INSTITUTO
UNIVERSITÁRIO
DE LISBOA

ASSESSMENT AND IMPROVEMENT OF THE STORAGE ACTIVITY AT NOS LOGISTIC CENTRE

Jorge Pereira dos Santos

Master of Science in Management

Supervisor:

Professor Sofia Kalakou, Assistant Professor, ISCTE Business School

December 2020

BUSINESS
SCHOOL

Department of Marketing, Operations and General Management

ASSESSMENT AND IMPROVEMENT OF THE STORAGE ACTIVITY AT NOS LOGISTIC CENTRE

Jorge Pereira dos Santos

Master of Science in Management

Supervisor:

Professor Sofia Kalakou, Assistant Professor, ISCTE Business School

December 2020

This thesis is dedicated to my mother,
for all the love and support .

Assessment and improvement of the storage activity in NOS Logistic Centre

ACKNOWLEGEMENTS

At the end of this journey, I would like to thank all the people that helped me achieve this milestone.

To my supervisor, Professor Sophia Kalakou, for the guidance and support throughout the execution of this project.

To my family, in particular my mother, for the unconditional support, encouragement and patience during the last year.

I would like to thank NOS for the opportunity, and specially to the logistics centre team for their collaboration and availability.

Last but not least, to my friends who accompanied me through this journey, for the motivation and friendship.

Assessment and improvement of the storage activity in NOS Logistic Centre

RESUMO

Ao longo dos últimos anos, a logística tem vindo a desempenhar um papel cada vez mais importante nas organizações, atuando como fonte de vantagem competitiva e de satisfação do cliente.

O presente projeto foca-se na análise e melhoria da atividade de armazenamento no Centro Logístico da NOS, grupo de comunicações e entretenimento português, classificado como um dos principais players no mercado das telecomunicações, oferecendo serviços de televisão, internet, voz e dados para todos os sectores, e atual líder de mercado na distribuição e exibição de conteúdos cinematográficos através da NOS Audiovisuais e NOS Cinemas.

O centro logístico e as atividades nele incorporadas foram analisadas, com maior foco na atividade de armazenamento, de forma a, numa primeira fase, identificar os principais desafios que caracterizavam a situação atual da empresa e, em segundo lugar, apresentar medidas de melhoria que respondessem aos problemas anteriormente identificados.

Deste processo resultaram várias soluções que, não só podem potenciar o desempenho da atividade de armazenamento, mas também de toda a operação logística, uma vez que os diferentes processos que constituem este sistema estão fortemente interligados.

Palavras-chave: Logística, Gestão de armazém, Armazenamento, Ocupação, Utilização de espaço

Sistema de Classificação JEL: L80 – General; L81 - Retail and Wholesale Trade • e-Commerce

Assessment and improvement of the storage activity in NOS Logistic Centre

ABSTRACT

Over the last few years, logistics has played an increasingly crucial role in organizations, as a source of competitive advantage and customer satisfaction.

This project focuses on the assessment and improvement of the storage activity in the Logistics Centre of NOS, a Portuguese communications and entertainment group, classified as one of the main players in the telecommunications market, offering television, internet, voice and data services for all sectors, and the current market leader in the distribution and exhibition of cinematographic content through NOS Audiovisuais and NOS Cinemas.

The logistics centre and inherent activities were analysed, particularly the storage activity, in order to, on a first stage, identify the main challenges that characterized the current situation of the company and, secondly, present improvement measures that responded to the problems previously identified.

From this process resulted several solutions that, not only can leverage the storage activity performance, but also the entire logistics operation, since the different processes that constitute this system are strongly connected.

Keywords: Logistics, Warehouse Management, Storage activity, Occupation, Space utilization

JEL Classification System: L80 – General; L81 - Retail and Wholesale Trade • e-Commerce

Assessment and improvement of the storage activity in NOS Logistic Centre

INDEX

FIGURE INDEX

TABLE INDEX

Assessment and improvement of the storage activity in NOS Logistic Centre

LIST OF ABREVIATIONS

B&C: Brand and Communications

FIFO: First In, First Out

LC: Logistics Centre

LM: Logistics Management

LOC: Location

PM: Promotional Material

RSC: Returns and Screening Centre

SC: Supply Chain

SKU: Stock Keeping Unit

TC: Technical Centre

WMS: Warehouse Management System

Assessment and improvement of the storage activity in NOS Logistic Centre

1. INTRODUCTION

1.1 Problem statement

In recent times, with the increasing globalization and fast market changes, being able to meet the customer´s needs and expectations as never been more crucial. The product portfolio widening and the reduction of the lead time to gather more clients and improve customer loyalty, has been putting a lot of pressure on the companies' supply chain and logistics activities. An important element of this system is the existence of warehouses or logistics centres, that work as a regulator between supply and demand, contributing to the continuous flow of material throughout the supply chain.

The storage of materials, which is an integral part of the warehousing process, is a crucial activity for maintaining a functional and sustainable operation. It must be planed, managed and monitored properly, in order to reduce the operational costs, promote the efficient utilization of warehouse space, support the operational workflow and fulfil the on-going and future needs of the business. However, this scenario does not represent the current status of NOS logistics centre.

NOS communications S.A is a telecommunications and entertainment group, created in 2014. The company business model is very diversified, including internet, television, voice and data services for various market segments, NOS cinemas and NOS Audiovisuais, related with the cinematographic industry, as well as sponsorship and organization of several cultural events in Portugal.

NOS Logistics Centre, which is located in Alverca, incorporates the company logistic operation and holds all the stock that supports their activity. Currently, this facility is struggling with some problems regarding the storage function of the warehousing process and the occupation level of the storage area, associated with the growth of the company in the last few years.

Even with great efforts by both NOS and the logistics operator - DHL, to keep a sustainable operation, with the increase of SKUs and volume handled, by the end of the third quarter of 2019, the logistics centre occupation level reached 94%.

The warehouse performance is being affected by the high occupation rate, with congestion being a constant issue, derived from the placement of goods in inappropriate places, and a decrease of the overall warehousing process efficiency (e.g. slower put way of items) has also been recorded.

Regarding the storage activity, the stock allocation process that is managed by the WMS – Warehousing Management System, is not working properly, compromising the efficient use of the limited space available to do so. Plus, the data displayed by the WMS is not aligned with the physical arrangement of the storage area.

Furthermore, the mechanisms implemented for the assessment and control of the space utilization within the LC, don't provide enough and precise information to consistently monitor this dimension and act according to its behaviour.

Considering the several challenges that NOS operation is currently facing, this project aims to analyse the storage dimension of the warehousing process and, based on the literature collected, suggest ways to improve its efficiency and the overall performance of the logistics centre.

1.2 Project Objectives

Considering the current condition of the logistics centre and the impact that could have on the company's supply chain, to improve the quality of the NOS operation, this project aims to:

- Assess and improve the occupation rate;
- Improve the storage activity performance,
- Increase occupation control and monitoring.

To accomplish these objectives, the following goals should to be achieved:

- Description of NOS warehousing process and inherent activities;
- Assessment of the storage activity and identification of main constraints;
- Development of an action plan for the improvement of the storage dimension;
- Present the improvement proposals and evaluate their impact on the current situation of the L.C.

1.3 Project Structure

This project has the following structure:

Chapter 1 – Introduction

In the first chapter, the problem in question is described as well as the objectives of this project.

Chapter 2 – Literature Review

In this chapter, the theorical support for the design and execution of this project will be presented, providing an overview of the main concepts and themes addressed. Given the scope of the project, the three major themes under analysis are the logistics management, warehousing process and, in more dept, storage activity.

Chapter 3 – Methodology

In the third chapter, the methodology applied in the execution of this project is addressed.

Chapter 4 – Case study

In chapter 4, the data collected regarding the current situation of NOS Logistics Centre, particularly the storage activity, is presented and an analysis is performed. With the outputs obtained from it, a plan of action is designed, implemented and the results evaluated.

Chapter 5 – Conclusion

In the last chapter, the project conclusions are present as well as its limitations and recommendations are made for future research.

Assessment and improvement of the storage activity in NOS Logistic Centre

2. LITERATURE REVIEW

2.1 Logistics Management

As a part of the supply chain framework, logistics plays a crucial role in today's dynamic and ever-changing environment, being a source of competitive advantage and serving as a channel for reaching customers satisfaction. For a better understanding of the subject, its concept is presented as well as the main activities that make up its structure.

2.1.1 Logistics Concept

The notion of logistics has been changing over the years, hand to hand with the increasing globalization and technological evolution. Given the several factors and conditions that influence its framework, it´s safe to say that there is no "true" definition that can be assigned to logistics.

The Council of Supply Chain Management Professionals (2016) refers that logistics is the "*Process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal and external movements*".

With a similar approach Christopher (2016: 2), stated that in general, this concept can be defined as *"...the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organisation and its marketing channels in such a way that current and future profitability are maximised through the cost-effective fulfilment of orders*".

The definition of logistics may differ considering the author's viewpoint, but one legitimate interpretation is that it integrates and controls the flow of goods and information between the suppliers and the marketplace, with the goal of serving the customers in the more cost-effective way.

In such a volatile atmosphere, the system must be dynamic and flexible enough to change accordingly to the various constraints and demands imposed upon it and achieve the desired performance (Rushton et al., 2010).

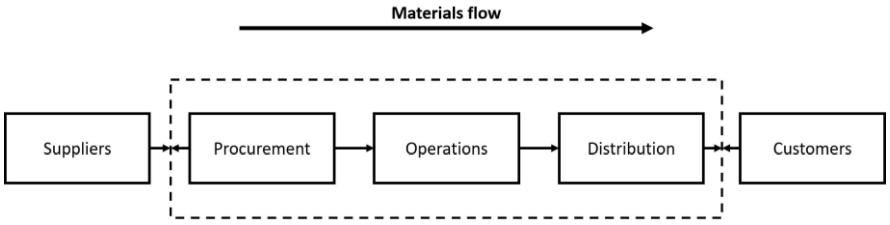

Figure 1 - Logistics Management Process

Source - Adapted from Christopher (2016)

Considering its very nature, logistics operates in an unstable environment, which makes the planning of the logistics process a complex task. To overcome this obstacle, organizations need to have an overall view of the system, by running it as a whole, with constant regard for the relations established between the various elements.

Inherent to the logistics process is the transformation of inputs that can be natural, human, financial or informational into outputs like goods or services. However, the careful planning and coordination of the logistics activities, is the key that allows organizations to differentiate themselves from competitors, gain and sustain competitive advantage and actually create value, through better delivery, greater responsiveness and lower costs. With the increased global competition and higher customer expectations, now more than ever, logistics plays a more strategic role in organizations.

In this current business setting, companies tend to be customer-oriented by meeting their requirements, lowering delivery times and offering a high-quality product. Therefore, delivering the right products, the right quantity, at the right place and time with minimum cost must be at the core of every logistics process. Hence, the LM scope can be divided into three dimensions: time, cost and service quality as presented by Carvalho *et al.* (2010).

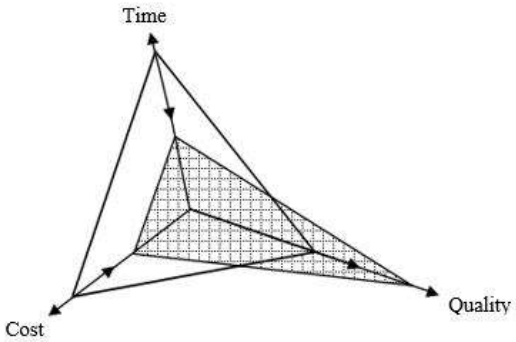

Figure 2 - Logistics Triangle

The decision-making process, regarding the planning and controlling of the logistics pipeline, should be based in these 3 variables but most importantly, in the trade-offs between them, since it's not sustainable to pursue all of them at the same time.

2.1.2 Logistics activities

The design and integration of the logistics activities is key to ensure the effective run of the business and the achievement of the organization's goals. Also, given the several tiers and stages involved in the SC, these processes must be cross-functional and SC oriented, to overcome the boundaries set among them (Christopher, 2016). The set of logistics activities may differ considering the environment where the logistics process is integrated. Nevertheless, the main ones are presented in Figure 3.

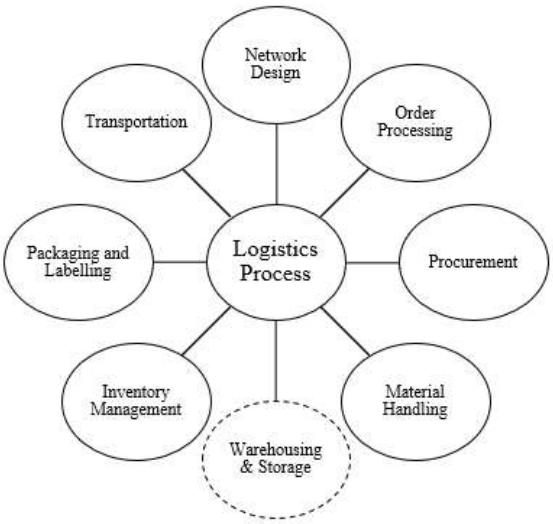

Figure 3 - Logistics Activities

Logistics works as a system, therefore all decisions regarding the different activities are interconnect and should always be taken considering the entire operational structure. According to Rushton *et al.*(2010: 7), "*... these functions and sub-functions need to be planned in a systematic way, in terms both of their own local environment and of the wider scope of the distribution system as a whole*".

Due to the scope of this project, the following literature will focus mainly on the warehousing and storage dimension.

2.2 Warehousing and Storage activity

This subchapter addresses the importance of warehousing as part of the logistics process, the role of warehouses in the SC and the activities performed within these facilities, with particular emphasis on the storage activity. Regarding this last one, concepts like type of inventory, storage systems and material handling will be presented, as well as storage methods and the overall influence of this dimension in space utilization. Later on, the importance of warehouse management systems and performance monitoring and reporting is also approached.

2.2.1 Warehousing Concept

Throughout the years, there has been a shift on the perception about what is the warehousing function and what purpose does it have on the logistics pipeline. "*Because of the value of strategic storage was not well understood, warehouses were often considered 'necessary evils' that added cost to the distribution process*" (Bowersox and Closs, 1996). Nowadays, the core of warehousing has changed from inventories at rest to inventories at motion.

Warehousing promotes the connection between producers and customers by supporting the continuous flow of goods across the supply chain. As stated by Stock and Lambert (2001, 390), warehousing can be referred as *"... part of a firm's logistics system that stores products (raw materials, parts, goods-in-process, finished goods) at and between points-of-origin and point-of-consumption, and provides information management on the status, condition, and disposition of items being stored*".

Considering the market volatility, when well-managed, warehousing becomes a fundamental mechanism to achieve competitive advantage, since it allows companies to meet the demand fluctuations, promotes economies of scale, continuous production and quick supply that translates into high customer service and cost reduction. Nevertheless, as a critical element of the supply chain "*it can only play this part if it is involved in the strategic aspects of the business*" (Emmett, 2005: 6), being essential a solid coordination between the warehousing activity and the business current and future needs. If mishandled, the increase of SKUs stored and the growth of product customization as well as customer service requirements, may compromise the warehousing operation performance, by inducing a decline in efficiency at all levels.

2.2.2 The role of warehouse facilities

The importance of warehouses for organizations worldwide, has been growing exponentially during the last few years. With the expansion of the SCs, to reach new and bigger markets and widen the target range, more and more businesses are acknowledging the impact that warehouses have in their success.

The notion that warehouses' only purpose is to hold inventory, is old-fashioned and does not reflect the large influence that these facilities have on the responsiveness of the logistics system.

From sourcing to distribution, warehouses are involved in several crucial processes that shape the SC, still, as an integral component of the system, the broader business context, i.e., market trends, corporate objectives and customer service levels, have to be considered when making key decisions about these facilities. The nature of warehouses may vary but generally, their main components are people, space, and equipments, such as storage systems(e.g. racks), material-handling devices and all of the hardware and software used to run a warehouse (Farahani *et al*., 2011). Together, these elements typically account for 20 to 30 per cent of logistics costs (Rushton *et al*., 2010), which shows why an efficient use of this resources is so important for a sustainable warehouse operation.

Warehouses for themselves don´t add value to a product, but the range of activities incorporated in these infrastructures, that is, warehousing, "*provides the time-and-place utility necessary for a company to prosper*" (Tompkins and Smith, 1998: 5).

2.2.3 Warehouse activities

The framework of every warehouse and its inherent activities must be adapted to the organization' business strategy and designed to meet the SC requirements (Christopher 2016). Internally, the management and control of the different activities must promote and support their integration, in order to minimize the friction between them and ultimately, avoid the constraints that may come from it. "*The key aspect to be considered in all these activities is the conflicting priority of maximising the use of the space allocated to each activity, while minimising the time taken to undertake the activity*"(Emmet, 2005:90).

Although warehouse activities may differ from company to company, considering the industry or sector where they operate, according to Myerson (2015), the main activities integrated in the warehousing system are the following:

- *Receiving*: Typically involves the scheduling of carriers to deliver goods and the unloading, inspection and quality control of the material. Sometimes it can also include tasks like unpacking and repacking in a format suitable for the following warehouse activities (Rushton *et al*., 2010). This subfunction usually entails a combination of lift truck, conveyors and manual processes;
- *Put-away*: Goods are identified by SKU or part number, sorted and put away with the location being recorded;
- *Storage*: Goods are stored in a designated location within the storage area in the warehouse. This may be racks, bins, shelves or even on the floor. When needed, the goods are moved to the shipping area or to replenish a picking location. This activity will be addressed in more detail later on in the subchapter;
- *Picking*: Depending on their size, customer orders are picked from either storage area or pick slots, which are replenished from storage locations (typically full pallets or cases), SKU's and quantities are then validated, and the selected items are brought to the shipping area;
- *Shipping*: Comprehends the scheduling of the carrier for pickup as well as the marshalling of goods in the shipping dock area and the loading onto a vehicle.

Other tasks performed by warehouses may range from packaging to cross docking or inventory tracking.

2.3 Storage activity

The storage activity incorporates the holding of materials, until they are needed, but also the management of the space required for it (Stock and Lambert, 2001). The floor area of a warehouse is limited and has to accommodate all of the different areas and activities related to the logistics process. Although it may vary, the storage area accounts for roughly 50% of the total usage of floor space, as seen in figure 4.

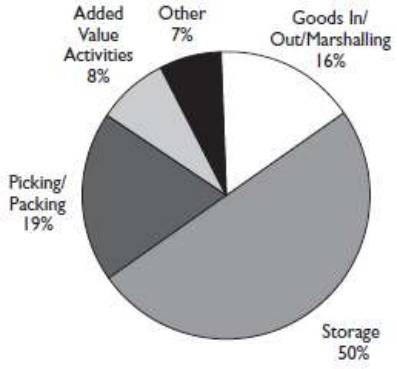

Figure 4 - Floor area usage

Source - Baker and Perotti (2008)

Considering the amount of space dedicated to storage and the important role that plays on the business' daily operation, this activity must be carefully designed and controlled to increase efficiency in the system and allow cost savings. Factors such as the type of inventory handled, storage systems (e.g. racks or shelves) and handling equipment utilized, stock allocation mechanisms as well as storage capacity and density, have to be strategically managed to boost the overall performance of the activity.

2.3.1 Types of inventory

In company SCs, there are various types of stock that can be found at strategic points along the logistics network, determined by the industry where the company operates and the different stages of the supply pipeline. To Rushton *et al*. (2010), stocks can be classified as:

- *Raw materials*: The materials, parts and components generally used to feed the production or manufacturing process;
- *Work-in-progress*: Semi-finished products usually held between different manufacturing processes;
- *Finished goods*: Goods that have finished the production process and are ready to be shipped out to the final customer.

Within the above categories, stock can again be broken down into other major classes:

- *Working stock*: Stock available for the normal demand of a product;
- *Cycle stock*: Stock with a predictable turnover and it reflects the batch sizes or production run lengths of the manufacturing process;
- *Safety stock*: Stock used to cover the unpredictable daily or weekly fluctuations in demand or replenishment;
- *Seasonal stock*: Speculative stock held for expected large increases in demand.

2.3.2 Storage systems and material handling

A well-designed storage system is a mix between maximum utilization of the available space and quick access to the stored goods. To Sople (2009), the ultimate goal of any storage system is to enable the placement and retrieval of material, while promoting space efficiency and minimum tracking, tracing and pickup time. Yet, storage management is based not only on the structures used for the storage of goods but also on the devices used to move them, i.e., handling equipment. Emmet (2005: 112) stated that " *there is a relationship between the two as they both need to exist side by side and be compatible"*. The proper management of both dimensions can result in effective use of warehouse space and operational efficiency.

Storage systems

Given the structural and functional characteristics of the materials stored, the selected system has to ensure that their integrity is not jeopardized, and they are kept in good condition until they are shipped or integrated in the picking process to fulfil an order or a production plan, while maximizing the space available. Therefore, when possible, such structures should be adapted to the configuration of the items stored.

Considering the size, type, capacity, density or automation desired, to Rushton *et al*. (2010) and Sople (2009), some of the storage systems available are: Block stacking, Drive-in and Drive- through racking, Push-back racking, Adjustable pallet racking (most common), Double-deep racking, Narrow-aisle racking, Shelves and Flow & Cantilever racks.

Material Handling

The material handling function has an impact on the efficiency and speed of the remaining warehousing activities, since its responsible for the movement of materials throughout the warehouse. Despite being a crucial part of the logistics process, the strategic decisions regarding material handling should be focus on reducing it to a minimum, to lower time waste and cut cost implications. According to Sople (2009), the main MH equipments available are: Pallets, Wheeled Trolleys, Conveyors, Monorails and Industrial vehicles like fork-lift or reach trucks.

The balance between the storage systems and the material handling equipments is a commitment that relates *"...the speed of operation, the storage density and the cost. It is often not a straightforward decision but should be one on which time is taken, before erecting relatively permanent fixed racking structures and perhaps also committing to semi-specialised and expensive handling equipment*."(Emmet 2005: 127).

2.3.3 Storage method

The way storage is conducted has a significant impact on the material handling and overall placement of SKUs within a warehouse. When designing it, the storage method should consider the space available (some use space more effectively than others), product characteristics, storage systems and handling equipment used, labour availability and information systems support (MULLER, 2011). According to Farahani *et al*. (2011), the storage of material can be executed by following three policies: Fixed or Dedicated storage, Randomized Storage, Zoning or Class-based storage.

Fixed or Dedicated storage

The products are stored in specific locations within the storage area, meaning *"...every item has a home and nothing else can live there*"(MULLER, 2011:54). It minimizes errors during put way and picking, allows more control over the location of the products and the allocation of SKUs in more suitable locations regarding their physical characteristics. However, this method entails large amounts of space for two reasons: the necessity of dimensioning the storage area for each item for the maximum stock that will be stored in the warehouse at one time, to have the required cubic space to hold that volume; promotes honeycombing, which happens when the available storage space is not being fully utilized. If a set of locations dedicated to an item A is empty, they cannot be used to store any other products in any circumstance.

The honeycombing ratio can be calculated through the ratio between empty and total storage locations but also with the amount of unused cubic feet.

Randomized Storage

The storage location is generated randomly and, when needed, the items are usually picked according to FIFO. This kind of allocation method promotes the maximization of space and arrangement flexibility since "*… there are no restrictions on where items can be stored in the storage area, so any item can be placed anywhere"*(Farahani *et al*., 2011). The randomized storage is generally aided by the use of predetermined algorithms, integrated in the WMS, that control the items placement.

The allocation process is based on the cubic space required to store the quantity of SKUs on hand at any given time, therefore, the constant updating of inventory records and monitoring of the storage area layout, is crucial to provide the software with accurate data inputs to operate efficiently and diminish the occurrence of errors. "*The WMS algorithm needs careful management input when being set up. It is not an automatic set-up process of the software and the default setting from the system's provider will need to be calibrated to the specific requirements"* (Emmet 2005: 96), which requires regular checking.

Zoning or Class-based storage

This method is a combination of the two earlier discussed, where products are grouped into classes, based on a principle, and stored in a specific area or rack section, in which the items' allocation is totally random. The implementation of this mechanism adds flexibility to the items' movement but still relies heavily on the WMS to properly function.

Even though it allows the segregation of items according to an ABC analysis or other criteria like popularity, cube-per-order index (i.e. the ratio of the item's storage-space requirement to its popularity) or more tangible features such as size and weight, regarding space utilization, "*as with dedicated systems the more tightly you control where a particular item will be stored, the more you will contribute to honeycombing or to the need to plan around maximum quantities*" (MULLER, 2011:61). Plus, if there is a rise on demand for a certain product and the defined storage zone is full, the remaining material must be stored elsewhere, causing dispersion of stock (Carvalho et al., 2010).

When deciding which storage method most fits the warehouse operation, organizations must ensure that the system, in its full extend, allows the tracking of the movement and storage of products throughout the facility and guarantee that the storage area is configurated to match the behaviour, dimension and characteristics of each item/group/class, to maximize the use of the available space and avoid the underutilization of locations cubic space or the inappropriate use of floor space.

2.3.4 Space utilization

When looking to the dimension of a warehouse or site, by removing the areas intended for the aisles, offices, production or others unfitted for holding material, there's only a limited amount of space to allocate stock. Given the importance that stock has for the logistics process, the space defined for its allocation must be designed and efficiently managed to ensure the operation productivity and lower costs. By maximizing the use of the total cubic space available, companies are able to utilize its full storage volume while maintaining low material handling costs. Still, one aspect that goes against this, is the fact that storage density tends to vary inversely to the number of different SKUs stored in the warehouse (Myerson, 2015). The more heterogeneous the inventory is, concerning shape and size, the more space and distinct storage systems will be required.

Other aspect managers need to pay close attention to is how full is the storage area, comparing to its total capacity, especially in warehouses/facilities that don´t have the storage of goods as their only purpose, i.e., have other functions. The rule of thumb regarding this measure is usually around 80%, which *"…is based on the fact that when a warehouse reaches this capacity, it takes longer to put something away*" (Tompkins and Smith, 1998: 61).

As the time to find a suitable storage location increases, the proper slotting of product starts to vanish and the service level declines, all due to poor space management. Continuously tracking the stock volume and space utilization, is the only way to anticipate when the warehouse will reach is full capacity and avoid the impact on labour productivity.

2.4 Warehouse Management System

Warehouse management systems support the efficient run of the ongoing warehouse operations on a daily basis, by managing the "*the receipt, movement and storage of materials within the "four walls" of a facility and process the related transactions necessary for receiving, put-away, picking, packing and shipping"*(Myerson, 2015:143). Moreover, it measures in real time what's happening across the warehouse through data capture and transmissions devices (e.g. bar codes and RFIDs) and, according to the specific requirements of each organization, makes the better utilization of space and resources to optimize the flow of products and ultimately address the customer demands. Thus, "*it goes a long way to ensure business success through adding value in terms of time, place and possession*" (Ackerman and Brewer, 2017:4).

When designing and implementing a WMS, to guarantee that it performs at its full potential, it's important to fully understand the connections and interactions between the several warehouse activities, and make sure that the databases that support the system architecture are accurate and match the actual physical environment.

WMS functionality covers all activities of the warehouse, from picking, by promoting product release prioritization and route optimization, to put way/storage, with automated location generation, space reduction suggestion and increased inventory monitoring (Rushton *et al*., 2010; Emmet, 2005).

2.4.1 Inventory monitoring

If a company can´t control every aspect of a product/material from both physical and recordkeeping standpoints, especially in a fast-paced environment like todays, the level of inventory accuracy will suffer and the general performance of the business decline. Inventory needs to be monitored whenever it's held but for the purpose of this project, this section will focus on the monitoring within the warehouse setting.

The monitoring of inventory is not simply a matter of stock checking but is about being aware of everything regarding the stock, to support the efficient management of the warehouse and the reliable feedback of information for management purposes. According to Ballard (1996), information about stock can be split into three categories:

- *Fixed information* – Specific aspects of an SKU usually permanent like code, description, dimensions, handling type (e.g. pallet), picking priority (e.g. FIFO) as well as preferred and secondary storage area or zone;
- *Variable information* – Dynamic elements that may change frequently during the ongoing operation such as unit load identifier, location of each unit load, number of

SKUs in each location , movement of each picked item and load status (e.g. available, QC hold);

- *Derived information* – Information obtained by analysing the fixed and variable information which can include movement rate per SKU, stock discrepancies or space utilization of the area/zone.

The task of collecting this kind of information can only be performed with some form of computerization, since the more automated the monitoring process, the more readily information becomes available. The WMS can easily gather this type of information considering the several features that possesses such as job sequencing, picking and location control, performance monitoring and reporting. However, sometimes due to certain system limitations, the WMS can generate the data but doesn´t turn it into information. The treatment of data supplies information that helps identifying weak areas/processes in need of improvement so, if the system is unable to provide it, information must be developed in other ways, perhaps through spreadsheets or other computerized tools. These instruments can be used to correlate fixed and variable elements to develop the needed derived information but are somewhat sensible to human error and require great effort and strict adherence to the disciplines regarding data entry. On the other hand, they can be tailored to attend specific concerns of the organization.

Some basic guidelines regarding inventory monitoring and WMSs in general, converge on the fact that information is key, it has to be accurate and up to date, not only to monitor the inventory but to control all warehouse performance, while minimizing errors and improve effectiveness. Information analysis is a gateway for improvements so it’s important to identify operational constraints, find their cause and if necessary, change procedures to eliminate errors that may be corrupting the optimum run of the operation.

2.4.2 Performance monitoring and reporting

Organizations that acknowledge the importance of measuring performance and establish core metrics that drive their business, avoid the analysis paralysis that some companies suffer when they gather too much pointless data. The continuous evaluation of performance is, without a doubt, crucial to monitor the operation' behaviour, particularly in warehouses which "*operate within tight service and cost standards, and failure to meet these standards can mean the difference between a successful and unsuccessful business"* (Rushton *et al*., 2010:318). To Sople (2009), the most common parameters used to measure the efficiency and effectiveness of the overall warehouse operations are:

- *Stock turnover ratio* – The ratio between sales and stock volume in a given time. Higher the ratio, the better utilization of warehouse space;
- *Warehouse cost-to-sales ratio* – Correlates the amount of goods handled with the operation costs. A lower ratio illustrates the efficiency of a warehouse;
- *Occupancy rate of warehouse space* – Indicates the actual space used as a percentage of available warehouse storage space. As mention in the space utilization subject, the rule of thumb value for this measure is around 80%.

In more dept, regarding the storage function, measures like the percentage of locations with correct stock (stock integrity) or percentage of storage capacity used by storage area/zone/location can also be looked at.

Besides identifying and measure this performance indicators, it's also important to display and spread this information across the three levels of detail (Hugos, 2011): Strategic - to help top management decide what to do; Tactical - to help middle management decide how to do it and Operational - to help people actually do it. This task can be achieved by pre-defined reports (e.g. summary or status reports of ongoing activities and performance indicators) generated by the WMS or, in case of system incapability to deliver such information, through other analytical tools like Excel, that allow the development of dashboards based on accurate data retrieved from the WMS. The main goal is to make sure that data is converted to information and information transformed into useful knowledge for decision making at all levels (Farahani *et al*., 2011).

3. METODOLOGY

This project is focused on providing solutions to overcome the challenges that the logistics centre of NOS in Alverca is currently facing and ultimately, improve the LC performance and contribute for a more sustainable operation in the future. Therefore, the methodology adopted to reach this target is described below:

1. Current situation and data gathering

On a first stage, a diagnose of the logistics centre is performed to get to know the ins and outs of NOS logistics operation. The facility's structure and overall warehousing processes were described, and, on a deeper level, the storage activity and inherent features were also documented. This initial breakdown of the current situation, conducted in October 2019, was based on company records and the WMS, as well as through direct observation of the operation and meetings with both NOS and DHL teams. The data collect during this period is presented below:

- Logistics centre layout and operational areas;
- Warehousing activities;
- WMS implemented;
- Stock families;
- Types of storage locations;
- Storage zones and deposits;
- Stock allocation method;
- KPI 's implemented.

2. Data analysis and identification of the main challenges

With the collected data, an analysis was executed to pinpoint the main problems that were contributing to high occupation level and low efficiency of the storage activity and, therefore, jeopardizing the operation performance, but most importantly, to identify the factors that were causing these issues.

3. Development of an action plan

The third stage of this project consisted in establishing a set of tasks, based on the information collected in the second stage, that could help to overcame the issues that characterize the LC current situation and, ultimately, improve the performance of the storage activity. The action plan developed included the following tasks:

i. Review all the storage zones, deposits and locations existent in the LC and perform the necessary changes in the WMS database.
ii. Identify structural improvement measures/opportunities;
iii. Implement mechanisms for a better control and monitoring of occupation /space utilization.

Considering the complexity associated with the execution of this tasks and the impact that they would have on the warehousing process, all of them were developed with the support of the NOS team and the various organizational areas or departments which participation was required (e.g. IT) as well as DHL personnel, mainly from the reporting team and the Stocks operational area of the logistics centre. Combining the knowhow of the operation from both sides, was crucial to guide the project in the right way and minimize setbacks.

Every week, a meeting was schedule, between NOS and DHL to discuss general concerns regarding the warehouse occupation and space utilization, and to see how the project was evolving and what were the next steps (these meetings happened throughout the entire length of the project).

4. Implementation of the action plan and analysis of the results

The last stage of the project was the more practical and time consuming, since it included the application of the action plan prior developed. Apart from making sure that the implementation of the defined measures was conducted properly along the way, in this context, was also important to analyse if the tasks established were fully completed and contributed for the fulfilment of the project goals and, if not, what limitations prevented this outcome and at what stage did the specific task stopped.

4. CASE STUDY

4.1 Business context

NOS is a communications and entertainment group, created in 2014, by the merger of two of the largest Portuguese companies in the telecommunications sector, ZON Multimedia and OPTIMUS, in the year prior. The union between these two companies allowed the establishment of a stronger position on the market and provided the required capacity and knowhow to deliver a better and more diversified service to customers.

Currently, it offers the latest generation fixed and mobile solutions for television, internet, voice and data, for all the market segments - personal, residential, business and corporate. On the entertainment spectrum, its market leader in the distribution and exhibition of cinematographic content through NOS Audiovisuais and NOS Cinemas, respectively, and organizes cultural events like the NOS ALIVE music festival.

Nationally, the company has 1.6 million television customers, 1.4 million broadband fixed internet customers, 1.8 million fixed voice customers and around 4.8 million mobile customers with 1.599 million euros in consolidated revenues, in 2019, and a net income of 143 million euros.

Figure 5 - NOS companies and subsidiaries

Source: NOS Website

In the long run, NOS business strategy is focused on increasing the company's market share in all segments and reduce the gap to Altice, which is the current market leader, and cement their position as the number one communications and entertainment group in Portugal, with a future-oriented mindset, bigger presence on the Portuguese everyday life and commitment to excellence and customer satisfaction.

However, as a crucial element for NOS business model, the LC has been struggling to keep up with the company's growth and diversification, which may jeopardize the achievement of the business goals set for the near future. The centralization of the different services under the same roof, left the LC in a delicate situation, almost reaching its full capacity, which promotes an unsustainable environment to run a logistics operation.

NOS Logistics Centre

NOS logistics operation is situated in a warehouse located in Alverca do Ribatejo. Even though the merger happened in 2013, the centralization of ZON and OPTIMUS operations in Alverca was fully completed only in October 2015, so the site is fairly new. The logistics centre its managed by a partnership between NOS Communications and DHL Supply chain, which is the logistics operator of the facility.

The NOS team permanently allocated to the logistics centre is constituted, at the moment, by 3 people that, in coordination with DHL, oversight the different activities of the warehousing process and the overall performance of the logistics operation. This team is integrated in a much larger department - Logistics and Terminal Management, which controls the entire logistics process of the company. The organizational structure of this department is presented in figure 6.

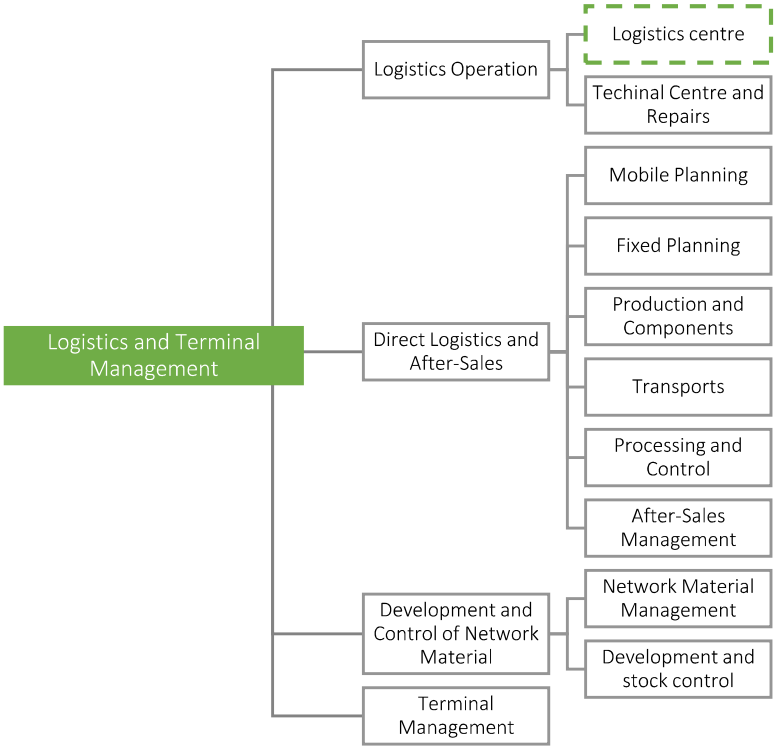

Figure 6 - Logistics and Terminal Management organizational chart

Source: NOS intranet

Every area integrated in this department manages and controls a specific element of the logistics system. Besides the logistics centre team, the technical centre and repairs (composed by 2 people), which handles the testing, repair and refurbishment of the equipments from the reverse logistics flow, is the only area that also interacts directly with the logistics operation, being partially allocated to the logistics centre. All the other areas are distributed between NOS headquarters in Lisbon and Porto. This project was conducted enterally in the logistics centre in Alverca.

NOS Office - Logistics Centre

NOS Headquartes - Lisbon

NOS Headquartes - Porto

Figure 7 - NOS headquarters and offices

4.2 Current situation and data gathering

In this chapter, the current situation of the logistics centre is presented, regarding the layout and operational areas, WMS, warehousing activities performed and, in particular, the storage process.

4.2.1 Layout and areas

The Logistics centre has 13.551 m^2 and is divided into 6 warehouses – B2, B3, B4, B5, B6 and B7. The facility has two floors, with the ground level being used for the operation and the 1ºfloor for NOS and DHL offices and the cafeteria. The logistics centre layout and main areas are presented in figures 8 to 13.

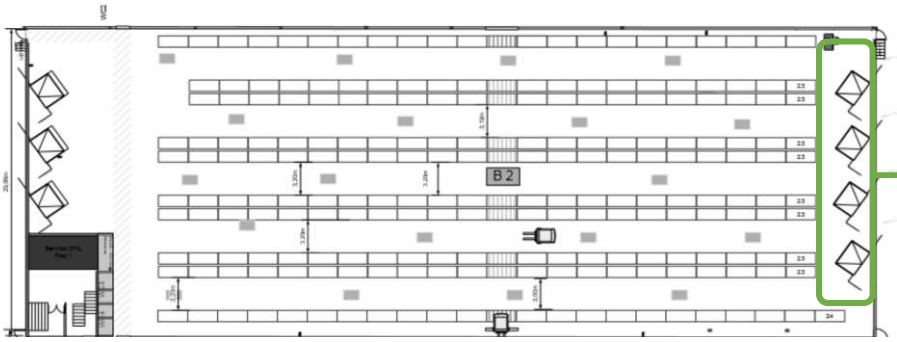

Figure 8 - Warehouse B2

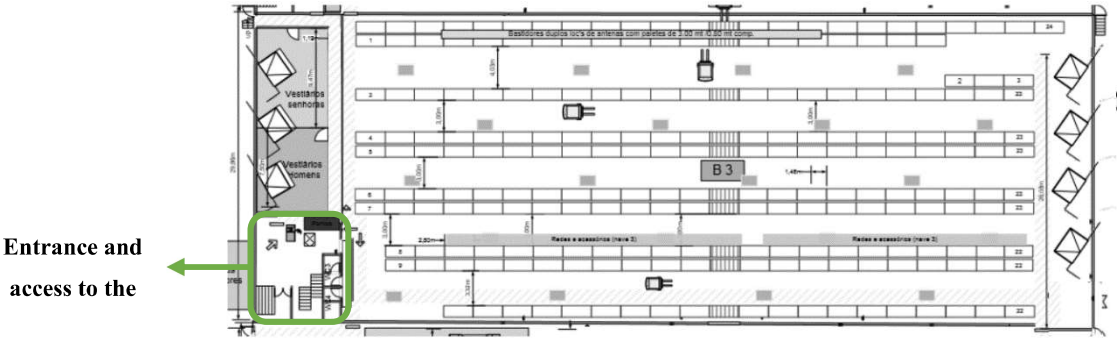

Figure 9 - Warehouse B3

Figure 10 - Warehouse B4

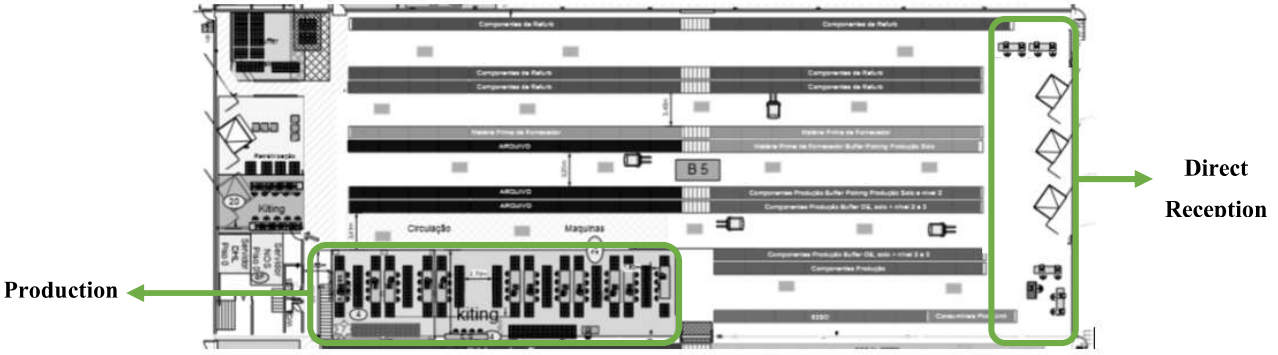

Figure 11 - Warehouse B5

Above the production area, DHL has a mezzanine where is located the reporting team office.

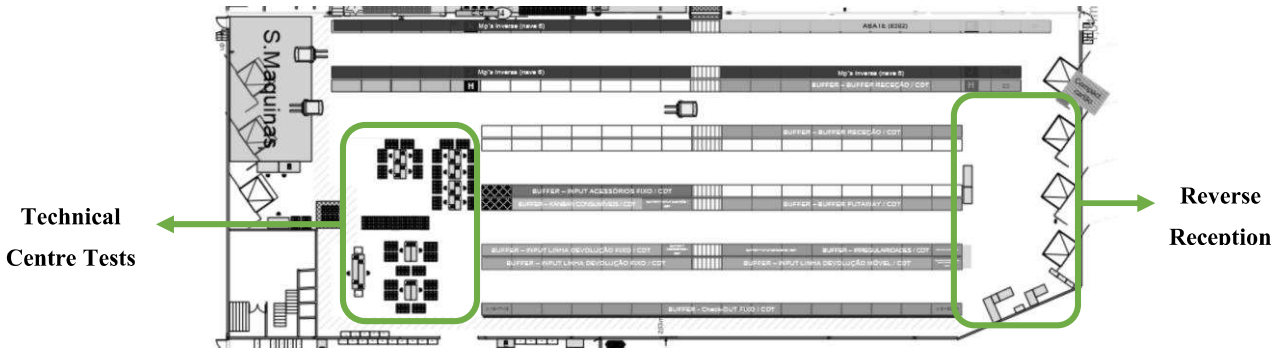

Figure 12 - Warehouse B6

Besides the testing area situated on the ground floor, outlined in Figure 12, the Technical Centre also includes another area located on the 1ºfloor (next to NOS office but separated from it), that runs across the warehouses B5 and B6.

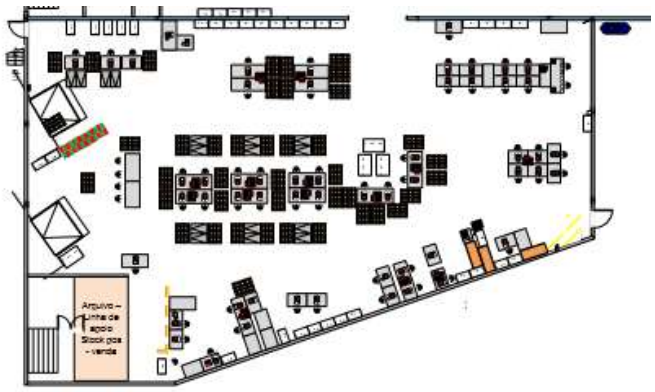

Figure 13 - Warehouse B7

The warehouse B7, which is the smallest of the logistics centre, is where the Return and Screening Centre is located.

4.2.2 WMS

SAP is the ERP system used in NOS, that connects the different branches of the organization. The WMS module of SAP is the one responsible for managing the overall logistics operation inside the Logistics Centre, by integrating and coordinating the warehousing activities performed, as well as the movement of stock throughout the facility.

According to each activity, the WMS has specific features that not only support their execution, but also help the monitoring process, by providing instant access to data. System transactions like lx03 and MB51, allow the user to extract data about all the locations in the LC regarding the type, stock allocated, storage zone and deposit associated and see all the stock movements per reference during a certain period (e.g. receptions, consumptions, shipments), respectively.

The WMS was implemented when the logistics operation was incorporated in the LC in Alverca and, since then, has suffered some software changes to better address the operation' specifications and contribute for a more efficient performance.

4.2.3 Warehousing activities

According to Myerson (2015), the main warehousing activities are receiving, put way & storage, picking and shipping. However, in this case, besides the standard activities, the warehousing operation also includes other tasks that are crucial for the business strategy of the company. The warehousing activities performed within the NOS logistics centre are presented below (Considering this project scope, the storage activity is addressed in more detail when compared to the others).

4.2.3.1 Receiving

In the Logistics centre, the receiving activity occurs in 3 different areas and each one them has a specific role:

- Network material Reception - This process occurs in the south side of the warehouse B2, has seen in figure 8, and it consist in the reception of all the material that supports the network coverage of NOS.
- Direct Reception – Placed in the warehouse B5, this area is responsible for receiving the larger volume of stock that enters into the logistics centre. Apart from the network category, all the material (i.e. raw materials, WP or finished goods) ordered by NOS to integrate the operation comes through this area.

- Reverse Reception – Located in B6, it receives all the equipments and different items from the reverse logistic pipeline.

Regarding the followed procedure, the network material and direct reception are very similar. The order number associated with the delivery is validated, the material is unloaded, and the SKUs reference, quantity and condition are verified. After this stage, if don't exist any anomalies to report, the operator checks in the items into the system (SAP) and material is put way in buffers or directly in the respective storage area.

The reverse reception process differs on the fact that, after the unloading and check-in into SAP of the material, the load is deconsolidated, and the items separated regarding their type – fixed equipments, mobile equipments or components) and the channel from where they came from (i.e. franchising, after-sales, stores or service providers like Futurcabo). Afterwards the material is place in the Returns and Screening Centre buffer.

A reception plan is established every week for each one of the areas, however, sometimes it isn't strictly followed by the suppliers. This uncertainty causes constraints in the areas and affects the storage activity, especially when a large amount of goods arrives at the logistics centre at once and there is no space available to store them. This typically happens with the fixed planning and fixed network material (presented in the storage chapter), that end up being placed in the aisles until there is room to store it.

4.2.3.2 Storage

This chapter is divided into the several elements that characterize the storage activity in NOS logistics centre.

Stocks area

The storage activity in the logistics centre is coordinated by the Stocks operational area, located in the warehouse B4 (see figure 10). This area is responsible for controlling the entire stock held in the facility, as well as support the movement of material between the different areas and activities that make up the warehousing process. In this context, their day-to-day job relies heavily on the WMS and regarding the material handling, this task is executed mainly with forklifts, reach trucks and order pickers. The Stocks team is operational 24h to ensure the efficient run of the logistics operation and that service levels are met.

Stock families

There exists a large variety of material stored in NOS Logistics Centre derived from the several businesses and areas of the company that are integrated in the facility. Thus, for a better control of the inventory, the stock is divided into 10 families. For the purpose of this project, the more relevant are presented below:

- *Fixed Planning*

This is the largest family in terms of volume handled in the Logistics Centre, occupying almost half of the storage area reserved for stock OK. It includes all the equipments and items related to NOS fixed solutions for tv, internet and voice services (e.g. TV boxes, Routers, phones) for the personal, residential and corporate segments, as well as all the components used in the kitting process (in production) and refurbishment of this equipments.

Considering the sheer size of this family and the importance that has for the company core business, the logistics department has a dedicated area (as seen in figure 6) that manages several aspects regarding this type of products (e.g. procurement process) and works closely with the Logistics Centre team.

- *Mobile Planning*

In this family are integrated all the equipments and accessories inherent to the mobile solutions offered by NOS for internet, voice and data services for the personal, residential and corporate segments. This group includes cell phones, routers, hotspots, wireless modems, simcards among others. Like the Fixed Planning family, this one also has an area dedicated exclusively to the management of this material (see figure 6).

- *Fixed and Mobile Network*

The fixed and mobile network are two separate families but have the same general purpose, which is to support the NOS global signal coverage for the tv, internet, voice and data services across the country. Regarding the stock held, the fixed network includes fiber-optic cable drums for the most part, which constitute the big dimension category, and the mobile network involves antennas, power distribution units (BTS), batteries and other electronic instruments.

This material is characterized by its large size and unconventional shape, which creates some challenges in the storage process. Since November 2018, the mobile network material has registered a growth in volume stored, with the start of a company project called ATENA. Moreover, the fixed network material held in the LC also increased, as a result of a big expansion in terms of fixed signal coverage.

The logistics internal area that oversees this stock family is the Development and Control of Network Material.

- *Cinemas*

As stated by the name, this family encloses the material associated with the cinema business. It was integrated in the Logistics Centre in February 2018, with the reception of 726 SKUs and 52000 units distributed between the following categories: 35mm, movie drives, pens and promotional material (i.e. posters, standees and statues).

- *Events & Promotional material*

This group refers to the structures and promotional elements used on cultural events sponsored by NOS (e.g. NOS Alive, NOS Primavera Sound or Comicon) or in brand activations.

The Brand & Communication department of NOS is the one responsible for this material, which was dispersed throughout several locations. So, to centralize the owl area in one place, in June 2019, it was stored in the Logistics Centre.

The integration process of the events material into the LCs had some setbacks. The majority of the objects had an irregular format and couldn't be palletized or stored in standard storage locations, therefore, some of them had to be scattered throughout the Logistics Centre and placed wherever there was available floor space to store them. On the other hand, the integration wasn't fully completed. Due to the large dimension of some structures (e.g. stands, NOS Alive entrance and stages) and the lack of suitable storage space, a portion of the items had to be stored in two other smaller warehouses (owned by NOS) in Forte da Casa and Santiago do Cacém. Currently there is no inventory of this material and it's not integrated in SAP, thus, nobody has visibility over these objects and, when they are needed, the process is to complex and time consuming, for the NOS LC team, the Brand & Communications area and for whoever makes the request.

- *Homevideo*

The homevideo family belongs to NOS Audiovisuais and aggregates the several DVDs distributed by this business. These items were incorporated in the Logistics Centre in October 2019, to cut the costs associated with the rented warehouse where they were previously stored. Even though the products are small and easily stored, the quantity of units received, at the time of the integration, was high, having a big impact on the warehouse occupation.

- *Business Solutions*

It includes the fixed and mobile solutions for the business market segment, like modems, routers and landline phones. This area was integrated in the LC in April 2019. Within some of these families, were also established different categories that classify the products according to their

characteristics and functionality. The 10 families and respective categories are displayed in Appendix A.

Storage systems

All the warehouses included in the Logistics Centre, except B7, have 10 rows of racks identified with the letter A to K. The letter I is not considered to avoid confusion with the letter J. The disposition and length of the rows, in each one of the warehouses, may differ considering the floor space occupied by the operational areas, as well as according to the material allocated to that specific rack section. For example, in warehouse B3, there is a section where the row J and K are in front of one other, because the antennas that are stored in that zone require locations with more dept that the standard ones.

Usually, each rack has 6 levels where stock can be allocated. However, since this storage system is adjustable, a specific rack can have as many levels as needed. Besides racks, the Logistics Centre has other storage systems adapted to certain product characteristics (e.g. small size), in order to maximize the space utilized, such as carts and shelfs. (see Appendix B).

All storage locations in which stock can be allocated, have an identification code that supports the tracking of the items inside the Logistics Centre. The general structure of this code is presented below.

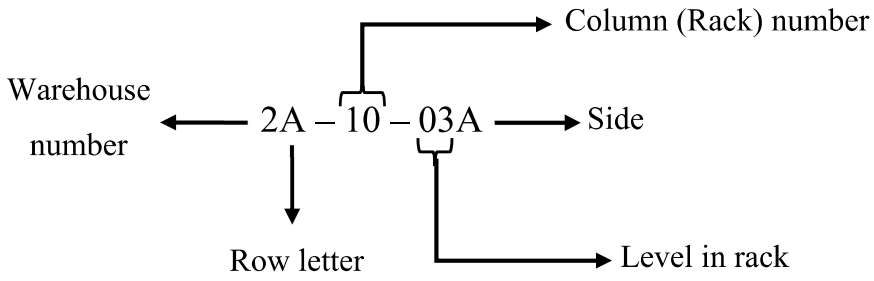

Figure 14 - Location identification code

The letter that indicates the side, A or B, it´s not common to all locations. This categorization is only present in locations that, instead of one, have two slots where items can be allocated (this matter will be addressed in the next chapter).

Regarding the carts and shelfs, the coding varies a little. Besides indicating the warehouse, row and column where the storage system is placed in the Logistics Centre, the identification code also points out the side (A or B) and the horizontal and vertical coordinates where the item is placed.

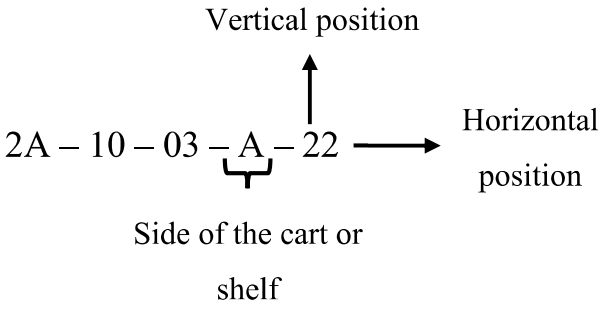

Figure 15 - Carts and Shelfs identification code

Types of storage locations

The storage locations placed throughout the Logistics Centre are classified according two principles – *volumetric space* and *role*. Regarding the first criterion and as presented by the WMS, locations can be categorized as follows:

Type of location	Description
E0	Dynamic location
E1	Loc. height < 0,75m
E2	Loc height 2m
EA	Loc < 16
AT	Antennas location
B1	Capacity 81 pal
B2	Capacity 279 pal
B3	Capacity 121 pal
B4	Capacity 135 pal
B5	Capacity 243 pal
B6	Capacity 423 pal
B7	Capacity 297 pal
BT	BTS location
C2	Safe zone Shelf
C9	Safe zone Pallet
D1	Cable drums location

Figure 16 - Types of location

The most common types of location existent in the Logistics centre are E2, E1 and E0. E2 is the standard pallet location in which most of the stock is placed. Of the three types, the second largest location is E1, that in some occasions, has not one but two slots where stock can be allocated (E1 Double). E0 is described as a dynamic location since it includes all the smaller storage systems (e.g. carts and shelfs) where lower quantities are stored.

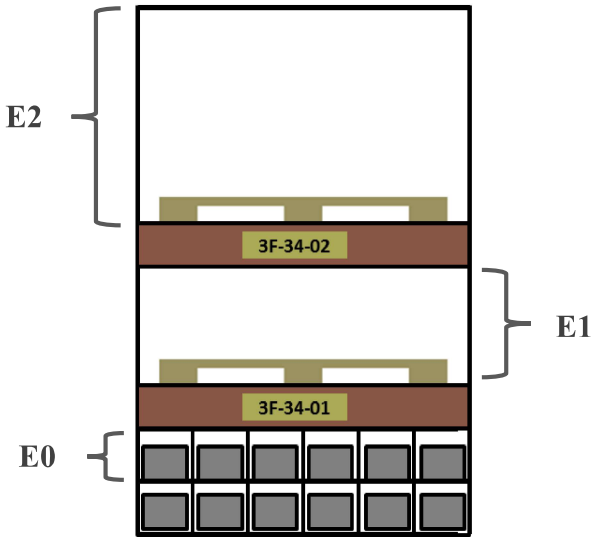

Figure 17 - E2, E1 and E0 locations

Classified as AT are the locations dedicated to the storage of antennas, which are mainly concentrated in warehouse B3, and D1 is the location type where fiber-optic cable drums have to be stored considering their size. Finally, BT is where BTS are stored and, C2 and C9 are restricted to the storage of simcards. Currently there are *23333* locations in the LC, from which 12196 are classified as *E2*, 3678 as *E1*, 3347 as *E0*, 420 as *AT* , 1126 as *D1*, 68 as *BT*, 1410 as *C2* and 1088 as *C9*.

As stated before, the storage locations can also be classified according to their role in the Logistics Centre. Within the facility, locs can be used to store:

- *Stock OK*: All the commercial stock related to the different businesses of NOS and integrated in the logistics operation (e.g. fixed and mobile planning material). This area occupies the largest volume of locations;
- *Obsolete inventory*: Obsolete or damaged material ready to be disposed of, since it can´t be sold/delivered to the final costumer and, therefore, doesn't create value for the company anymore. To minimize the losses, sometimes these products are sold to other companies (brokers) and certain components, that still are in good condition, are used as spare parts in the operation. This material is stored in warehouse B2;
- *Archives*: In warehouse B5, there is a specific area where company records are stored during a certain period of time, due to legal reasons;
- *DHL material*: Locs restricted to the storage of DHL material.
- *CGD material*: A portion of warehouse B2 is currently being rented to Caixa Geral de Depósitos Bank, as a result of an agreement made between NOS and CGD at the strategic level.

Storage locations can also be used as *Buffers*, i.e., locs placed at the ground level and next to each one of the operational areas, that are used in their day-to-day activity. These locations work as a midpoint between the storage area, where the items are stored, and the operational area where the items will be integrated into a specific activity.

Figure 18 - Buffers utilization

There are also *blocked* storage locations. In these positions are placed certain items that were isolated from the stock OK due to specific reasons like: No codes, QC suspended, incomplete, reserved or by NOS indication. These locs are associated to a specific storage zone.

Storage zones

The storage area reserved for the placement of stock OK is divided into zones, that are determined based on the stock families and product categories held in the LC, and on the inputs and outputs of the warehousing activities. Currently, there are over 50 zones in the storage area and each one aggregates a certain type of items. The main storage zones are presented in figure 19.

Storage Zone	Description
101	Terminals (I)
102	Terminals (H)
103	Accessories
104	Packs mobile
107	Production Components
116	Packs card
111	Advertisement material, gifts and consumables
117	Packs return
120	Network Mat – Cable drums
121	Network Mat – BTS
122	Network Mat - Antennas
123	Network Mat - Networks
125	Consumables
1SO	Functional w/ damage
204	Kits direct
207	Refurb Components
217	Kits reverse
222	Treatment Reverse

Figure 19 - Storage Zones

Within a storage zone, the area is also split into different sectors called *deposits*, which indicate in what stage/area of the warehousing process a certain item is or what is its destination. Throughout the LC, there are *38* deposits and most of them are common to more than one storage zone. A few of them are presented below.

Deposit	Description
8301 – General stock	Stock available for production and supply the commercial channel
8302 – Obsolete stock	Stock to be destroyed or sold to brokers
8303 – Reception	Deposit of material entry into the LC, to physical evaluation and QC
8304 – B2C	Stock available for production and supply the final customer
8306 – Returns	Deposit of material entry into the LC from reverse logistics
8307 – Tests	Equipments waiting for testing
8308 – Refurb	Equipments waiting for refurb
8309 – Corporate	Stock available for production and supply the corporate channel
8310 – Business	Stock available for production and supply the business channel
83X1 – Construction/Maintenance	Fixed and Mobile network stock available for shipping

Figure 20 - Deposits

The full list of storage zones and deposits is presented in Appendix C.

Storage method

The allocation method of material in the storage area is based on a zoning or class-based model. The crossover between the storage zones and deposits, presented earlier, creates specific regions, where the items are placed. The WMS manages the stock allocation method and does it, according to the following procedure:

1- When items are ready to be placed in the storage area, in SAP, the operators from the different operational areas, indicate the reference of item, number of units on hand at that time and the destination deposit. Through the reference, the system already knows to which of the storage zones the item belongs to;

2- Then, for each reference, the system has what's called a " Palletization data", where is established the maximum number of units that fit into an E2, E1 and E0, regarding the volume occupied (see figure 21). According to the number of units being stored, the system selects the smallest type of location where that quantity can be allocated, to maximize the space utilization;

3- In the WMS, every location in the storage area reserved for stock OK, has a code, type, storage zone, deposit and status (empty, occupied, blocked) associated. Thus, at last, the system suggests a location that complies with the parameters established in steps 1 and 2 and that is empty. If there is a location that is occupied but not entirely full, in which the material already placed there shares the same characteristic (e.g. reference, storage zone and deposit) with the material being stored and, according to the palletization data, the space available is enough to accommodate these units, the system is able to consolidate the stock in that specific loc – *Stock Consolidation*.

Reference	Name	Max Qt	Type	Max Qt	Type	Max Qt	Type
25678	Router Alcatel ST546v6-2 preto	150	E2	10	E1	1	E0

Figure 21 - Palletization data of item 25678

In general, the stock allocation process is constituted by these 3 steps, however, two important aspects should be mentioned. First, not all references have the 3 levels of palletization, since the number of units being stored at any given time is pre-established, i.e., doesn't vary. On the other hand, there are certain types of material which, the allocation on the storage area is not managed according this system. For example, the fiber-optic cable drums storage, limited to the warehouse B2, is based essentially on the space available (empty D1 locations) within the respective storage zone and deposit.

Key performance indicators

Every week, a meeting is schedule between the NOS logistics centre team and the DHL monitoring team, to present the performance indicators of each operational area. The information exhibited is based on data provided by the WMS, through the lx03 transaction, that afterwards is integrated into a Balanced Scorecard. Regarding the storage activity, the main KPI's presented are:

- Logistics Centre occupation rate;
- Occupation rate per warehouse and storage zone;
- Weekly stock consolidation rate.

The KPI's presented in the BSC are only for internal use, i.e., for the running of the logistics operation. In terms of storage space utilization, there are no other performance indicators or dashboards implemented.

Occupation rate	Global
Capacity (# of locs)	23 333
Occupation (# of locs)	21 932
Occupation rate (%)	94%

Figure 22 - BSC: Occupation Rate

Currently, the LC occupation rate is *94%*. According to DHL, the items that occupy more storage space is the fixed planning equipments, as a result of the elevated number of units held and weekly received in the LC, and the fibre-optic cable drums of the fixed network area, which take a considerable portion of the available room considering the large cubic(m^3) space required to store them.

Figure 23 - Fibre-optic cable drums storage

4.2.3.3 Production

In this logistics operation, the production process consists on the assemble of packs of fixed and mobile equipments with the respective components or accessories such as remotes, fliers, chargers or simcards. The production schedule is based on a weekly plan established by a dedicated team in the logistics department of NOS, which is then reviewed by the NOS logistics centre team and DHL personnel. If both parties agree on it, a daily production schedule is elaborated, and the picking orders are recorded in the WMS. After the production process is concluded, the pallets with the finished goods are filmed, placed in the output buffer of the area and then stored in the storage area, on the respective storage zone and deposit.

4.2.3.4 Picking

The picking process for production is done, on a first stage, by the stocks area that collects the required equipments and accessories and puts them in the input buffers of the production area, and then by the line feeders, which feed each one of the production lines. Regarding the shipping activity, the picking method has 3 levels:

1- The picking is executed according to a group of orders – batch picking, to minimize the distance travelled by the pickers. After being picked, the items are putted into the shipping area buffers. This stage is performed by the Stocks area;
2- The items are separated by supply channel – zone picking;
3- For each specific order, the operator gathers the respective items – picking by order.

In both cases, the picking strategy used is FIFO.

4.2.3.5 Shipping

This process includes the fulfilment of the shipping orders according to the daily plan designed and verified on the day prior. The shipping area is divided into zones that facilitate the picking process for each one of supply channels like Service Providers, B2C, Corporate, Audiovisuais, REX (exclusive retail) and PM – Promotional Material. The transportation of the goods is outsourced.

4.2.3.6 Return and Screening Centre

This area is located in warehouse B7 and is responsible for the sorting, check-in and evaluation of all products coming from the reverse logistics pipeline. Within this area, there are specific zones dedicated to a particular type of material, i.e., fixed equipments, mobile equipments and components. Fixed equipments like tv boxes or routers are checked-in into the system and segregated according to their status: TNSG – no warranty, TNEG – with warranty or ABATE – obsolete. Then, in the fixed check-out zone, pallets are formed per reference and status and then stored in the respective storage zone, in the deposit 8307 to be tested (if status is TNSG or TNEG) or 8302 (if status is ABATE).

Regarding the TNEG and TNSG, this classification is performed because, the software repair of the equipments that still are within the warranty period (initially provided by the manufacturer), doesn´t have any associated costs for NOS. Therefore, in the picking process for the tests area, where is assessed if the equipments need any repair, regarding their software, the TNEG status is prioritized.

Mobile equipments are checked-in into SAP, sorted by category, evaluated, tested and, if needed, refurbished. In the end, they are stored in mono-reference pallets in the storage area. At last, the components are separated by type, i.e., accessories or chargers, tested (only chargers) and physically assessed. If they are in good condition, the items are cleaned, checked-in into the system and stored. If not, the items are placed on the electron.

4.2.3.7 Technical Centre

The Technical Centre, located in warehouse B6, is divided into two areas: Tests and Refurb. In the tests area, firstly, the fixed equipments are tested, using high-tech platforms that evaluate if they're functional, and then segregated according to the test result – OK or NOK. If NOK, the equipments are sent to deposit 8312 for repair. If OK, the equipments are physically checked to see if they need any kind of repair. In this stage, if the equipments require refurbishment, they're divided into pallets according to two status – PRAC (high cost refurb) or PRBC (low cost refurb) and go to the Refurb area. Otherwise, if the items are not physically damaged in any manner, the equipments are labelled RFS (ready for service) and stored.

In the Refurb area, the refurbishment of the visually damaged equipments is executed, by changing the broken components for new ones. After this process is completed, the items are labelled RFS, full pallets are formed and the equipments are stored.

4.3 Data analysis and identification of main challenges

Considering the problem at hand, an analysis was conducted to assess the current situation of the storage activity, focused on three dimensions: Space overcrowding, WMS inaccuracy and limitations, and occupation control and monitoring.

Space Overcrowding

The Logistics Centre occupation rate has reached an all-item high of *94%*, which is way over the 80% - 85% rate recommended for an efficient warehouse operation. The increase in volume of stock held and the integration of several businesses into the LC, since 2018, had a strong impact on the LC performance.

Figure 24 - Businesses integration timeline

In a short period of time, four new stock families were added to the already extensive portefolio of products held in the LC. This not only affected the space organization, with material occupying floor space all over the storage area, but also increased considerably the occupation level, as seen in figure 25, which jeoperdized the efficiency and sustainability of the operation. The centralization of the company's whole activity in one place allowed more control over the stock, but the LC capacity and the operation responsiveness weren´t ensured in the long term. As a result, the occupation rate increased 7% between the third quarter of 2018 and 2019.

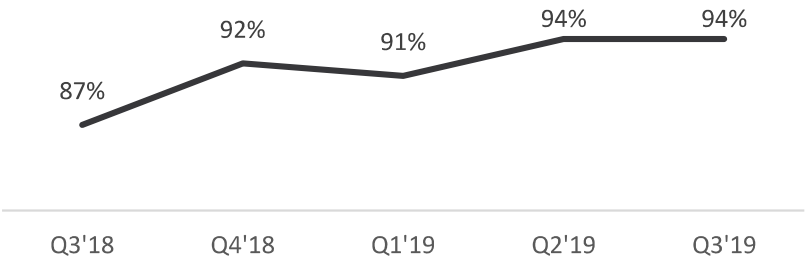

Figure 25 - LC occupation rate evolution

By looking to the storage area itself, some issues can also be pinpointed. The increase of SKUs handled in the LC, with unregular shapes and sizes, contributed for the underutilization of space within the storage locations, since the storage systems are not completely adapted to the items physical characteristics (see figure 26). So, besides the high occupation rate, there is also space being wasted.

Figure 26 – Cinema posters storage

WMS inaccuracy and limitations

By comparing the data obtained by the WMS, particularly through the lx03 transaction, regarding the locations, storage zones and deposits that virtually existed, with the physical arrangement of the storage area, several discrepancies were identified (the time of the observation was October 15th):

- The types of locations presented by the system don't translate all the different locations that physically exist across the storage area;
- Locations mapped in the WMS that in reality don´t exist and vice versa;
- Non-existent locations in the WMS, that physically exist and have stock allocated to them;
- Locations duplicated in the system - the same loc has two different types and is associated to different storage zones, which is wrong;
- Storage zones and deposits displayed by the system, that don´t exist anymore;
- Groups of material/locations that don´t have any storage zone associated like obsolete inventory, buffers, homevideo, among others.

The mismatch between the information exhibited by the system and the physical environment, prevents the smooth run of the storage activity as well as the accurate control of the occupation level. The system' inability to easily create or eliminate locations in large scale, when certain changes are made to the racks arrangement, is one of two reasons that contribute for this disparity. The other one, concerns the low maintenance of the WMS database.

Regarding the stock allocation process, the WMS also shows some limitations. At times, when assigning items to a location, the system doesn´t consider locs where stock consolidation is possible and selects an empty location instead (see figure 27), which prevents the maximization of the storage space used.

Currently, this process has to be complemented with an analysis of the stock placement across the storage area, performed manually by the Stocks, to identify situations in which items can be consolidated.

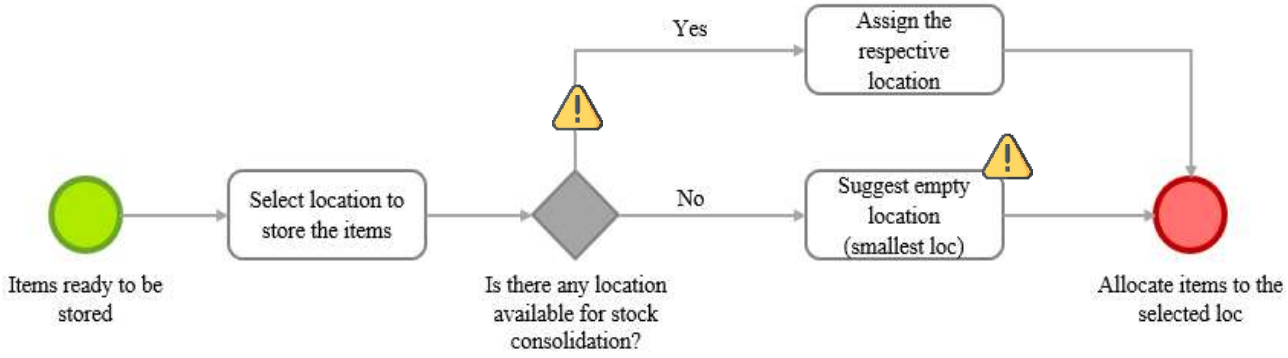

Figure 27 - Location selection process

Moreover, in some situations, when allocating stock, the system only considers E2 locations regardless of the quantity being stored, which also contributes for the underutilization of space. This usually happens in the put way process of fixed equipments from the several operational areas. To mitigate the impact that this error has on the storage space occupation, to a certain extent, the Stocks area manually transfers the items to more suitable location like E1s.

Occupation control and monitoring

The method through which the assessment and presentation of the LC occupation indicators is executed, its flawed and doesn´t provide the required visibility to accurately monitor this dimension and support the decision making at the different organizational levels.

The inefficiency of this process can be, on a first stage, attributed to the fact that since the performance indicators, related to LC occupation, are determined according to the WMS database which, as explained in the prior chapter, as several errors, the information gathered is not totally accurate.

Furthermore, the calculation of the occupation rate is based on the ratio between total vs occupied locations (locked locs are not consider) and not on the cubic space used within the total storage area volumetric capacity. The utilization of the total vs occupied ratio would be more appropriate if all the storage locations had the same dimensions, which does not apply in this case. Also, some assumptions are wrongfully taken like considering buffers as locked locations and not as occupied ones, which means that they're not integrated in the calculus.

At last, the performance report and the few KPI's established don't allow a deep and continuous analysis of the LC occupation and space utilization (e.g. floor space being used) at different levels. Plus, the sharing of useful information, regarding this manner, with the areas responsible for the stock held in the LC, is very limited.

4.4 Development of an action plan

After determining and characterizing the focal problems that were at the core of the LC precarious situation, a plan was proposed to overcome these challenges and, ultimately, promote the reduction of space occupied within the facility. The strategy blueprint was divided into three major tasks:

- Review and inventory all the storage zones, deposits and locations existent in the LC and perform the necessary changes in the WMS database;
- Identify structural improvement measures/opportunities;
- Develop mechanisms for better control and monitoring of occupation/space utilization.

Each one of the established tasks is described below.

Inventory of the storage area elements and adjustment of the WMS database

The disparity between the WMS and the physical setting of the storage area needed to be eliminated, in order to guarantee efficiency in the storage activity but also to accurately assess the occupation rate. The match between these two dimensions provides a better view of the storage area, more responsiveness when dealing with space necessity and allows the identification of inefficiency situations.

Accordingly, the inventory of all storage zones, deposits and locations was planned to identify the differences and perform the required changes in the WMS. The cubic space of the several types of location identified was also addressed.

Structural improvement measures/opportunities

In this stage, by looking to not only the storage activity but to the overall logistics operation, several improvement measures were identified that could increase the storage space available but also leverage the productivity in some warehousing processes. The opportunities were determined by meetings with DHL operators from several operational areas, such as Stocks, Tests, Refurb and Return and Screening Centre, through which, 8 opportunities were pinpointed. These opportunities were then presented to the LC team and relevant parties, and classified on a scale of 0 to 4, according to the following criteria: Difficulty to implement, IT effort and Need of investment (human or financial resources) and Impact on Occupation/Efficiency (in this criterion, 4 is the best score).

Opportunities	Difficulty to implement	IT effort	Need of investment	Impact in occupation/efficiency
1 - Eliminate the status TNEG and TNSG segregation in the RSC Check-Out	2	2	1	2
2 - Eliminate the status PRAC and PRBC segregation in the Tests Check-Out	2	2	1	2
3 - Eliminate the storage segregation between mobile phones from direct and reverse logistics	1	2	1	2
4 - Implement carts with shelves for the cinema posters storage	2	1	3	3
5 - Monthly disposal of NOK chargers from the RSC	1	0	1	2
6 - Change the system behaviour related to the picking process for the shipping area regarding mobile equipments	4	4	3	3
7 - Change the storage of obsolete stock in 222-Treatment reverse (storage zone) from mono-reference to multireference pallets	2	1	1	2
8 - Use of E1 locations for the check-out and picking of fixed equipments	4	4	3	3

Table 1 - Improvement opportunities classification

Considering the classification of the identified opportunities, presented in table 1, the ones selected for implementation were 1, 2, 3, 4, 5 and 7. Within these, I was responsible for conducting number 4. Although number 6 and 8 had a potential strong impact on space utilization and process efficiency, both were very difficult to implement, in a short timeline, and required a large effort and investment, since a dedicated IT project would be needed for each one of them.

Mechanisms for better control and monitoring of occupation/space utilization

This last task consisted on the development of mechanisms that, not only could provide a more accurate awareness regarding the occupation level of the LC, with different layers of scrutiny, but also tools that could help improve the inventory control, in terms of space used, and assist the WMS functions that are not performing in the desired manner like the stock consolidation. With this in mind, one performance report was created, and an analytical tool was designed, which are presented below:

- *Weekly Occupation Report;*
- *Storage Optimization Model;*

The developed mechanisms are described in more detail in the next chapter.

4.5 Implementation of the action plan

In this stage of the project, the improvement measures prior identified and included on the action plan developed, are described and its impact is assessed.

4.5.1 Inventory of the storage area elements and adjustment of the WMS database

According to the action plan established on the previous stage of the project, the inventory of the storage zones, deposits and locations existent in the LC was executed. The results of the inventory were then analysed and compared to the data presented by the WMS, and the necessary adjustments were made to the system.

Storage zones and deposits

On the initial inventory, there were identified *54* storage zones and *38* deposits. The role of each one of them was assessed, as well as if it was being used on the ongoing operation. The results of this analysis are presented below.

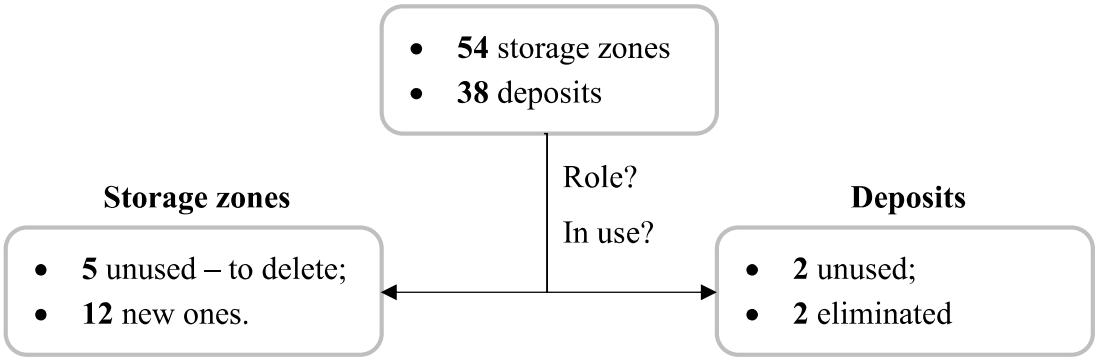

Figure 28 - Storage zones and deposits inventory results

As presented in figure 28, 5 storage zones didn´t had any purpose on the operation and, therefore, are being eliminated from the system. Plus, it was identified the necessity to create 12 new zones related to obsolete inventory, archives, buffers, homevideo, CGD and DHL material, as a way to have more visibility regarding the space used by each one of these areas (see table 3). Concerning the deposits, 2 unused were identified and eliminated from the WMS.

Storage Zone	Description
401	Obsolete Inventory
402	Archives
403 to 409	Buffers (from the several operational areas)
411	Homevideo
412	CGD
413	DHL

Table 2 - New storage zones

Storage locations

The global inventory of all storage locations existent on the logistics centre was conducted with the help of DHL personnel. The results are presented below.

Type of location	Description	Location code model	Total	B2	B3	B4	B5	B6	Stock family where is used
BTS	BTS	3H-46-01	26	0	26	0	0	0	Network material
BTS (Double)	Double BTS	3K-51-01A/B	51	0	51	0	0	0	Network material
D1	Cable Drum (until 140cm)	2G-05-03	460	460	0	0	0	0	Network material
D2	Double Cable Drum (2 drums stacked)	2B-41-01	388	388	0	0	0	0	Network material
D3	Cable Drum (until 180cm)	2F-06-03	423	423	0	0	0	0	Network material
D4	Double Cable Drum (2 x 2 drums stacked)	2A-04-01	63	61	2	0	0	0	Network material
E0 (1/18)	Cart with 18 small locs	4H-58-A-11	108	0	0	108	0	0	Transversal
E0 (Cx 15)	Cart with boxes of 15 items	3F-40-A-11	15	0	15	0	0	0	Transversal
E0 (Cx 3)	Cart with boxes of 3 items	3F-42-A-11	1130	0	340	790	0	0	Transversal
E0 (Cx 9)	Cart with boxes of 9 items	3F-41-A-11	570	0	180	390	0	0	Transversal
E0 (Unit)	Movibloc shelf	4H-16-A-11	1160	0	0	1160	0	0	Transversal
E1 (Double)	High-density (40cm width)	6H-43-03A/B	3079	240	602	1595	102	540	Transversal
E1 (Simple)	High-density (80cm width)	6G-20-04	1440	184	234	549	39	434	Transversal
E2	Standard pallet	2A-04-03	11859	1718	2777	1964	2638	2762	All
E3	Double standard pallet in depth	3K-01-06	201	0	201	0	0	0	Network material
E3 (E1 Double)	Double high-density standard pallet in depth	3K-01-02A/B	156	0	156	0	0	0	Network material
E3 (E1 Simple)	High-density standard pallet in depth	3K-01-03	18	0	18	0	0	0	Network material
Simcards	Locs exclusive to Simcards	5E-07-01	30	0	0	0	30	0	Transversal
E0 (shelf)	Shelf for network material	BK4901E11	381	0	381	0	0	0	Network material
E0 (HV)	Homevideo Carts	4A-40-A-11	3566	0	0	3566	0	0	Homevideo
		Total	**25124**	**3474**	**4983**	**10122**	**2809**	**3736**	

Table 3 - Storage locations inventory results

As seen in table 3, more than 25k locations were identified, which are divided into 20 different types. By confronting the inventory with the data displayed by the WMS, *1783* new locations had to be created, *387* were deleted, the associated storage zone was changed in *1599* locations and *8* unused types of location were also eliminated (EA, B1, B2, B3, B4, B5, B6 and B7). To simplify this process and support the maintenance of the system database, with the support of the IT department, a tool was developed to create/delete locations in large scale.

Besides classifying and quantifying the several types of locations existent, their dimensions and volume was also analysed. As presented in table 4, the volume of each type was converted into *E2*, since, this is the standard location within the LC and to better understand and compare the volume of the different types.

Type of location	Description	Total	Hight (cm)	Width (cm)	Depth (cm)	Volume (E2)
BTS	BTS	26	190	80	120	1,5
BTS (Double)	Double BTS	51	190	80	300	3
D1	Cable Drum (until 140cm)	460	140	80	120	1
D2	Double Cable Drum (2 drums stacked)	0	280	80	120	2
D3	Cable Drum (until 180cm)	423	190	80	120	1,5
D4	Double Cable Drum (2 x 2 drums stacked)	0	280	80	240	4
E0 (1/18)	Cart with 18 small locs	108	40	40	40	0,06
E0 (Cx 15)	Cart with boxes of 15 items	0	200	80	40	0,1
E0 (Cx 3)	Cart with boxes of 3 items	1130	40	40	24	0,03
E0 (Cx 9)	Cart with boxes of 9 items	570	40	40	40	0,05
E0 (Unit)	Movibloc shelf	1160	22,5	20	40	0,02
E1 (Double)	High-density (40cm width)	0	70	40	120	0,25
E1 (Simple)	High-density (80cm width)	1440	70	80	120	0,5
E2	Standard pallet	0	140	80	120	1
E3	Double standard pallet in depth	201	140	80	300	2
E3 (E1 Double)	Double high-density standard pallet in depth	0	70	40	300	0,5
E3 (E1 Simple)	High-density standard pallet in depth	18	70	80	300	1
Simcards	Locs exclusive to Simcards	30	40	20	120	1
E0 (shelf)	Shelf for network material	381	-	-	-	0,07
E0 (HV)	Homevideo Carts	3566	22	40	20	0,02

Table 4 - Storage locations dimensions and volume (E2)

Although the integration of this data (i.e. types of locs) into the WMS, could support the uniformization between the system and the reality as well as improve the stock allocation process, such task was not possible to execute. Considering the complexity of the system and the rules that dictate its behaviour, it was required an extensive IT project to reach this objective.

To counterweight this situation, a baseline was created in Excel, based on the inventory performed, where, for each storage location, the following aspects are presented:

- Warehouse;
- Row;
- Code;
- Type;
- Role (e.g. Stock, obsolete inv., buffers);
- Storage Zone;
- Status (empty, occupied, blocked);
- Volume (converted to E2);
- Reference of the item placed in the loc (if occupied);
- Area (stock family) and category of the item (if occupied).

The baseline is presented in figure 29.

A	B	C	D	E	F	G	H	I	J
Warehouse	Row	Code	Type	Role	Storage Zone	Status	Volume	Reference	Area + Category
2	2H	2H-17-06	E2	Stock	123	Occupied	1,0	1700104562	Fixed Network Material - Big dimension
2	2H	2H-18-01	D2	Stock	120	Occupied	2,0	1700109602	Fixed Network Material - Big dimension
2	2H	2H-18-03	D3	Stock	120	Occupied	1,5	1700109610	Fixed Network Material - Big dimension
2	2H	2H-18-04	D1	Stock	120	Empty	1,0	-	
2	2H	2H-18-05	E2	Stock	123	Occupied	1,0	1700104679	Fixed Network Material - Big dimension
2	2H	2H-18-06	E2	Stock	123	Occupied	1,0	1700103501	Fixed Network Material - Big dimension
2	2H	2H-19-01	D2	Stock	120	Occupied	2,0	1700109602	Fixed Network Material - Big dimension
2	2H	2H-19-03	D3	Stock	120	Occupied	1,5	1700109610	Fixed Network Material - Big dimension
2	2H	2H-19-04	D1	Stock	120	Empty	1,0	-	
2	2H	2H-19-05	E2	Stock	123	Occupied	1,0	1700104679	Fixed Network Material - Big dimension
2	2H	2H-19-06	E2	Stock	123	Occupied	1,0	1700104562	Fixed Network Material - Big dimension
2	2H	2H-20-01	D2	Stock	120	Occupied	2,0	1700109602	Fixed Network Material - Big dimension
2	2H	2H-20-03	D3	Stock	120	Occupied	1,5	1700109610	Fixed Network Material - Big dimension
2	2H	2H-20-04	D1	Stock	120	Occupied	1,0	1700109340	Fixed Network Material - Big dimension
2	2H	2H-20-05	E2	Stock	123	Occupied	1,0	1700104679	Fixed Network Material - Big dimension
2	2H	2H-20-06	E2	Stock	123	Occupied	1,0	1700104679	Fixed Network Material - Big dimension
2	2H	2H-21-01	D2	Stock	120	Empty	2,0	-	
2	2H	2H-21-03	D3	Stock	120	Occupied	1,5	1700109610	Fixed Network Material - Big dimension
2	2H	2H-21-04	D1	Stock	120	Occupied	1,0	1700109340	Fixed Network Material - Big dimension
2	2H	2H-21-05	E2	Stock	123	Occupied	1,0	1700108130	Fixed Network Material - Big dimension
2	2H	2H-21-06	E2	Stock	123	Occupied	1,0	1700103538	Fixed Network Material - Big dimension
2	2H	2H-22-01	D2	Stock	120	Empty	2,0	-	
2	2H	2H-22-03	D3	Stock	120	Occupied	1,5	1700109610	Fixed Network Material - Big dimension

LX03 002 | LX03 300 | Baseline

Figure 29 - Baseline

The columns in white are static and manually updated, if, by necessity, any change is performed regarding the location's physical characteristics. On the other hand, the remaining columns (colour grey) are updated automatically with the *lx03* file extracted from the WMS, considering that the data provided is now accurate.

4.5.2 Structural improvement measures/opportunities

In this subchapter, the alternative storage system for cinema posters, referenced on chapter 3, is presented as well as the results obtained from it.

Carts with shelves for the cinema posters storage

Within the storage area, the cinema posters are allocated to E2 and E1 locations, in mono or multireference pallets considering the rotation of that specific item, i.e., active, slow mover or non-mover. The references are classified as active if their last shipment occurred within the last 90 days, slow mover if it happened between 90 and 180 days and non-mover if it took place more than 6 months ago. The stock distribution between these 3 categories, as well as the space occupied by each one of them is presented below.

	Last shipment (days)	Number of references	Volume (units)	Average stock per reference
Active	< 90	103	15650	152
Slow Mover	90 - 180	47	7220	154
Non-Mover	> 180	108	18130	NA

Table 5 - Posters stock distribution

	E2	E1
Active	60	51
Slow Mover	19	26

Table 6 - Storage locs occupied by posters

While mono-reference pallets are formed with active or slow mover objects to simplify the picking process, multireference pallets are used for non-mover items that can be stored together to maximize storage space utilization. Since this pallet formation is already optimum, considering the items behaviour, the locs where non-movers are stored were not accounted for this improvement suggestion and, therefore, are not present in table 6**.**

The main concern regarding the storage of posters is the LC is associated with high underutilization level of the E2 and E1 locations used for this purpose. According to the palletization data of several poster references, in average, the maximum number of units that fit into an E2 and E1 locations is 1000 and 400 respectively. However, when looking into the average stock per reference that is placed in these locations, the number of units stored is around 150 in both categories (i.e. active and slow movers), which is considerably lower.

To measure the amount of space not being used, the underutilization percentage was calculated for either types of location.

E2

$$\frac{1000 - 150}{1000} * 100 = 75\%$$

E1

$$\frac{400 - 150}{400} * 100 = 62{,}5\%$$

Figure 30 - Underutilization percentage

In both cases, the storage capacity available is far from being fully utilized, with more that 50% of the space being empty. Thus, is necessary to evaluate other solutions that may not only be more suitable for the storage of posters, regarding the physical characteristics of this material, but also reduce the space wasted and increase the storage density. With this in mind, the proposed solution consists on the implementation of carts with shelfs, as presented in figure 31.

Figure 31 - Cart with shelves

The carts would have 9 shelves and be placed in E2 locations, at the ground level. The number of levels determined, maximizes the utilization of the available space within E2's and, simultaneously, increments the density on the posters' storage.

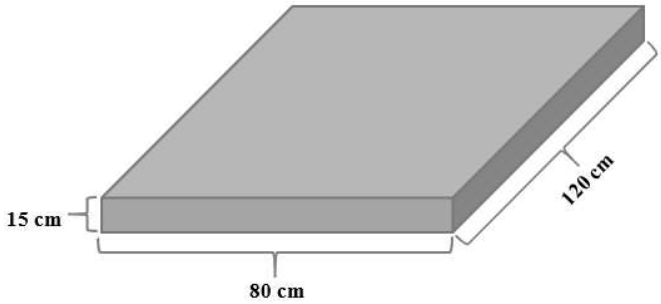

Figure 32 - Position dimensions

Each position on the cart has the same dimensions, which are presented in the figure above. Considering that there are 9 locations per cart, the total volume of space available to store is 1,29 m^3, that represents 96% of the cubic volume of E2's (i.e. 1,34 m^3,), therefore, a considerable share of the space is preserved. The remaining 4% are reserved for the layers that divide the cart into the different levels.

To identify the locations, both physically and in the WMS, each one would have a code associated, with the following structure: 3A-10-P01. It keeps the standard configuration used in the LC and the letter "P" added, is a reference to the material stored in these locations.

Regarding the storage capacity, since the average stock per reference is around 150 units and considering that in one location can only be allocated a single SKU, each position in the cart would hold in average *150* units of a specific item and, in total, a cart would have the capacity to store *1350* posters. If this storage system was implemented, what would be the impact on the space occupied by both categories?

	Volume (units)	Space Occupied (E2)	Carts required (E2)	Savings (E2)
Active	15650	85,5	15650/1350 = 11,59 ≈ **12**	85,5 – 12 = **73,5**
Slow Mover	7220	32	7220/1350 = 5,34 ≈ **6**	32 – 6 = **26**
Total	**22870**	**117,5**	**18**	**99,5**

Table 7 - Carts implementation impact on space occupation

Active posters

Currently, there are 15650 units stored in *60* E2's and *51* E1's which, if converted into E2's, results in *85,5* locations. Assuming that the entire stock is allocated in carts, would only be necessary roughly *12* carts, i.e., *12* E2's to accommodate this material. In this case, the savings obtained by this change reach *73,5* locations, which represents an *86%* decrease in the storage space used by this category.

Slow Mover posters

This category has 7220 units stored in *19* E2's and *26* E1's, which translates into ***32*** E2's. If this material was placed into carts, only *6* units would be required to fulfil this task. Thus, *26* E2 locations could be freed, which is an *81%* cut on the space occupied by slow mover posters. In total, with the implementation of 18 carts, the LC can gain nearly *100* E2 locations, that represent *0,6%* of the global storage space. Although the impact on the overall occupation may be residual, the empty space potentially obtained through the application of this storage system may provide some of the needed clearance to address some occupation problems regarding other stock families. Furthermore, it also contributes for a more efficient picking process, since, in this scenario, the posters would be placed at the ground level and concentrated in specific locations, improving the accessibility to this material.

4.5.3 Mechanisms for better control and monitoring of occupation/space utilization

Weekly Occupation Report

To address the lack of information issue regarding the occupation status of the LC, a weekly report was created. This tool was developed in Excel, being supported by the baseline of storage locations and the products catalog.

As presented earlier in the project, the baseline provides an in-dept view of all storage locations inside the LC and inherent characteristics (e.g. code, type, volume(E2), reference allocated). On the other hand, the products catalog incorporates all the items held in the facility, indicating the reference, description, area (stock family) and category of each one of them, which is a relevant input when trying to assess the occupation level at different dimensions.

By working on the data provided by the baseline and correlating it with the catalog, it was possible to determine the following KPI's:

- Occupation rate:
  - Global;
  - Per warehouse;
  - Per storage zone.
- Weight (%) per location' role (e.g. Stock OK, Obsolete inv.) within global occupation;
- Weight (%) per area (stock family) within Stock Ok;
- Weight (%) of each product category within the respective area;
- Floor space used;
- Blocked locations per storage zone.

Although other performance indicators could be added to the report, considering the data inputs gathered, the ones presented above, clearly illustrate the condition of the storage area, with several cuts, and allow the monitorisation of this environment. Some elements of the report are presented in figure 30. The information depicted is related to the 13th week of 2020. The remaining KPIs can be found in Appendix D.

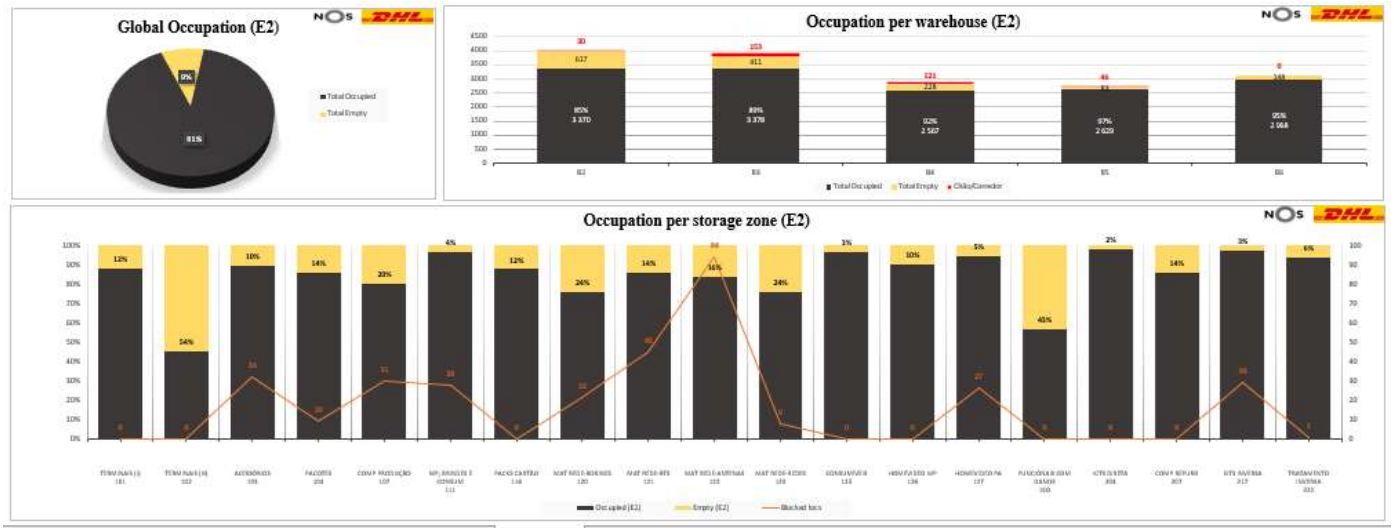

Figure 33 – Occupation report

Since the volume of all locations is converted into E2, the standard location is the unit in which the performance indicators are based, providing an accurate view over the space occupied. Thus, the occupation level, at the several dimensions, is calculated through the ratio between volume (E2) used and the total volume (E2) available.

To keep track of the blocked locations and their whereabouts in the storage area, the red line that runs across the bottom graph, related to the occupation level per storage zone, indicates the number of blocked locations associated to the respective zone

The floor space occupied is also reflected on the dashboard, in the bar chart related to the occupation level per warehouse (top right), highlighted in red. This data is introduced manually into the dashboard, considering the volume (E2) that, in theory, the material that is placed on the floor (e.g.in isles) of a specific warehouse, would occupy if it was properly stored. For example, if 10 full pallets of fixed equipments were placed on the isles near the direct reception, which often happens, 10 E2s would be added to bar associated to warehouse B5.

This report is intended for internal use, i.e., for the LC operation management, with a weekly periodicity, allowing a continuous monitoring of the storage area occupation, more responsiveness regarding lack of space, global or in particular situations, and more visibility concerning the space used by stock that is not yet reflected in the WMS.

Storage Optimization Model

This model was firstly created as a response to one of the problems identified regarding the stock allocation system, concerning its inability to efficiently consolidate stock and prevent the underutilization of storage space. Since this task was being partially performed manually, by the Stock area, this mechanism aimed to simplify and automate the analysis conducted and provide a valuable output. However, besides having this functionality, the applied model also allowed the assessment of the optimal occupation rate, i.e., if the stock allocation system worked perfectly and every material was stored in the most ideal way, considering the rules established for this process and how the storage area is structured, what would be the occupation level. By embracing these two perspectives of how this tool could be helpful for the operation, its implementation supported the achievement of the following objectives:

- Identification of stock consolidation opportunities;
- Assessment of the optimal occupation rate;
- Evaluation of the gap between the real and optimal occupation rate.

The model was developed in excel and is sustained by macros specifically created for this purpose. To ensure that both the L.C team and DHL can easily use this tool, a user guide was created, that explains in detail how the tool is operated, which databases are required and how to obtain them.

On a first stage, within the vast portfolio of products stored in the LC, the model was only applied to certain stock families/category such as fixed and mobile planning, fixed network (small dimension), cinemas (drives) and business solutions, which represent 71% of the stock OK. This selection was based on the material that, by record, had the highest consolidation potential and, therefore, had to be prioritized.

How does it work?

For the stock families/categories selected, were identified the two set of rules that dictated how and where the respective stock can be consolidate: the aggregation criteria followed by the WMS and the types of locations where that specific material can be allocated. Both aspects are presented in table 8.

Stock families	Criteria	Type of locations
Fixed planning	Consolidation per reference, storage zone, deposit and status - only applies for deposits **8307** and **8312**	E2, E1(Simple)
	Consolidation per reference, storage zone and deposit - applies to all deposits except **8307** and **8312**	E2, E1(Simple), E1(Double), E0 (Cx 15), E0 (1/18), E0 (Cx 9), E0 (Cx 3), E0 (Unit)
Mobile Planning	Consolidation per reference, storage zone, deposit and type of package	
Fixed Network (small dimension)	Consolidation per reference, storage zone and deposit	
Cinemas (Drives)		
Business Solutions		E2, E1(Simples), E1(Double)

Table 8 - Stock consolidation rules per stock family

The stock consolidation criteria and the types of locations associated with each family, vary according to the products characteristics and their physical flow throughout the L.C.

According to the pre-determined rules, per reference, the model will assess the optimization index, i.e., the impact in occupation obtained through stock consolidation. The analysis performed by the model includes the following steps:

1. Considering the stock consolidation criteria applied, and based on the data provided by the lx03, the model determines the volume of stock available to be consolidated;
2. The number of units being aggregated is divided by the E2 palletization of the reference, i.e., the maximum number of units that fit into an E2, to determine the volume (E2) required to store the material, if the storage was optimized.
3. According to the rules applied regarding the types of location that can be used, the model allocates the volume (E2) in the most space efficient way to minimize the underutilization of storage space. The utilization of standard locations is always prioritized.
4. Considering the locs arrangement determined in step 3, the model calculates the total volume (E2) used and compares it with the actual occupation, provided by the baseline, to determine the optimization index.

To demonstrate this process, an example is presented regarding the reference 2700005061 (Box 1.0 HD + DVR) from the fixed planning family.

Location	Type	Storage Zone	Deposit	Stock (units)
4D-22-02	E2	217	8307	75
4D-24-03	E2	217	8307	86
5F-29-04	E1	204	8301	23
5F-51-03	E2	204	8301	15
5F-62-03	E2	204	8301	75
5G-07-04	E2	204	8301	60
5G-07-06	E2	204	8301	88
5G-08-02	E2	204	8301	100
5G-29-06	E2	204	8301	70
5H-36-02	E2	204	8301	98
5J-41-05	E2	204	8301	15
6F-55-03	E2	222	8307	90
6G-40-02	E2	222	8307	78

Table 9 – Box 1.0 HD+DVR stock distribution

The reference 2700005061 stock placement throughout the storage area is displayed in table 9. This example will be focused on the storage zone *204* and deposit *8301*. In this setting, the equipment is currently occupying 8 E2s and 1 E1 which translates into *8,5* E2s in terms of volume. The process followed by the model to determine the optimization index is described below.

Current Occupation (E2)	Stock available (units)	E2 palletization	Volume required (E2)	E2 locs fully utilized	Remaining volume (E2)	Most suitable loc?	Total volume (E2)	Optimization index (E2)
8,5	544	100	544 / 100 = 5,44	5	0,44	E1(0,5)	5 + 0,5 = 5,5	8,5 – 5,5 = **3**

Table 10 – Optimization index

From the 873 units placed in the storage area, there are *544* available for stock consolidation considering the storage zone and deposit selected. By dividing the stock available by the E2 palletization, which is *100*, the volume(E2) required to store this quantity is determined – *5,44* E2s. If this volume was stored in standard locations, only **5** E2s would be entirely occupied, therefore, the remaining volume – *0,44* E2s, which does not completely fill an E2, has to be allocated into a more suitable loc where the space utilization is maximized. At this stage, according to the consolidation rules applied to this reference, the system selects the smallest one (see table 11).

Type of location	Volume (E2)
E0 (1/18)	0,06
E0 (Cx 15)	0,1
E0 (Cx 3)	0,03
E0 (Cx 9)	0,05
E0 (Unit)	0,02
E1 (Double)	0,25
E1 (Simple)	0,5

Table 11 - Location selection

In this case, the most suitable location is the E1. This means that, in total, if the 544 units were consolidated, they would occupy 5 E2s and 1 E1, which represents a volume of *5,5* E2s. Thus, the stock consolidation would allow a decrease of *3* E2s in terms of space used - optimization index.

The application of this model allows the assessment of the total optimization index per reference, contributing for identification of stock consolidation opportunities and, in a much wider scope, the appraisal of the optimal occupation rate (global) as well as the evaluation of the volume (E2) occupied per area/family and category in this setting. Additionally, it supports the measurement of the gap between the real and optimal dimensions. The results of the analysis conducted are presented in a report integrated in the tool.

As stated earlier, the storage optimization model was only applied to some of the stock families present in the L.C. In tables 12 and 13, the results of analysis, carried out at the end of March, are presented (the values are rounded up). The analysis per category can be seen in appendix E.

	Real		Optimal		
Area	**Volume occupied (E2)**	**Weight (%)**	**Volume occupied (E2)**	**Weight (%)**	**Δ (E2)**
Cinemas	360	2%	301	2%	-58
Consumables	349	2%	349	2%	0
HomeVideo	902	6%	902	6%	0
Fixed Network	2288	15%	2239	16%	-49
Mobile Network	1077	7%	1077	8%	0
Events&Promotional Material	420	3%	420	3%	0
Others	1	0%	1	0%	0
Fixed Planning	5489	37%	5052	36%	-437
Mobile Planning	694	5%	521	4%	-173
Business Solutions	260	2%	200	1%	-60
Obsolete inventory	558	4%	558	4%	0
Archives	276	2%	276	2%	0
Buffers	1420	9%	1420	10%	0
CGD	445	3%	445	3%	0
DHL	106	1%	106	1%	0
Blocked locs	329	2%	329	2%	0
Total	**14974**	**100%**	**14196**	**100%**	**-778**

Table 12 – Real and optimal occupation per area

	Volume Occupied (E2)	Total volume (E2)	Occupation Rate
Real	14974	16386	91%
Optimal	141966	16386	87%

Table 13 - Real vs Optimal occupation rate

In terms of volume (E2) occupied, the areas/stock families that were not integrated in the analysis remained constant, i.e., the optimal occupation is equal to the real occupation.

According to the results obtained by the storage optimization model, through stock consolidation in the families/categories considered, it was possible to vacate around *774* E2s and reach an occupation rate of *87%*, which represents a decrease of *4%*.

Regarding the optimization index, the report presents the top 5 references, within each stock family, with the highest index. This can be seen in table 14.

Stock family	Category	Reference	Description	Volume Occupied (E2)	Total Optimzation Index (E2)
Cinemas	Drives	77394	DRIVE - BAD BOYS FOR LIFE (2D LPT)	4,05	2,05
Cinemas	Drives	76871	DRIVE -STAR WARS:SKYWALKER 2D3D 5171 SUE	4,75	2,83
Cinemas	Drives	76397	DRIVE - FROZEN II 2D/3D 5171 DUB	3,50	2,22
Cinemas	Drives	77622	DRIVE - ONWARD 2D3D 5171 SUBDUB	2,00	1,50
Cinemas	Drives	77662	DRIVE - FANTASY ISLAND (2D_VDO_LPT)	2,80	1,20
Fixed Network	Small dimension	70296	(Telenco) Parafuso 300mm M16 (Cx 25un)	17,00	6,90
Fixed Network	Small dimension	54260	Mordente Passagem ADSS 12_144 (Cj 20)	29,00	5,00
Fixed Network	Small dimension	69889	Módulo GW-HD 24 SC/APC Full_v2	8,00	4,00
Fixed Network	Small dimension	77128	Mordente p/Cabo Drop	4,00	3,50
Fixed Network	Small dimension	62712	(TFO) Cabo RG11 preto AS (1 BOB - 305m)	6,00	3,25
Fixed Planning	ETC NET	2700005585	MP ROUTER WI-FI 4.0 (ARRIS TG249NO)	61,25	18,25
Fixed Planning	Refurb Components	2700004277	PANEL CASE ROUTER (HUB BVW3653) PRETO	103,00	16,75
Fixed Planning	ETC NET	2700005090	MP ROUTER WI-FI (HUB3.0 CVE30360_v3)_SIP	184,50	16,00
Fixed Planning	ETC TV	2700005003	MP BOX 2.0 HD (CABO DCR 7151)	167,25	15,50
Fixed Planning	ETC TV	2700005498	DTA (INTEK)	47,50	13,00
Mobile Plannning	Mobile equipment	73742	Telemóvel Alcatel 1C 2019 Preto	7,50	5,40
Mobile Plannning	Mobile equipment	60629	Telemóvel Nokia 216 Dualsim Preto	5,52	4,89
Mobile Plannning	Mobile equipment	74189	Telemóvel Samsung Galaxy A10 Preto	7,73	4,63
Mobile Plannning	Pen/Router/Hotspot	61929	Pack Router Internet Huawei B310 DTH_v1	5,00	4,00
Mobile Plannning	Pen/Router/Hotspot	58660	MP Router Wifi Huawei E5172s_v1 preto	4,80	3,30
Busines Solution	NA	40001049	Cisco SPA508G Cinza	3,00	2,75
Busines Solution	NA	40001046	Cisco SPA501G Preto	4,80	2,55
Busines Solution	NA	40001040	Cisco CP-7940G	2,80	2,55
Busines Solution	NA	40001041	Cisco CP-7942G	2,75	2,50
Busines Solution	NA	40001065	Yealink T48S	3,00	2,00

Table 14 - Top 5 references per stock family with highest optimization index

Assessment and improvement of the storage activity in NOS Logistic Centre

5. CONCLUSION

This project was focused on the assessment and improvement of the storage activity incorporated in the Logistics Centre of NOS, which, by the end of September 2019, was struggling with the high occupation level of the storage area, as a reflexion of the company's growth in the last few years, and the impact that it was having on the overall warehousing process.

Considering the problem at hand, by analysing the storage dimension, it was possible to identify the main factors that not only were contributing for this situation, but also were susceptible to improvement, which laid the foundation for the plan of action later developed.

The inventory of the storage area elements (i.e. locs, storage zones and deposits) and the rearrangement of the WMS database, allowed the reduction of the disparity between the system and the physical environment, however, this task wasn´t totally completed since the integration of the new types of locs categorized, into the WMS, was not possible to execute. Nevertheless, the storage locations baseline created in the process , provides in-dept view of the storage area and allows a more rigorous control over this element.

Regarding the assessment of structural improvement opportunities, the outcome of this task was positive, with the identification of 8 improvement measures, from which, I was responsible for the implementation of one, concerning the storage of cinema posters. The results of the proposal indicate that, theoretically, almost 100 E2 locations can be vacated through the application of 18 carts, which represents 0,6% of the overall storage space. Also, it would benefit the picking process of these items. Yet, the actual impact on occupation and handling process, can only be evaluated after the implementation of the storage system is complete.

Concerning the occupation level and space utilization monitoring, two separate mechanisms were developed, each one with a specific objective. The weekly occupation report fills a void that previously existed by presenting a wider range of KPIs, relevant for the control of the occupation rate as well as for the management of the ongoing operation, since it provides an accurate view of the storage dimension. On the other hand, the storage optimization model complements the stock allocation system by identifying situations where stock consolidation can be performed and allows the evaluation between the real vs optimal occupation, at different levels, encouraging the development of solutions, in addition to stock consolidations, to reduce the gap between them. Considering the scenario established for the first iteration of the model, the results point to a potential 4% reduction in the occupancy rate.

Overall, the project met the objectives that were set at the beginning, still, some recommendations are proposed for further research:

- Development of a monthly occupation report for internal sharing of KPIs with the business areas;
- Review and improvement of the stock allocation system;
- Extension of the storage optimization model to the remaining stock families and optimization of the mechanism;
- The fixed equipments and fiber-optic cable drums account for 58% of the stock OK and represent 46% of the storage space occupied. Therefore, given their predominance within the L.C, the forecasting of the variation of the space occupied induced by the inbound and outbound movements of the material, i.e. reception and dispatch, could provide a prediction concerning how much space will be vacated and, on the other hand, anticipate future needs of storage space, which contributes for the responsiveness of the operation.

6. BIBLIOGRAPHY

Ackerman, K. B., & Brewer, A. M. (2017). Warehousing: A Key Link in the Supply Chain. *Handbook of Logistics and Supply-Chain Management*, 2, 225-237. https://doi.org/10.1108/9780080435930-014.

Baker, P., & Perotti, S. (2008) *UK Warehouse Benchmarking Report*, Cranfield School of Management.

Ballard, R. L. (1996) Methods of inventory monitoring and measurement. *Logistics Information Management*, 9(3), 11 – 18. http://dx.doi.org/10.1108/09576059610116653.

Bowersox, D. J., & Closs, D. J. (1996). *Logistical Management: The Integrated Supply Chain Process* (1st ed.). McGraw-Hill College.

Carvalho, J. C., Guedes, A. P., Arantes, A. J. M., Martins, A. L., Póvoa, A. P. B., Luís, C. A., Dias, E. B., Dias, J. C. Q., Menezes, J. C. R., Ferreira, L. M. D. F. Carvalho, M. S., Oliveira, R. C., Azevedo, S. G., & Ramos, T. (2010). *Logística e gestão da cadeia de abastecimento*. Edições Silabo.

Christopher, M. L. (2016). *Logistics & supply chain management* (5th ed.). Pearson.

Emmet, S. (2005). *Excellence in Warehouse Management: How to Minimise Costs and Maximise Value* (1st ed.). John Wiley & Sons.

Farahani, R., Shabnam, R., & Kardar, L. (2011). *Logistics Operations and Management: Concepts and Models* (1st edition). Elsevier.

Gu, J., Goetschalckx, M., & McGinnis, L. F. (2010). Research on warehouse design and performance evaluation: A comprehensive review. *European Journal of Operational Research*, *203*(3), 539–549. https://doi.org/10.1016/j.ejor.2009.07.031

Hugos, M. H. (2011). *Essentials of supply chain management* (3rd ed.). New Jersey: John Wiley & Sons.

Kovács, A. (2011). Optimizing the storage assignment in a warehouse served by milk run logistics. *International Journal of Production Economics*, *133*(1), 312–318.

Min, H. (2006) The applications of warehouse management systems: an exploratory study. *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management*, 9(2), 111-126. http://dx.doi.org/10.1080/13675560600661870.

Muller, M. (2011) *Essentials of Inventory Management* (2nd edition). AMACOM.

Myerson, P. A. (2015). *Supply Chain and Logistics Management Made Easy: Methods and Applications for Planning, Operations, Integration, Control and Improvement, and Network Design* (1st ed.). Pearson FT Press.

Rushton, A., Croucher, P., & Baker, P. (2010). *The handbook of logistics & distribution management* (4th ed.). London: Kogan Page.

Sople, V. V. (2009) Logistics Management (2nd ed.). Pearson.

Stock, J. R., & Lambert, D. M. (2001). *Strategic logistics management* (4th ed.). McGraw-Hill/Irwin.

The Council of Supply Chain Management Professionals. (2016). *CSCMP Supply Chain Management Definitions and Glossary*. https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx.

Tompkins, J. A., & Smith, J. D. (1998) *Warehouse Management Handbook* (2nd edition). Tompkins press.

7. APPENDIX

7.1 Appendix A – Stock families and categories

Stock family	Category
Cinemas	35MM
	Drive
	Cinemas PM
	Pens
Fixed Network	Big dimension
	Small dimension
Fixed Planning	Accessories
	Antennas
	Simcards
	Production Components
	Refurb Components
	Corporate
	ETC NET
	ETC NET not serial
	ETC TV
	ETC Voice
Mobile Planning	Accessories
	Simcards
	Production Components
	Demo&Dummy&Mockup
	Mobile Equipments
	Pen/Router/Hotspot
	TV
Business Solutions	Business Solutions
Consumables	Consumables
Homevideo	Homevideo
Mobile Network	Mobile Network
Events&Promotional Material	Events&Promotional Material
Others	Others

Table 15 - Stock families and categories

7.2 Appendix B – Storage systems

Figure 34 - Racks

Figure 35 - Carts 5x2x5

Figure 37 - Carts 5x2x3

Figure 36 - Carts 5x1x3

Figure 38 - Carts 9x2x6

Figure 40 - Sliding shelving

Figure 39 - Metal shelving

7.3 Appendix C – Storage zones and deposits

Storage zone	Deposits
100	Production area
101	Terminals (I)
102	Terminals (H)
103	Accessories
104	Packs Mobile
105	Functional with damage
106	Novis and clix
107	Production Components
108	Components picking zone
109	Safety zone
110	Components - labels
111	Advertisement material, gifts and consumables
114	No conformities zone
116	Packs card
117	Packs return
118	SIM Cards - duplicates
119	Safety zone SIM cards
120	Network Mat - Cable drums
121	Network Mat - BTS
122	Network Mat - Antennas
123	Network Mat - Networks
124	Picking zone - crossdocking
125	Consumables
128	Cinemas products
150	Production area evalu. SID
190	Peripheral zone
1SO/83SO	Functional with damage
905	RSC entry
906	TC entry
910	SM zone – general

Storage zone	Deposits
914	SM zone - production order
916	Shipment
919	SIM Cards movements
920	Stocks transfer
RO2	Middle zone reception
C01	Middle zone QC
S01	Middle zone Slow movers
200	Middle zone picking 2 stages
204	Kits direct
207	Refurb Components
208	Picking refurb components
217	Kits reverse
219	Smartcards
222	Treatment Reverse
230	Slow Movers
250	Middle zone collective picking
260	Middle zone collective pallet picking
350	Production area evalu. SI
901	EM Zone - production
902	Goods entry zone
904	Returns entry
905	RSC entry
906	TC entry
910	SM zone - general
914	SM zone - production order
916	Shipment
919	SIM Cards movements
920	Stocks transfer
RO2	Middle zone reception
C01	Middle zone QC
S01	Middle zone Slow movers

Table 16 - List of storage zones

Deposit	Description
8301 – General stock	Stock ready for production and supply the commercial channel
8302 – Obsolete stock	Stock to be destroyed or sold to brokers
8303 – Reception	Deposit of material entry into the LC, to physical evaluation and QC
8304 – B2C	Stock ready for production and supply the final customer
8306 – Returns	Deposit of material entry from reverse logistics
8307 – Tests	Equipments waiting for testing
8308 – Refurb	Equipments waiting for refurb
8309 – Corporate	Stock ready for production and supply the corporate channel
8310 – Business	Stock ready for production and supply the business channel
8311 – Internal requests	Deposit for the management and supply of the PM channel and shipments of internal requests for NOS employees
8312 - Repairs	Equipments waiting for repair
8314 - Quarantine	Mobile equipments on hold in the reverse logistics flow
8315 – Temporary/LOGIN	Deposit reserved for new processes
8316 – Temporary 83X1	Transition deposit to 83X1
8317	Network safety stock
8318 – SP NOS	Stock ready to supply the service providers channel
8319 – Cards stock	SIM and Smart cards stock ready for production (kitting)
8326 – Business Solutions	Business solutions material received through direct reception
8329 – Cards Production	SIM and Smart cards stock integrated in production
8380 – PM Audiovisuais	Audiovisuais promotional material
8381 – PM cinemas	Cinemas promotional material received through direct reception
8382 – Cinemas returns	Cinemas material received from reverse logistics
8383 – PM Homevideo	Homevideo promotional material received through direct reception
8384 - SA Homevideo	-
83FD – Functional w/ damage	Transition deposit to 83S0
83LP – REX	Stock available for exclusive retail
83ND – REX level 2	-
83OF – ON-OFF	Deposit reserved for the project ON-Off
83RE	Electronic material and non-functional components, serial and non-serial
83RG – Obsolete stock (non – electronic)	Non-electronic material to be destroyed
83RM – Mobile Refurb	Mobile equipments waiting for refurb
83SO – Functional w/ damage	Mobile material damaged – phones, routers, pes, hotspots, chargers
83X1 – Construction/Maintenance	Fixed and Mobile network stock available for shipping
83X2 - Maintenance	Network safety stock for maintenance
83X3 – Construction/Repair	Network material wanting for test/repair
9990 – Workflow	Transition deposit

Table 17 - List of deposits

7.4 Appendix D – Weekly Occupation Report

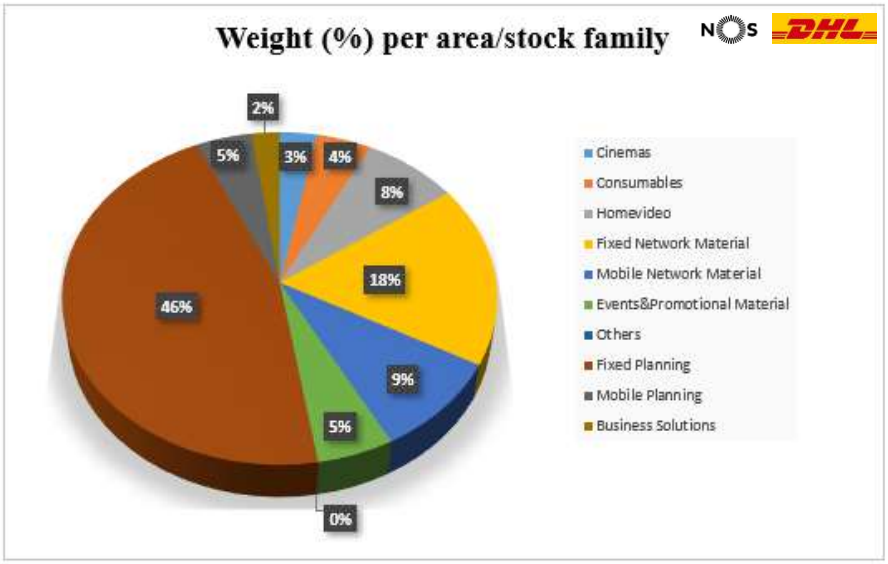

Figure 41 – Weight (%) per area/stock family

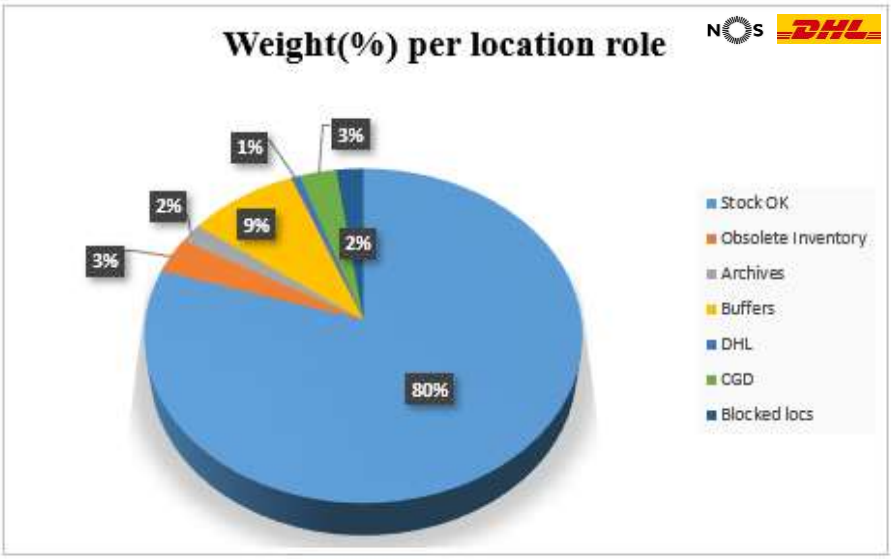

Figure 42 – Weight (%) per location role

Area	Category	Occupied locs	Weight (%)
Cinemas	35MM	26	7%
	Drive	84	23%
	Cinemas PM	250	69%
	Pens	4	1%
Fixed Network	Big dimension	1388	66%
	Small dimension	712	34%
Fixed Planning	Accessories	594	11%
	Antennas	207	4%
	Simcards	0	0%
	Production Components	117	2%
	Refurb Components	637	12%
	Corporate	128	2%
	ETC NET	2067	38%
	ETC NET not serial	26	0%
	ETC TV	1562	29%
	ETC Voice	108	2%
Mobile Planning	Accessories	56	10%
	Simcards	47	9%
	Production Components	51	9%
	Demo&Dummy&Mockup	15	3%
	Mobile Equipments	205	38%
	Pen/Router/Hotspot	59	11%
	TV	112	21%
Business Solutions	Business Solutions	272	100%
Consumables	Consumables	529	100%
Homevideo	Homevideo	929	100%
Mobile Network	Mobile Network	1103	100%
Events&Promotional Material	Events&Promotional Material	623	100%
Others	Others	1	100%

Table 18 - Weight (%) of each product category within the respective area

7.5 Appendix E – Storage optimization model

		Real		Optimal		
Area	Category	Volume occupied (€)	Weight (%) per category	Volume occupied (€)	Weight (%) per category	Δ (€)
Cinemas	35MM	25	7%	25	8%	0
	Drive	84	23%	26	9%	-58
	Cinemas PM	242	67%	242	80%	0
	Pens	8	2%	8	3%	0
Fixed Network	Big dimension	1560	68%	1560	70%	0
	Small dimension	728	32%	679	30%	-49
Fixed Planning	Acessories	593	11%	511	10%	-83
	Antennas	159	3%	144	3%	-15
	Simcards	0	0%	0	0%	0
	Production Components	105	2%	85	2%	-20
	Refurb Components	731	13%	651	13%	-81
	Coeporate	143	3%	105	2%	-37
	ETC NET	2024	37%	1951	39%	-74
	ETC NET not serial	41	1%	22	0%	-19
	ETC TV	1528	28%	1472	29%	-55
	ETC Voice	165	3%	112	2%	-52
Mobile Planning	Acessories	54	8%	45	9%	-8
	Simcards	62	9%	60	12%	-2
	Production Components	47	7%	18	3%	-30
	Demo&Dummy&Mockup	15	2%	4	1%	-10
	Mobile Equipments	237	34%	175	34%	-62
	Pen/Router/Hotspot	64	9%	22	4%	-42
	TV	216	31%	196	38%	-20
Business Solutions	Business Solutions	260	100%	200	100%	-60
Consumables	Consumables	349	100%	349	100%	0
HomeVideo	HomeVideo	902	100%	902	100%	0
Mobile Network	Mobile Network	1077	100%	1077	100%	0
Events&Promotional Mater	Events&Promotional Materi	420	100%	420	100%	0
Others	Others	1	100%	1	100%	0
Obselote Inventory	Obsolete Inventory	516	92%	516	92%	0
	Contaminated	42	8%	42	8%	0
Archives	Archives	276	100%	276	100%	0
Buffers	Buffer RSC	569	40%	569	40%	0
Buffers	Buffer CTR	13	1%	13	1%	0
Buffers	Buffer TC-Tests	87	6%	87	6%	0
Buffers	Buffer Shipping	105	7%	105	7%	0
Buffers	Buffer Production	245	17%	245	17%	0
Buffers	Buffer Reception	237	17%	237	17%	0
Buffers	Buffer Refurb	120	8%	120	8%	0
Buffers	Buffer Reworks	24	2%	24	2%	0
Buffers	Buffer TRC	21	1%	21	1%	0
CGD	CGD	445	100%	445	100%	0
DHL	DHL	106	100%	106	100%	0
Blocked locs	Blocked locs	329	100%	329	100%	0
Total		14974	-	14196	-	-778

Table 19 - Real and optimal occupation per category