above is useful to calculate the m^2 per stored pallet and is the core information of the current analysis. This calculation can be done according to Equation 2:

$$m^2 \text{ per stored pallet} = \frac{m^2 \text{ per pallet capacity}}{\% \text{ storage bin utilization}} \quad \text{Equation 2}$$

Where the % of storage bin utilization can be calculated as shown in Equation 3:

$$\% \text{ storage bin utilization} = \frac{\text{Actual pallets stored per lot}}{\text{Actual pallets stored per lot} + 0.5 \text{ bin capacity}} \quad \text{Equation 3}$$

The goal is to identify the best results, that is, the minimum m^2 per stored pallet as this means that one needs less m^2 in order to store one pallet. This calculation is done for every single part number, and for each strategy.

At the end of this analysis, the best top five results are highlighted, and the corresponding five best strategies are identified.

Then it is necessary to simulate the allocation of all goods in the best identified strategy. However, one cannot forget that it is not possible to store items in all locations. The abovementioned restrictions must be taken into consideration. Therefore, it is necessary to see what bin, out of the possible locations, has that best storage strategy and to select it.

After theoretically placing all products in bins with the best identified strategy, it is important to take a closer look at the percentage of storage usage, in order to check if it is really viable to store goods in the best theoretically calculated option. To do so, Equation 4 should be followed.

$$\% \text{ storage usage (pallets)} = \frac{\text{Capacity (in no. of pallets)}}{\text{No. of pallets allocated to that bin}} \quad \text{Equation 4}$$

Sometimes, it is not possible to store all goods under the best theoretically identified strategy, as this would imply surpassing the possible capacity. Therefore, when there is not enough capacity for all goods to be stored in the best storage strategy, several interactive improvements are carried out, following an analysis by groups.

Firstly, the allocation of goods with heavy restrictions must be assured, and within this group of products, the ones with only one possible location have priority as they have no other space in which they may be stored. Then the other products with heavy constraints but more possible locations are allocated, following an ascending order of possible locations. Subsequently, goods without heavy restrictions should be analysed following an ascending order of possible locations.

In this line of thought, the first task is to see if it is possible to allocate goods in more than one bin. If it is not possible, the problem is solved in itself. Even if there is no capacity, since that is the only permitted space, goods should be allocated there.

If there is more than one bin where it possible to store goods, then, it is necessary to identify the best storage strategy. Afterwards, it is important to see if there is more than one bin, out of the possible ones, that has the best calculated storage strategy.

On the one hand, if there is more than one bin with the best storage strategy where the goods can be stored, the one with the highest capacity should be identified. Then it should be checked if it is possible to store all goods from that group in that bin. If this is the case, then the goods should be allocated to that bin.

If not, it is necessary to identify the next bin with the highest capacity and with that storage strategy. Then it is important to analyse if it is possible to store all goods there. If it is, goods should be allocated there. If not, then it is necessary to verify the combined capacity of the analysed bins. Afterwards it should be confirmed if it is possible to divide goods between the bin with the highest capacity and the other one which is being analysed.

If such is true, goods should be allocated to the analysed bins respecting the size of the lot, favouring the best storage strategy and trying to fill the bin with the highest capacity. In case it is not possible to divide between the bin with the highest capacity and the other previously analysed, it is necessary to check if there is another possible bin available in that storage strategy. If there is, the bin with the next highest capacity with that storage strategy should be identified and the same steps should be followed.

If there is no available one, other possible best storage strategies should be analysed. It is important to see if there is a next best storage strategy available. In case there is none, goods should be allocated to the analysed bins respecting the size of the lot, favouring the best storage strategy and there should be an attempt to fill the bins, ideally the ones with higher capacity.

If there is, the bin with the next best storage strategy should be identified and it should be confirmed if there is more than one bin with the next best storage strategy. If that is the case, the bin with the highest capacity and with that storage strategy should be identified and the following procedures should flow as mentioned above. If there is not, the capacity of that bin should be

analysed. If it is possible to store all goods in that bin, then that is the one which should be used. Otherwise, the combined capacity of the analysed bins should be evaluated, and the rest of the previously mentioned procedure should be followed.

On the other hand, if there is not more than one bin with the best storage strategy where the goods can be stored, the capacity of that bin should be analysed. Afterwards, it is necessary to evaluate if it is possible to store all of the goods in that bin. If this is the case, all goods from that group should be allocated to that bin. Otherwise, it is necessary to analyse the other storage strategies and evaluate if there is another available one, following the same line of thought.

The summarized decision flow can be seen in the flowchart of Figure 3.

At the starting point of this analysis, all goods should be allocated to the initial bin (determined in the top 5 analysis). Then, in each interaction, the space of the bin should take into consideration the goods already allocated. Moreover, the percentage of allocation of that bin should be calculated as the number of pallets already analysed and allocated to that bin, divided by the bin capacity.

If, after analysing all groups, the allocation is still uneven, one should try to balance the percentage of occupation by suggesting different locations (in a top down perspective) targeting the most saturated location in each interaction. To do so, the same procedure should be followed but the starting point should be the next-best bin available.

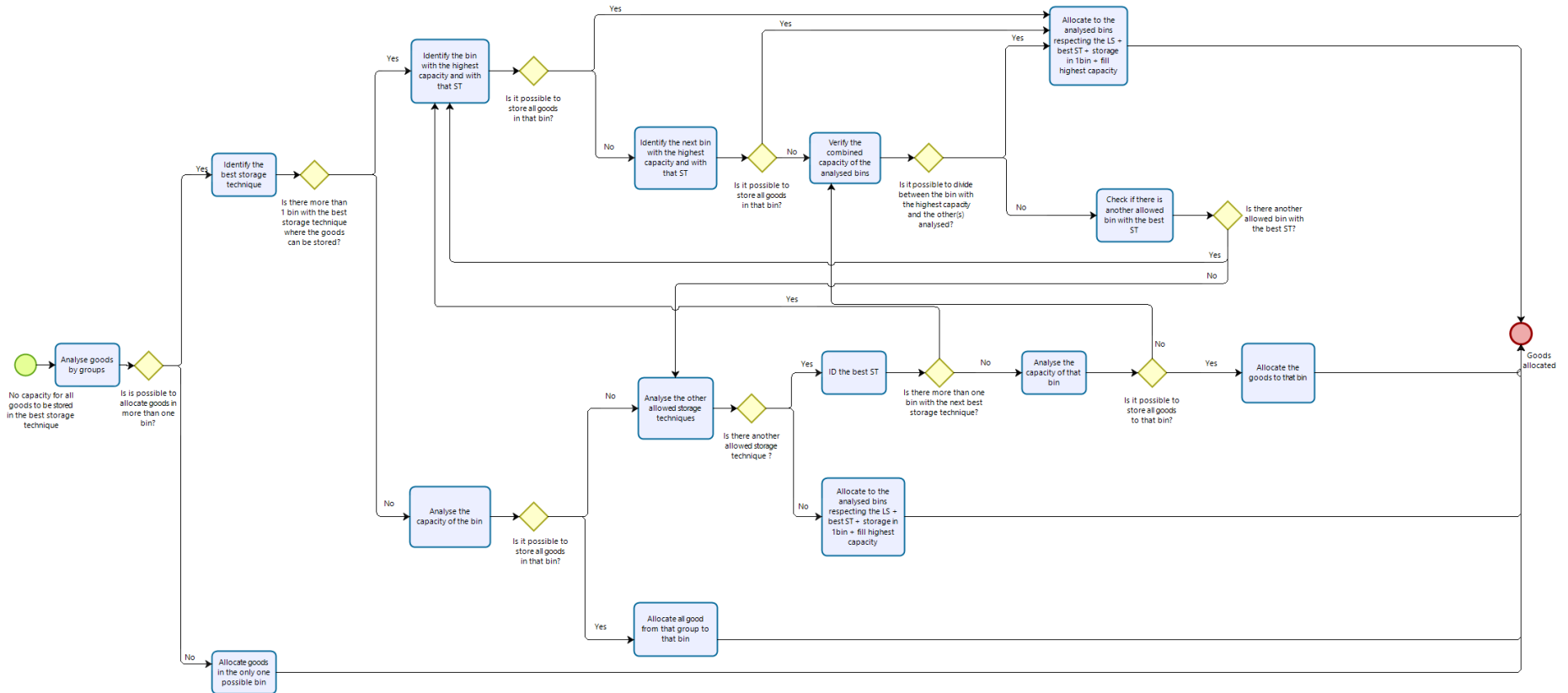


Figure 3 - Flowchart of “N” Company’s decision flow when there is no capacity to store goods

3.2. The author's suggested approach

With a clear understanding of the way "N" Company works, a different methodology is proposed based on identified opportunities for improvement. The idea is to take into consideration a volume approach while analysing the capacity of the warehouse. With this perspective in mind, an analysis of the warehouse should be conducted in order to increase the capacity of the plant. Moreover, products with more demand and higher rotation need to be closer to the exit. Thus, a new layout and approach to storage assignment emerges.

My suggestion has two scopes: the capacity and the allocation. Regarding the capacity a volume approach should be taken into consideration both in terms of the products and regarding the bins. Moreover, opportunities to achieve better space usage are presented by suggesting additional or different bins. In terms of allocation, my suggestion is to implement a class-based storage policy in which products have a random allocation in each class, using an ABC analysis. This should boost a high space utilization and decrease traveling distances as due to the considered volumetry, there should be more space in the ABC areas.

The goal of the suggested methodology is to reduce costs and traveling time (in this way also decreasing waiting time from production and customers). Furthermore, an increase in the capacity of the warehouse is expected. In a less tangible perspective, an increase in safety which is of extreme importance is also aimed at. Besides this, the new approach should be very visual so that it can reduce errors and should also help minimizing the damages caused to the items.

3.2.1. The author's suggested view on the warehouse capacity

In the "N" Company's approach a storage strategy is analysed, for each bin, by evaluating the number of pallets that can fit in that bin. This involves going to the shop floor, seeing the number of pallets that are stored and deciding what the optimal amount should be. This depends on the way the bin is divided.

However, by looking at Figure 4, it is possible to see that, depending on the type of material, and on the way goods are packed, the same bin can have different capacities. For instance, if one places big bags in the bin, then only one pallet can be stored. However, if one thinks about smaller bags, then two pallets can be allocated per level.



Figure 4 - Different capacities | Area vs volume

Therefore, it is vital to define the quantity, of each material, that could actually fit in the bins. So, a different approach which takes the volume into consideration is proposed. This analysis can be divided into three major tasks:

- 1) Calculation of the available volume in the bins
- 2) Determination of the volume of each material
- 3) Understanding how many goods can be stored in each bin

In order to calculate the available volume, firstly it is necessary to list all the possible locations. For each bin, the length, depth, and height should be registered. In this calculation, the dimensions of the bars (both lateral and longitudinal) and the safety distances previously mentioned, should be taken into consideration, and immediately deducted. It is important to note that each level can have different heights. High importance should be given to safety distances as these can have a profound impact both on the infrastructures and the employees.

Regarding the volume of each pallet of goods, the dimensions of the length, depth, and height of a full pallet of each material must also be known. Therefore, a corresponding type of pallet must be registered. It should be possible to extract this information out of SAP system. As this was not made available, 170 full pallets were measured one by one and a corresponding type of pallet was registered. Since it was not possible to measure the 743 references, with the list used from “N” Company’s methodology, the measures, and types of pallets of the remaining materials were extrapolated. These dimensions should be placed in SAP for future analysis.

In order to understand the number of pallets of each material that can fit per level in each bin, firstly it is necessary to divide the depth of the bins by the depth of a pallet full of those materials. Then, the width of the bin by the width of a pallet full of those materials. After that, it is important to divide the height of the bins by the height of a pallet full of those materials and round down each result. Afterwards, it is necessary to divide the depth of the bins by the width of a pallet full of those materials, the width of the bins by the depth of a pallet full of those and round down each result. This is possible as the company has adapted racks that allow pallets to be stored in a horizontal or vertical way (as shown in Figure 5 – images adapted from Paletes Madeira Isométrica (n.d.)).



Position A – vertical pallet

Position B – horizontal pallet

Figure 5 - Different ways to store a pallet

Afterwards, it is necessary to multiply, for both options, and for each level, the capacity in depth by the capacity in width and by the capacity in height of the level under analysis. By choosing the highest value between the two options, the capacity of each product in each location is determined.

3.2.2. The author's suggested view on the allocation assignment

After having a clear understanding of the space, it is important to understand what type of materials enter the warehouse and their relative importance.

In order to do so, the ABC analysis should be conducted. This allows the understanding of the relative importance of each group of materials. To do so, a list of all the materials that entered the warehouse should be provided, as well as their demand. The list should be organised in decreasing order of demand. With this information, the data should be divided into three groups: "A" with a demand of up to 80%, "B" with the next 15% of demand and "C" with the remaining 5%

After applying the ABC analysis, it is important to remember that there are some constraints, the heavy restrictions previously mentioned, that do need to be considered, as they refer to quality and/or safety matters. In fact:

- Liquid containers must be kept in LIQ for safety reasons
- Materials that need low temperature need to be stored in FRU or CMF for safety and quality motives
- Allergens and organic products need to be stored separately, for safety and quality purposes
- Chicory must be stored in a place that allows for the high height that these goods have

Bearing this in mind, it is essential to understand the type of materials that is being dealt with, taking this into consideration and further analysing any types of constraints associated to the product.

If goods are liquids, they should be allocated to LIQ (this is very visual as liquids are always stored in cubic containers). If products need low temperature, they should be allocated to FRU or CMF. These items are also transported under controlled temperature vehicles. Furthermore, there should be a separate and defined place to clearly separate allergens and organic items. Therefore, regarding the allergens, products with gluten should be stored in LBB, products with lactose should be allocated to BBH. As POPUP is a separate area in the warehouse that can be easily and visually divided into colours, organic products and goods with soy should be allocated to POPUP. An increase of demand regarding products with soy is expected as well as a decrease in demand of

products with lactose, so this information should be taken into consideration when analysing the allocation of materials to the bins. Hence, products with restrictions are stored in one specific space. Special attention should be given to chicory – the most expensive component - which needs to be allocated to Cores due to the height of its packaging. This is currently a space on the floor. As products should not be stored on the floor, there is a possibility to acquire Cantilever beams, a type of structure specially conceived to store these types of loads (Mecalux, n.d.). Therefore, it is suggested that Cantilever beams be added to the current plant.

If products do not have heavy restrictions, the ABC analysis (in terms of demand) should be applied. In case they are in the group in which demand is greater or equal to 80%, goods should be allocated to the A area. In case they are in the group that has up to 15% of demand, they should be allocated to the B area, and lastly, if they are in the remaining 5% of the group they should be allocated to the C area. Bearing these factors in mind, a new layout of the plant arises. A-area should have the bins closest to the entrance until all demand for A-products is fulfilled. B-area should have the next closest bins until demand of B products is fulfilled. The C-area should have the remaining space required. Afterwards, the allocation of goods should flow in accordance with this division.

Another important aspect is that the allocation of goods must be very visual. Therefore, each area should have a coloured line on the floor, representing the corresponding group. The summarized decision process can be seen in the flowchart of Figure 6.

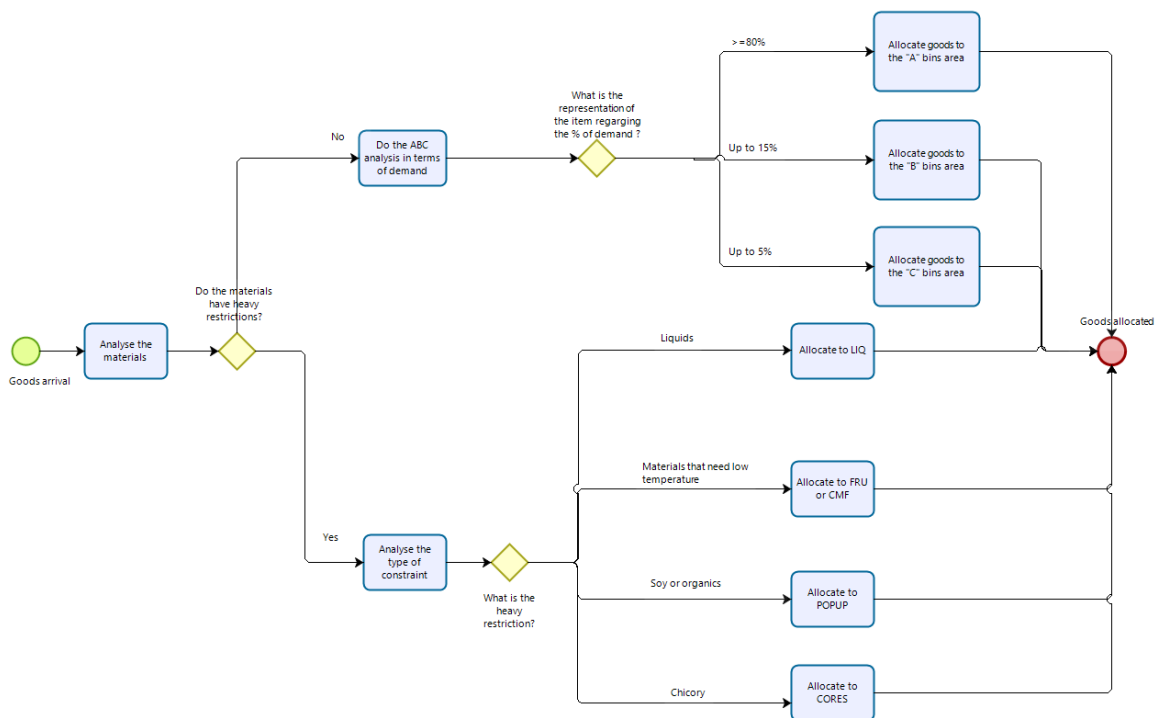


Figure 6 - Flowchart of a different allocation assignment

After allocating the goods to a group, there should be an analysis listing all the possible locations for the A, B and C products (the A, B and C zones respectively) as well as the locations of goods with heavy constraints. This list should also compare the demand of the products with the available space of the zone. It is important to ensure that there is enough space to store all goods from the group. By using a volume approach a more accurate understanding of space should be achieved.

3.3. Comparing ideas

To compare the solutions, firstly it is necessary to understand the average traveling distances. To do so, all the routes from the entrance until the exit, while passing by each location, should be highlighted in the plant. Then, the distances from each trajectory should be calculated. For every case, there should be a minimum and a maximum traveling distance.

In “N” Company’s approach there is a fixed location for each material, therefore, the traveling distance considered should be the average between the closest and the furthest part of the specific location. In the ABC methodology there is no specific place to store goods, but a set of possible locations within each group. Therefore, in order to calculate the average traveling distance, the average between the minimum and maximum traveling distance of each location should be calculated and, afterwards, an average of that should be considered as the average traveling distance for the zone. To quantify the improvements in terms of distances, a comparison between these results should be carried out.

4. RESULTS AND DISCUSSION

In this chapter the results are shown, taken from the Excel tool that was built by the author, and a discussion is carried out, in order to reach concrete solutions. For a clearer understanding of the analysis, results are shown in the same way as the research was followed. Therefore, firstly the findings of the “N” company are presented and afterwards the ones from the methodology proposed by the author are provided.

4.1. Results I “N” Company’s approach

In this section the results of the analysis of “N” company are presented.

4.1.1. Initial status

According to the current data, the warehouse of “N” Company has the capacity to store 5.137 pallets in the 668 modules, organized in 73 sets of bins distributed in 24 locations. To find out this information, it was necessary to go to the warehouse, to understand how the it was organised and to register, for each set of bins, the number of pallets that could fit in depth as well as the number of levels that each set of bins had.

According to the information extracted from SAP, in 2019, a variety of 743 different products entered the warehouse with an average of 5.261 pallets per month. As shown in Table 2, currently there is an overall occupation of 103,06% with bins that are very saturated, namely CAC, CMF, CPL, CXP, CXS, EST, GLU, MSK and ROT, highlighted in red in the table. Special attention should be given to EST, MSK and CPL as they show an occupation of above 200%, reaching the 630,58% These values do not take into consideration BLQ as this is reserved for products blocked for production (as they are out of date or not in the right quality), and information regarding these materials was not made available.

Table 2 - Current status of “N” Company I Occupation analysis

Location	No. Pallets allocated	Capacity of the location (No. of pallets)	% allocation of pallets
BBH	148	360	41,11%
CAC	307	276	111,23%
CMF	35	18	194,44%
Cores	68	96	70,83%
CPL	221	108	204,63%
CXP	877	490	178,98%
CXS	546	400	136,50%
DOS	38	46	82,61%
EST	1835	291	630,58%
FRU	54	240	22,50%
GLU	328	210	156,19%
GPQ	15	108	13,89%
LBB	285	510	55,88%

LIQ	55	252	21,83%
LSC	1	148	0,68%
MSK	134	63	212,70%
NEU	182	252	72,22%
NPQ	3	60	5,00%
POPUP	12	599	2,00%
RES	0	300	0,00%
ROT	90	63	142,86%
TPF	6	63	9,52%
UNI	21	152	13,82%
Total	5.261	5.105	103,06%
BLQ		32	

*Note: Cores is a space on the floor, not a set of bins

The warehouse under study stores raw and packaging materials. The warehouse is mainly organized with block stacking and drive-in bins that ensure that the last product entering the bins are the first ones to exit.

For a clear understanding of the way “N” Company was organised, the layout and organization of the warehouse was divided, as can be seen in Figure 7. Here it is possible to see the groups of bins according to the names they have. The light green arrows represent the entrance of goods. The darker green one symbolizes the exit of materials which feed the production lines. Goods can enter from the supplier’s trucks (as seen on the right), and they can also enter the warehouse from the factory, as leftovers from production (arrow on the left).

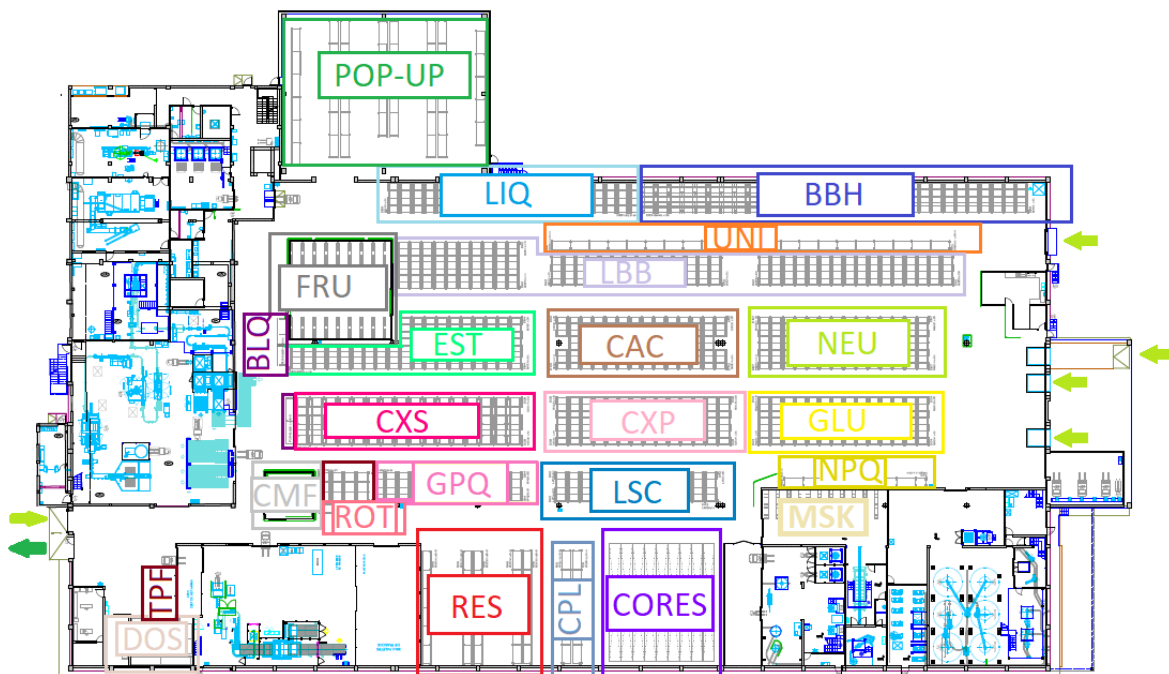


Figure 7 - “N” Company's layout

4.1.2. Improvement process

With the understanding of the flow of materials, “N” company’s improvement process was followed. This analysis was made easier with a tool that was built from the beginning in Excel.

In order to clarify the capacity that was seen, for each location the admissible storage strategies, the number of pallets and the number of modules were schematised in a table. The detailed analysis, is shown in Appendix A and can be summarized in Table 3:

Table 3 - Summary of the capacity and strategies of each location

Location	Admissible storage strategies			Capacity (regarding no. of pallets)	No. of modules
BBH	4x3			360	30
BLQ	1x3	1x4		32	9
CAC	2x3	3x3	4x3	276	28
CMF	1x2			18	9
Cores	12x1			96	8
CPL	1x4	1x5		108	24
CXP	3x5 §	4x5 §		490	28
CXS	2x5 §	3x5 §		400	32
DOS	1x2	1x3		46	16
EST	3x3	4x3		291	29
FRU	3x3	7x3		240	16
GLU	2x3	3x3		210	28
GPQ	1x3	2x3	3x3	108	20
LBB	2x3	3x3	4x3	510	50
LIQ	3x4§			252	21
LSC	1x4	2x3	4x4	148	23
MSK	3x3			63	7
NEU	3x3			252	28
NPQ	1x4			60	15
POPUP	1x4	1x5		599	133
RES	1x5			300	60
ROT	1x7			63	9
TPF	3x3			63	7
UNI	1x4			152	38
Total				5.137	668

Note: The symbol “§” means that there is a level in the bin with a different capacity from the other levels.

Then, the available area was analysed. In order to obtain this information bins were manually measured one by one in terms of length and width. The dimensions of the bars that supported the bins and the dimensions needed to ensure safety (in accordance to Table 1) were subsequently subtracted. The compiled analysis of the available space can be seen in Appendix B.

This information, was useful to understand the overall space, making it possible to determine the m² available for each strategy, as well as the m² necessary per number of pallets. This information is shown in Table 4:

Table 4 - Compiled information regarding the capacity of the warehouse

Strategy	No. of modules	m ² available for the strategy	m ² per number of pallets
1x2	11	2,69	0,45
1x3	26	32,18	1,34
1x4	146	144,07	2,40
1x7	9	8,85	1,26
2x3	46	152,15	5,07
2x5 §	16	59,44	5,94
3x3	109	423,54	3,62
3x4§	21	110,18	9,18
3x5 §	30	133,04	4,43
4x3	82	412,55	5,73
4x4	3	15,76	0,99
7x3	8	56,66	2,70
12x1	8	166,65	4,63
Total	668	1.918,6	53,37

Later, a list of all the goods that were stored in the warehouse in 2019 was extracted from SAP. With the help of the warehouse team, it was possible to identify the current location of the 743 references, as well as the characteristics of these goods. This was relevant to then divide goods into groups and to determine their current and possible locations. All the materials were divided into groups and, for each one of them, a set of admissible storage strategies and locations was determined. A part of this division can be seen in Appendix C.

Moreover, the total number of pallets and lots of each part number was defined based on historical data. With this information it was possible to calculate the average number of pallets and lots per month, as well as the average number of pallets per lot per month. These data were useful to then try to gather the amount of references in one bin. A part of this division is shown in Table 5:

Table 5 - Extract of proposals of locations

Material	No. of pallets	No. of lots	Average of pallets per month (rounded up)	Average of lots per month (rounded up)	Average of pallet per lot per month (rounded up)	Current location	Characteristics
27731131	3.033	158	253	14	20	GLU	Big Bags
27731148	1.323	48	111	4	28	NEU	Big Bags
27739313	1.088	40	91	4	28	MSK	Bags
43088896	1.029	47	86	4	22	LBB	Big Bags
43933062	428	20	36	2	22	EST	Flattened Boxes
43933061	411	21	35	2	20	EST	Flattened Boxes
43373007	398	150	34	13	3	EST	Boxes

Note: Some products are bought together, so as to take advantage of discounts. However, the detailed information regarding what products were under this situation was not made available.

With this information it was possible to determine the m² per stored pallet. This was calculated for each reference with the Excel tool. The tool is able to recognize the admissible storage strategies that were previously listed (with vlookup functions), and to calculate the m² per stored pallets as well as the percentage of storage bin utilisation as shown in APPENDIX D. Afterwards the best top 5 results and storage strategies are highlighted by the tool (with if, index and match functions). Subsequently, the tool suggests a storage location respecting the admissible storage strategies and locations (with index, match, indirect and address functions), as it can be seen in APPENDIX E.

Looking at the current status, 44,28% of the goods are stored in bins with the first best strategy, 46,57% in the second-best strategy, 8,75% in bins with the third best storage strategy and, lastly, 0,40% in locations with the fourth-best storage strategy. Moreover, no products should be stored in the fifth-best storage strategy and all goods have a location to go to. This can be easily seen in the graph of Figure 8.

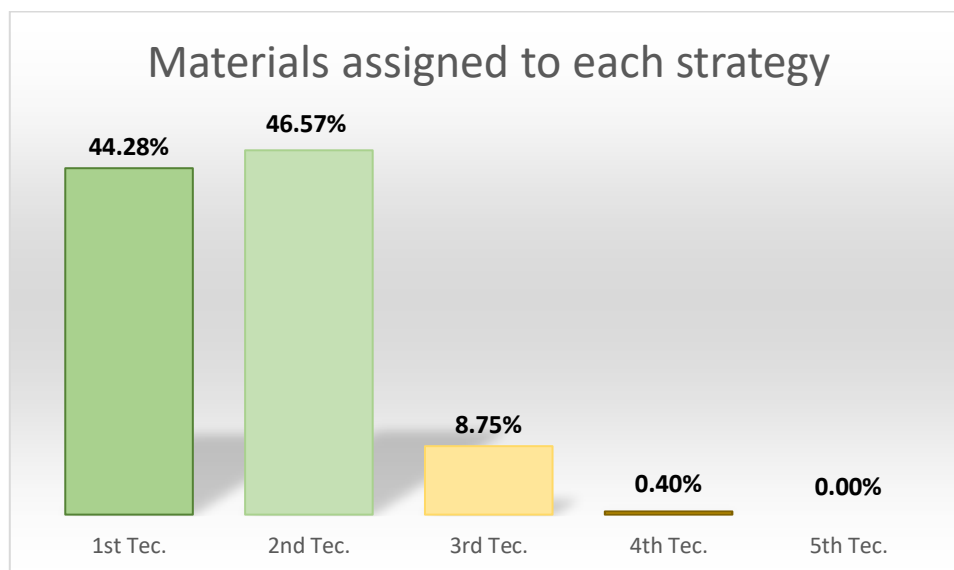


Figure 8 - Graph of the materials currently assigned to each strategy

Afterwards there was a simulation of the possibility of allocating all goods to the best identified strategy. However, it was necessary to calculate the percentage of storage usage (in terms of pallets), in order to check if it was realistic to allocate all goods to the first best identified storage strategy.

Allocating all items to the best calculated storage strategy would imply an exceeding of the storage capacity as shown in Table 6.

Table 6 - Analysis of the capacity of the bin | 1st best identified strategy

Location	No. of pallets allocated	Capacity of pallets in the location	% of allocation of pallets
BBH	60	360	16,67%
CAC	307	276	111,23%
CMF	35	18	194,44%
Cores	68	96	70,83%
CPL	53	108	49,07%
CXP	938	490	191,43%

CXS	2	400	0,0%
DOS	50	46	108,70%
EST	344	291	118,21%
FRU	54	240	22,50%
GLU	0	210	0,00%
GPQ	343	108	317,59%
LBB	38	510	7,45%
LIQ	55	252	21,83%
LSC	550	148	371,62%
MSK	0	63	0,00%
NEU	0	252	0,00%
NPQ	185	60	308,33%
POPOP	100	599	16,69%
RES	0	300	0,00%
ROT	90	63	142,86%
TPF	0	63	0,00%
UNI	1989	152	1.308,55%
Total	5.261	5.105	103,06%
BLQ		32	

Note: Red cells highlight an exceed in the capacity of the locations and white cells, under occupation. BLQ is reserved for blocked products and no data were provided regarding the average number of pallets.

Therefore, a set of interactive improvements were carried out, according to the decision process described in Figure 3. An example of this analysis are products with cocoa.

The first step consisted of identifying the allowed locations and strategies, as shown in APPENDIX C, and sorting the strategies from the best to the least good calculated one, as shown in Table 7.

Table 7 - Suggested strategies for products with cocoa

Material	Top 1 Location	Average no. Pallets/Month	Average no. Pallets/Lot	1 st Suggested strategy	2 nd Suggested strategy	3 rd Suggested strategy	4 th Suggested strategy	5 th Suggested strategy
27731178	CAC	15	10	3x3	2x3	12x1	4x3	
26310989	CAC	2	1	2x3	3x3	12x1	4x3	
27731149	CAC	4	2	2x3	3x3	12x1	4x3	
43337208	CAC	1	2	2x3	3x3	12x1	4x3	
43421325	CAC	1	3	2x3	3x3	12x1	4x3	
43751774	CAC	1	3	2x3	3x3	12x1	4x3	
43776780	CAC	1	1	2x3	3x3	12x1	4x3	
29000782	CAC	3	3	2x3	3x3	12x1	4x3	
43119215	CAC	3	3	2x3	3x3	12x1	4x3	
104490292	CAC	1	5	2x3	3x3	12x1	4x3	
43986122	CAC	1	1	2x3	3x3	12x1	4x3	

Afterwards, it was necessary to check the available capacity, as some goods had already been allocated, as shown in Table 8.

Table 8 - Available space

Admissible locations	Available capacity (in terms of pallets)
BBH	300
CAC	2
Cores	28
EST	0
TPF	10

As Table 7 shows, the first suggested strategy is 2x3, for all products except the first one (27731178). By looking at the example, it is possible to see that, despite being the bin with the best storage strategy, CAC did not have enough capacity to receive all products (only 2 pallets still available). Therefore, only part number 26310989 was allocated to CAC, filling that bin completely, respecting the lot size.

The next step was to try to allocate part number 27731178 to the first best storage technique calculated (3x3). By analysing the space, it was possible to see that, despite existing many locations with this storage strategy, only three were allowed (CAC, EST and TPF). This can be shown in Table 9, where grey cells symbolize the prohibited space for the articles, blue cells highlight strategy 3x3 in the available space and the pink cell is highlighting the storage strategy 2x3.

Table 9 - Analysis of the locations with the desired storage strategies

Location	Admissible storage strategies			Bin Capacity (regarding No. of pallets)	No. Of Modules
CAC	2x3	3x3	4x3	276	28
EST	3x3	4x3		291	29
FRU	3x3	7x3		240	16
GLU	2x3	3x3		210	28
GPQ	1x3	2x3	3x3	108	20
LBB	2x3	3x3	4x3	510	50
LSC	1x4	2x3	4x4	148	23
MSK	3x3			63	7
NEU	3x3			252	28
TPF	3x3			63	7

As CAC was already full, the other first best storage strategy (for part number 27731178) was analysed. From the allowed bins shown in Table 8, only TPF had available capacity. As it was necessary to respect the lot size, ten units of 27731178 were allocated to that bin. The remaining five, needed to be allocated to the next best storage strategy, as there were no more available bins with that one. The next best storage strategy was 2x3 but there were no more available bins. Therefore, the following best storage strategy was identified. From the available bins (BBH and Cores), only Cores had the storage strategy 12x1. Therefore, the remaining 5 units were allocated there. Regarding the other references, the same line of thought was followed. They were allocated to Cores as there were no more available bins with the storage strategy 3x3 and the following best storage strategy, 12x1, could only be found in Cores.

Table 10 - Analysis of "N" Company's allocation method

Location	No. Pallets allocated	Capacity (No. of pallets)	% allocation of pallets	Comment
BBH	60	360	16,67%	
CAC	276	276	100,00%	
CMF	18	18	100,00%	1.10 Separate - 7
Cores	89	96	92,71%	3.2. Separate +5
CPL	80	108	74,07%	
CXP	549	490	112,04%	
CXS	400	400	100,00%	
DOS	46	46	100,00%	
EST	291	291	100,00%	
FRU	71	240	29,58%	1.10 Separate +7
GLU	210	210	100,00%	1.8. Separate -53
GPQ	133	108	123,15%	1.8. Separate +53
LBB	209	510	40,98%	
LIQ	55	252	21,83%	
LSC	148	148	100,00%	
MSK	63	63	100,00%	
NEU	252	252	100,00%	
NPQ	60	60	100,00%	
POPUP	268	599	44,74%	
RES	0	300	0,00%	
ROT	63	63	100,00%	
TPF	63	63	100,00%	3.2. Separate -5
UNI	1857	152	1.221,71%	
Total	5.261	5.105	103,06%	
BLQ		32		

(*) Note: Green cells represent 100% of occupation, red cells highlight an exceed in the capacity of the locations and white cells under occupation. BLQ is reserved for blocked products and no data were provided regarding the average number of pallets.

Graphically, the occupation can be seen in the graph of Figure 9:

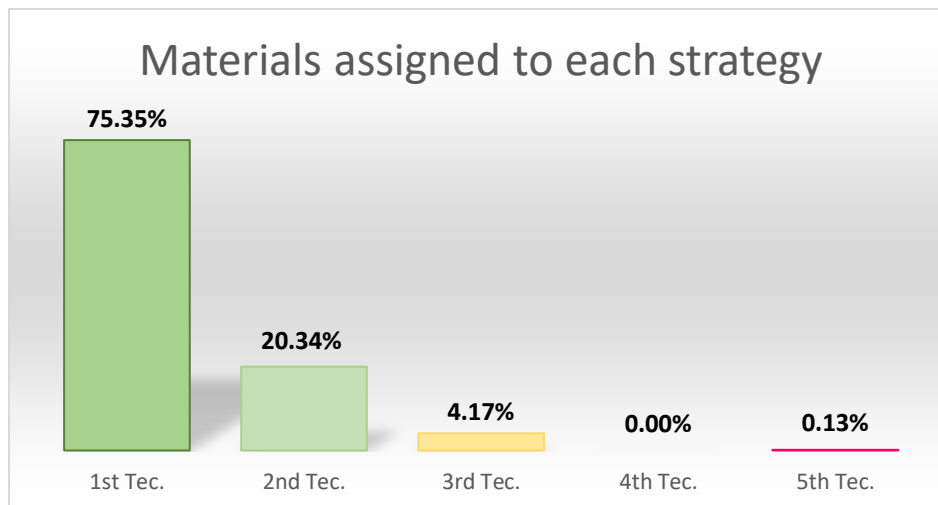


Figure 9 - Graph of the materials assigned to each strategy with the "N" Company's process

Note: Sum equals 99,99% due to rounding

As can be seen, 75,35% of the goods were allocated to the best strategy, 20,34% to the second best one, 4,17% to the third best one and 0,13% to the fifth best one. There were no goods without destination, neither allocated to the fourth best strategy.

However, it is possible to see that there is an overload of bins, namely CXP, GPQ and UNI. Therefore, a second set of interactions were carried out in an attempt to balance the percentage of occupation of the different locations, following a top down analysis.

The most occupied location was UNI with 1.221,71% of occupation Therefore, it was necessary to evaluate all the possible locations for products allocated to UNI, following the same procedure as in Figure 3, but looking for other bins, rather than UNI.

So, for instance, by analysing the group of materials stored in bags that were allocated to UNI, it was necessary to check if there were other allowed bins and with available space. As the admissible locations were only POPUP and UNI, and there was still available space in POPUP, these materials were allocated to POPUP (as shown in Table 11).

Table 11 - Further analysis on UNI

Location according to top 1	New proposed location	Material (bags)	No. Pallets/ Month	Pallets/ Lot	1st Suggested strategy	2 nd Suggested strategy	3 rd Suggested strategy
UNI	POPUP	43321462	3	2	1x4	1x5	
UNI	POPUP	27731215	1	1	1x4	1x5	
UNI	POPUP	27731133	1	1	1x4	1x5	
UNI	POPUP	27837311	1	1	1x4	1x5	
UNI	POPUP	27731506	1	2	1x4	1x5	
UNI	POPUP	41071848	1	3	1x4	1x5	
UNI	POPUP	41031206	1	1	1x4	1x5	

The final set of allocations to UNI can be consulted in APPENDIX F.

After all bins were analysed it was possible to see that, with the restrictions regarding locations, it was not possible to have a balanced allocation of goods. APPENDIX G shows the register of some of the changes that were carried out. As it is possible to see in Table 12, after the changes, there was an exceeding of capacity in CPX, GPQ, POPUP and UNI.

In fact, there was a decrease in the most saturated location, in comparison to the previous status. However, a new bin (POPUP) was overloaded, and UNI continued to have an excessively high occupation.

Table 12 - Final allocation of goods | “N” Company’s process (analysis of the locations)

Location	No. Pallets allocated	Capacity (No. of pallets)	% allocation of pallets (*)	Comment
BBH	60	360	16,67%	
CAC	276	276	100,00%	
CMF	18	18	100,00%	1.10 Separate - 7
Cores	89	96	92,71%	3.2. Separate +5
CPL	80	108	74,07%	
CXP	549	490	112,04%	

CXS	391	400	97,75%	
DOS	46	46	100,00%	
EST	291	291	100,00%	
FRU	71	240	29,58%	1.10 Separate +7
GLU	210	210	100,00%	1.8. Separate -53
GPQ	133	108	123,15%	1.8. Separate +53
LBB	510	510	100,00%	
LIQ	55	252	21,83%	
LSC	148	148	100,00%	
MSK	63	63	100,00%	
NEU	125	252	49,60%	
NPQ	60	60	100,00%	
POPUP	676	599	112,85%	
RES	0	300	0,00%	
ROT	63	63	100,00%	
TPF	63	63	100,00%	3.2. Separate -5
UNI	1284	152	844,74%	
Total	5239	5.105	103,06%	
BLQ		32		

(*) Note: Green cells represent 100% of occupation, red cells highlight an exceed in the capacity of the location and white cells under occupation. BLQ is reserved for blocked products and no data were provided regarding the average number of pallets

By looking at the graph of Figure 10, that analyses the storage strategies, it is possible to see that all products were allocated to the first, second or third-best storage strategy (61,76%, 34,04% and 4,17% respectively), demonstrating an improvement when compared with the previous situation.

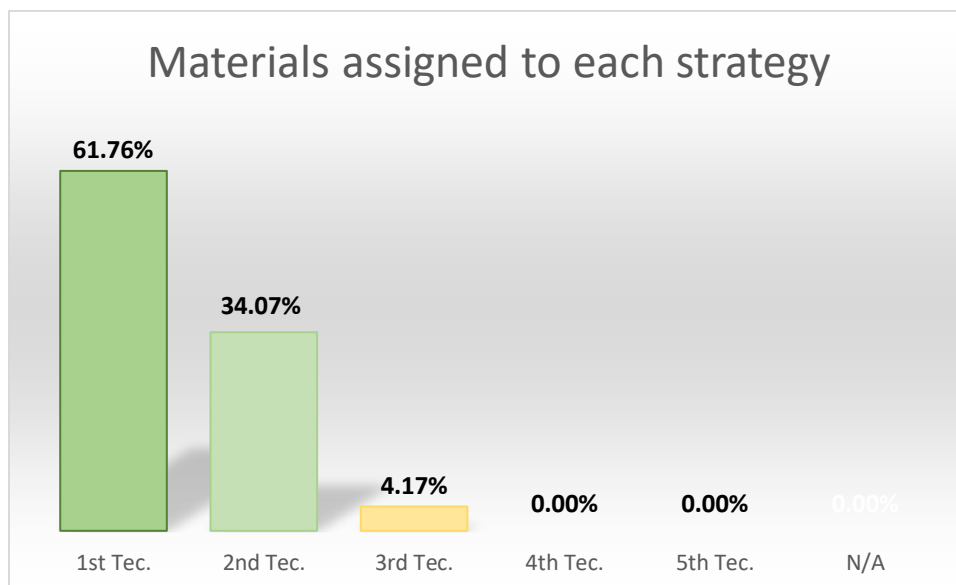


Figure 10 – Graph of the final allocation of goods I “N” Company’s process

4.2. Results: the author's suggested methodology

For comparative purposes, the findings of the analysis of the "N" company are highlighted.

4.2.1. The author's suggested way to analyse the capacity

As mentioned in chapter 3.2, there seemed to be space for improvement regarding the analysis of the capacity of the warehouse.

Bearing this in mind, in order to quantify the capacity of the warehouse, instead of taking into consideration the available area, or capacity in terms of pallets, it was decided to take the volume into consideration. To do so, it was necessary to find out the volume of the materials, of the bins and then, to calculate their capacity.

As stated in chapter 3.2, since these dimensions of the materials were not made available, 170 items were measured. The dimensions of the remaining 573 materials, as well as the type of pallets that supported them, were extrapolated in accordance with the grouping done together with the warehouse team. APPENDIX H shows a part of this analysis. This study led to the conclusion that there was a need of 8.618,150 m³ per month to store the goods.

Considering the bins, APPENDIX I shows a part of the analysis of the available space of the bins (despite only the first level being shown, all levels for each bin were analysed, leading to the volume that is shown in the last column). The total calculated available volume of the warehouse is 11.015,42 m³ (BLQ is not being taken into consideration as no data were provided regarding blocked products and the company did not want to change this location).

In this analysis, high importance was given to the factor of safety. Much more than simply taking into consideration these measures, it was very important to make it easy for the warehouse team to perceive the maximum height up to which the goods could safely be stored. In an attempt to make this very visual, and easy to respect, a red ribbon was placed on the bins, highlighting the maximum height permitted, as can be seen in Figure 4.

In this manner, it was possible to analyse the capacity of the warehouse per product by building a tool in Excel. In APPENDIX J it is possible to see an analysis of the capacity of bins BBH01 to BBH13 (as an illustrative example), where safety distances are already taken into consideration. The process is shown in the five tables. The summary of the content of Table 1 from APPENDIX J can be found in Table 13, the summary of the content of Table 2 from APPENDIX J can be seen in Table 14 and the brief of Table 3 and table 4 from APPENDIX J is shown in Table 15.

Table 13 - Summary of Table 1 (APPENDIX J)

	Compares	With	In order to know
Table 1 (APPENDIX J)	Depth of the bin	Depth of each product	Capacity in terms of depth with option 1
	Width of the bin	Width of each product	Capacity in terms of width with option 1
	Height of the bin	Height of each product	Capacity in terms of height with option 1

Table 14 - Summary of Table 2 (APPENDIX J)

	Compares	With	In order to know
Table 2 (APPENDIX J)	Depth of the bin	Width of each product	Capacity in terms of depth with option 2
	Width of the bin	Depth of each product	Capacity in terms of width with option 2
	Height of the bin	Height of each product	Capacity in terms of height with option 2

In these two options, comparisons are made by dividing the dimensions of the bins by the dimensions of the products.

Table 15 - Summary of Table 3 and Table 4 (APPENDIX J)

	Compares	With	And	In order to calculate
Table 3 (APPENDIX J)	Capacity in terms of depth in option 1	Capacity in terms of width in option 1	Capacity in terms of height in option 1	Maximum quantity of each product in that bin with option 1
Table 4 (APPENDIX J)	Capacity in terms of depth with option 2	Capacity in terms of width with option 2	Capacity in terms of height with option 2	Maximum quantity of each product in that bin with option 2

These comparisons are made taking into consideration the product of each option.

Lastly, Table 16 compares the maximum of each result from Table 3 and Table 4, in order to find out the maximum value, that is, the maximum capacity of the bin per product.

Table 16 - Capacity of BBH01 - BBH13

Material	BBH01 - BBH13								
	Bin	Module	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
43289601	156	12	6	3	3	0	0	0	0
43665770	156	12	6	3	3	0	0	0	0
43774482	156	12	6	3	3	0	0	0	0
43826067	117	9	3	3	3	0	0	0	0
27836148	117	9	3	3	3	0	0	0	0
43538225	117	9	3	3	3	0	0	0	0
43735292	78	6	2	2	2	0	0	0	0
40515604	0	0	0	0	0	0	0	0	0

Thus, it was possible to find out which materials and in what amount could fit in each bin.

4.2.2. The author's suggested approach: know your space

Every day, there was an amount of materials that were sent to an external warehouse. This represents an extra cost for the company. Unfortunately, for reasons of confidentiality, the information regarding the number of products or amount spent with this external warehouse was not made available for this research. However, it was possible to see that there was not enough capacity to store all goods. Therefore, a study of the current layout was conducted.

Bearing the safety distances in mind, it was possible to see that there was a possibility to add seven more bins (highlighted with green arrows in Figure 11). These bins (Extra bin A1.1, Extra bin A1.2 and Extra bin C), would add an extra available space of 160,16 m³ increasing the overall capacity by 1,45%.

Moreover, Cores is currently a space on the floor because there are no bins with enough height to store chicory. Therefore, the acquisition of Cantilever beams, is proposed. The orange arrows in Figure 11 highlight the simulation of these bins. With this, the available space of the location would increase from 230,40 m³ to 1.119,74 m³, an increase of 386% of the capacity of the location and 8,07% of the overall capacity.

Another aspect is to change ROT transforming the seven levels into four, reducing the height of each. If such were possible, the available volume of ROT would increase from 37,61 m³ to 55,10 m³, an increase of 46,50% of the location and 0,16% of the overall capacity.

All these changes would represent an overall increase of capacity of 9,77% (1.066,99 m³).

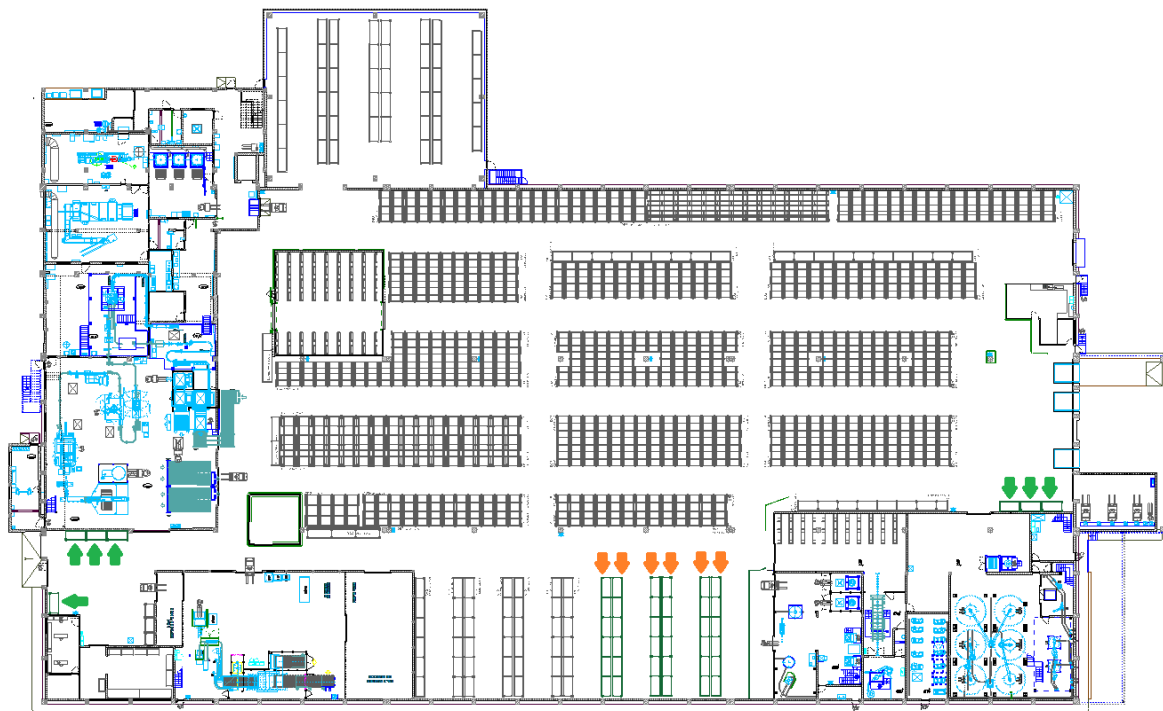


Figure 11 - A different look at the capacity: layout

4.2.3. The author's suggested way to group goods

Having acquired this new perspective of the capacity of the warehouse, the allocation of goods was conducted.

Based on the literature research, and with the goal of reducing traveling time, a new perspective arose, with the suggestion of grouping goods according to their demand. In order to do so, the ABC analysis was carried out, in accordance with chapter 3.2.

Goods were sorted in a decreasing order of demand and then gathered in three classes. APPENDIX K shows an excerpt of this analysis. Class A, gathers products with up to 80,42% of demand, class B, with 15,08% and class C with the remaining 4,50%, as can be seen in Figure 12.

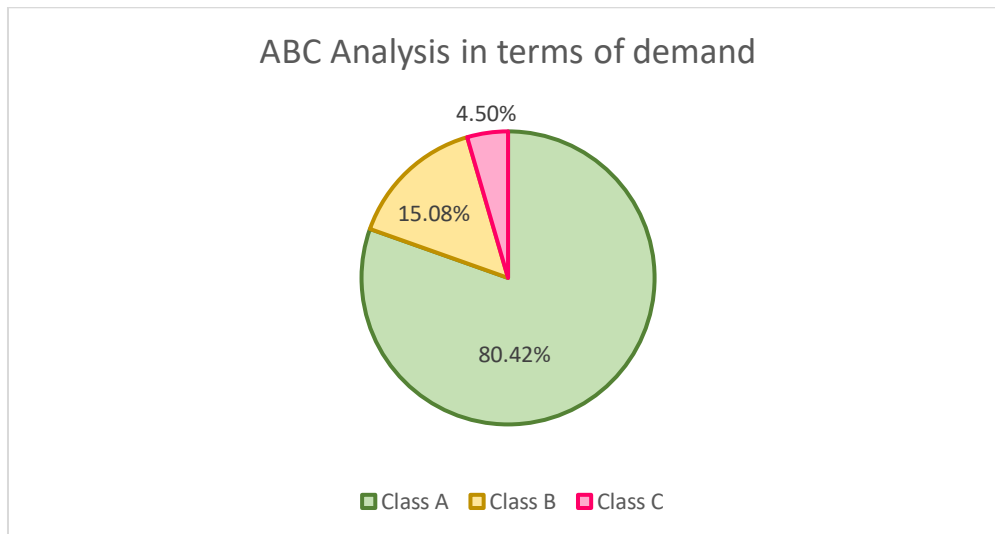


Figure 12 – Graph of the ABC analysis in terms of demand

In another perspective, by analysing the weight in terms of variety of products, it is possible to see, by looking at Table 17, that class A gathers 24,90% of the diversity of products and class B, 43,34% of the variety of articles. Lastly, class C receives 31,76% of the goods.

Table 17 - Weight regarding demand and variety of products

Class	Weight regarding demand	Weight regarding variety of products
A	80,42%	24,90%
B	15,08%	43,34%
C	4,50%	31,76%

4.2.4. The author's suggested approach: new allocation

With the knowledge of the capacity of the warehouse from the perspective of the volume and having the new perception of the layout in mind, it was necessary to allocate goods to the locations. To do so, the decision process shown in Figure 13 was respected. Thus, a new distribution of the warehouse arose. Some constraints, the ones previously entitled as heavy restrictions, had to be kept and were respected.

As can be seen in Figure 13, there is a clear division of the space. Apart from chicory, that needs a specific type of bin, and materials that need low temperature, all goods with heavy restrictions (represented in blue) should be stored on the upper part of the plant in Figure 13.

A-products are closer to the exit (delimited by the green line) and B-products are closer to the entrance (within the yellow line). C goods are further away (as the red box shows). For an even clearer division of the plant, a line on the floor should be painted. Each colour should represent a specific group.

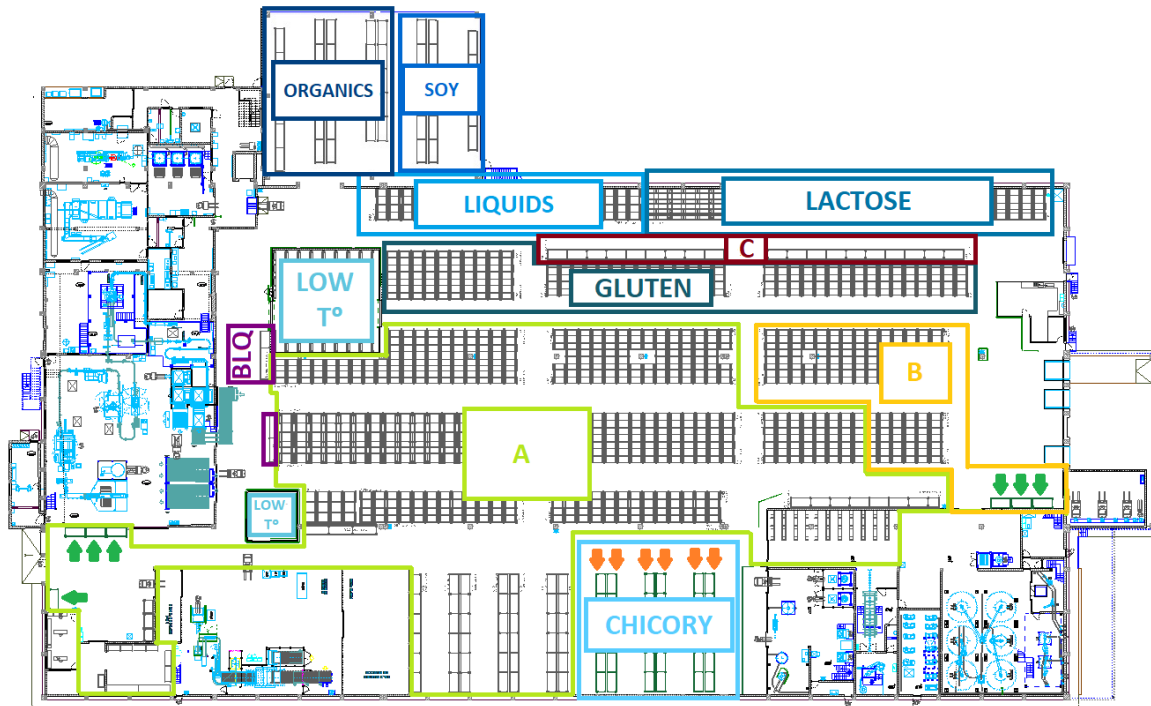


Figure 13 - New layout

Considering the capacity, on the one hand, there are 5.229,08 m³ available for A-products, 980,522 m³ ready to receive B-items and 236,877 m³ for the C-products. On the other hand, there is a need of 5.022,668 m³ of A-items, 968,637 m³ for B-products and 167,965 m³ for C-goods. Furthermore, there are 549,532 m³ available to receive organic products and a need for 354,620 m³ for these goods. Regarding products with soy, there is a space of 308,758 m³ and a need for 80,350 m³. As previously mentioned, there is a forecast of an increase in demand for these products. Furthermore, there are 891,472 m³ available for products with lactose, 687,074 m³ for liquids, 1.612,696 m³ for gluten, 475,888 m³ for products that need low temperature and 1.119,744 m³ for chicory. Furthermore, there is a demand for 785,520 m³ for products with lactose, 79,050 m³ for goods with liquids, 858,550 m³ for items with gluten, 97,210 m³ for goods that need low temperature and 203,580 m³ for chicory. Lastly there is an available space of 38,629 m³ ready to store blocked products.

The complete analysis of the division can be seen in Table 18

Table 18 - Analysis of the ABC allocation (capacity)

Group	Locations	Available space in the location (m ³)	Sum of the volume of products of the group (m ³)	Occupation
A	DOS	43,334	5.022,668	96,05%
	TPF	178,366		
	Extra bins A.1	22,879		
	Extra bins A.2	68,638		
	ROT	55,100		
	GPQ	413,564		
	RES	372,444		
	CPL	151,097		
	LSC	293,578		
	MSK	187,679		
	NPQ	126,985		
	CXS	752,829		
	CXP	821,407		
	EST	668,992		
	CAC	623,549		
GLU	448,639			
Subtotal A		5.229,080		
B	GLU	261,000	968,637	98,79%
	NEU	650,884		
	Extra bins C	68,638		
Subtotal B		980,522		
C	UNI	236,877	167,965	70,91%
POPUP Organics	POPUP	549,532	354,620	41,32%
POPUP Soy	POPUP	308,758	80,350	9,36%
Lactose	BBH	891,472	785,520	88,11%
Liquids	LIQ	687,074	79,050	8,87%
Gluten	LBB	1.612,696	858,550	96,31%
Low temperature	FRU + CMF	475,888	97,210	10,90%
Chicory	CORES	1.119,744	203,580	22,84%
Total		12.091,629	8.618,150	71,27%
BLQ		38,629		

Note: In this analysis, the demanded volume of organics, soy, lactose, liquids, gluten, chicory and products that require low temperature were deducted from the needs of groups A, B and C. BLQ was not taken into consideration as it needs to be reserved for blocked products of which information was not made available

It is possible to see that on average, there should be an occupation of 96,05% of the A-zone, 98,79% of the B-region and 70,91% of the C-location. Regarding the bins with special goods (the ones with the heavy restrictions), there is an average of 41,32% of occupation of POPUP Organics and only 9,36 % of POPUP Soy. This is favourable as it is expected that in the (near) future the demand for this type of products will increase. Moreover, there is an average occupation of 88,11% of Lactose, 8,87% of the Liquids, 96,31% of the Gluten location, 10,90% of the low temperature zone and

22,84% of the Chicory location. BLQ was not considered in this analysis because there were no data related to the average need of these types of products.

In the current situation, it is possible to see an overall available space of 12.091,629 m³ (12.130,271 m³ if BLQ is considered) and an overall average demand of 8.618,150 m³, leading to an overall occupation of 71,27%

4.3. Discussion of results

This study tries to make the warehouse an opportunity for competitive advantage in accordance with Farahani et al. (2011) and Zenieris (2014). As seen before, customers are more demanding than ever (Hyken, 2016). Therefore, organizations need to keep identifying their weaknesses and to think about ways to convert them into opportunities. This research has shown a possibility for improvement regarding several aspects, namely costs and time, which allows companies to boost competitiveness. It is possible to analyse results in terms of capacity and allocation methods.

One of the beginning points in “N” Company’s methodology is to understand the number of bins that exist and the quantity of pallets that can fit in each bin. However, this analysis can be biased.

As shown in Figure 4, the number of pallets that can fit in each location is dependent on the material that is stored in that place on the day of the analysis. As it was possible to see in the BBH example (Table 16), depending on the type of materials, a different number of products could be stored. In fact, storing goods according to the way they are packed, to the characteristics they have, or both has led to an uneven occupation of the bins, which has been mathematically proved.

Moreover, in “N” Company’s analysis, some of the acquired information was based on human knowledge namely the usual location of the goods and the characteristics they had. According to the proposed solution all this information should be documented (dimension, weight of the products and relevant restrictions) and based on data that come from the supplier. This leads to more accurate information.

Another aspect is that “N” Company’s approach has several restrictions, which leads to an increase in the probability of error. The proposed solution is more user friendly as it is easier to treat data and to make decisions. The core information that my solution presents (ABC analysis in terms of demand) can be done almost automatically without further costs with the help of Excel.

In the initial situation, it was possible to see that several locations were saturated, with some surpassing 200% of occupation (EST, MSK and CPL). Regarding the bin occupation, in the initial status, there was a bin occupation of 103,06% With the proposed solution, the occupation of the bins is 71,27% This is due to the possibility of storing several goods in the same bin.

“N” Company’s methodology contributed to an increase of allocation of materials to the first best storage strategy (followed by an allocation to the second and third best storage strategy). From the nine over-occupied bins only four continued to exceed the allocation capacity. Moreover, eleven bins had 100% of theoretical allocation. While some bins continued to be overloaded (with occupations up to 844,74%), others had no goods at all, or an occupation under 50%. On a daily basis, this leads to the storage of goods in other locations that are assumed as not allowed. With some locations being overloaded and with goods stored in other prohibited locations, more

damages in the bins occur. This has led to the blocking of 12% of the bins, increasing the need to store goods in another warehouse outside of the firm and fostering a vicious circle.

In order to solve this problem, the proposed methodology has suggested a critical view of the layout of the warehouse. This has led to several changes and had impact in costs and service level, in accordance to what was defended by several authors (Zhang, 2017), (Bowlby et al., 1984), (Grant & Fernie, 2008), (Cagliano et al., 2011), (Bottani et al., 2012), (Battista et al., 2014).

On the one hand there was an increase in the available space to store goods. To accomplish this, the addition of seven more bins (Extra bin A1.1, Extra bin A1.2 and Extra bin C) was suggested.

Moreover, by proposing the acquisition of Cantilever beams, it is possible to store goods with several dimensions in more than one level and to gain an increase in safety. An extra advantage of this solution is that any load would be able to be collected. In the current status, as the materials are stored in line, if the materials needed are the ones at the end of the line, other products, either from the sides or in front, need to be removed and then, placed again. With this solution, it is possible to choose the materials that are needed and directly remove them (saving time and preventing damages). The budget for the acquisition of these structures (considered in the analysis), varies between a total of 9.936€ and 17.064€ depending on the brand and quality of the infrastructure.

Moreover, a change in the bins was also proposed. ROT has a structure with many levels, but each level has very little height. The proposal of altering the number of levels of these bins from seven to four would, however, require the approval of legal authorities that would need to go to the field and evaluate the risk of the change in terms of safety. Also, although the degree of material damages was not made available, since the materials stored in CORES are the most expensive ones, this solution would represent a decrease in costs.

On the other hand, a new allocation method was suggested: a class-based storage policy in which products have a random allocation in each class, using an ABC analysis. In order to compare methodologies, a simulation of all trajectories from the entrance to each bin and from each bin to the exit was carried out to find out the minimum and maximum traveling distance required as shown in Figure 14.

The overall analysis shows that while in “N” Company’s method, on average, there is a need to travel 957,88 km per month, with the new proposed method this number would be reduced to 927,93 km per month, which is a decrease of 29,96 km per month. An excerpt of the analysis of the impact of these changes can be seen in Table 19.

Table 19 - Excerpt from the comparison of both methodologies

Material ID	ABC	Current situation		“N” Company's method		Proposed method (ABC)	
		Location	Average distance per month (m)	Location	Average distance per month (m)	Location	Average distance per month (m)
43897428	A	CORES	1.529,28	CORES	1.529,28	CHICORY	1.529,28
40527748	A	LBB	1.894,80	LBB	1.894,80	LACTOSE	1.841,10
43518547	B	NEU	876,15	NPQ	834,30	POPOP ORGANICS	1.038,30
27731164	C	LIQ	177,18	LIQ	177,18	LIQUIDS	177,18
		Total (m)	949.613,52		957.887,49		927.932,12

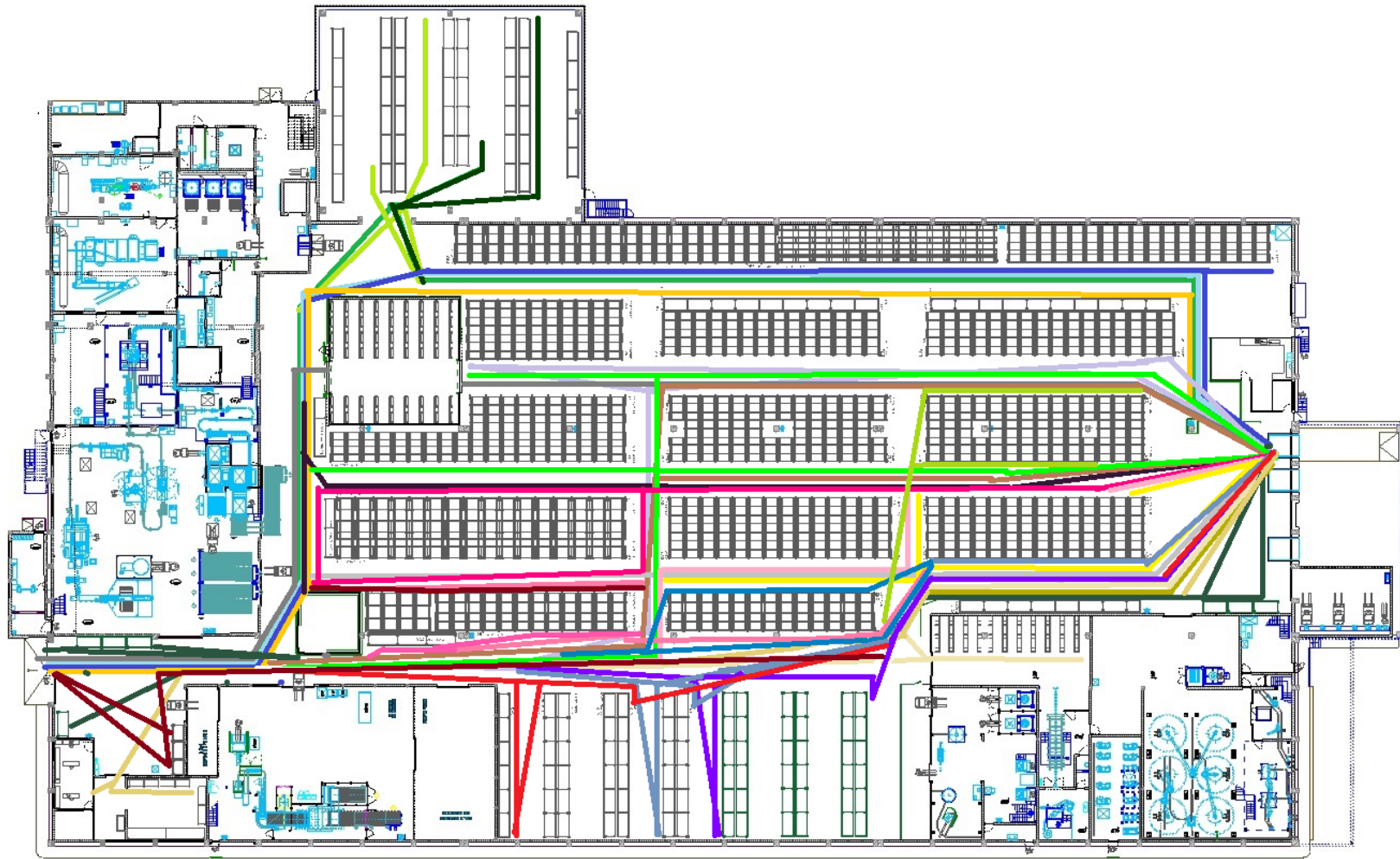


Figure 14 - Study of movements (minimum and maximum distance)

Taking into consideration that in the company, a forklift travels at an average of 8 km/hour, the application of the proposed method would represent a decrease of 2,71 hours per month (approximately 2 hours and 43 minutes). This represents a saving of 32,52 hours per year (approximately 32 hours and 31 minutes). As the company uses temporary workers, this could represent a decrease in one person for four days (and 2,52 hours).

In short, regarding the improvements in capacity, one of the greatest advantages that this solution permits is an increase in the storage capacity, allowing for an additional 12 bins and an overall increase of 9,77% in the storage capacity. Regarding the suggestion of a different storage policy, this leads to savings of 32,52 hours per year.

In this analysis, however, it would also be possible to add the savings regarding the materials that would not be damaged as well as the savings that would be achieved in not having to send goods to the external warehouse (both in terms of traveling distances and renting costs). These costs are considerable but were not made available for confidential reasons.

It is also possible to gain an increase in security. Despite being hard to quantify the safety level, during the six months of study there was a near accident because the height of the products was not taken into consideration. The proposed solution overcomes this both by bearing in mind the height when calculating the bin capacity and by adding a ribbon highlighting the maximum allowed height.

5. CONCLUSION

In this chapter, the conclusions of the dissertation are presented, limitations are identified, and further research is suggested.

5.1. Final conclusions

The goal of the study was to find ways to increase an agile flow of materials in a warehouse while comparing different methodologies and this was achieved.

To achieve the goal, firstly, a detailed literature review was held. Chapter 2 allowed to understand relevant aspects for the study, namely the value of a solid and functional supply network and the important role of warehouses as a source of competitive advantage. This chapter also helped to understand the methods and the problem under focus. Chapter 3 details how the methods were used. After understanding how the company worked, and identifying some opportunities for improvements, it was necessary to analyse both perspectives in a systematic and quantified way. Bearing this in mind, a tool was built in Excel making it possible to quantify results of both perspectives and to compare them. Firstly, data were obtained, which meant getting familiar with SAP system, getting in touch with several people from different areas of the factory and also going to the warehouse to measure some items. After gathering data, these had to be treated. As there was no tool available, a new one was made from the beginning in Excel. This tool can now be used for future analysis just by introducing updated data in Excel. Suggestions were proposed in terms of the way that the capacity can be analysed, the layout and the storage strategies. Finally, chapter 4 presents results, and compares both perspectives.

This project analyses two different methodologies: the “N” Company’s methodology and a different one, made by the author that emerges as a result of the identified opportunities for improvement. This last one can be divided in two main areas: the capacity and the allocation. On the one hand, looking in the capacity, there is a suggestion to follow a volume approach rather than the area. Thus, some suggestions to increase capacity of the space are carried out by suggestion addition of bins or changes in the existing ones. On the other hand, a change in allocation method is also carried out. Therefore, a class-based storage policy in which products have a random allocation in each class, using an ABC analysis is suggested.

Initially it was necessary to understand the flow of “N” company and how it was organized. The company had the capacity to store 5.137 pallets in 668 modules, that were organized in 73 sets of bins and 24 different locations. To find out this information, it was necessary to go to the field and analyse, for each set of bins, the number of pallets that could fit in depth and the number of levels that each set of bins had. According to the information extracted from SAP, in 2019 a variety of 743 different products entered the warehouse with an average of 5.261 pallets per month. Excluding a location reserved for blocked products for which no data were provided, the warehouse had an occupation of 103,06% In order to better understand the flow of materials, the layout was designed highlighting the existing organization of bins as well as the flow of the materials. Afterwards, it was necessary to see how the firm’s improvement process was conducted. To do so, an Excel tool was built.

It was important to know the available space. To make this clear a table was built summarizing the admissible storage strategies, the number of pallets and the number of modules that were seen in the warehouse. To get a better understanding of the available space, the available area was determined.

Having a better understanding of the space, it was required to know more about the materials that entered the warehouse, namely the characteristics of the goods and the way they were packed. This information was obtained with the knowledge of workers. Together with the warehouse team, goods were grouped according to the characteristics they had, to the way they were packed or both. For each group, a set of possible locations was defined (and subsequently the correspondent admissible storage strategies were attributed). Afterwards, for each material the information regarding number of pallets, lots and pallets per lot was compiled and the current location was attributed, in accordance with the characteristics the goods presented.

Then there was a study of the m^2 per stored pallets. For each part number, the Excel tool was able to recognize the admissible storage strategies that were previously listed (with vlookup functions), to calculate the m^2 per stored pallets and the percentage of storage bin utilisation. Afterwards the best top 5 results and storage strategies were highlighted by the tool (with if, index and match functions). With this, the tool suggested a storage location respecting the admissible storage strategies and locations (with index, match, indirect and address functions). This led to the simulation of allocating all goods to the best calculated storage strategy. Doing so proved not to be feasible as the percentage of storage usage of some locations surpassed 100% and it could go up to 1.308,55%. It was then necessary to make two sets of interactive improvements: one to allocate goods to the best strategies respecting a set of rules, and a second one that aimed to balance the percentage of occupation of the different locations. Both processes were manual (yet also carried out in Excel), and required a thorough analysis case by case, taking into consideration several aspects such as the number of possible locations, the allowed storage strategies, the locations that already had goods allocated to and the lot size. Despite the long time, this led to better results, with all materials being stored in the first, second or third best storage strategy. However, some bins continued to be overloaded, while others had an occupation under 50%, resulting in the storage of goods in other locations that were assumed as prohibited, leading to material damages.

With all this, a different approach was suggested. One of the starting points in "N" Company's methodology is to analyse the number of pallets that can fit in each bin. However, depending on the type of material, a different number of pallets can be stored. Therefore, it was suggested to take the volume perspective into consideration, and this should be taken regarding both the dimensions of each location and the dimensions of the materials. Due to the lack of more accurate information, the width, depth and height of 170 articles were measured and the dimensions of the remaining materials were extrapolated in accordance with the grouping discussed with the warehouse team. All the safety distances were taken into consideration.

This study led to the conclusion that there was a need of 8.618,150 m^3 per month to store the goods and a capacity to store 11.015,42 m^3 (11.054,05 m^3 if BLQ is considered). The company has adapted racks that allow pallets to be stored in a horizontal or vertical way. Therefore, in order to determine the real available volume, the depth, width and height of the bins was compared with the depth, width and height of the products (dividing each correspondently). Afterwards, the depth, width and height of the bins was compared with the width, depth and height of the products (dividing each

correspondently). Then the product of each scenario was analysed and lastly the maximum of the two options was chosen so as to identify the maximum capacity of the bin per product. This was also done with a tool that was built with Excel. With this, it was possible to better understand the maximum number of products that could fit in each bin.

On a daily basis, it was possible to see that every day, there was an amount of materials that were sent to an external warehouse, due to lack of space, which represented high costs to the company. Therefore, a study of the current layout was conducted.

The study suggested an addition of seven more bins in order to make the most of the space that was not used, adding 160,16 m³ of space. Moreover, some loads were stored on the floor as they did not fit in any bin. In this space the most expensive goods were stored, and material damages were frequent. To overcome this, the acquisition of Cantilever beams was suggested, increasing the available space in 889,34 m³. These beams allow the storage of goods with several dimensions in more than one level and in safety conditions. Additionally, any load could be collected without the need to remove other materials, saving time and decreasing the number of accidents and material damages. Another suggestion, which lacks the approval of competent entities, consisted of changing the design of the current bins adding 17,49 m³. These changes would result in an increase in capacity of 9,77%

After knowing the possible capacity of the warehouse, it was then important to choose a way to group goods. Bearing in mind the literature research and the goal of the study, there was an option to choose a class-based storage policy, following the ABC criteria to group goods. By placing goods with higher demand next to the exit it was expected to see a reduction in traveling time. With this, a new layout was proposed which led to a more even distribution of goods. Some materials were allocated to locations that previously had no goods allocated to, such as RES. Moreover, bins now had better usage as they were more filled. The savings of the solution also covered the security aspect, with the proposal of the coloured ribbon that should be placed in the bins, highlighting the maximum height allowed for the products in each bin. With this, not only an increase of safety is obtained, but also a decrease in material damages, which despite not being quantifiable for confidential reasons, are significant.

It is possible to identify a reduction of 29,96 km per month of traveling distance, which represents a decrease of 32,52 hours per year (approximately 32 hours and 31 minutes). Thus, a temporary worker would be unnecessary for four days (and 2,52 hours). It is important to note that the company has been investing in continuous improvements, namely regarding the warehouse during the last three years. Moreover, economic savings could also include the amount saved in material damages, in external warehouse renting and in the traveling distances needed to load these shipments, but this information was not made available.

In short, the solution enables a combination of ease of use with the guarantee of tangible results without implying high implementation costs or great deals of resources. The proposed solution entails increased safety and lowers the probability of errors and material damages. In addition, it has increased the capacity of the warehouse, and has led to a reduction of costs, traveling time and distances (as well as the waiting time from the production and customers' perspective).

In an overall analysis the proposed solution has targeted the aspects that, according to Reyes et al., (2018) the allocation assignment problem tries to deal with: the allocation of goods in the space they can be stored in, a reduction of handling costs, and better usage of the storage space.

5.2. Limitations and future research

One of the limitations felt was the lack of some specific information. Accurate data regarding the weight and dimensions of the products would be useful. Moreover, the knowledge of the weight of every product, the possibility of stackability, and concrete dimensions, would make it possible to take into consideration the security restrictions, leading to more trustworthy results and a more complete analysis. One important aspect is that all these data should come from entities that truly have this knowledge such as the suppliers and be documented for future research.

For further research, smart tools capable of forecasting the demand are suggested.

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APPENDIX A – WAREHOUSE CAPACITY: “N” COMPANY’S METHODOLOGY

Location	Set of bins	Storage strategy	No. of pallets in depth by level	No. of levels	No. of pallets per module	No. of modules	No. of pallets in the location
BBH	BBH01 - BBH13	4x3	4	3	12	13	156
BBH	BBH14 - BBH30	4x3	4	3	12	17	204
CAC	CAC01; CAC14; CAC15; CAC28	2x3	2	3	6	4	24
CAC	CAC02 - CAC13	3x3	3	3	9	12	108
CAC	CAC 16 - CAC27	4x3	4	3	12	12	144
Cores (*)	Cores: Verde	12x1	12	1	12	2	24
Cores (*)	Cores: Branco	12x1	12	1	12	4	48
Cores (*)	Cores: Preto	12x1	12	1	12	2	24
CPL	CPL01-1 - CPL12-5	1x5	1	5	5	12	60
CPL	CPL13-1 - CPL24-4	1x4	1	4	4	12	48
CXP	CXP01 - CXP14	4x5 §	4	5	20	14	280
CXP	CXP15 - CXP28	3x5 §	3	5	15	14	210
CXS	CXS01 - CXS16	3x5 §	3	5	15	16	240
CXS	CXS17 - CXS32	2x5 §	2	5	10	16	160
EST	EST01 - EST09	3x3	3	3	9	9	81
EST	EST10 - EST19	3x3	3	3	9	10	90
EST	EST20 - EST29	4x3	4	3	12	10	120
GLU	GLU01 - GLU14	3x3	3	3	9	14	126
GLU	GLU15 - GLU28	2x3	2	3	6	14	84
GPQ	GPQ01 - GPQ03 e GPQ05 -GPQ09	1x3	1	3	3	8	24
GPQ	GPQ13 - GPQ20	2x3	2	3	6	8	48
GPQ	GPQ4 e GPQ10 - GPQ12	3x3	3	3	9	4	36
LBB	LBB01 - LBB10	2x3	2	3	6	10	60

LBB	LBB11 - LBB20	3x3	3	3	9	10	90
LBB	LBB21 - LBB34	4x3	4	3	12	14	168
LBB	LBB35 - LBB50	4x3	4	3	12	16	192
LIQ	LIQ01 - LIQ21	3x4§	3	4	12	21	252
LSC	LSC 06, 07 e 13	4x4	4	4	16	3	48
LSC	LSC01 - LSC05 e LSC08 - LSC12	1x4	1	4	4	10	40
LSC	LSC14 - LSC23	2x3	2	3	6	10	60
NEU	NEU01 - NEU14	3x3	3	3	9	14	126
NEU	NEU15 - NEU28	3x3	3	3	9	14	126
NPQ	NPQ01-1	1x4	1	4	4	1	4
NPQ	NPQ02-1 - NPQ15-4	1x4	1	4	4	14	56
RES	RES01-1 - RES12-5	1x5	1	5	5	12	60
RES	RES13-1 - RES24-5	1x5	1	5	5	12	60
RES	RES25-1 - RES36-5	1x5	1	5	5	12	60
RES	RES37-1 - RES48-5	1x5	1	5	5	12	60
RES	RES49-1 - RES60-5	1x5	1	5	5	12	60
ROT	ROT01-7 - ROT01-9	1x7	1	7	7	9	63
UNI	UNI01-4 - UNI20-1	1x4	1	4	4	20	80
UNI	UNI38-1 - UNI21-4	1x4	1	4	4	18	72
TPF	TPF01 - TPF03	3x3	3	3	9	3	27
TPF	TPF04 - TPF07	3x3	3	3	9	4	36
BLQ	BLQ01-BLQ02	1x3	1	3	3	2	6
BLQ	BLQ08-BLQ09	1x3	1	3	3	2	6
BLQ	BLQ03-BLQ05	1x4	1	4	4	3	12
BLQ	BLQ06-BLQ07	1x4	1	4	4	2	8
DOS	DOS01-DOS02	1x2	1	2	2	2	4
DOS	DOS03-DOS04	1x3	1	3	3	2	6
DOS	DOS05-DOS07	1x3	1	3	3	3	9
DOS	DOS08-DOS10	1x3	1	3	3	3	9
DOS	DOS11-DOS14	1x3	1	3	3	4	12

DOS	DOS15-DOS16	1x3	1	3	3	2	6
POPU	ARP01-1 to ARP18	1x5	1	5	5	18	90
POPU	ARP19-1 to ARP20	1x4	1	4	4	2	8
POPU	ARP21 to ARP35	1x4	1	4	4	15	60
POPU	ARP36 to ARP37	1x4	1	4	4	2	8
POPU	ARP38 to ARP52	1x4	1	4	4	15	60
POPU	ARP53 to ARP67	1x4	1	4	4	15	60
POPU	ARP68 to ARP82	1x5	1	5	5	15	75
POPU	ARP83 to ARP84	1x5	1	5	5	2	10
POPU	ARP85 to ARP99	1x5	1	5	5	15	75
POPU	ARP100 to ARP101	1x5	1	5	5	2	10
POPU	ARP102 to ARP116	1x5	1	5	5	15	75
POPU	ARP117 to ARP118	1x4	1	4	4	2	8
POPU	ARP119 to ARP133	1x4	1	4	4	15	60
MSK	MSK01-MSK03	3x3	3	3	9	3	27
MSK	MSK04-MSK07	3x3	3	3	9	4	36
FRU	FRU01-FRU08	7x3	7	3	21	8	168
FRU	FRU09-FRU16	3x3	3	3	9	8	72
CMF	CMF01	1x2	1	2	2	4	8
CMF	CMF02	1x2	1	2	2	5	10
Total						668	5.137

*Note: Cores is not a bin, but a space on the floor

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APPENDIX B – AVAILABLE AREA

Storage strategy	Set of bins	Area (m ²)
1x2	DOS01-DOS02	1,91
1x2	CMF01	0,34
1x2	CMF02	0,44
1x3	GPQ01 - GPQ03 e GPQ05 -GPQ09	12,83
1x3	BLQ01-BLQ02	2,08
1x3	BLQ08-BLQ09	1,99
1x3	DOS03-DOS04	1,91
1x3	DOS05-DOS07	3,65
1x3	DOS08-DOS10	3,69
1x3	DOS11-DOS14	4,81
1x3	DOS15-DOS16	1,22
1x4	CPL13-1 - CPL24-4	13,18
1x4	LSC01 - LSC05 e LSC08 - LSC12	16,62
1x4	NPQ01-1	1,28
1x4	NPQ02-1 - NPQ15-4	16,77
1x4	UNI01-4 - UNI20-1	21,97
1x4	UNI38-1 - UNI21-4	19,77
1x4	BLQ03-BLQ05	1,16
1x4	BLQ06-BLQ07	0,72
1x4	ARP19-1 to ARP20	1,55
1x4	ARP21 to ARP35	11,99
1x4	ARP36 to ARP37	1,55
1x4	ARP38 to ARP52	11,99

1x4	ARP53 to ARP67	11,99
1x4	ARP117 to ARP118	1,55
1x4	ARP119 to ARP133	11,99
1x5	CPL01-1 - CPL12-5	13,18
1x5	RES01-1 - RES12-5	13,18
1x5	RES13-1 - RES24-5	13,18
1x5	RES25-1 - RES36-5	13,18
1x5	RES37-1 - RES48-5	13,18
1x5	RES49-1 - RES60-5	13,18
1x5	ARP01-1 to ARP18	14,39
1x5	ARP68 to ARP82	11,99
1x5	ARP83 to ARP84	1,55
1x5	ARP85 to ARP99	11,99
1x5	ARP100 to ARP101	1,55
1x5	ARP102 to ARP116	11,99
1x7	ROT01-7 - ROT01-9	8,85
2x3	CAC01; CAC14; CAC15; CAC28	11,71
2x3	GLU15 - GLU28	44,35
2x3	GPQ13 - GPQ20	29,21
2x3	LBB01 - LBB10	30,96
2x3	LSC14 - LSC23	35,93
2x5 §	CXS17 - CXS32	59,44
3x3	CAC02 - CAC13	39,83
3x3	EST01 - EST09	31,86
3x3	EST10 - EST19	35,40
3x3	GLU01 - GLU14	58,98
3x3	GPQ4 e GPQ10 - GPQ12	21,02
3x3	LBB11 - LBB20	41,15
3x3	NEU01 - NEU14	56,18
3x3	NEU15 - NEU28	56,10

3x3	TPF01 - TPF03	12,27
3x3	TPF04 - TPF07	17,54
3x3	MSK01-MSK03	12,39
3x3	MSK04-MSK07	16,52
3x3	FRU09-FRU16	24,31
3x4§	LIQ01 - LIQ21	110,18
3x5 §	CXP15 - CXP28	51,37
3x5 §	CXS01 - CXS16	81,67
4x3	BBH01 - BBH13	66,08
4x3	BBH14 - BBH30	74,77
4x3	CAC 16 - CAC27	55,65
4x3	EST20 - EST29	42,23
4x3	LBB21 - LBB34	81,12
4x3	LBB35 - LBB50	92,70
4x4	LSC 06, 07 e 13	15,76
4x5 §	CXP01 - CXP14	68,32
7x3	FRU01-FRU08	56,66
12x1	Cores: Verde	41,66
12x1	Cores: Branco	83,33
12x1	Cores: Preto	41,66
Total		1.918,60

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APPENDIX C – CURRENT AND ADMISSIBLE LOCATIONS (ANALYSIS OF PRODUCTS WITH COCOA)

Current location	Material	Admissible warehouse storage strategies														
		1x2	1x3	1x4	1x5	1x7	2x3	2x5 §	3x3	3x4§	3x5 §	4x3	4x4	4x5 §	7x3	12x1
CAC	27731178						2x3		3x3			4x3				12x1
CAC	26310989						2x3		3x3			4x3				12x1
CAC	27731149						2x3		3x3			4x3				12x1
CAC	43337208						2x3		3x3			4x3				12x1
CAC	43421325						2x3		3x3			4x3				12x1
CAC	43751774						2x3		3x3			4x3				12x1
CAC	43776780						2x3		3x3			4x3				12x1
CAC	29000782						2x3		3x3			4x3				12x1
CAC	43119215						2x3		3x3			4x3				12x1
CAC	104490292						2x3		3x3			4x3				12x1
CAC	43986122						2x3		3x3			4x3				12x1

Admissible Locations				
BBH	CAC	CORES	EST	TPF

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APPENDIX D – ANALYSIS OF THE M² PER STORED PALLETS

Material	Initial proposal	Average of pallet per lot (rounded up)	m ² per stored pallets															
			Storage strategy	1x2	1x3	1x4	1x5	1x7	2x3	2x5§	3x3	3x4§	3x5 §	4x3	4x4	4x5§	7x3	12x1
			m ² per pallet capacity (theoretically)	0,45	1,34	2,40	2,21	1,26	5,07	5,94	3,62	9,18	4,43	5,73	0,99	3,42	2,70	4,63
			Bin Capacity (regarding pallets)	2	3	4	5	7	6	10	9	12	15	12	16	20	21	12
27731630	FRU	3								9,05								
43858521	CXS	3							15,85			15,52			14,80			
43464783	CXP	8								5,66		8,59	10,03		7,69			
43771193	CXP	24								4,30		5,82	7,16		4,84			
43990631	CXP	26			2,59				5,66	7,09	4,25	5,71	7,05		4,73			
27739322	LBB	4			3,60				8,88		7,69		14,32	2,96				
27739333	LBB	12			2,80				6,34		4,98		8,59	1,64				
43088895	LBB	12			2,80				6,34		4,98		8,59	1,64				
43088896	LBB	22			2,62				5,76		4,36		7,29	1,34				
43351259	LBB	11			2,84				6,46		5,10		8,86	1,70				
43510777	LBB	4			3,60				8,88		7,69		14,32	2,96				
43511157	LBB	10			2,88				6,59		5,25		9,17	1,77				

Note: The calculation was done only for the admissible storage strategies for the material. For instance, part number 27731630 could only be stored on a bin with the storage strategy 3x3, whereas part number 43858521 could be stored in bins with the storage strategy 2x5§, 3x5§ or 4x5§

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APPENDIX E – TOP 5 BEST ANALYSED STRATEGIES

Material	Initial proposal	Average of pallets per lot per month (rounded up)	Best identified results					Best storage strategies					Locations according to TOP 1	
			TOP 1	TOP 2	TOP 3	TOP 4	TOP 5	TOP 1	TOP 2	TOP 3	TOP 4	TOP 5		
27731630	FRU	3	9,05						3x3					FRU
43858521	CXS	3	14,80	15,52	15,85				4x5 §	3x5 §	2x5 §			CXP
43891436	CXS	11	6,52	7,46	8,65				4x5 §	3x5 §	2x5 §			CXP
43759181	CXS	3	14,80	15,52	15,85				4x5 §	3x5 §	2x5 §			CXP
27836090	CXP	1	19,91	37,57	37,69	40,11			3x3	4x5 §	3x5 §	4x3		EST
43518547	NEU	7	3,09	5,95					1x4	3x3				NPQ
31100192	NEU	1	7,20	19,91					1x4	3x3				NPQ
43202082	NEU	4	3,60	7,69					1x4	3x3				NPQ
43543229	NEU	1	7,20	19,91					1x4	3x3				NPQ
43990631	CXP	78	2,46	3,83	3,85	4,86	5,27		1x4	3x3	4x5 §	3x5 §	2x3	UNI
43924864	CXP	8	7,69	8,59	9,66				4x5 §	3x5 §	2x5 §			CXP
43975676	CXS	10	6,83	7,76	8,92				4x5 §	3x5 §	2x5 §			CXP
44009990	CXS	3	14,80	15,52	15,85				4x5 §	3x5 §	2x5 §			CXP
43770007	CXS	5	10,25	11,09	11,89				4x5 §	3x5 §	2x5 §			CXP
43771062	CXS	2	20,50	20,80	21,06				4x5 §	2x5 §	3x5 §			CXP

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APPENDIX F – EXTRA ALLOCATION OF UNI

Location according to top 1	New proposed location	Material	No. Pallets/Month	Pallets/Lot	1 st Suggested strategy	2 nd Suggested strategy	3 rd Suggested strategy	4 th Suggested strategy	5 th Suggested strategy
UNI	UNI	43933062	107	65	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43933061	103	59	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43826066	94	63	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43826110	57	36	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43878629	47	41	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43963084	25	30	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43724656	24	15	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43787617	24	29	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43849614	24	24	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43916282	23	23	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43878670	24	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43646166	19	21	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43745292	21	28	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43826069	14	11	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43849688	19	38	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43850619	21	18	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43852010	19	17	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43852012	19	28	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43852013	19	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43849687	18	18	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43866870	18	18	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43994502	17	51	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43689610	14	32	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43865268	14	14	1x4	2x3	3x3	4x5 §	3x5 §

UNI	POPUP	43899386	14	34	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43915965	15	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43933063	13	15	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43968666	13	75	1x4	3x3	4x5 §	3x5 §	2x3
UNI	LBB	43990631	13	78	1x4	3x3	4x5 §	3x5 §	2x3
UNI	LBB	43646655	12	20	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43801702	11	32	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43863313	10	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43865594	10	11	1x4	2x3	3x3	4x5 §	3x5 §
NEU	POPUP	43866818	11	13	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43936705	12	28	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43948227	11	42	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43949438	11	33	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43949552	12	69	1x4	3x3	4x5 §	3x5 §	2x3
UNI	POPUP	43970033	11	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43970060	11	42	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43975677	12	34	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43982671	11	33	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43949538	12	18	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43735031	7	19	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43780995	7	19	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43863287	7	11	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43863316	9	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43865593	8	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43866816	7	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43866872	9	14	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43866873	7	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43868482	9	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43915966	7	13	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43915967	7	15	1x4	2x3	3x3	4x5 §	3x5 §

UNI	UNI	43943994	9	34	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43948255	8	45	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43948271	8	44	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43951122	7	75	1x4	3x3	4x5 §	3x5 §	2x3
UNI	LBB	43951124	6	31	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43955027	8	32	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43958262	9	53	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43961525	8	48	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43968657	9	34	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43973844	9	34	1x4	3x3	4x5 §	2x3	3x5 §
UNI	LBB	43975691	9	25	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43999765	8	44	1x4	3x3	4x5 §	2x3	3x5 §
UNI	POPUP	43949143	9	20	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43951120	9	21	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43963075	6	21	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43966467	9	51	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43966489	8	30	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43966500	9	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43970032	7	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43970050	9	36	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43538825	5	13	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43678647	4	13	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43742042	5	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43800058	5	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43804086	4	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43850618	5	13	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43861885	6	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43861900	4	6	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43863288	5	11	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43863289	5	10	1x4	2x3	3x3	4x5 §	3x5 §

UNI	POPUP	43863311	4	10	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43863314	5	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43863315	6	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43865595	4	6	1x4	2x3	3x3	4x5 §	3x5 §
NEU	POPUP	43866817	4	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43866871	4	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43868480	4	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	UNI	43868481	4	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43880721	4	7	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43913874	4	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43913876	4	20	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43933196	4	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43935019	6	33	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43936706	4	10	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43948270	4	20	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43949547	5	60	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43951123	4	21	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43958271	4	23	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43964081	5	19	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43966488	4	15	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43966495	4	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43970031	5	30	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43970034	6	32	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43970036	4	42	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43970481	4	24	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43973076	5	26	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43982637	4	16	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43994510	6	22	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43852103	4	14	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43878628	5	4	1x4	2x3	3x3	4x5 §	2x5 §

UNI	LBB	43948126	4	15	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43963065	4	14	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43966468	4	23	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43966497	5	29	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43970007	5	57	1x4	3x3	4x5 §	2x3	3x5 §
UNI	UNI	43660104	2	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43684342	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43684343	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	UNI	43695129	1	2	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43741152	2	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	UNI	43771537	2	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43772034	1	2	1x4	2x3	3x3	2x5 §	4x5 §
UNI	UNI	43800059	1	5	1x4	2x3	3x3	4x5 §	2x5 §
UNI	POPUP	43819973	3	18	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43826478	1	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43826479	1	2	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43829215	2	5	1x4	2x3	3x3	4x5 §	2x5 §
UNI	UNI	43848854	2	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43848855	2	5	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43848856	1	2	1x4	2x3	3x3	2x5 §	4x5 §
UNI	UNI	43848857	2	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43858966	3	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43861881	2	11	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43861883	3	7	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43861887	2	5	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43863310	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43863312	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43865596	3	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	UNI	43866349	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	UNI	43866815	1	9	1x4	2x3	3x3	4x5 §	3x5 §

UNI	UNI	43868459	2	4	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43879615	1	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43904652	2	5	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43913792	3	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43913875	2	7	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43935080	2	5	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43935290	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43935291	2	7	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43935292	1	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43935293	1	5	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43935294	1	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43939149	1	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43943995	3	27	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	43948127	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43949444	2	11	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43949539	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43949548	1	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43951098	2	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43951103	2	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43951121	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	UNI	43955014	2	12	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43955036	3	18	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43964080	3	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	POPUP	43966487	1	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43968239	1	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43970016	2	24	1x4	3x3	2x3	4x5 §	3x5 §
UNI	UNI	43970040	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43974386	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43975684	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	UNI	43977066	1	6	1x4	2x3	3x3	4x5 §	2x5 §

UNI	LBB	43977077	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43978709	1	5	1x4	2x3	3x3	4x5 §	2x5 §
UNI	UNI	43982660	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43982670	1	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43985320	1	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	UNI	43987009	2	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43994479	2	21	1x4	3x3	2x3	4x5 §	3x5 §
UNI	POPUP	43994718	1	6	1x4	2x3	3x3	4x5 §	2x5 §
UNI	LBB	43999748	3	15	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43948104	3	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	UNI	43951097	2	8	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	43966469	2	21	1x4	3x3	2x3	4x5 §	3x5 §
UNI	LBB	104394477	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104455884	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104455974	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104455989	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104455996	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104456020	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104475041	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104513137	1	9	1x4	2x3	3x3	4x5 §	3x5 §
UNI	LBB	104518450	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104531375	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104543989	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104544002	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104544007	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104545941	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	104547815	1	3	1x4	2x3	3x3	2x5 §	4x5 §
UNI	LBB	43320563	1	1	1x2	1x3	1x4		
UNI	POPUP	104636348	1	3	1x4	2x3	3x3	2x5 §	4x5 §

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APPENDIX G – “N” COMPANY ANALYSIS I PARTIAL OVERALL CHANGES

		Keep	Change	Change	Change	Keep	Change	Change	Keep	Change	Change	Keep	Change	Change	Change	Keep	Keep
Location	Available space	1.1	1.7	1.8	1.10	2.5	2.6	2.7	2.8	2.9	2.10	2.11	3.1	3.2	3.3	3.4	4.3
BBH	300																
BLQ	32																
CAC	0													2			
CMF	0				18												
Cores	7													21			
CPL	28									27						53	
CXP	-30					318	172						30				
CXS	0					1	123	267							9		
DOS	0										46						
EST	0												291				
FRU	170	43			17												
GLU	0			210													
GPQ	-25			133													
LBB	0		171														301
LIQ	197																
LSC	0		148														
MSK	0		63														
NEU	0														127		
NPQ	0																
POPOP	748								95			1				113	-374
RES	300									63							
ROT	0																
TPF	0												53	10			
UNI	-968										4	9			1794		-675

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APPENDIX H – DIMENSIONS OF PRODUCTS

Material	Type of material	Width with pallet (mm)	Depth with pallet (mm)	Height with pallet (mm)	Volume (in m ³)	Width (mm)	Depth (mm)	Height (mm)	Type of pallet	Width (mm)	Depth (mm)	Height (mm)
27731632	Barrel	800	1.200	565	0,54	390	390	405	Plastic pallet	800	1.200	160
43858531	Boxes	1.000	1.344	574,5	0,77	988	1.344	412,5	Wood pallet	1.000	1.200	162
43891437	Boxes	1.205	1.252	622	0,94	1.205	1.252	460	Wood pallet	1.000	1.200	162
43891461	Boxes	1.205	1.252	622	0,94	1.205	1.252	460	Wood pallet	1.000	1.200	162
27739320	Big Bags	1.150	1.230	2.052	2,90	1.150	1.230	1.890	Wood pallet	1.000	1.200	162
27739337	Big Bags	1.030	1.200	2.042	2,52	1.030	1.200	1.880	Wood pallet	1.000	1.200	162
43088899	Big Bags	1.070	1.200	1.962	2,52	1.070	1.120	1.800	Wood pallet	1.000	1.200	162
43088898	Big Bags	1.110	1.210	1.862	2,50	1.110	1.210	1.700	Wood pallet	1.000	1.200	162
43664712	Boxes	800	1.200	333	0,32	752	1.162	189	Wood pallet	800	1.200	144
43978872	Boxes	841	1.212	540	0,55	841	1.212	396	Wood pallet	800	1.200	144
43603243	Boxes	800	1.204	669	0,64	690	1.204	525	Wood pallet	800	1.200	144

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APPENDIX I – DIMENSIONS OF THE BINS (EXCERPT)

Location	Levels	Depth (mm)	Width (mm)	Width of the vertical bars (mm)	Width without bars and considering the safety distances (mm)	Individual width available (mm)	Height of the bar on top (mm)	Height (mm)			No. of modules	Available volume of the location taking into consideration safety distances (m ³)
								Level 1				
								Height (mm)	Height without bars (mm)	Height considering the upper safety distance (mm)		
BBH01 - BBH13	3	3.710,00	1.680,00	80,00	1.370,00	1.370,00	90,00	2.209,80	2.209,80	2.134,80	13	418,22
BBH14 - BBH30	3	3.620,00	1.525,00	80,00	1.215,00	1.215,00	0,00	2.209,80	2.209,80	2.134,80	17	473,26
LIQ01 - LIQ21	3	3.700,00	1.590,00	11,00	1.418,00	1.418,00	90,00	2.626,00	2.536,00	2.461,00	21	687,07
LBB01 - LBB10	3	2.430,00	1.582,00	79,00	1.274,00	1.274,00	0,00	2.285,00	2.285,00	2.210,00	10	202,93
LBB11 - LBB20	3	3.230,00	1.582,00	79,00	1.274,00	1.274,00	0,00	2.285,00	2.285,00	2.210,00	10	269,74
LBB21 - LBB34	3	4.555,00	1.580,00	79,00	1.272,00	1.272,00	0,00	2.286,70	2.286,70	2.211,70	14	532,01
UNI01-4 - UNI20-1	4	1.100,00	2.380,00	79,00	1.997,00	998,50	100,00	1.447,00	1.347,00	1.272,00	20	120,16
UNI38-1 - UNI21-4	4	1.100,00	2.380,00	79,00	1.997,00	998,50	100,00	1.447,00	1.347,00	1.272,00	18	108,14
LBB35 - LBB50	3	4.555,00	1.580,00	79,00	1.272,00	1.272,00	0,00	2.286,70	2.286,70	2.211,70	16	608,01
NEU01 - NEU14	3	3.155,00	1.580,00	79,00	1.272,00	1.272,00	0,00	2.160,00	2.130,00	2.055,00	14	325,70
NEU15 - NEU28	3	3.150,00	1.580,00	79,00	1.272,00	1.272,00	0,00	2.160,00	2.130,00	2.055,00	14	325,18
CAC02 - CAC13	3	2.630,00	1.570,00	79,00	1.262,00	1.262,00	0,00	2.150,00	2.150,00	2.075,00	12	231,68
CAC 16 - CAC27	3	3.675,00	1.570,00	79,00	1.262,00	1.262,00	0,00	2.150,00	2.150,00	2.075,00	12	323,74
EST01 - EST09	3	2.850,00	1.550,00	79,00	1.242,00	1.242,00	0,00	2.143,30	2.143,30	2.068,30	9	194,66
EST10 - EST19	3	2.850,00	1.550,00	79,00	1.242,00	1.242,00	0,00	2.143,30	2.143,30	2.068,30	10	216,29

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APPENDIX J – ANALYSIS OF THE BIN CAPACITY REGARDING THE NUMBER OF PALLETS

Table 1 - Analysis of the capacity in depth, width and height of BBH01 to BBH13 while comparing the depth, width and height of the bins with the depth, width and height of the products (correspondingly)

Material	Depth (mm)	Width (mm)	Height (mm)	Capacity in depth	Capacity in width	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
				3.710	1.370	2.134,8	2.109,8	2,084,8	0	0	0	0
27731630	1200	800	565	3	1	3	3	3	0	0	0	0
43858521	1344	1000	574.5	2	1	3	3	3	0	0	0	0
43891436	1252	1205	622	2	1	3	3	3	0	0	0	0
43891460	1252	1205	622	2	1	3	3	3	0	0	0	0
43929391	1312	974	655	2	1	3	3	3	0	0	0	0
43961544	1312	974	655	2	1	3	3	3	0	0	0	0
43271352	1312	1000	687	2	1	3	3	3	0	0	0	0
43487445	1378	1000	687	2	1	3	3	3	0	0	0	0
43759181	1378	1000	687	2	1	3	3	3	0	0	0	0
43571462	1390	1000	687	2	1	3	3	3	0	0	0	0
43289601	1203	1000	1062	3	1	2	1	1	0	0	0	0
43665770	1268	1000	1062	2	1	2	1	1	0	0	0	0
43774482	1268	1000	1062	2	1	2	1	1	0	0	0	0
43826067	1245	1205	1082	2	1	1	1	1	0	0	0	0
27836148	1312	1000	1152	2	1	1	1	1	0	0	0	0
43538225	1312	1000	1152	2	1	1	1	1	0	0	0	0
43735292	1440	800	1144	2	1	1	1	1	0	0	0	0
40515604	1250	1160	2280	2	1	0	0	0	0	0	0	0

Table 2 - Analysis of the capacity in depth, width and height of BBH01 to BBH13 while comparing the depth, width and height of the bins with the width, depth and height of the products (correspondingly)

Material	Depth (mm)	Width (mm)	Height (mm)	BBH01 - BBH13								
				Capacity in depth	Capacity in width	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
				3.710	1.370	2.134,8	2.109,8	2.084,8	0	0	0	0
27731630	1200	800	565	4	1	3	3	3	0	0	0	0
43858521	1344	1000	574.5	3	1	3	3	3	0	0	0	0
43891436	1252	1205	622	3	1	3	3	3	0	0	0	0
43891460	1252	1205	622	3	1	3	3	3	0	0	0	0
43929391	1312	974	655	3	1	3	3	3	0	0	0	0
43961544	1312	974	655	3	1	3	3	3	0	0	0	0
43271352	1312	1000	687	3	1	3	3	3	0	0	0	0
43487445	1378	1000	687	3	0	3	3	3	0	0	0	0
43759181	1378	1000	687	3	0	3	3	3	0	0	0	0
43571462	1390	1000	687	3	0	3	3	3	0	0	0	0
43289601	1203	1000	1062	3	1	2	1	1	0	0	0	0
43665770	1268	1000	1062	3	1	2	1	1	0	0	0	0
43774482	1268	1000	1062	3	1	2	1	1	0	0	0	0
43826067	1245	1205	1082	3	1	1	1	1	0	0	0	0
27836148	1312	1000	1152	3	1	1	1	1	0	0	0	0
43538225	1312	1000	1152	3	1	1	1	1	0	0	0	0
43735292	1440	800	1144	4	0	1	1	1	0	0	0	0
40515604	1250	1160	2280	3	1	0	0	0	0	0	0	0

Table 3 – Analysis of the capacity by analysing the multiplication of depth, width and height of the bins with the depth, width and height of the products (correspondingly)

Material	BBH01 - BBH13								
	Location	Module	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
27731630	351	27	9	9	9	0	0	0	0
43858521	234	18	6	6	6	0	0	0	0
43891436	234	18	6	6	6	0	0	0	0
43891460	234	18	6	6	6	0	0	0	0
43929391	234	18	6	6	6	0	0	0	0
43961544	234	18	6	6	6	0	0	0	0
43271352	234	18	6	6	6	0	0	0	0
43487445	234	18	6	6	6	0	0	0	0
43759181	234	18	6	6	6	0	0	0	0
43571462	234	18	6	6	6	0	0	0	0
43289601	156	12	6	3	3	0	0	0	0
43665770	104	8	4	2	2	0	0	0	0
43774482	104	8	4	2	2	0	0	0	0
43826067	78	6	2	2	2	0	0	0	0
27836148	78	6	2	2	2	0	0	0	0
43538225	78	6	2	2	2	0	0	0	0
43735292	78	6	2	2	2	0	0	0	0
40515604	0	0	0	0	0	0	0	0	0

Table 4 - Analysis of the capacity by analysing the multiplication of depth, width and height of the bins with the width, depth and height of the products (correspondingly)

Material	BBH01 - BBH13								
	Bin	Module	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
27731630	468	36	12	12	12	0	0	0	0
43858521	351	27	9	9	9	0	0	0	0
43891436	351	27	9	9	9	0	0	0	0
43891460	351	27	9	9	9	0	0	0	0
43929391	351	27	9	9	9	0	0	0	0
43961544	351	27	9	9	9	0	0	0	0
43271352	351	27	9	9	9	0	0	0	0
43487445	0	0	0	0	0	0	0	0	0
43759181	0	0	0	0	0	0	0	0	0
43571462	0	0	0	0	0	0	0	0	0
43289601	156	12	6	3	3	0	0	0	0
43665770	156	12	6	3	3	0	0	0	0
43774482	156	12	6	3	3	0	0	0	0
43826067	117	9	3	3	3	0	0	0	0
27836148	117	9	3	3	3	0	0	0	0
43538225	117	9	3	3	3	0	0	0	0
43735292	0	0	0	0	0	0	0	0	0
40515604	0	0	0	0	0	0	0	0	0

APPENDIX K – EXCERPT OF THE ABC ANALYSIS

ID Material	Cumulative % of demand	ABC Analysis	% of goods	Cumulative % of goods
27731131	0,048	A	0,001	0,001
27731148	0,069	A	0,001	0,003
43933062	0,090	A	0,001	0,004
43617943	0,110	A	0,001	0,005
43933061	0,130	A	0,001	0,007
27739313	0,147	A	0,001	0,008
43532048	0,164	A	0,001	0,009
43088896	0,181	A	0,001	0,011
43866873	0,79	A	0,001	0,236
43863287	0,79	A	0,001	0,237
43963482	0,79	A	0,001	0,238
43866816	0,80	A	0,001	0,240
31238507	0,80	A	0,001	0,241
43902595	0,80	A	0,001	0,242
43910601	0,80	A	0,001	0,244
43956930	0,80	A	0,001	0,245
43927413	0,80	A	0,001	0,246
27739333	0,80	A	0,001	0,248
43935019	0,80	A	0,001	0,249
43951123	0,81	B	0,001	0,250
43970034	0,81	B	0,001	0,252
43994510	0,81	B	0,001	0,253
43852103	0,81	B	0,001	0,254
43703413	0,81	B	0,001	0,256
43883545	0,81	B	0,001	0,257
43698874	0,95	B	0,001	0,681
43732836	0,95	B	0,001	0,682
43732839	0,96	C	0,001	0,684
43770814	0,96	C	0,001	0,685
43903864	0,96	C	0,001	0,686
43908720	0,96	C	0,001	0,688
43917555	0,96	C	0,001	0,689
43917556	0,96	C	0,001	0,690
104654455	1,00	C	0,001	1,000