



IMPROVEMENTS IN A DSV WAREHOUSE THROUGH A WMS IMPLEMENTATION

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ABSTRACT

The purpose of this study is to present a solution to a problem in the DSV warehouse of Vila do Conde - the inefficiency of the system used to manage warehousing and storage operations. The goal was to achieve improvements to the performance of the warehouse and increase efficiency through the implementation of the warehouse management system internally created by DSV (ILIAS).

This study focused, firstly, on a thorough literature review, that allowed for an understanding of relevant subjects for the study. The method utilized to achieve the goal initially set was the implementation of the warehouse management system ILIAS. The implementation was divided into 4 phases: business requirements, configuration, testing and deployment.

The results were collected after the testing phase - a functionality checklist to assess the viability of the WMS, a new scheme for the process flow within the warehouse for inbound and outbound operations, and a comparison between the values of the warehouse performance indicators from before the implementation and after the implementation.

The analysis of the functionality checklist led to the conclusion that the WMS solution can perform the fundamental operations for managing a warehouse. However, the results collected demonstrated that of the 63 checked functionalities, the software implemented only possessed 27 (about 43%). The addition of the WMS solution for managing inbound and outbound operations resulted in a change of the process flow of the warehouse for the activities of inbound and outbound. These changes led to improvements measured by several warehouse performance indicators. The results showed that the average picking time suffered a reduction after the implementation of the WMS. The percentage of time gained was between 9% and 15% for each client which corresponds to a total reduction of 363 minutes (6.05 hours) in picking time for the period of a month. In addition to the picking time reduction, KPIs were measured, namely the storage utilization, dock to stock time, order accuracy, orders per hour, movements per hour and inventory accuracy. The results for the measurement of the KPI's showed an improvement of 3% for the storage utilization, 68% for the average dock to stock time, 12% for the order accuracy, 26% on the number of orders picked per hour and 30% for the movements executed per hour. The inventory accuracy had no term of comparison but with the implementation of the presented solution this KPI reached an accuracy of 99%.

In an overall analysis, the goals initially set were achieved and this research adds relevant literature on a pertinent topic, contributing to the scientific community. It is also a great contribution to DSV since, despite the discovered limitations of the software that led to DSV deciding not to continue further with the implementation, this work shows the improvements that can be achieved with the implementation of a WMS which led the company to maintain in its plans the idea of implementing a WMS in its warehouse but with another software.

KEYWORDS

Warehouse Management System (WMS), WMS Implementations, Key Performance Indicators (KPI), Warehouse Improvement, Stock Management

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RESUMO

O objetivo deste estudo passa por apresentar uma solução para um problema no armazém da DSV em Vila do Conde - a ineficiência do sistema utilizado para gerir as operações de armazenagem. Assim, este estudo visou melhorar o desempenho e aumentar a eficiência do armazém da DSV através da implementação de um sistema de gestão de armazéns (WMS) criado internamente pela DSV (ILIAS).

Este estudo centrou-se, em primeiro lugar, numa revisão detalhada da literatura, que permitiu uma compreensão de temas relevantes para o estudo. O método utilizado para alcançar o objetivo estabelecido foi a implementação do sistema de gestão de armazéns ILIAS. A implementação foi dividida em quatro fases: requisitos empresariais, configuração, testes e lançamento.

Os resultados foram recolhidos após a fase de testes – uma *checklist* de funcionalidades para avaliar a viabilidade do WMS, um novo esquema para o fluxo das operações de entrada e saída e uma comparação entre os valores obtidos para os indicadores de desempenho do armazém (KPI) antes da implementação e depois da implementação.

A análise da *checklist* levou à conclusão de que a solução WMS pode realizar as operações fundamentais para a gestão de um armazém. Contudo, a partir dos resultados recolhidos, verificou-se que, das 63 funcionalidades verificadas, o software implementado possuía apenas 27 (cerca de 43%). A adição da solução WMS, na gestão das operações de entrada e saída resultou na alteração do fluxo do processo do armazém para as atividades de entrada e saída. Estas alterações conduziram a melhorias que foram medidas por vários indicadores de desempenho do armazém. Começando pela redução do tempo de picking, os resultados mostraram que o tempo médio de picking sofreu uma redução após a implementação do WMS. A percentagem de tempo ganha situou-se entre 9% e 15% para cada cliente, o que corresponde a uma redução total de 363 minutos (6,05 horas) no tempo de picking durante um mês. Além da redução do tempo de picking, foram medidos os KPIs, nomeadamente a percentagem de armazenamento utilizado, o tempo até a armazenagem, a precisão das encomendas, as encomendas por hora, os movimentos por hora e a precisão do inventário. Os resultados para a medição dos KPIs mostraram uma melhoria de 3% para a utilização do armazenamento, 68% para o tempo médio até a armazenagem, 12% para a precisão das encomendas, 26% para o número de encomendas recolhidas por hora e 30% para os movimentos executados por hora. A precisão do inventário não tinha termo de comparação, mas com a implementação da solução apresentada os KPIs atingiram uma precisão de 99%.

Numa análise global, os objetivos inicialmente estabelecidos foram alcançados, esta investigação acrescenta literatura relevante sobre um tópico pertinente, contribuindo para a comunidade científica. Este trabalho foi de grande contribuição para a DSV, apesar das limitações que foram descobertas ao nível do software que levaram a DSV a não continuar com a implementação, uma vez que mostra as melhorias que podem ser alcançadas com a implementação de um WMS levando a empresa a manter nos seus planos a ideia de implementar um WMS no seu armazém, mas com outro software.

PALAVRAS-CHAVE

Warehouse Management System (WMS), Implementações WMS, Indicadores de Desempenho (KPI), Melhoria do Armazém, Gestão de Stock

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LIST OF ABBREVIATIONS

List of Abbreviations

| | |
|----------|--|
| ADR | Agreement concerning the International Carriage of Dangerous Goods by Road |
| AR | Action-Research Methodology |
| BPMN | Business Process Model and Notation |
| CSCMP | Council of Supply Chain Management Professionals |
| RFID | Radio Frequency Identification |
| WMS | Warehouse Management System |
| EAN | European Article Number |
| EDI | Electronic Data Interchange |
| FIFO | First In First Out |
| HTML | HyperText Markup Language |
| IDC | International Data Corporation |
| ISEP | Instituto Superior de Engenharia do Porto |
| IT | Information Technology |
| KPI | Key Performance Indicator |
| NASDAQ | National Association of Securities Dealers Automated Quotations |
| P. Porto | Instituto Politécnico do Porto |
| SKU | Stock Keeping Unit |
| TEU | Twenty-foot Equivalent Unit |
| TMS | Transport Management System |
| UPC | Universal Product Code |
| URL | Uniform Resource Locator |
| XML | Extensible Markup Language |

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1. INTRODUCTION

This chapter introduces the research that is going to be presented in further chapters. It starts by highlighting the framework and relevance of the study for the scientific community, then an introduction of the company where the research was conducted is displayed, followed by a description of the issues that originated the necessity for the current investigation, as well as a formulation of the investigation question and the objectives that this work aims to achieve. Later, the methodologies that were followed in order to develop the thesis are explored and an overall structure of the dissertation is presented.

1.1. Framework and Relevance

According to Blecker and Kersten (2014), innovation is a really important factor in giving companies an advantage over their competition. As such, companies undergo a continuous process of changing and adapting, in the struggle for their survival (Bizoi and Sipos, 2014). These days, customers are more demanding than ever (Hyken, 2016) and trying to differentiate from competitors is even more essential for organizations resulting in a constant effort to try to provide their customers with new and innovative products and services. As a response to this innovation, the management of supply chains and the elements within them (people, goods, etc.) is being changed by the technological advances that the world is witnessing (Speranza, 2018).

One of the focuses of close attention, in the management of supply chains, is warehousing logistics. This activity always remains a big source of costs (for example, Amazon lost about seven billion dollars in logistics in 2017), and often the cost of delivery exceeds the revenue from the delivery itself (Volodymyr et al., 2020). Also, according to Fumi et al. (2013), about 23% of logistics costs in the United States and 39% in Europe are due to warehouse capital and operating costs. Worldwide, warehousing operations cost companies about €300 billion each year, and that amount is growing as global supply chains and the prevalence of e-commerce lead to greater complexity (Herrmann et al., 2019).

In line with other activities, Hamdy et al. (2018) state that warehousing operations have become more complex with the increase in the number of elements to be processed in the warehouse and that therefore, manual warehouse management methods are no longer adequate and practical to manage the vast number of operations performed. The increase in operation complexity makes it even more important to take actions to improve processes and gain advantages over the competition, which means that, in order to obtain this advantage, companies have to resort to integrated information systems, seeking to automate their production process through technologies, among them, the Warehouse Management System or WMS (Ribeiro and Freitas, 2011; Žunić et al., 2018 and Miralam, 2017)

A warehouse management system primarily aims to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, put-away and picking (Andiyappillai and Prakash, 2019). The implementation of such a system will provide an increase in accuracy and add value, a reduction in operation costs (administration cost, labor and supervision cost), and a greater ability to service the customer by reducing cycle times, not only leading to inventory reduction but also to greater storage capacity (Miralam, 2017).

Based on the research works published in the journals, conferences and other fonts, (Andiyappillai and Prakash, 2019; Apak et al., 2014; Mostafa and Alawady, 2020; Žunić et al., 2018; Hamdy et al., 2018; Assis and Sagawa, 2018 and Miralam, 2017), the issue of implementation of a WMS is clearly identified as of great importance. However, even Andiyappillai and Prakash (2019) have said that only limited researches have been done in recent times on WMS implementations and those researches have revealed both the benefits and constraints of using the system. Hence, by conducting a case study to analyze the implementation of a WMS in a working warehouse, this research attempts to contribute to the scientific community on this topic.

1.2. Company Presentation

DSV Panalpina A/S is a Danish transport and logistics company. The organization offers global transport services by road, air, sea, and rail as well as logistics operation services related to warehousing in a network of more than 80 countries. These services are provided both in the Portuguese market (national customers) and in the international market (foreign customers). In Portugal, DSV has three facilities, one in Vila Franca de Xira (Lisbon), another in Vila do Conde (Porto) and another in Pombal (Leiria).

DSV Panalpina A/S is listed on NASDAQ (National Association of Securities Dealers Automated Quotations) Copenhagen (Denmark) and is included in the C25 index as one of the 25 most actively traded shares on the Copenhagen stock exchange (DSV Panalpina A/S, 2021). DSV Panalpina A/S is the parent company, and the group is divided into three divisions: DSV Air & Sea, DSV Road and DSV Solutions.

- DSV Road: Is one of the leading road freight operators in Europe with distribution networks in North America and Africa. Annually, more than 30 million shipments are handled and every day more than 20,000 trucks are used to carry goods;
- DSV Air & Sea: Offers alternative routings and flexible schedules to suit the most demanding logistical requirements to and from all parts of the world. It handles more than 2,600,000 TEUs (twenty-foot equivalent units) of sea freight and 1,700,000 metric tons of air freight every year.
- DSV Solutions: Partners with specific and more complex customers to design and deliver logistic solutions, adding value by increasing operation and cost efficiency. It operates hundreds of logistics facilities comprising a total of 6,000,000 m².

DSV's vision is to be a leading global supplier, fulfilling customer needs for transport and logistics services, targeting extensive growth and being among the most profitable in the industry (DSV Panalpina A/S, 2021).

DSV's vision is also supported by four strategic focus areas (DSV Panalpina A/S, 2021):

- Customer statement: DSV aims to offer their customers global and competitive transport and logistics services of a consistent high quality.
- Growth: DSV actively pursues profitable growth balanced between a solid above market organic growth and an active acquisition approach.
- Operational Excellence: It is crucial in order to operate with the highest productivity, enabling DSV to be competitive and deliver timely and high-quality services to customers.
- People: DSV strives to attract, motivate, and retain talented people by offering responsibility, empowerment, and growth opportunities.

DSV Panalpina is among the top five players in the global freight forwarding market and has an estimated market share of almost 5%. Together, the top 20 players have an estimated market share of 30-40% of the global freight forwarding market. The remaining market consists of a long tail of regional and local freight forwarders (DSV Panalpina A/S, 2021).

According to the DSV Panalpina Annual Report (2021), in 2020, the group completed the Panalpina integration. This integration was accomplished in 15 months. Driven by this acquisition, a growth of 26.0% was registered and the gross profit was impacted positively and grew 23.5%. These impacts were felt especially in the Air & Sea division, but all three divisions delivered strong results and achieved significant growth compared to 2019.

COVID-19 impacted the markets and financial results in February and March of 2020 since DSV saw volumes decline and uncertainty increase. DSV reacted by adjusting its capacity and its COVID-19 cost savings initiatives ended up reducing the cost base by approximately 10%. This strict cost discipline was a main driver for the growth in earnings during the second half of 2020 and is one of the reasons why DSV is very interested in the realization of this investigation.

This study, will focus exclusively on the warehousing facility located in the north of Portugal, more exactly in Vila do Conde for the branch of DSV Road.

1.3. Investigation Question and Objectives

The problem that this work aims to solve in DSV's warehouse is the inefficiency of the system currently used to manage warehousing and storage operations.

The system presents several drawbacks that generates frequent slowdowns and stops in picking operations. Stock checking and errors occur with some frequency in the composition of outgoing and incoming orders to the warehouse. These situations translate into direct financial costs to the company, for example, costs related to stock losses, too much time spent on picking operations, or indirect costs, such as the inability to incorporate new customers, when they require an update on the status of their stock, or the inability to deal with a customer with high turnover (frequent entries and exits of goods).

The current management system is based on a customized management of incoming and outgoing goods, i.e., it is done in different ways depending on the customer and the type of product. The storage location of the products is decided by the operator and there is no record of the locations where the stock was provisioned, only the operator who stored the product knows where it is and there is no way to know the amount of stock in the warehouse or the available storage capacity without doing a physical count.

In this sense, DSV has outlined, as one of its goals for the year 2020, the reduction of the "cost associated with managing and operating the supply chain" (DSV, 2019). To this end, the company has prepared a set of initiatives carried out to achieve these goals. One of these initiatives is the implementation of a WMS (Warehouse Management System) in the Vila do Conde warehouse. A WMS is used to optimize storage decisions and can integrate software to monitor, manage and control everything in the warehouse (Mostafa and Alawady, 2020). Its use is also found to have a positive impact on companies' performance in the management of operations (Nee, 2009).

DSV is a large multinational company that has the particularity of having built its own WMS. The software was designed for another warehouse, but the company now intends to adapt it to meet the needs of all the group's warehouses. So far, the software has been implemented in only a few facilities, but the corporate goal is to have it operational in all warehouses within the next few years. In this sense, this work differs from others since it will address a more specific theme of the WMS implementation, which is the adaptation of a WMS created specifically for a warehouse, to another warehouse with completely different needs and context.

Thus, considering the research problem presented, and the solution that is endorsed, the following research question is enunciated: Can the implementation of the selected warehouse management system in the DSV warehouse lead to improvements in its performance?

To answer the research question, the following general objective is defined: Generate improvements to the warehousing process through the implementation of the selected WMS.

To accomplish the general objective, the following specific objectives were established:

- Highlight the importance of a WMS implementation;
- Survey the physical characteristics of the warehouse;
- Review the requirements and characteristics of the warehouse processes;
- Configure the software to match the mentioned requirements and characteristics;
- Execute a total or partial implementation of the WMS in the DSV warehouse of Vila do Conde;
- Assess the functionalities and capabilities of the WMS;
- Analysis and use of metrics (example: order accuracy) that allow the evaluation of improvements in warehouse performance.

1.4. Methodological Options

Methodology deals with the methods and principles used in an activity. It explains how a research is done, the methods for data collection, materials used, subjects interviewed, or places visited. It details out the how and when the research is carried out (Jabar et al., 2009).

The present investigation followed an action-research (AR) methodology. AR consists on a set of approaches to research which, at the same time, systematically investigate a given situation and promote change and collaborative participation (Burns, 2015). With this methodology, the process that the researcher goes through to achieve an understanding of the problem is a cycle consisting of four major phases: planning, acting, observing, and reflecting (Zuber-Skerritt, 1991).

According to Hopkins (2008), those phases follow a characteristic cycle:

- 1) In the first stage an understanding of a problem is developed and plans are made for intervention;
- 2) Then the intervention or action is carried out;
- 3) During and after intervention, observations are collected in various forms;
- 4) Data is reflected on and revisions are made on the initial plan;
- 5) The new interventional strategies are carried out, and the cyclic process is repeated, continuing until a sufficient understanding of the problem is achieved.

Andiyappillai and Prakash (2019) presented an AR methodology specific for WMS implementation. In this work that same variation was followed. This methodology contemplates four phases:

- 1) Business Requirements: Assessment of the state of affairs, layout, processes, existing information, analysis, and review to identify processes/procedures, opportunities for improvement and gaps;
- 2) Configuration: Set up necessary software applications, gadgets and connections (printers, scanners);
- 3) Testing: Run the WMS in the conference room making changes regarding client necessities, test scenarios, optimize processes. It includes the configuration of the warehouse, articles, and customers on the WMS. In this research, this is the stage from where data will be collected, and results will be retrieved on the form of a functionality checklist, new process flow schemes and analysis of selected KPIs;
- 4) Deployment: Formation and training of the people who are going to use the WMS and close assistance when it is time for the solution's "Go-Live".

This method allows for a full WMS implementation and an assessment of its results which after posterior analysis and discussion will lead to an answer about the question that this investigation tries to answer.

1.5. Structure of the Work

The dissertation is divided into five chapters.

The first chapter introduces the research that is going to be presented in further chapters. It highlights the framework and relevance of the study for the scientific community, introduces the company where the research was conducted, describes the issues that originated the necessity for the current investigation and formulates the investigation question and the objectives that the dissertation aims to achieve. In the end, it explores the methodologies that were followed in order to develop the thesis and presents the overall structure of the dissertation.

The second chapter presents a survey of the literature consulted when researching the bibliographic sources gathered for this research project. This chapter intends to provide a literature review on relevant topics of the thesis.

The third chapter focuses on a description of the utilized and applied methods in the implementation of the warehouse management system solution that consists in an implementation in four phases. In this chapter each phase is shown and explained.

On the fourth chapter the results collected from the implementation of the warehouse management solution are shown and discussed. The discussion section attempts to interpret the results within its relevance to the research question with support from the consulted literature.

In the fifth and final chapter, the conclusions of the dissertation are presented along with a description of the limitations encountered throughout the investigation and the suggestions made for future work.

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2. LITERATURE REVIEW

This chapter presents a survey of the literature consulted when researching the bibliographic sources gathered for this research project. It intends to provide a literature review on relevant topics of the thesis

The literature review chapter is divided into seven sub-chapters. A selection of the most important concepts related to the main theme of the project was carried out. These concepts name the subchapters and are the following: logistics and supply chain management, warehouse management, warehousing operations, information management and technologies used for this type of management, EDI (Electronic Data Interchange), RFID (Radio Frequency Identification), and WMS (Warehouse Management System). The WMS is reviewed in a more specific way, as it is a central area of the project. The sub-chapter of the WMS falls on several topics, ranging from its concept and relevance to the warehouses, up to the implementation. As the last sub-chapter, a review on warehouse performance indicators is also introduced.

2.1. Logistics and Supply Chain Management

According to Szymonik (2012), logistic operations have always been accompanying life in human societies. Szymonik (2012) also emphasizes that the origin of the term “Logistics” comes from the Greek, indicated by words such as “*logos*” – counting or reason, “*logistike*” – the art of calculation, that became the source of “*logistique*” – the French word for transport, accommodation, and supply of troops. That term evolved to the origin of the English word “logistics” in its military sense.

The concept of “right product/service in the right place at the right time”, was initially developed in military terms, more specifically in war times, due to the constant need for a strong logistic capacity for advancing troops while maintaining large quantities of men and war supplies on the battlefronts. This idea slowly made its way into the corporate world and once it was fully understood it became essential and it has been a part of it ever since (Carvalho and Encantado, 2006).

With time, several thinkers came out with different definitions for logistics. One of such definitions is the “Seven R’s of Logistics” by E. Grosvenor Plowman (1952), which, according to Rutner and Langley Jr. (2000) and Bielecki and Galinska (2017), “defines logistics as ensuring the availability of the right product, in the right quantity and the right condition, in the right place, at the right time, for the right customer, at the right cost”. The Cambridge Dictionary (n.d.) defines logistics as “the careful organization of a complicated activity so that it happens in a successful and effective way” while the Oxford Dictionary (n.d.) states that logistics is “the business of transporting and delivering goods”. Other definitions exist, such as the one proposed by the Council of Supply Chain Management Professionals (CSCMP) that defines logistics as “part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements” (CSCMP, 2013).

Supply chain and supply chain management have played a significant role in corporate efficiency and have attracted the attention of numerous academicians over the years (Janvier-James, 2011). This is evident with the increasing globalization that, according to Oláh et al. (2017), promotes the

development of supply/distribution logistics by expanding purchasing and sales markets which in turn creates a necessity of fast and liquid flows of materials, products, and information. In this sense, supply chain management becomes essential to maintain high levels of customer service (Oláh et al., 2017).

According to Chopra and Meindl (2013), the objective of every supply chain should be to maximize the overall value generated (or supply chain surplus), which is translated by the difference between the value, to the customer, of the final product and the costs incurred by the supply chain in filling each customer's request. The supply chain starts and ends with the customers (Wen and Gu, 2013) but alongside them, other actors have to be considered when designing a supply chain: Retailers, Wholesalers/distributors, Manufacturers, and Components/raw material suppliers (Chopra and Meindl, 2013). The importance of these elements is stated on the supply chain management definition itself, in which the Council of Supply Chain Management Professionals (CSCMP), defines supply chain management as a field that "encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistic management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies".

A supply chain is also referred to, by Min and Zhou (2002) and Farahani et al. (2017) as an integrated system, as shown in Figure 1 which synchronizes a series of inter-related business processes to:

- 1) acquire raw materials and parts;
- 2) transform these raw materials and parts into finished products;
- 3) add value to these products;
- 4) distribute and promote these products to either retailers or customers;
- 5) facilitate information exchange among various business entities (e.g. suppliers, manufacturers, distributors, third-party logistics providers, and retailer).

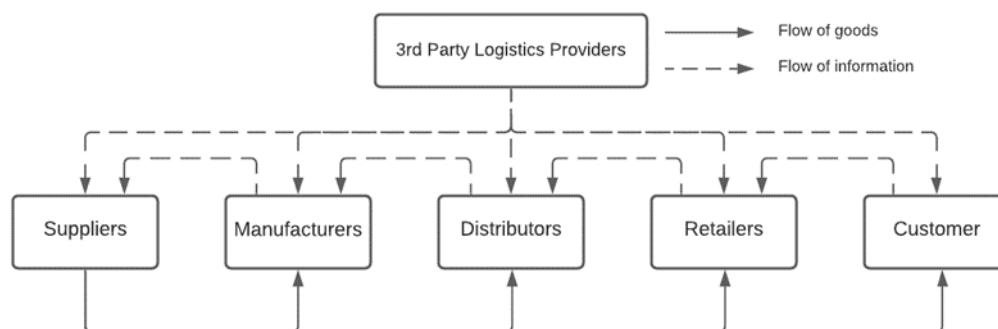


Figure 1 - Supply Chain Process, adapted from Min and Zhou (2002) and Farahani et al. (2017)

2.2. Warehouse Management

According to Farahani et al. (2011), organizations keep inventory, for several reasons:

- to protect a firm against unexpected changes in customer demand;
- to take advantage of economies of scale;
- to be able to meet demands when it is higher than the available supply (e.g., products that have a seasonal demand);

- to hedge against contingencies such as labor strikes, fires, and flood, and others.

As is the case of any practice, inventory keeping, and management, has costs. More specifically it amounts for 25-40% of the logistics costs (R. Farahani et al., 2011) coming from different sources and according to Silver (2008) and Farahani et al., (2011) inventory holding costs include:

- Replenishment Costs: Costs incurred each time that a replenishment action is taken;
- Costs of Insufficient Supply in the Short Run: Unsatisfied demand leads to immediate costs of back-ordering and/or lost profit on sales;
- System Control Costs: Costs of acquiring the data necessary for the adopted decision rules, the computational costs, and other costs of implementation (including training and the possible adverse behavioral effects of a new system);
- Opportunity (capital) Cost: the return on investment the firm would have realized if money had been invested in a more profitable economic activity instead of inventory;
- Inventory Service Cost: Costs of tax and insurance;
- Risk Cost: The result of pilferage, deterioration of stock damage, and stock obsolescence;
- Storage-space Costs: The direct cost of the space used for storage.

A practice such as inventory keeping, which is widely useful but can also generate high costs, creates the need for methods (warehouse management) and a facility (the warehouse) to hold and maintain such inventory efficiently and productively.

Warehouse management includes all planning and control procedures to operate the warehouse (Faber et al., 2013). It plays a critical role not only regarding the control of the inventory system but also in ensuring high levels of customer service and overall supply chain performance (Razik et al., 2017).

The warehouse itself, the facility where warehousing is performed, is commonly used for storing or buffering products (raw materials, goods-in-process, finished products) at and between points of origin and points of consumption. It is also an important element of the supply chain process (Banabakova et al., 2018) and plays a vital role in mitigating variations in supply and demand, providing value-added services (Sainathuni et al., 2014).

The literature differs into what the function of a warehouse should be. Accorsi et al. (2014) say that the main function of the warehousing system is to receive products, to store materials until they are requested, and then, to extract products from inventory and ship them in response to the customers' orders. Others state that operations such as order picking, stock management, and packing are also value-added operations and an important part of the warehouse ((Longo, 2011), Farahani et al. (2011)). According to Chopra and Meindl (2013), firms must first decide the purpose of the warehouse, they should, for example, determine whether they will be, primarily, cross-docking facilities or storage facilities because, depending on the decision, the same warehouse can have different functions. At cross-docking facilities, inbound trucks from suppliers are unloaded, the product is separated into smaller lots and is quickly loaded onto trucks that will deliver to stores and other customers. In most cross-docking procedures, there is not enough value added in operations such as order picking or stock management while for storage facilities, firms must select the products to be stored at each facility and manage them. As such, the previously mentioned operations can add a good amount of value to the firm, in this case.

Because of the natural change and progress of logistics and supply chain-based businesses and an ever-increasing demand from customers resulting in higher competition between firms, managing complex warehouses effectively and efficiently has become a challenging task (Faber et al., 2013). An important question, therefore, is how warehouse management, as a collection of planning and control decisions and procedures, is organized to meet today's challenges since an efficient warehouse has the ability to fulfill customer needs quickly and increases a firm's performance (Jermsittiparsert et al., 2019).

2.3. Warehousing Operations

There are many steps in warehouses from receiving goods until their delivery to customers (R. Farahani et al., 2011) and even though warehouses can serve quite different ends, most share the same general pattern of material flow (Bartholdi and Hackman, 2019). The following list contains operations found in most warehouses. In Figure 2 is also indicated the material flow throughout these operations.

- Receiving: According to Bartholdi and Hackman (2019), receiving accounts for 10% of the operating costs in a typical distribution center. Some authors consider receiving only as of the process where goods are unloaded from shipment vehicles and delivered to the warehouse personnel (R. Farahani et al., 2011). However, it can be more than that. Other authors say that "Receiving" may begin before anything even arrives at the warehouse. The advance notification of the arrival of goods that allows the warehouse to schedule receipt and unloading to coordinate accordingly can also be considered a part of the "Receiving" operation (Bartholdi and Hackman, 2019). Then comes the part of effectively collect the good which is usually executed along processes of conference, inspection, and quality control of materials to assure the quantity and quality of the ordered materials (Frazelle, 2002), scanning to register its arrival so that ownership is assumed, payments dispatched, and so that these materials are known to be available to fulfill customer demand (Bartholdi and Hackman, 2019). Other, not so frequent procedures may occur at this stage such as labeling, packaging, or repalletization whenever it is necessary.
- Put-Away: It is an operation in which goods are transported to the storage area (R. Farahani et al., 2011) where they will be kept. An efficient put-away determines to a large extent how quickly and at what cost you later retrieve it for a customer, meaning that you must know at all times what storage locations are available, how large they are, how much weight they can bear, in order to use that information to construct efficient picking lists to guide the order-pickers in retrieving the products for the customer (Bartholdi and Hackman, 2019). Put-away includes material handling, product placement, and location verification (Frazelle, 2002). Put-away typically accounts for about 15% of warehouse operating expenses and can require a fair amount of labor because a product may need to be moved a considerable distance to its storage location (Bartholdi and Hackman, 2019).
- Storage: Storage is the physical containment of merchandise while it is awaiting demand (Frazelle, 2002). It not as much of an operation as it is a phase in which goods stay for a portion of time. However, it is still a part of the material flow.

- Order-picking: Is the process of removing items from storage to meet a specific demand (Frazelle, 2002). According to (Bartholdi and Hackman, 2019), it is the beginning of the outbound process and it is initiated by the receipt of a customer order. After the receipt of this list, the warehouse must perform checks such as verifying if the inventory is available to ship. Each entry on the list is referred to as an order-line and typically consists of the item and quantity requested. Then the warehouse must produce picking lists to guide the order-picking. Depending on the type of picking being done, these lists may be a physical sheet of paper or a sequence of requests communicated by light, radiofrequency, or others. In the end, the warehouse must produce any necessary shipping documentation and schedule the order-picking and shipping. Order-picking is by far the most complex operation in the warehouse and it can be done using several different methods (R. Farahani et al., 2011):

- 1) Discrete Picking: one order is filled;
- 2) Batch Picking: a group of orders is filled by one order picker;
- 3) Zone Picking: And order picker is in charge of a zone of the warehouse and picks the items stored in that zone;
- 4) Wave Picking: Orders are released in waves (e.g., hourly or in the morning/afternoon).

These activities are typically accomplished by a warehouse management system, a large software system that coordinates the processes. Bartholdi and Hackman (2019) also state that order-picking typically accounts for about 55% of warehouse operating costs and that order-picking itself may be further broken into four main activities: Travelling, Searching, Extracting and Paperwork, and other activities. From which, as it can be observed in table 1, Travelling represents the higher amount of costs.

Table 1 - Percentage of Order-picking time, adapted from Bartholdi and Hackman (2019)

| Activity | % Order-picking time |
|--------------------------------|----------------------|
| Travelling | 55% |
| Searching | 15% |
| Extracting | 10% |
| Paperwork and other activities | 20% |

- Preparation: Phase of the process that consists of getting items ready for delivery (R. Farahani et al., 2011). It can include procedures such as preparing shipping documents (packing lists, address labels, and bills of landing), weighting shipments, and packaging (Frazelle, 2002). Packaging in itself can be labor-intensive because each piece of a customer order must be handled and because customers generally prefer to receive all the parts of their order in as few containers as possible to reduces shipping and handling charges (Bartholdi and Hackman, 2019). This phase becomes very important since it is the stage where the warehouse checks if the customer order is complete and accurate. Order accuracy is a key measure of service to the customer where errors can generate costs specifically with return handling and enables the disruption of a customer's operation which can make a customer lose confidence in the warehouse (Bartholdi and Hackman, 2019).

- Shipping: Last stage of the material flow. It is an activity that involves physically moving and loading assembled orders onto transportation carriers and updating inventory records (R. Farahani et al., 2011). It includes the accumulation of orders for an outbound carrier and the loading of the trucks (Frazelle, 2002). Shipping generally handles larger units than picking, because items were already consolidated into fewer containers on the preparation stage (Bartholdi and Hackman, 2019).

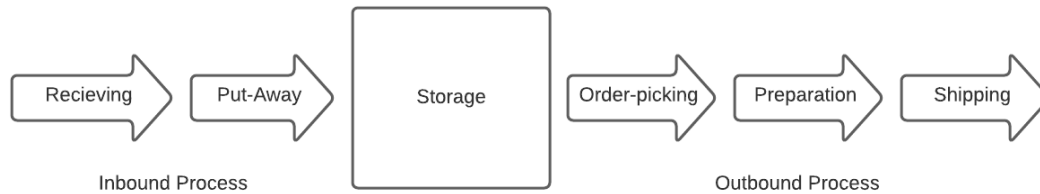


Figure 2 - Material flow in the warehouse, adapted from Bartholdi and Hackman (2019)

It is also important to note that there are cases where the warehouse is not a storage facility. A warehouse can do storage operations, cross-docking operations, or both simultaneously. Cross-docking is another type of operation that occurs independently of the storage (Chopra and Meindl, 2013). A pure cross-docking operation only organizes the transfer of materials from the inbound receiving dock to the outbound dock, eliminating nonvalue-adding activities such as put away, storage, and order filling (R. Farahani et al., 2011). In a cross-docking operation, the material flow is just comprised of the receiving operation and shipping with some preparation in between the two and, in contrast to traditional warehouses, cross-docking operations seek to reduce as much as possible the build-up of inventories at the terminal (Novaes et al., 2015).

2.4. Information Management

Information is the most important mechanism of interaction of an organization with its environment and, for this reason, the organization needs to collect, store, process, and distribute information (Azevedo, 2012). Management of information is especially important in securing projects due to the sharing of relevant information, which allows firms in the supply chain to make better decisions, making it undeniable that business processes gain value when information across the supply chain is managed accordingly (Sundram et al., 2018).

Availability of technological information will enable accessibility of more efficient communication and control, which is essential to a competitive global logistics capability (Nee, 2009). An effective supply chain management relies heavily on the integration and coordination of flows between and within companies with the aid of information systems (Sundram et al., 2018). Therefore, organizations must be capable of fast, radical changes and those that aspire to be best must lead in changes (Nee, 2009).

In present times this becomes even more relevant as electronic commerce (e-commerce) is taking over the world. Electronic commerce is a concept that crept into the business vocabulary during the 1970s, includes any form of economic activity conducted via electronic connections and is changing the processes of how companies design, produce, and deliver their products and services (Aparicio et al., 2021) (Wigand, 1997). E-commerce registered a growth increase of 21% from 2017 to 2018. The development of this way of doing business brings new challenges to the logistics

industry. Higher requirements towards logistics and warehousing emerge, including the shorter delivery time and higher operation accuracy when processing massive SKUs (stock-keeping units) and orders (Kong et al., 2019).

The logistical dimension of electronic commerce is usually called e-fulfillment. E-fulfillment incorporates activities such as order management, inventory management, electronic invoicing, and shipping/dispatching of items ordered electronically (Carvalho and Encantado, 2006). It essentially covers the procedures related to the distribution of goods and services to e-commerce customers (Caroline et al., 2019). As portrayed in Figure 3, e-fulfillment entails the integration of the front office with back-office processes, activities, and functions (marketing and sales, finance, and logistics) that support the fulfillment of customer orders and, as a result, helps in the improvement of logistical efficiency, and the decrease of inventory and transportation costs (European Commission, 2006).

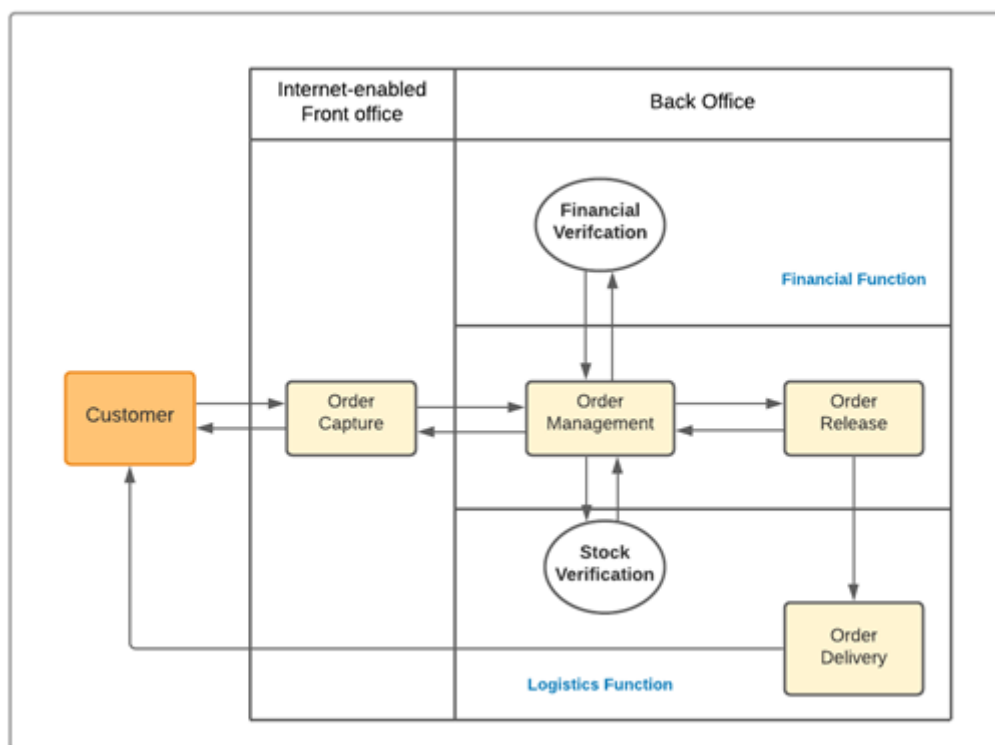


Figure 3 - E-Fulfillment Process, adapted from European Commission (2006)

According to Carvalho and Encantado (2006), the number of firms that can incorporate e-fulfillment processes in their activities is very limited. This has to do in part with a lack of capacity to integrate the process with the existing software. Usually, the technological infrastructure that is used in firms is very divided throughout the administrative divisions within a company (sales, accounting, logistics). This translates into a poor, non-automatic information flow requiring manual effort to establish communication between each division.

Integration is very important, processes need to communicate with each other to ensure the flow of data (European Commission, 2006). E-fulfillment should provide that integration utilizing IT (Information Technology) tools to help ensure cost-efficient activity (Masudin et al., 2020). Masudin et al. (2020) also state that there are several IT tools in the market delivering efficiency enhancement and effective management of stock in inventory or warehouse that allow for better communication across the company by enabling the data to be transferred faster and to be utilized

automatically. Tools such as EDI, bar code scanners or readers, especially with RFID, and warehouse management systems.

2.5. EDI

Electronic Data Interchange (typically referred to as EDI) consists of exchanging data electronically, computer to computer, using messages formatted according to predefined standards (Carvalho and Encantado, 2006). EDI allows for the transmission of purchase orders, shipping documents, invoices, invoice payments, and other documents between web-based businesses and their trading partners (European Commission, 2006). Sokol in the book "From EDI to electronic commerce: a business initiative", argues that by enabling faster, reliable, and more efficient exchange of information amongst business partners EDI possess the capability to increase and improve trading services output in addition to enhancing the possibility of a decreased lead-time for customer orders for production and/or retail companies (as cited in Masudin et al., 2020).

EDI is a mature technology with well-established standards and its information flow differs from the traditional information flow seen in companies, as we can see in Figure 4.

For a very long time, EDI has been widely viewed as a technology pivotal to supply chain management that has also provided benefits to firms on multiple levels (Narayanan et al., 2009). International Data Corporation (IDC) estimated the total value of EDI grew from \$1.99 trillion in 2003 to \$ 2.68 trillion in 2007 (as cited in Narayanan et al., 2009).

Although most companies still use EDI, it is considered to be a "rigid" and costly solution (European Commission, 2006). However, due to new technologies and security development, user-friendly web or e-mail applications are readily available on the market. Also, as the Internet has been adopted by EDI as its preferred transmission platform new structuring formats have been developed such as WebEDI, which retains the same characteristics as the initial EDI, or the cross-linking of the traditional EDI format with the new Internet document standard, XML (extensible markup language), an evolution of the HTML (HyperText Markup Language) format (Carvalho and Encantado, 2006; Janssens, 2011).

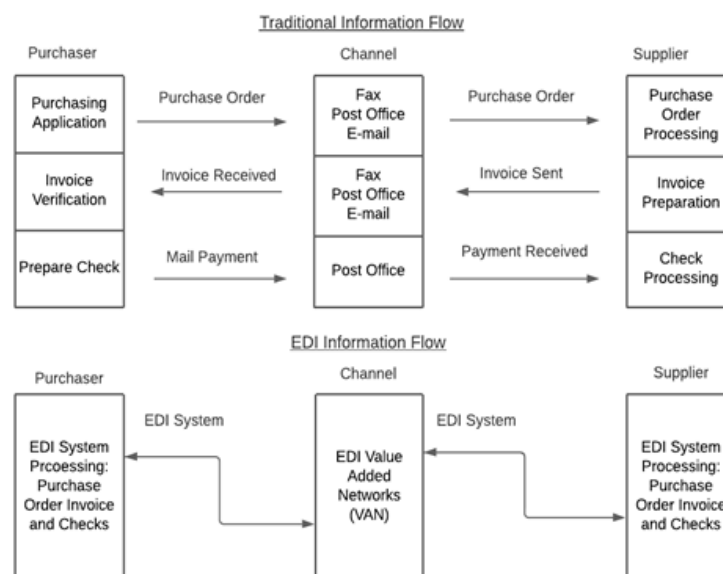


Figure 4 - EDI Process Flow, adapted from Emmelhainz (1993) and Ramdeen et al. (2009)

2.6. RFID

According to Carvalho and Encantado (2006) and Pihir et al. (2011), product coding plays a key role in providing a common reference base for the supply chain/network as a whole. It automates processes, allows better stock control, and facilitates product tracking at all stages. It is thus, a basis for integration with other technologies, including EDI and WebEDI, and integration of the supply chain/network itself.

Barcode was first used back in the late 1970s and early 1980s. And yet, it is still today the most widely used in designating and identifying products throughout the world (Pihir et al., 2011). In Europe, products are coded using EAN (European Article Number), which is also the standard in most countries except North America where the UPC (Universal Product Code) system is more commonly used (Carvalho and Encantado, 2006). According to (Pihir et al., 2011) the most common barcoding standards are EAN8, EAN-13, UPC-12, and EAN/UCC-14. They generate unique serial numbers that contain specific information about a single article.

In the same technological family of barcodes, we have RFID. RFID is an automatic system that uses wireless technology to identify, and track labeled items in the form of a unique serial number (Pandey and Mahajan, 2010). It is a technology that aims for just-in-time data analysis and real-time data collection transferring it through the radio waves emitted from the labels (Akbari et al., 2015).

A basic RFID system is composed of three layers: a tag containing a chip, a reader and its antennas, and a computer (Lefebvre et al., 2006). According to Seufitelli et al. (2009), an RFID based operation occurs as follows: The reader emits a radio frequency signal through the antenna, which can be attached to the reader or connected by a wire to it, to locate the tags that capture and emit the signal constantly when it is in the area covered by the reader. In this way, the tag responds to the reader also by radio frequency, sending all the product information contained in the tag. The reader sends, in real time, this information received to the computer system making it possible to recognize and identify this information, thus obtaining the privilege of being able to do the necessary management for the proper functioning of this system.

In the word of Seufitelli et al., (2009), the disadvantage of RFID that stands out has to do with its very high costs followed by operational complexity, lack of technical expertise, and knowledge in utilizing RFID data (Abugabah et al., 2020). Its benefits include accuracy of data, availability of timely data, improved register check-out productivity, customer service, and increased system flexibility (Pihir et al., 2011), with some authors, namely Wamba and Chatfield (2010) asserting that RFID technology can decrease the put-away labor costs by 20 to 30% and order-picking labor costs by around 30 to 50%. According to Wamba and Chatfield (2010), RFID also increases inventory accuracy, efficiency, speed, reduces scarcity, handling, and distribution cost, and improves the organization profit margin by decreasing the number of stock-outs which is useful for any firm.

The worldwide RFID market amounted to US\$1.95 billion in 2005 and US\$26.9 billion in 2015 and is expected to grow more in the future since it appears to be a disruptive technology (Lefebvre et al., 2006) and useful in many different fields besides warehousing, for example in health care services (Abugabah et al., 2020).

2.7. Warehouse Management Systems (WMS)

The necessities of the logistics world keep rising and, as part of that world, the process of warehousing is becoming more and more complex. Since companies may gain a competitive advantage when they have efficient logistics, the use of tools for the management and control of material handling and storage is essential for fast and efficient logistics (Assis and Sagawa, 2018). One of such tools is the WMS.

2.7.1. Concept and Relevance

A Warehouse Management System (WMS) is an information system that supports stock management and administration in the warehouse. It is used to increase the performance of the warehouse by supporting the management processes systematically (Apak et al., 2014). It primarily aims to control and record the movement and storage of materials and information within a warehouse and its flow reducing routines and maximizing the use of available space and the performance of tasks associated with logistics (Assis and Sagawa, 2018; Ramaa et al., 2012). The WMS is an important part of the company's business and it can make processes simple to keep track of (Žunić et al., 2018).

Any WMS application regardless of the business complexity should be able to support some basic logistics functions. The WMS must possess tools and functions to support the main steps and logistic processes of inbound, production, and outbound, such as pre-receiving of materials, receiving, inbound quality control, storage, transfer, picking, and shipping (Andiyappillai and Prakash, 2019).

The WMS guides the warehouse workers in their daily tasks and requires confirmation that the tasks have been carried out. This implies a constant exchange of information between the system and the operators and from the operators to the system. Tasks are sent wirelessly to operators in the warehouse, they execute the tasks and confirm their actions with bar-code scans. The location of every item in the warehouse is tracked in real-time, and there is no or little administrative work required to operate the warehouse (Nee, 2009).

2.7.2. Implementation

The challenges most often cited as justification for investing in a WMS include errors in receiving, picking, and shipping, too much time lost searching for products because there is no location management, manual recording of transactions, high labor costs, low turnover, inventory loss, lack of lot traceability, low order fulfillment rate, inefficient space utilization, performance measurement issues, and customer demands (Hill, 2003).

The implementation of a WMS will necessarily provide an increase in accuracy, reduction in labor costs if the labor employed to maintain the system is less than the labor saved on the warehouse floor, and a greater ability to service the customer by reducing cycle times. Also, the WMS will not only lead to inventory reduction but also greater storage capacity (Ramaa et al., 2012). In the case study proposed by Nee (2009) it was reported that, with the implementation of the warehouse management system, the percentage of customer complaints due to warehouse mistakes reduced

from 43% to 11%, the outbound lead-time for air freight was reduced from 9.94 days to 4.29 days, which is a reduction of 57% and inventory accuracy improved from 98.34% to 99.52%.

The implementation of WMS for a company demands significant investment not only financially but also in terms of time since it can take several months. Such investment must be justified with the benefits obtained after implementation. The firm should be prepared to change the entire process and system storage because WMS implementations without changing processes do not lead to cost savings or efficiency improvements, it will only reduce errors due to human factors (Ramaa et al., 2012)

According to Assis and Sagawa (2018), the WMS counts on the support of some technologies, some of which were already mentioned in the previous chapters. Assis and Sagawa (2018) speak mostly of two technologies: barcode reading and RFID. The bar code reading consists of the use of a scanner to read information from a barcode label and comes as an important ally to the WMS as it assigns a reference to a particular item and defines its identity and relevant information. When the use of collectors and bar codes is also necessary, there should be printers available for issuing labels, computers, and a server. Another possible WMS integration technology is RFID. The RFID can overcome the imperfections of the bar code such as errors of readings, duplicate readings, torn labels that do not allow for the barcode to read and is much simpler and faster since it is not necessary to turn the packaging in search for the bar code. However, RFID technology is much more expensive to obtain and implement.

The implementation of a WMS has to consider not only the needs of the warehouse and the firm but also the functionalities it wants from the WMS in order to fulfill those needs. The functionalities differ from each WMS, but Assis and Sagawa (2018) proposed a set of functionalities for the Warehouse Management System with classification categories or system characteristics based on the revision of the works from Banzato (2005), (Moura, 2010), (Costa and Júnior, 2008) and Klabusayová (2013). No system is likely to possess all the functionalities, but the set presented is a good guideline for what to search for in a WMS. The set proposed is listed in table 2.

Table 2 - WMS Functionalities, adapted from Assis and Sagawa (2018)

| Possibility of integration and customization | | |
|---|--|--|
| Enables integration w/ radiofrequency system; | Enables interface w/ customers and suppliers; | Possess its own register; |
| Enables integration w/ barcode system; | Enables customization; | Accepts different rules/policies for items; |
| Enables integration w/ RFID; | Enables parameterization; | |
| Receiving and inspection | | |
| Manages receiving/staging area; | Manages scheduling and order entry; | Controls batches; |
| Executes "blind" conference on the receiving; | Automatically designates storage locations; | Controls quantities; |
| Controls concierge; | Generates labels; | Checks each item in the order; |
| Supports systematic classification of items; | | |
| Storage processes | | |
| Controls FIFO; | Checks storage at the correct addresses; | Confirms transfer and replenishment |
| Updates records in real-time; | Supports resources' allocation; | Recognizes the physical storage; limitation of each address; |
| Assigns the addresses automatically; | Defines usage characteristics for each storage location; | Stores accurately; |
| Management Support | | |
| Plans and controls capabilities | Allocates human resources for the activities | Supports the whole inventory management process |
| Manages backorders | Supports productivity measurements | Tracks all operations |
| Monitors performance of activities | | |
| Order Separation | | |
| Drives picking activities | Controls routes | Generates picking list |
| Shipment | | |
| Generates shipping sequence/schedule | Calculates the needs for packaging | Generates shipping documents |
| Updates system for issuing invoices | Calculates dimensions of packages | |
| Cyclic Counting | | |
| Manages cyclic counting | Identifies and records inventory receipts based on storage | Tracks all inventory by location |

In relation to the implementation that is the purpose of this project, research on literature of related projects was made. Similar work carried out by:

- Caridade et al. (2017), with the implementation of a Warehouse Management System (WMS) in order to improve the warehouse responsiveness to production by controlling stock inventory and storage locations;
- Pereira et al. (2019) with work based on the development and implementation of a localization system in a manual warehouse of a retail company, with the main goal being the optimization of picking tasks and the improvement of the warehouse operations, as well as stock management;
- Fauzan et al. (2020) whose objective was to analyze the running system and design a warehouse management information system for a company in Indonesia;
- Shashidharan and Anwar (2021) with a study on the efficiency of the overall performance of warehouse operation, the integration of technology in the operations and the importance of an efficient warehouse management system;
- Perera and Kumarage (2013) reporting a before and after study of a Warehouse Management System (WMS) implementation at a selected warehouse where its impact on five major performance measures, namely service level, resource utilization, space utilization, cycle time and stock integrity were analyzed;
- Žunić et al. (2018) describing the concept of a smart WMS that is implemented in a distribution company in Bosnia and Herzegovina. The work describes the complete warehouse workflow that includes stock planning, initial product placement, transfer from stock to pick zone, order picking process, transport, and tracking;
- Ramaa et al. (2012) highlighting the findings of the study carried out to evaluate performance levels and enhance productivity of the manual warehouses by developing a WMS framework and cost benefit analysis;
- Assis and Sagawa (2018) with a study that had as a central objective, analyzing the results of the implementation of a WMS system in a manufacturer of mechanical parts, in terms of operational efficiency and quality;
- Andiyappillai and Prakash (2019) that attempts to understand the latest trends and developments in WMS implementations based on a case study conducted in a leading Logistics and Supply Chain enterprise.

2.8. Warehouse Key Performance Indicators

A warehouse performance measurement is a method to measure activity performance, program or service which is provided by a warehouse (Kusrini et al., 2018). The continuous measurement of performance is absolutely necessary to monitor process improvement of the supply chain where the warehouse is usually the last link before final delivery to the customer (Perera and Kumarage, 2013).

The main instruments for assessing performance are performance indicators, also named key performance indicators (KPIs) (Livi et al., 2009). There is no agreement among researchers about which KPIs are more suitable for a warehouse (Kusrini et al., 2018). Also, different methods have been employed by various researchers to classify indicators. For instance, Frazelle (2002) uses a model where the indicators are divided into the five main warehouse operations (Receiving, Put-

Away, Storage, Order Picking and Shipping) and each operation is also separated into five categories (Financial, Productivity, Utilization, Quality and Cycle Time) as can be consulted in table 3.

Table 3 - Warehouse KPIs, adapted from Frazelle (2002)

| | Financial | Productivity | Utilization | Quality | Cycle Time |
|----------------------|----------------------------------|---|---|---|--------------------------------------|
| Receiving | Receiving cost per line | Receipts per man-hour | % Dock door utilization | % Receipts processed accurately | Receipt processing time per receipts |
| Put-Away | Put-Away cost per line | Put-Away per man-hour | % Utilization of Put-Away labor and equipment | % Perfect put-away | Put-away cycle time (per put-away) |
| Storage | Storage cost per item | Inventory per square foot | % Locations and cube occupied | % Locations without inventory discrepancies | Inventory days on hand |
| Order Picking | Picking cost per order line | Order lines picked per man-hour | % Utilization of picking labor and equipment | % Perfect picking lines | Order picking cycle time (per order) |
| Shipping | Shipping cost per customer order | Orders prepared for shipment per man-hour | % Utilization of shipping docks | % Perfect Shipments | Warehouse cycle time |

Another model for structuring KPIs is the one presented by John M. Hill in his book “Warehouse Performance Measurement “ from 2007 where he groups KPI’s in three types of indicators: order fulfilment, inventory management and warehouse performance (as cited in Liviu et al., 2009). These can be consulted in tables 4, 5 and 6.

Table 4 - Warehouse KPIs: Inventory Management, adapted from (Liviu et al., 2009)

| Inventory Management | |
|----------------------------|---|
| Measure | Calculation |
| Damaged Inventory (min.) | Total Damage / Inventory Value |
| Days on Hand (min.) | Avg. Month Inventory (lei) / Avg. Daily Sales/Month |
| Storage Utilization (max.) | Avg. Occupied Sq. m. / Total Storage Capacity |
| Dock to Stock Time (min.) | Total Dock to Stock Hrs. / Total Receipts |

Table 5 - Warehouse KPIs: Warehouse Performance Indicators, adapted from (Liviu et al., 2009)

| Warehouse Performance Indicators | |
|---|---|
| Measure | Calculation |
| Orders per Hour (max.) | Orders Picked / Total Warehouse Labour Hrs |
| Items per Hour (max.) | Items Picked / Total Warehouse Labour Hrs |
| Cost per Order (min.) | Total Warehouse Cost / Total Orders Shipped |
| Cost as % of Sales (min.) | Total Warehouse Cost / Overall Sales |

Table 6 - Warehouse KPIs: Order Fulfilment Indicators, adapted from (Liviu et al., 2009)

| Order Fulfilment Indicators | |
|------------------------------------|---|
| Measure | Calculation |
| On-Time Delivery (max.) | Orders On-Time / Total Orders Shipped |
| Order Fill Rate (max.) | Orders Filled Complete / Total Orders Shipped |
| Order Accuracy (max.) | Error-Free Orders / Total Orders Shipped |
| Order Cycle Time (min.) | Actual Ship Date – Customer Order Date |
| Perfect Order Completion (max) | Perfect Deliveries / Total Orders Shipped |

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3. DESCRIPTION OF APPLIED METHODS

The following chapter focuses on a description of the utilized and applied methods in the implementation of the warehouse management system solution.

As referred in the introduction chapter, section 1.4, this work it followed the Andiyappillai and Prakash (2019) methodology for WMS implementation. This methodology contemplates four phases:

- 1) Business Requirements: Assessment of the state of affairs, layout, processes, existing information, analysis and review to identify processes/procedures, opportunities for improvement and gaps;
- 2) Configuration: Set up necessary software applications, gadgets and connections (printers, scanners);
- 3) Testing: Run the WMS in the conference room making changes regarding client necessities, test scenarios, optimize processes, includes the configuration of the warehouse, articles, and customers on the WMS. In this research, this is the stage from where data will be collected, and results will be retrieved in the form of a functionality checklist, new process flow schemes and selection and analysis of KPIs;
- 4) Deployment: Formation and training of the people who are going to use the WMS and close assistance when it is time for the solution's "Go-Live".

This chapter starts with phase 1, "Business Requirements". The first section of this chapter will elaborate on the initial state of affairs, the methods used by DSV to manage the warehouse as well as a presentation of the warehouse itself, its dynamics, clients, layout, and necessities using Business Process Model and Notation (BPMN) tools such as swimming lanes diagrams. Next, the "Configuration" where it is presented the various software applications and connections that were configured on the solution. On phase three, "Testing" a detailed description of how to establish, in the WMS, information about the warehouse, articles, and the customers as well as an extensive explanation of the basic operations (inbound and outbound) available on the software. In between the phases three and four, data was retrieved and assessed if the WMS should be deployed or not. However, the deployment did not happen. The next chapters offer an explanation as to why the solution was not deployed as well as an analysis of the results gathered throughout testing to support the decision.

3.1. Business Requirements

Before any change is to be made, an assessment of the current situation is necessary in order to not only identify flaws within the operation and understand where the implementation of the WMS can be of use but also to understand the business processes and their necessities. It is required to have full knowledge of how the warehouse currently works and create notions about how it should be working with the assist of WMS. Each warehouse has its own necessities and characteristics and DSV's warehouse in Vila do Conde is no exception. It has specific customers with their own needs, which influence the warehouse's layout and can make a difference in terms of how warehousing operations are carried out.

3.1.1. Layout and Constraints

The first step to collect the business requirements for the warehouse is to look at the general plant and understand how it is organized. The layout of the warehouse directly affects the way goods are stored and vice-versa. Therefore, it is relevant to understand the set up in place in the warehouse.

DSV's warehouse in Vila do Conde has a total working area of roughly 800 square meters with about 60% of it being destined to cross docking activities. The remaining portion of the warehouse is dedicated to the storage of goods, and it is the object of study in this project. As it can be seen in annex A, the warehouse possesses eighteen different sets of racks or rows, twelve of them have thirteen racks each, two of them have twelve racks, one of them has eight, another one has four, another has three and there is one row that is singled racked i.e., has only one rack. Racks can differ on the number of shelves. They range from one (in the rack only one shelf exists or is available) to 6 shelves. This results in a total of 907 shelves which is the same number of storage locations, since each shelf is considered to be a location.

Each location is coded with the format: *Row.Rack.Shelf*. Which means that a location whose code is, for example, K0102 can be found on row K, first rack, third shelf. The shelf numeration is similar to floors on a building with the first shelf in each rack being the ground floor shelf that is identified with the number 0.

The allocation of goods is usually divided by customer. It is, however, very dependable on the warehousing contract that a customer has with DSV where it may or may not require a specific area of the warehouse to be assigned to only one customer. This means that a customer can rent the space, pay a fix amount every month and a certain number of locations belong to him. In these locations products from other customers cannot be stored. The customer can also be charged by the number of pallets stored or its movements (in and out), which makes it so that, to the customer, it does not matter where the warehouse stores the pallets. Still, whenever it is possible, DSV opts to organize the warehouse by customer with each customer having one row (or more if necessary) assigned to it and attempts not to mix goods from different customers on the same row as much as possible.

This criterion for storage of goods is, however, supplanted by certain product necessities. While analyzing the products, one needs to take into consideration if the materials have special characteristics, for instance, ADR products (Agreement Concerning the International Carriage of Dangerous Goods by Road). Therefore, goods can be stored according to:

- Different types of products: For example, ADR products have a corridor (two rows) exclusively for them. Also, there are types of goods that cannot be near other types, whether it being from customer requirement or due to safety or law related reasons, for instance, food products cannot be place in the same row as chemical products or corrosive products should never be stored above flammable products.
- Packing format: DSV handles all types of different goods, with all shapes and sizes. Therefore, goods can arrive in different types of pallets (euro-pallets, american-pallets, etc..), boxes of all sizes, rolls (for example, for products such as pool screens and covers), drums/barrels and other irregularly shaped loading devices. This creates different necessities in terms of storage, meaning that certain loading devices cannot be stored or can only be stored on some locations.

Therefore, the type of constraints each one of the goods has is verified constantly. If goods have restrictions related to packaging or type of product, the constraining element is identified and then goods are allocated to a place that meets the requirements. These constraints influence the whole warehousing process.

3.1.2. Warehousing Process and Offered Services

Although some practices may vary depending on the customer, the overall scheme of the warehousing process contemplates most of the same steps and processes. The essence of the warehousing process can be divided in two: Inbound process and Outbound Process. Throughout both processes the materials flow through the more fundamental warehouse activities: Receiving, Put-away, Storage, Order-picking, Preparation and Shipping. The scheme for warehouse flow in the inbound process can be shown on Figure 5:

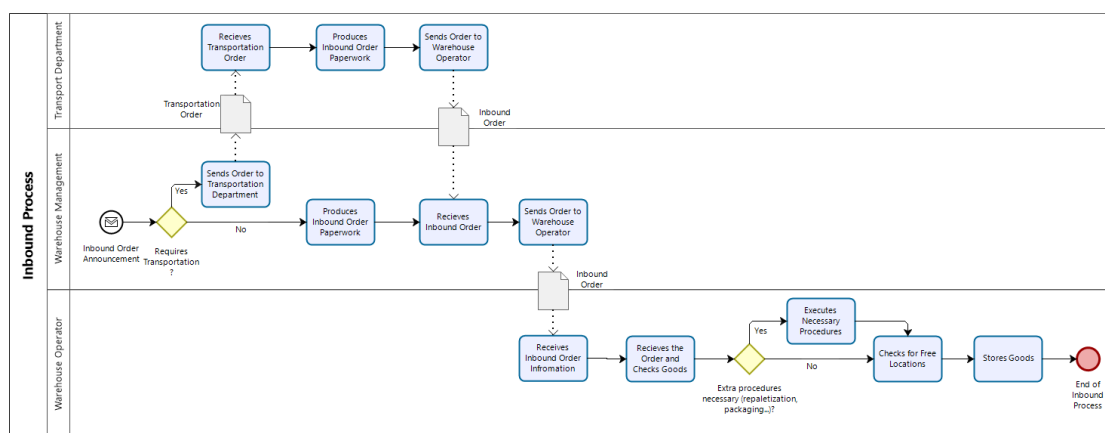


Figure 5 - Inbound Process

The inbound process begins with the announcement of the inbound order by the customer informing what goods are going to arrive at the warehouse. The customer also indicates whether they will be requesting a transportation service, meaning that the customer can opt to carry said goods to the warehouse themselves or request DSV's transportation service to pick the goods from their origin and take care of the delivery process. This situation implicates the existence of a possible division in the course of the warehousing process, with one option requiring the involvement of another department besides warehouse management, in this case, the transportation (or operational) department. In both alternatives, the warehouse operator is given information about the cargo that is going to arrive at the warehouse in a form of a sheet of paper, usually the same sheet sent by the customer when announcing the inbound.

In opposition to the transportation processes, which are subjected to a more complex system of procedures aided by various software and optimization methods, there is no treatment whatsoever, in any software, for the warehousing activities and management. Usually, no indication is provided as to where the operator should store the goods that are about to be received. All the information that is provided to the operator is the name of the articles to store, the quantities (number of boxes, bags, or weight) and the owner of those goods. However, the operator has access to information that might be present on the goods themselves such as, batch number, expiration date, manufacturing date but these are not collected or reported to management, they are only used by the operator to facilitate the outbound process.

The operator then checks the goods that arrive at the warehouse, to check order quality and if it matches the discrimination of the inbound order. In case there is any issue with the order (leaking recipients, physical damage, dents, etc.) the warehouse reports the situation to warehouse management. Warehouse management asks the customer how it wants the situation to be handled and, depending on the situation, the customer either allows for the storage of the product in the mentioned conditions or resends another order to replace the damaged one. In any case, once the order is considered clear for storage, other procedures might be done on the order. These may be necessary in order to make it possible to store the order, for example change the loading device, usually a pallet, if it is too big or too small to fit in the warehouse racks, or because the customer required extra procedures such as bagging, unboxing, or labelling.

After all procedures are completed, the operator searches the warehouse for a single location or multiple locations to store the order. In the warehouse it is common practice for an operation of a customer to be assigned to a single operator, meaning that it is always the same operator who decides where the order will be stored. This happens mostly because since there is no record keeping on the products locations, only the assigned operator knows exactly where the goods belonging to that customer are, and only he might have a specific storage strategy for that customer. It is also general strategy to assign a row to a customer or if that is not enough, assign the same corridor (two rows, one in front of the other). If the goods have certain characteristics that require special attention (for instance, ADR), they will be stored accordingly. After the goods are stored, the inbound process is over. There is no reporting to be made to warehouse management or data to be exchanged.

The outbound process is the other part of the warehouse process and its scheme is presented on Figure 6.

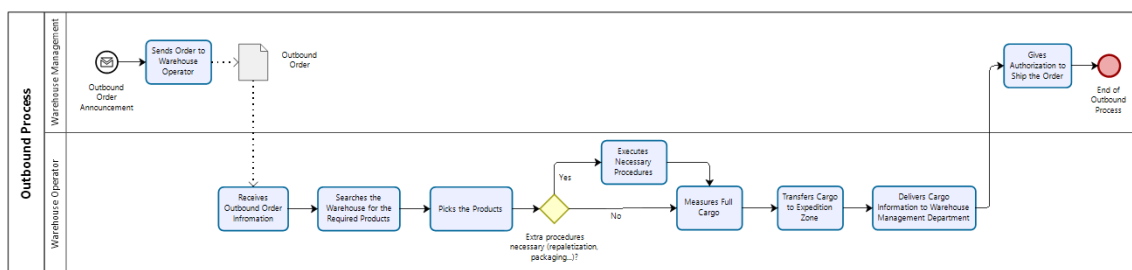


Figure 6 - Outbound Process

The outbound process, similarly, to the inbound process, also begins with an order announcement. The customer requests for a certain set of items to be delivered in a certain place. This request might be made by email or through DSV's booking platform called "MyDSV". In either case, the result of the announcement is a document containing the outbound order. The structure of the document is not always the same, it differs depending on the customer. Nevertheless, all documents possess the identification of the articles (name or code), quantities, weight, batch number, delivery address, billing address, order identification number and date of delivery.

After being received by the warehouse management department, this information is sent directly to the warehouse operators. No more information is added, nor a picking list is made, the operator must execute the picking activity with the available information. As previously mentioned, the operator in charge of a client is the only one taking care of the orders of that client, unless for some reason, that operator is not working at the time of the order's arrival (order arrived before or after

his shift, vacation, sickness, etc.). Since there is no inventory keeping, this operator is the one who can execute the order more efficiently, still, it can take him some time to identify, in the warehouse, the article to pick, if the number of total references present in the warehouse for that client is high and the products look similar. Nonetheless, the operator, by memory and by no criteria other than its own good sense, retrieves the necessary goods from their locations and prepares them for shipping. Usually, there is a need for procedures such as wrapping, labelling and others. After that, the cargo is measured, the number of loading devices is counted and the dimensions of each one is registered, normally on the outbound order sheet, and delivered to warehouse management to be able to instruct shipping, know how much space each order will occupy on the truck and transfer that information to the transportation department. Finally, the cargo waits, at the shipping zone, for instructions as to what truck and at what time it will be shipped. When those instructions arrive, the goods are loaded onto the truck and the order is considered shipped.

To DSV, warehousing products is a source of revenue. It can, however, assume different sources within the warehouse business. DSV celebrates contracts with its customers where it offers, a range of services from which the customer can choose to hire. Those services include:

- **Storage:** The customer pays for the service of keeping stock. Depending on what is negotiated with the customer, the billing model might differ. The billing might be done by pallet per month (more common, but can also be by day, week, or year), meaning that an agreed value will be charged for each pallet present in the warehouse by the end of the month. A customer can be charged by metric ton (or kilograms) that similarly to the pallet per month model charges an amount for each ton of goods present in the warehouse by the end of the month. Or it can be done through a fixed cost system, where the customer rents a portion of the warehouse, most frequently a fixed amount of square meters, and it is charged the same amount every month whether it uses that space or not. In case the customer needs more space, it can always renegotiate the contracted area to increase its available space;
- **Handling In and Handling Out (or picking):** The customer pays for the service of handling inbound and outbound orders. This service is very common and hired by every customer with exception of the ones that only need storage. It basically includes the whole warehousing process. A fee is charged for every unit (pallet, kilogram, box) that is managed in the warehouse due to inbound or outbound procedures. Preparation services that are necessary for every order, such as labelling, repalletization and others, are included at this stage;
- **Administrative Services:** Handling paperwork and bureaucracy. Each incoming or outgoing order might require the creation of documentation that the customer can opt to pass the responsibility to DSV, and as such each document processed is invoiced to the customer. In this service can be included legal responsibilities such as doing the necessary procedures related to custom authorities;
- **Handling Returns:** The customer may hire DSV to handle returns. Returns are charged differently than normal inbound orders because it may entail a different approach since they do not arrive from the normal inbound process. Also, returned goods might require a different type of handling in the warehouse depending on the reasons for its return or what the customer decides what to do with the goods. If goods are returned because of a quantity mistake, the goods are stored normally, but if they are returned because they are damaged or have poor quality, special treatment to these goods might be necessary;

- Additional Regular Services: Regular services, paid monthly or yearly if hired by the customer. These include insurance costs, office and warehouse supplies and other fixed cost services;
- Additional Irregular Services: Services that might be required ever so often, that are not in the initial contract because they are not necessary on a day-to-day situation. These include labelling, repalletization (to articles that usually do not require it), loading and unloading of containers or tanks, supply of pallet (pallet belongs to DSV, the customer pays to use it) and others that might be necessary and are negotiated with DSV.

3.1.3. Process Gaps and Opportunities for Improvement

At the end of the process and operation analysis, information is gathered, and it is possible to identify three main gaps and opportunities for improvement in the described methods that can be tackled with the implementation of a WMS.

- Inventory Keeping: DSV has no effective way of keeping a record of the goods present in the warehouse. Some basic methods are used, for a very small number of customers, but for the most part inventory keeping is something that is not done. This can lead to some inconveniences, such as not knowing how much to charge to the customer at the end of the month because the number of pallets, units, or metric tonnes of goods present in the warehouse is not known. At the end of the month (or day), to be able to know how much to charge each customer, the warehouse either has to constantly count the quantities of goods existent in the warehouse or check the archives for outbound orders (in paper) and calculate the differences between what was charged last month (or day) and the values of this month's moved goods, or, if there are too many orders and there is no time to count stock, an estimate is made about the amount to charge. These situations, specially the last one, always lead to customer complaints (too much stock charged) or losses of money (very little stock charged). Other inconveniences include picking mistakes because this activity is left to the good sense of the operator and he can make mistakes by picking the wrong products or the wrong batches, which in turn can lead to a situation where there are differences between the stock that the customer thinks it has at the warehouse and the real stock. In this situation the warehouse might not have enough stock to fulfill a customer order and the mistake, depending on the product, might generate costs in the order of hundreds or even thousands of euros if not found in due time. The WMS should be capable of assisting in this regard by keeping a real time stock of each customer to facilitate proper billing and maintaining an order history and a record of each movement of every item in the warehouse so management can detect mistakes rapidly.
- Order Management: Orders are managed in a very primitive way. The constant use of numerous sheets of paper or very raw excel tables with no treatment or indication as to where to place or remove goods is something that slows the process considerably. It can also lead to mistakes, especially human error since there is no system safeguard or backups. Paper files always have the risk of being lost or damaged which leads to no other choice than to restart the process (for instance, picking). The WMS should be able to eliminate or at least reduce the amount of paperwork necessary for a daily operation allowing for a faster and more straight forward communication between departments and people, and a better flow and storage of data regarding, specially, but not only, inbound and outbound orders.

- **Storage Planning:** The warehouse follows no specific policy regarding storage of goods. The safety concerns and restrictions exist, where it is established that, for example, corrosive products always have to be placed below flammable goods. Apart from that, little to no planning is made regarding storage. The decision of where one should store a certain product comes entirely from the operator that is executing the put-away of said product. The operator has no tools nor knowledge of what the optimal way for storing units should be. He has no indication from management, storing products the way he believes will take him the least amount of time to pick or find the products. Usually, the operator's assumptions are only focused on the short term, he has no regard for the long term. For example, the operator does not consider the fact that goods with high turnover should be stored close to the expedition zones (ABC analysis) unless it is an obvious case, because he has no way of making this type of analysis himself. This is also valid for picking activities, the retrieval of goods, the where, when and by what order to do the task is also up to the operator. In reality, this type of analysis should be done by warehouse management which in turn should provide that information to the operator, however, management does not have the tools nor the information processing capabilities to make this type of planning fast enough for it to be more feasible than letting the operator decide. This process limits the warehouse efficiency and its activities. Picking activities take longer than they should because of poor planning. Operators walk too much, take too much time to think about where the products are or where they should place them, spend a lot of time transporting goods and there is no register, only one operator knows where certain goods are. When that operator is not working for some reason, picking takes even more time. The wasted time in activities translates into costs and that is why, storage planning is a functionality that is a requirement for the WMS. The WMS should be capable of providing an optimized or at least feasible inbound and outbound strategy that shortens the time needed for each activity, leading to less costs.

3.2. Configuration

The configuration phase usually includes setting up a virtualized environment (for cloud deployments) or installation of the software on the hardware (for on-premise deployments) (Aptean, 2019).

During this stage, IT services from DSV central configured all necessary database and server connections. IT services also installed all of the software applications and set up the appropriate permissions for the requested users resulting in a ready to test environment. Therefore, in this section a study of the configuration phase is described. It includes a presentation and description of the WMS solution and the software installed.

3.2.1. WMS ILIAS

ILIAS is DSV's solution focused on warehouse management for the DSV Road branch and is described as a WMS. In short, this WMS is a software designed to simplify the management of warehouses and all the associated processes in order to monetize the investment made in the of storage and inventory keeping.

ILIAS arises from a current need for rigorous storage and distribution of goods by organizations. To meet the exact delivery times of an order, with quality and accuracy, is a constant pressure, so ensuring a quick and exact response is complex, especially when there are so many variables at stake.

A WMS aims to solve the problems of organization and management of storage spaces, eliminate errors in order management, optimize the planning of deliveries and boost profitability and efficiency in distribution and delivery management. The use of a warehouse management solution is thought to have a positive impact on the entire supply chain and accelerate processes with comprehensive, integrated warehouse management. ILIAS's purpose is also to assure customers, that DSV is a reliable supplier capable of making deliveries on time, in the right quantity, with the desired quality and with an above-average quality of service.

ILIAS is a project directed to DSV's Road framework. It is a DSV owned software, created specifically for a warehouse in Germany. The results of that implementation were favorable which led DSV to believe it could be used in other warehouses. Portugal is one of the first countries where a full-scale implementation is being attempted outside of Germany.

This WMS solution requires certain technical elements for the operating system, memory, and readability. In addition, the architecture of the solution naturally requires that there be a server and an organization's database. It is also required that there is equipment such as: label printer and scanners. These components were setup by IT services.

3.2.2. Intra Sys and WILIAS

ILIAS exists on two levels: on a terminal level and on a frontend level.

The terminal level can be considered an extension of the WMS, in a sense that it provides the exchange of information between system administrators and warehouse operators. It allows for the confirmation of inbound orders and outbound orders. It is often used with a barcode reader, for example, but can also be used on a computer through an emulator. The frontend level is the "brain" of the WMS. It manages all of the information and possesses all available functionalities in the WMS solution. The frontend elaborates the orders that are going to be confirmed with the terminal and receives the confirmation when it is done. The interconnection of a WMS with warehouse terminals or other types of technologies is a crucial point because that is how it is possible to have a real-time management of receipts and dispatches, movements, picking actions, among others. This situation is made possible with ILIAS since it is divided into two applications: Intra-Sys and WILIAS.

- Intra-Sys: Is an application meant to run as a terminal and desktop frontend application simultaneously (for now). On scanning devices Intra-Sys functions as a terminal application and, on a computer, it functions as a terminal emulator and a frontend application along with WILIAS. Figure 7 presents the main menu of Intra-Sys.

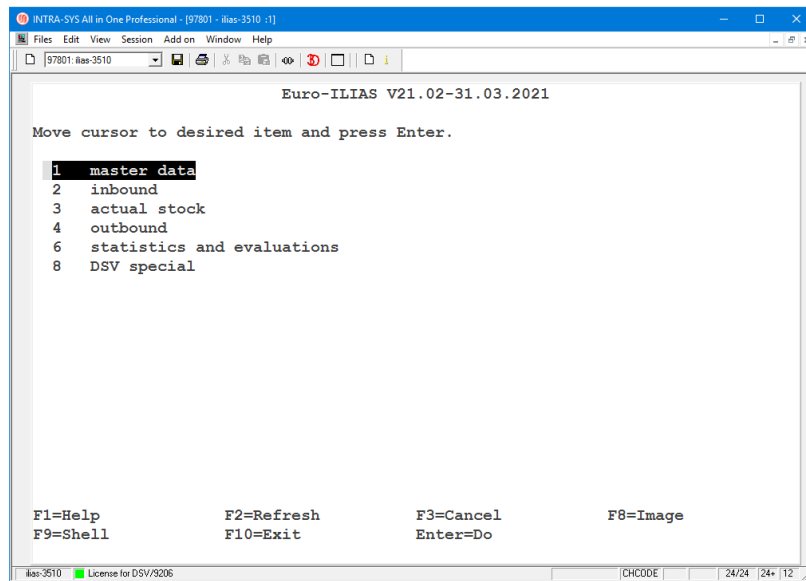


Figure 7 - Intra-Sys

- WILIAS: Is a web application that works in a frontend capacity along with Intra-Sys. As of today, both applications are necessary since they possess different functionalities. It is important to note, however, that this situation is not meant to be kept for long. WILIAS was created to replace Intra-Sys as the frontend application, it has a more modern design and a more user-friendly interface. Once the migration of all functionalities is complete, Intra-Sys will stop being used in a frontend capacity. Intra-Sys will be solely the terminal application and WILIAS will be the only frontend application. The main screen in WILIAS is shown in Figure 8.

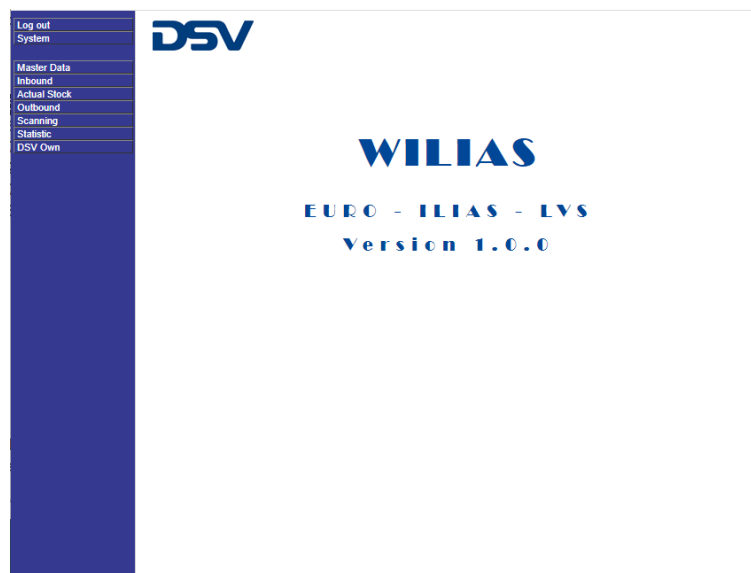


Figure 8 – WILIAS

3.3. Testing

This phase includes testing the requirements against the system functionalities to ensure the WMS will run correctly. Warehouse and customer setups are made at this stage, along with their article's characteristics, because these were subjected to testing and suffered modifications throughout this phase. It is also described how support from IT services influence the implementation process. This phase takes a long time and includes a great deal of testing to optimize location workflows and configure business requirements all to make sure processes from receipt to shipping are operating correctly. Testing for EDI and other possible system integrations to exchange data properly was also done during this staged. In this subchapter, a detailed description of the operations and setups that were tested in ILIAS are presented.

3.3.1. Formation and Support

The testing phase begins with a short formation on ILIAS. The formation was provided by DSV central and the ILIAS support team. It centered around ILIAS's most basic operations and gave knowledge about what functionalities were available in both WILIAS and Intra-Sys without really explaining how to use them to optimize processes, leaving that part to the user's exploration. The topics approached in this formation included:

- Overview of both applications (Intra-Sys and WILIAS): A brief explanation of menus, such as Masterdata, Inbound, Storage Check, Outbound, Statistics, and others, along with the functionalities that are available for users were shown throughout the formation
- Masterdata overview: An overview of the ILIAS masterdata and its fields was shown in WILIAS. These fields include creating and managing articles category of products and loading devices, managing the warehouse storage types and storage places, and define and alter outbound strategies, customer settings and article settings. The masterdata may contain fields that are only permitted to the ILIAS support team, with users not being allowed to access, becoming necessary to ask ILIAS support team for help if any change is needed
- Set-up overview: Information about how to create the warehouse, customers, their customers (recipients/destinations) and goods (articles) was given. The formation did not teach users how to create each element directly. Instead, an excel template was provided by the support team to aid in the creation of storage locations, customers, recipients and articles and users were informed that the template should be filled and sent to ILIAS support team for upload. The formation followed with an explanation of what fields were necessary to fill and their purpose. Other sub-menus, such as articles category of products and loading devices and warehouse outbound strategies were mentioned but not explored
- Inbound and Outbound Process: A step-by-step formation on the inbound and outbound process from the user point of view was shown. The use of both applications was explained along with the employment and possible role of the scanners was presented

3.3.2. General Set-Ups

Like any other WMS, ILIAS has configuration needs besides software and hardware. Any WMS solution needs information about the warehouse, customers, and goods that are going to be handled.

For the testing phase, it was decided that only four customers, would be considered. Testing would be done for these customers in order to decide if the WMS solution was worth continuing to the deployment phase. Once these four customers continued to the deployment phase, the remaining portion of the warehouse would enter the testing phase and after that they would also be deployed.

The testing phase started with the warehouse set up in ILIAS. As mentioned, the support team provided a template that should be filled and sent back to the team. The support team would then upload it to ILIAS and create the warehouse. In order to fill the template, a process of data collection was initiated that included, for example, the measurement of all locations. A short version of the template can be consulted in appendix A and possesses the following columns to fill:

- 1) Branch: A DSV internal number used to identify the warehouse. In the case of this warehouse in particular the number is 3511;
- 2) Storage type: ILIAS works with storage types. Storage types are groups of locations. They can be as many as the number of existing locations. There can be no location assigned with two storage types. In this case, three storage types were created: RPAL (locations for pallets), RSMP (locations for small parts such as boxes or flasks) and RBLK (single bulk location, represents the ground floor);
- 3) Storage place: A storage place is a location for storage. Consists of the code for each location, for example, A0100 (row A, first rack, first level/shelf);
- 4) Description: Describes each storage place;
- 5) Length, Width and Height: Represent respectively, the length/depth, width and height of the storage place;
- 6) Kind of utilization: It indicates the type of utilization. It is set to "S" for all storage places, meaning a standard utilization. The indications given in the formation were to just leave it as standard. No other kind of utilization was shown, besides "S";
- 7) Storage place utilization: Percentage of the storage place allowed for storage;
- 8) Allowed QTY ME1: Quantity of number one units (ME1) allowed in the storage place. Number one units are the largest units that an article can be aggregated into, for example, an article can arrive in a form of 500 kg distributed through five bags of 100 kg and those bags are placed on a pallet. This means that the pallet is unit one, the bag is unit two and the kilograms are unit three. In this warehouse, all pallet locations (RPAL) can hold a maximum of three pallets. The other locations (RSMP e RBLK) have higher limits, being only restricted by the space and maximum weight allowed in the location;
- 9) Max weight: Maximum weight allowed in the storage place;
- 10) Distance inbound: Priority given on the inbound process. The lower the number, the higher the priority. It was decided that the priority should be higher in the lower levels. The system should try and store goods on the lower-level locations first and only then go to the levels above. Also, in this warehouse, it was decided that the first rack would be the rack of the end of the corridor, meaning that that the row starts with rack 13 and goes in decreasing order. The reasoning behind this decision is that, due to the layout of the warehouse, the corridor ends in a wall. If it becomes necessary to add more racks, one can only do it at the start of the corridor. So, it makes more sense to just continue numbering racks, going from

13 to 14, instead of renumbering all racks every time a new rack is added. In this case, lower numbered storage places are further from the exit/entrance of the corridor, so they have a lower inbound priority;

- 11) Distance outbound: Priority given on the outbound process. For the outbound, the priorities are the same as in the inbound. Lower levels have the priority because it is easier and takes less time to execute picking actions on lower placed locations;
- 12) Re-filling: Yes or no field, or in this case “J” (*Ja*) or “N” (*Nein*) because the software was originally written in German and it still has bits of German in it. This field indicates whether a storage place allows for a re-filling, meaning that if a pallet leaves a storage place, its place can be taken by another pallet. In this case all locations allow for re-filling;
- 13) Different article allowed: Indicates whether a location is allowed to have more than one article (different references). It was left as “J” because not allowing it would remove a lot of available storage space;
- 14) General use: Indicates whether only one or many categories of products can be stored in a location. In this case all storage places allow for general use.

The data used on the template was gathered with on-site measurements of the storage places since no information was available.

After the template is filled and sent, ILIAS support team uploads it and after that the storage places are available in ILIAS for individual editing, if necessary. In WILIAS, as it is shown on appendix B the user can edit the storage places. It can edit the fields that were filled in the template and can explore others. In this case the ones that are worth mentioning and exploring further are the cubic meter allowed and the square meter allowed. The cubic meter and square meter fields indicate the amount of cubic meters and square meters of goods allowed in the storage place, respectively. It is not necessary to be filled in the template because ILIAS does this calculation automatically by multiplying the length of the location by the width and height of the location, for the cubic meter and just the length by the width for the square meter. However, this is also an editable field, meaning that one can write any number in this field.

3.3.3. Customer Set Ups

Customer set ups are configurations that were made for every customer (general set ups were made only once for the entire warehouse). Each customer is different, has different needs and characteristics and as such, each one of them requires a special attention. However, the methods for setting up a customer are standardized and that is what is going to be described.

Creation of the customers in the system is the first step. In this case, as explained previously only four customers were created onto the system. The process was simple, with the support team providing once again a template to create customers. The template can be consulted in appendix C, and it asked for the following information:

- 1) Customer Name: Indicates the name of the customer;
- 2) Street: Address of the company. It is usually the billing address;
- 3) House number: Complement to the address if necessary;

- 4) Zip Code: Zip code of the customer;
- 5) Place: City, municipality, or county;
- 6) Branch: Branch to which this customer will be associated (3511).

In similar fashion to the previous case, in WILIAS, as it is shown on appendix F, the user can edit the customer information. There are many fields that according to ILIAS's support team are not to be used because its functionality is not available. The addresses of the customer's clients are introduced via a separate template or directly through WILIAS.

The next step is the creation of the goods in the system. For the system to be able to control stock coming in and going out, it needs information about the characteristics of the goods. To accomplish such task, IT support, provided once more, a template to insert the characteristics that ILIAS needs to analyze, to be able to manage goods. The template can be consulted in appendix D and appendix E. The fields needed to be filled are the following:

- 1) Branch: Branch of the warehouse;
- 2) Customer number: Customer number generated automatically by ILIAS when creating a customer;
- 3) Article number: Code or reference that identifies the article. In ILIAS, has a limit of 15 characters;
- 4) Description: Name or expression that identifies the article;
- 5) Category of products: Similar to the concept of family of product. It is a 3-letter code that is used to group articles into categories that create the possibility of restricting a certain group of articles to a specific number of locations. Example: CHE (chemical) and GEN (generic);
- 6) Goods properties: It is similar to the concept of sub-family and follows the same logic of the categories of products. Each category can be divided into a property. Example: CHE can be divided into FLA (flammable), COR (corrosive) and CHE (regular chemical);
- 7) Qtu1, Qtu2 and Qtu3: Specifies the possible formats that the article can assume. In ILIAS there is a limit of three formats and each one is identified by a 2-letter code. These formats should account for any relevant format for storage, outbound or inbound, meaning that, for example, an article can be a regular unit, can arrive in a pallet with any number of units or if it is relevant and useful one can look at the article considering the weight in kilograms that each unit has. A customer can ask for x kilograms of an article, or a number of units. The article can also arrive and be stored in full pallets, so it is important to have all these formats in consideration. The formats include FP (euro-pallet), UN (unit), KG (kilogram), BG (bag), JC (jerrycan), LT (liter), and others;
- 8) Qtu2 and Qtu3 quantity: It specifies how many units of Qtu2 can fit into Qtu1 and how many units of Qtu3 can fit into Qtu2. There is no quantity for Qtu1 because Qtu1 must be the unit that contains all the others. These quantities cannot be fractional numbers. Example: A pallet can have 40 bags (Qtu2 quantity) and each bag can have 25 kilograms;
- 9) Qtu1, Qtu2 and Qtu3 length: Length of each loading device (format). Along with the width and height, represent the dimensions of each format and are used to calculate the amount

of space the article occupies in the location. Each format is dimensioned with the sum of all units, for example, a pallet dimension equals to the dimension occupied by the pallet with the units/boxes/bags;

- 10) Qtu1, Qtu2 and Qtu3 width: Width of each loading device (format);
- 11) Qtu1, Qtu2 and Qtu3 height: Height of each loading device (format);
- 12) Qtu1, Qtu2 and Qtu3 gross weight: Gross weight of each Qtu;
- 13) Qtu1, Qtu2 and Qtu3 net weight: Net weight of each Qtu;

One can always edit, in WILIAS, the data for each individual article, as shown on appendix G. The article data insertion is important, correct article dimensions and weights allow for a better spatial awareness by ILIAS. In order to gather such data, on the field work was necessary because even the owners of the goods had little to no recorded data available regarding the dimensions or weights of the articles. As such the information was obtained by measuring and weighting every unit of every article along with every box/pallet/bag where those units were contained. This became the most time-consuming task in the implementation process.

The final step before starting to operate basic activities with ILIAS is to insert the initial stock that each customer possesses at the moment in the warehouse. This step could have been done by inbounding the articles using the WMS's inbound functionality but, in some cases, large amounts of stock exist in the warehouse which makes the inbounding process not practical. For a situation such the one referred to previously, IT support provides the option of inserting the initial stock directly into ILIAS's database. In order to do that, one has to fill yet another template, such as the one shown on appendix H. The information needed is:

- 1) Customer no.: Customer number generated automatically by ILIAS when creating a customer;
- 2) Article no.: Code or reference that identifies the article;
- 3) Storage type: Storage type associated with the location in which the article is stored (ex: RPAL – pallet location);
- 4) Storage place: Location for storage where the article is placed (ex: M0203);
- 5) ME1 qty, ME2 qty and ME3 qty: Quantities of the article present in the designated storage place in format one, two and three, respectively. For example, in storage place L0403 there is two (ME1) pallets with 16 (ME2) rolls (each pallet has 8) and 66000 square decimeters of material (each roll has 4125 square decimeters);
- 6) Handling type: Describe the type of handling. Only one type was explained during formation: ST – Standard Inbound;
- 7) Date of inbound: Date of entry of the goods in the warehouse. For cases where it is not relevant to consider the entry date of the products, meaning, the outbound criterion is not FIFO or even LIFO, it is not necessary for the date of inbound to be precise. If it is, in fact, relevant to consider the entry date, then one must find out exactly when an article was stored;
- 8) Charge: Batch number of the article. ILIAS allows for a management of batches, if necessary. An article can have many batches and they might be relevant or not;

- 9) Order: Order number or code identifying and entry order. If it is a normal, user made, inbound order, ILIAS gives it a unique number. But in this case, one can choose whichever characters one might want;

The template is then sent to ILIAS support team to be inserted, the stock gets uploaded, and then the system is ready to operate user made inbound and outbound orders.

3.3.4. Pilot Testing

After setting up the customers in the system, a pilot test was conducted, to make sure all customizations worked properly. This pilot was performed in the “conference room” with real data, meaning that the operations handled within this phase corresponded to the operations accomplished in the warehouse.

At this point, only one person, in the conference room, interacted directly with ILIAS. With exception of the picking and storage assignment lists that were made in ILIAS but handed to operators to perform the operations. These operations required a close monitoring in order to find out what should be improved or what could even be complicating a worker’s job in comparison to his previous way of doing things.

The situations that were the primary focus of testing were the inbound of goods as well as the outbound and inventory management (internal transfers of those goods from one storage place to another, storage checking, etc..). A scheme of how the process should flow within ILIAS was given during formation and can be consulted in annex B. Throughout testing, experiences were performed to find out, specifically, which actions and steps are necessary to execute within the flow of each operation. For inbound management operations, the process flow in ILIAS follows the subsequent steps:

- 1) Login in Intra Sys: The first steps in managing an inbound order are performed in Intra-Sys. As such, one must log in to the application with a username and password. An image of the Intra-Sys login screen can be found in Figure 9. The login procedure leads the user to Intra-Sys main menu.

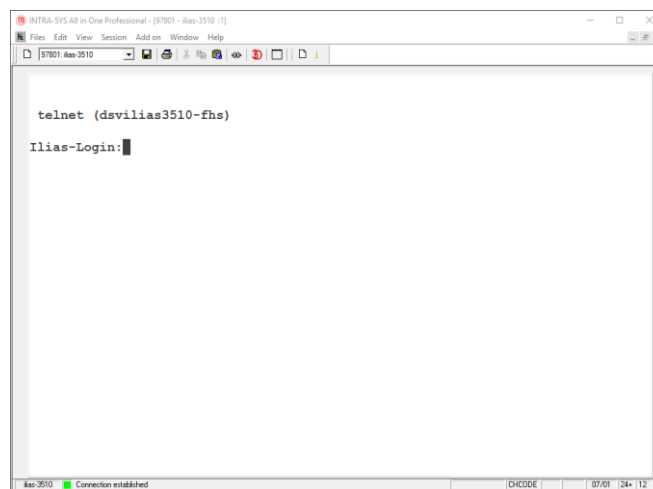


Figure 9 - Login Intra-Sys

- 2) Open the inbound menu: On the Intra-Sys main menu, shown on Figure 10, the user must select the option named “Inbound”.

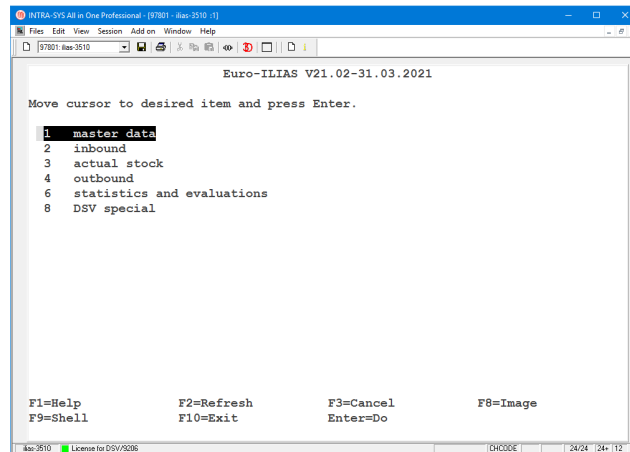


Figure 10 - Menu Intra-Sys

- 3) Select the Inbound option: On the inbound menu, various options are available, as can be confirmed in Figure 11. ILIAS works with the concept of masks, each option is a different mask, and the ID of each mask appears on the left of the name of each one. One can opt to create an inbound order (mask L2150), print the assignment list (L2260) after creating the inbound order, edit a not yet released inbound (L2320) and delete an inbound (L2370). The other options are not available. The release/confirmation of the inbound is done only in WILIAS. In this case, to generate a new inbound, one should select the “Inbound” mask;

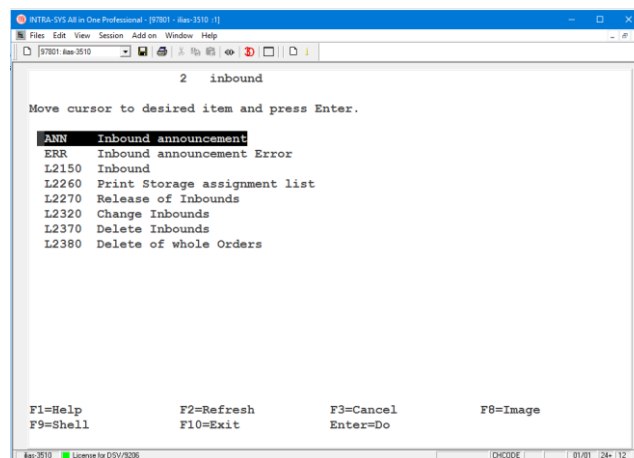


Figure 11 - Menu Inbound

- 4) Inbound Data: In the mask L2150, demonstrated on Figure 12, one can start to create an inbound order. It starts by selecting the customer to whom the inbounding goods belong. After that, the mandatory fields are the order number, a unique identifier of the order that the user can choose or ILIAS creates one automatically, and the handling type (only one type is known: ST – Standard Handling);

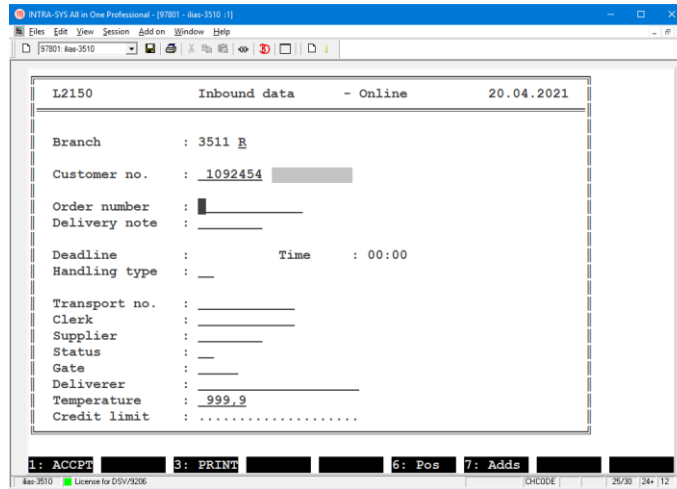


Figure 12 - Inbound Data

- 5) Specify Inbound: Then one has to select the articles that are going to be inbounded. In one of the fields, by pressing F8, the user can choose one of the articles to be inbounded from a list of articles that belong to the previously selected customer. This can be consulted in Figure 14. After choosing the article, one has to insert the batch number (if the article has a batch), and the quantities. At last, the user can choose the storage places for the articles or let ILIAS decide. These steps are shown in Figure 14 and Figure 13. After that the user confirms and does this process for every article in the order

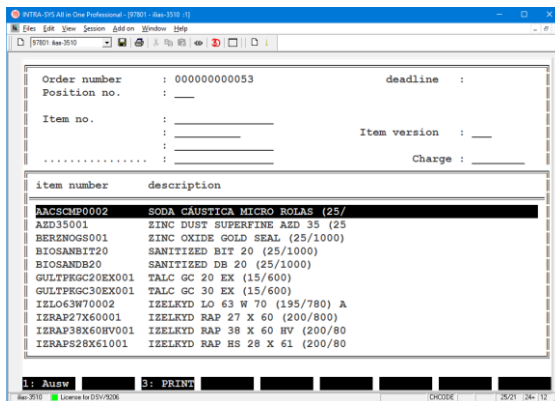


Figure 14 - Inbound: Article List

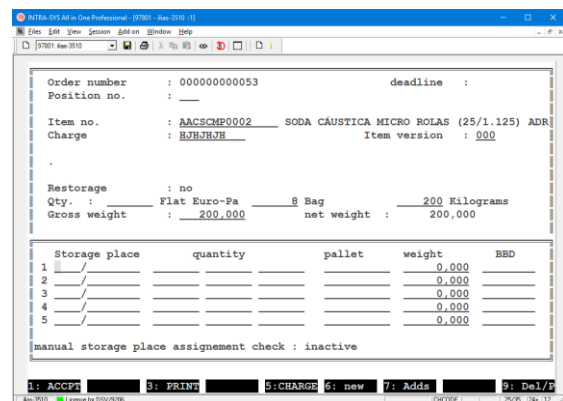


Figure 13 - Inbound: Storage Places

- 6) Print Assignment List: After creating the inbound, if there are no changes to be made, one can print a storage assignment list, on the inbound menu (Figure 11) by selecting mask L2260, in order to be used by the warehouse operators. An example of this list can be consulted in Figure 15 (not related to the previous inbound). The includes information such as the name of the customer, the article number, article description, batch number (charge), the storage place and the quantities. The list is the given to the warehouse operator to perform the put-away activity.

| Item number | description | Charge | shelf-lif limit |
|-----------------------------|--|----------|-----------------|
| 35X70001 RPAL:L0103 | TELA PVC 1,5 C SA 71004 267A 20X1,00 : 1 Flat Euro- | 11 Rolls | 22000 Square D |
| 81040003 RSMP:L1200 | COLA ALKOR 81040 10LT COR 81040 : 1 Flat Euro- | 15 Units | 150 Liters |
| 81005001 RPAL:M1300 | GEOT ALKOR 81005 2X75 : 2 Pallet Non | 8 Rolls | 120000 Square D |
| 81044001 RSMP:L1200 | LIQ. LIMPEZA 81044 1LT. : 4 Dummy Load | 4 Carton | 24 Units |
| 35177034/0015 RPAL:M0405 | TELA PVC 1,5 C VV 15 X 2,10 : 3 Pallet Non | 33 Rolls | 103950 Square D |

Figure 15 - Storage Assignment list

- 7) Login in WILIAS: The next steps have to be made in WILIAS. WILIAS is a web application which means that, in order to access it, one has to use a browser. In this case it is only compatible with Google Chrome. Once you get the corresponding URL (Universal Resource Locator), one has to login with the same credentials that were used in Intra-Sys. The WILIAS login screen is shown on Figure 16.

Figure 16 - WILIAS Login

- 8) Booking the Inbound: The inbound process is only completed with the booking of the inbound. The booking should only happen when the operator checks the inbound order for any errors in quantities or quality of the goods, and after he stores the goods in the places that were assigned in the list. If any of these steps have flaws that require for a change or deletion of the inbound order, one can manage it with masks L2320 "Change Inbound" and L2370 "Delete Inbound" on the Inbound menu but only before the booking of the inbound. Once the inbound is booked no changes can be made to the inbound order and the goods are stored on the previously defined locations. In WILIAS, as shown on Figure 17, to book the

inbound, on the menu, one has to go to Inbound -> GI Control Center, check the box for the inbound order one wants to book, and click on “Booking” (or press F4)

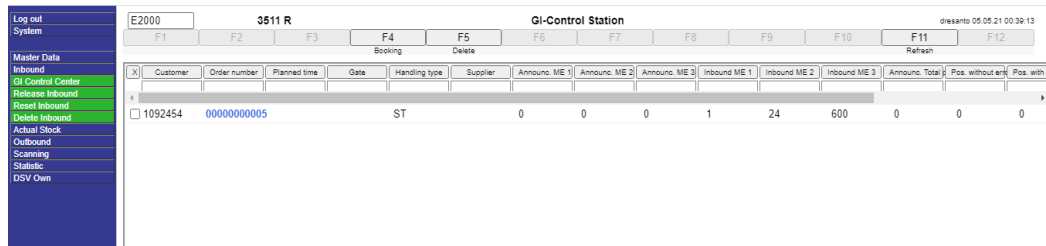


Figure 17 - Inbound Booking

Once the orders are booked or when there is stock in the warehouse, one can perform many activities related to internal inventory management, such as:

- 1) Storage place transfers: Changing goods from one location to another;
- 2) Change the goods or storage place state: Goods/Locations are marked as available, unavailable, or damaged;
- 3) Checking stocks: Using the statistic station one can consult the existent stock in the warehouse, as can be seen on appendix I;
- 4) Item movement tracking: The user can track the movements of the items on the warehouse, as it can be seen on appendix J. WILLIAS records every transfer of every item including internal transfers, and inbound and outbound movements;
- 5) Define strategies for the Outbound: A criterion is defined for each storage type regarding how to outbound goods. The default criterion is FIFO (first in first out), but other strategies can be implemented (ex: outbound by unit ascending - the software prioritizes locations and pallets with the least amount of goods);

With the articles in stock, correctly managed and with the outbound strategies set, the outbound of goods can be performed. Throughout testing, different outbound strategies were tested, and these strategies can always change depending on the customer or the types of goods. Still, regardless of the defined strategy the outbound process activities stay the same and it adheres to the following flow:

- 1) Open Outbound mask in Intra-Sys: The process is similar to the inbound and it also starts in Intra-Sys. The user has to login if it is not logged in already and, on the main menu, access the Outbound menu. In the Outbound menu, the user is presented with several options that include the edit of outbounds, change of outbounds and deletion of outbounds. The outbound menu can be consulted in Figure 18. The user should select the “Edit of Outbounds” option (mask L4050) to start creating an outbound order;

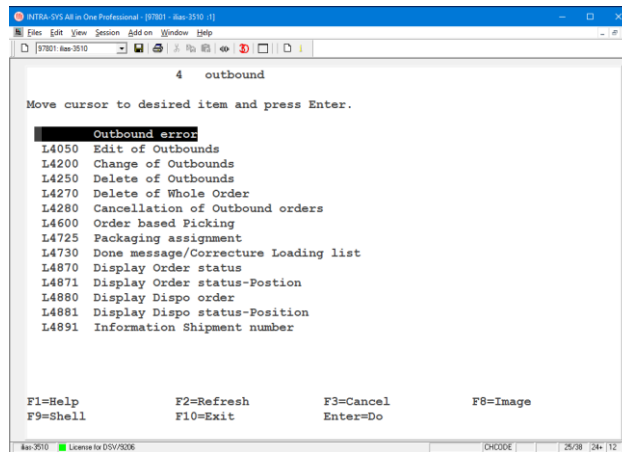


Figure 18 - Intra-Sys: Outbound Menu

- 2) Outbound Data: The user has to fill an outbound dispatch indicating the outbound information. The dispatch can be consulted in Figure 19. The mandatory fields include the customer number, the order number (can be created automatically by the system), the name of the recipient (entity that is going to receive the goods), delivery address (postal code, location, street, and country) and date of shipment (it is set to the present day by default);

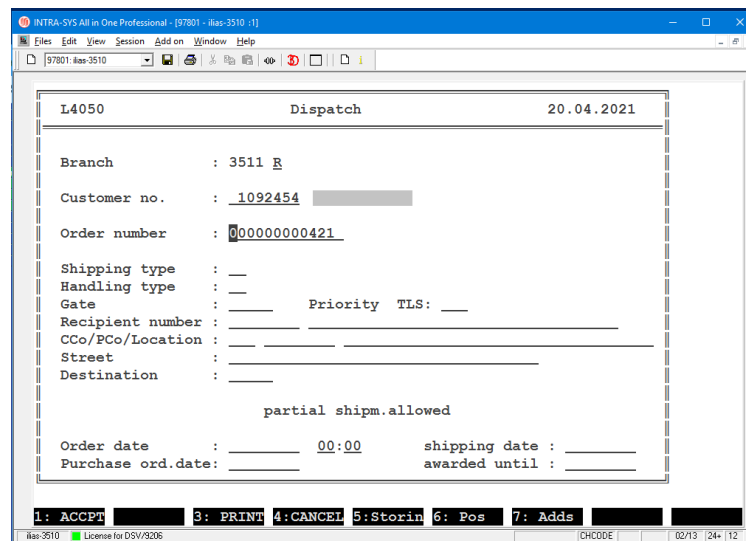


Figure 19 - Outbound Data

- 3) Specify Outbound: To specify the outbound order, one has to indicate the item number, either by pressing F8 and select form a list of articles that belong to the customer or by inserting the item number manually, then select the batch number (charge), and then indicate the quantities, there is obligation to indicate the location, the software will decide from where to retrieve the goods, unless the user decides he wants articles from a specific location in which case he can specify it. In the end, confirm with the F1 key and repeat the

process for all necessary articles. In Figure 20, we can observe the previously mentioned fields;

INTRA-SYS All in One Professional - [97801 - itas-3510 :1]

Files Edit View Session Add on Window Help

[97801: itas-3510]

Order number : 00000000425 Date : 20.04.21
 Recipient : 1092591

Position internal: _____ Document out : _____
 external:
 Item number : IZRAP38X60HV001 IZELKYD RAP 38 X 60 HV (200/800) ADR
 Charge : 2005224 Pallet number :

Picking : quantity

| Quantity | Flat Euro-P | Drums | Liters | net weight |
|--------------|-------------|-------|--------|------------|
| Quantity : 1 | | 4 | 800 | 800,000 |
| available: 4 | | 16 | 3200 | 3200,000 |
| total : 4 | | 16 | 3200 | 3200,000 |

Item version : _____ Temperature : _____,0
 Internal charge : _____ Date of expiry : _____
 Special mark : _____ Goods state code : _____
 Goods state : available Inbound order : _____
 Storage location : _____/_____ Delivery note : _____
 int. pallet no. : _____ Inbound date : _____

1: ACCEP 2: DK 3: PRINT 4: ABO 5: Serie 7: Texts 9: DEL

Mar-2010 License for DSV/S206 CHCODE CAPS 25/21 124+ 12

Figure 20 - Outbound Order

- 4) Create picking list: The outbound order is then confirmed and printed using WILIAS. The user can access the WILIAS Outbound menu, then go to “Related Picking”, to open a screen as the one shown on Figure 21. The user then selects the order and presses “Picking” or the F4 key;

WILIAS - [97801 - itas-3510 :1]

Picking - Display Single Order

| Item | Customer | Order | Description | Receiver | Unit Type | Position | Date | Pallets | Volume |
|------|----------|-------------|-------------|----------|-----------|----------|------|---------|--------|
| 1 | 1004454 | 00000000425 | 00036500 | N | A750 | 20.04.21 | | 000.00 | 6.9900 |

WILIAS 91 18 10-10-1988000 9802 COMPANIES (C) 1998-2010 BY DSV-MITTEL

Figure 21 - WILIAS Picking List Creation

- 5) Picking List: A picking list equal to one shown on Figure 22 is printed. The picking list includes basically all the data inputted whilst creating the outbound order: recipient data, articles to pick, quantities, the storage place, and the order number. The picking list has barcodes with two purposes, one to identify the order number and other to identify each item number. These barcodes can be used to input data with a scanner at the order booking stage;

DSV GST 3511 ILIDCL55 20.04.2021 11:52:14 Page: 1
 P I C K I N G L I S T Number: 303 Gate: TOR
 Branch: 3511 R Customer: 1092454 Order : 00036500

00036500

Name :

Packing note:

| Pos. | place | item nuber | Item description | Picking unit | Charge no. |
|--------------|-------|----------------------------|------------------|--------------|------------|
| ----- | | | | | |
| Palett shelf | | | | | |
| 1 | K0603 | IZRAP38X60HV001 | 1 FP | 4 DR | 800 LT |
| | | IZELKYD RAP 38 X 60 HV (20 | 2005224 | | |

00036500

Figure 22 - Picking List

- 6) Order status: The order status can be consulted on WILIAS in Outbound -> Order Overview. In this menu we can consult all orders that were created. Each order is identified according to its status. If it has a green circle, it means the order is ready for picking, like the one represented on Figure 23. If it is yellow, it was cancelled and if it is purple, it means the order is closed and the goods were shipped. The user can reset the picking of an order and make changes to it only if that order is marked as green, once the order is closed no changes can be made;

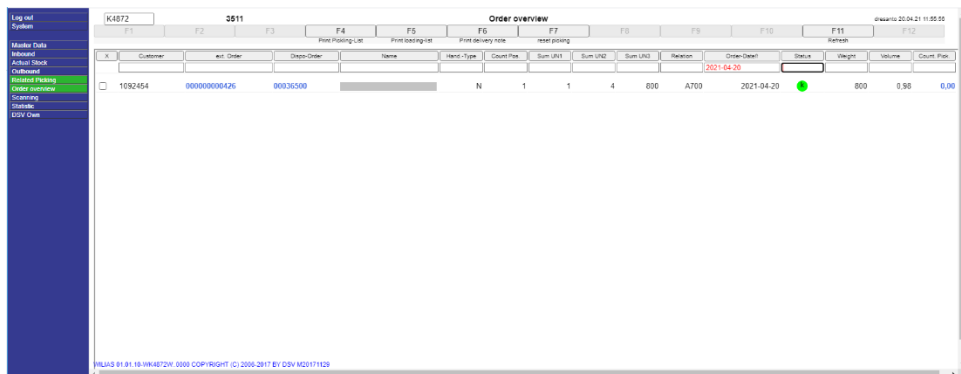


Figure 23 - Picking Screen

- 7) Order Booking: An order is only confirmed during or after the picking activity. This confirmation can be done in two different ways. One of them is using the Intra-Sys app on a computer (an emulator) where the user books the whole order once the goods leave the warehouse, the other is using the Intra-Sys app on a barcode scanner to read the order number and the item number. In this testing phase the first method was used most of the time. The barcode scanner was thought to take a more active use in the deployment phase. At this point, the user must login the Intra-Sys with the credentials of the scanner itself and essentially input the data present on the picking list. It starts with the customer number, then the order number, and for each order, the user has to insert the item number of each article, as seen on Figure 24. In the end, it has to confirm with the dimensions and weight of the whole order and the order is considered booked;

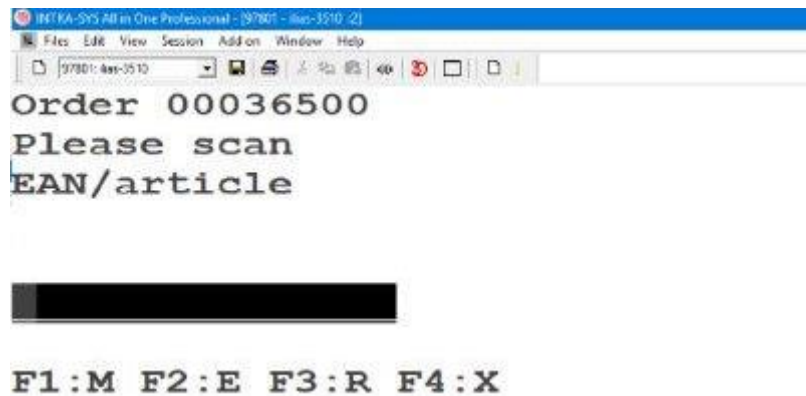


Figure 24 - Scanning Screen

The testing phase was performed with real data although being from a conference room. What this means is that there was a real communication between the warehouse operators and the implementation team, with the team utilizing the solution to create picking lists and assignment lists that the warehouse operators would use to perform their activities. Whilst the operations were carried out, data was being gathered about the process as well as the opinion of the workers that was also taken under consideration for further tests and to assess the overall usefulness of the system.

In the end, results were collected and analyzed to decide if the implementation process would move on to the deployment phase. The methods utilized consisted in the development of a functionality checklist to identify the main functionalities of the WMS, similar to the work of Assis and Sagawa (2018) and Costa and Júnior, (2008), the construction of a new process scheme for the operations of inbound and outbound, the collection of data through direct observation, time measurements and, calculation of indicators in order to quantify the improvements generated in the warehouse by the implementation.

3.4. Deployment

The deployment phase is the last phase of the implementation. It includes system training for everyone in the organization from associates and managers in the warehouse to executives in the boardroom. The people that are going to be involved with the solution receive a training focused above all, on how to perform daily activities. It is also in this phase that the organization will “Go-Live” with the system. The WMS team has to be there to make sure the launch occurs as expected and to resolve any issues that may arise.

This phase, as explained previously, is conditional. The solution would only be deployed if, after an analysis of the results gathered throughout testing, the organization reached the conclusion that the solution is capable of fulfilling the needs that the company has.

In this case, the deployment did not happen. The results gathered throughout testing as well as the reasons why the solution was not deployed are explained on the coming chapters.

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4. RESULTS AND DISCUSSION

In this chapter the results collected from the implementation of the warehouse management solution are shown and discussed.

In the first section, the results are presented. Four main points are taken into consideration, the collection and evaluation of the available functionalities in the solution, the construction of a new general process flow for inbound and outbound operations, a calculation of the reduction in the picking time and the calculation of key performance indicators such as storage utilization, dock to stock time, order accuracy, orders per hour, movements per hour and inventory accuracy.

In the second section, a discussion of the results presented in the first section can be consulted. The discussion attempts to interpret the results within its relevance to the research question with support from the consulted literature.

4.1. Presentation of Results

In this section the results obtained from the implementation of the warehouse management system in the testing phase are presented.

4.1.1. Functionality Checklist

The assessment of a WMS viability starts with an analysis of its functionalities. As mentioned in one of the previous chapters, the implementation must consider not only the needs of the warehouse and the firm but also the functionalities it wants from the WMS in order to fulfil those needs.

In line with what was said, a functionality check list was made to collect the information about the solution's capabilities. The functionalities to check were based not only on the set of functionalities proposed by Assis and Sagawa (2018), but also others deemed relevant for this particular work, having in consideration DSV's warehouse needs and future goals. The investigation, through the continuous use and exploration of the solution lead to the collection of the results presented in table 7.

Table 7 - ILIAS Functionality Checklist

| ILIAS Functionality Checklist | | | | |
|---|-------------------------------------|-------------------------------------|--------------------------|--|
| 1. Structure and Adaptability | Yes | No | N/A | Comments |
| 1.1. Available support team | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Key feature for DSV |
| 1.2. Allows interconnected operation with "native" or "non-native" ERP's | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Important feature for DSV to make WMS communicate with their ERP's |
| 1.3. Application for mobile devices | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance for DSV |
| 1.4. Creation of customized alerts | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV to allow a quick response to orders |
| 1.5. Customization of general menus (can be customized?) | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance for DSV but it would be good to have that flexibility |
| 1.6. Definition of several types of users | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV to manage use permissions |
| 1.7. Interconnection with hardware considered essential | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential for DSV to connect barcode scanners, printer, etc. to the WMS |
| 1.8. Process adaptation to different scenarios | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Key feature for DSV since different customers generates different approaches |
| 2. Warehouse Configuration | Yes | No | N/A | Comments |
| 2.1. Warehouse configuration. | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |
| 2.2. Creation of more than one warehouse | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Key feature since DSV has more than one warehouse |
| 2.3. Posterior warehouse customization | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Key feature since the warehouse changes its configuration often |
| 2.4. Visual Representation of the warehouse | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Not essential but it would be a good way of understanding the warehouse occupation |
| 3. Pre-Reception | Yes | No | N/A | Comments |
| 3.1. Direct customer order into the WMS | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV since it would decrease the number of steps needed to create an order |
| 3.2. Manages scheduling and order entry | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV for optimizing processes |
| 3.3. Direct notification to the supplier once the order arrives | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV since it would be a great extra for the service provided |
| 4. Reception, Conference and Quality Control | Yes | No | N/A | Comments |
| 4.1. Receipt of goods in warehouse | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |
| 4.2. Report to the supplier of any error in his order in relation to what arrived | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV since it would make for a faster information exchange |
| 4.3. Edit inbound orders if necessary | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |

| | | | | |
|--|-------------------------------------|-------------------------------------|--------------------------|---|
| 4.4. Validates/Confirms each item in the order with a scanner | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV since it would be a faster way to confirm arriving items |
| 4.5. Handle Irregularities | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV |
| 4.6. Generates Labels | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Could be relevant depending on the type of process needed |
| 5. Put-away and Storage | Yes | No | N/A | Comments |
| 5.1. Creates inbound orders | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |
| 5.2. Automatically designates storage locations; | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV since it uses the software to optimize the put away operation |
| 5.3. Distinction between picking and storage areas/locations | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance since all storage areas in DSV can be used as picking areas |
| 5.4. Select storage criterion | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV since a different criterion is used for each customer |
| 5.5. Recognizes the physical storage limitation of each location | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant functionality since it enhances the storage optimization process |
| 5.6. Defines usage characteristics for each storage location | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant functionality since it enhances the storage optimization process |
| 6. Inventory Management | Yes | No | N/A | Comments |
| 6.1. Real time inventory | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |
| 6.2. Storage place occupation | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |
| 6.3. Tracking of Goods (by order, customer, and storage place) | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV specially for the case of tracking mistakes |
| 6.4. Allows for internal stock movement | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV |
| 7. Picking and Shipping | Yes | No | N/A | Comments |
| 7.1. Direct receipt of customer (customer's clients) orders | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV since it would decrease the number of steps needed to create an order |
| 7.2. Generates outbound orders | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV |
| 7.3. Generates picking list | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV since it improves the picking operation |
| 7.3. Create picking waves | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV to generate a faster picking operation |
| 7.4. Manage additional services | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature since DSV provides additional services. Ex: boxing, unboxing, etc.. |
| 7.5. Confirmation of orders receipt by the customer | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV since it would be a great extra for the service provided |
| 7.6. Select picking criterion | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Ex: FIFO, LIFO. Essential feature for DSV since a different criterion can be used for each customer |

| | | | | |
|--|-------------------------------------|-------------------------------------|--------------------------|---|
| 7.7. Generates shipping documents | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV to take that task away from the warehouse managers |
| 8. Process Control | Yes | No | N/A | Comments |
| 8.1. Damaged Goods Management | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV |
| 8.2. Batch Management | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential for DSV, there are cases where the customer orders by batch |
| 8.3. Operation mistake control | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Ex: alerts if a worker picks only 3 boxes when the order is 4. Relevant for DSV |
| 8.4. Search articles by production dates or batches | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Essential for DSV, there are cases where the customer orders by batch |
| 8.5. Order History Overview | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential feature for DSV specially for the case of tracking mistakes |
| 8.6. Updates Records in real-time | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV |
| 8.7. Manages Human Resources | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance for DSV |
| 8.8. Tracks all operations | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV |
| 9. External Services | Yes | No | N/A | Comments |
| 9.1. Invoicing | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant feature for DSV to improve invoicing efficiency |
| 9.2. Communication of Stocks to third parties | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV to inform customers of their current stock in the warehouse |
| 9.3. User access to database to alter, in bulk, articles, locations, etc.. | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV to make adjustments without relying on the support team |
| 10. Returns Management | Yes | No | N/A | Comments |
| 10.1. Record Keeping of Returned articles/orders | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV |
| 10.2. Communications to customer/supplier | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV since it would make for a faster information exchange |
| 10.3. Distinction between types of returns | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV since different types of returns are charged differently |
| 11. Reporting and Analysis | Yes | No | N/A | Comments |
| 11.1. Inventory Reports | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | Essential for DSV |
| 11.2. Space Optimization Analysis | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant functionality since it enhances the storage optimization process |
| 11.3. ABC Analysis | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant functionality since it enhances the storage and picking processes |
| 11.4. Routing Optimization | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant functionality since it enhances the storage and picking processes |

| | | | | |
|--|--------------------------|-------------------------------------|--------------------------|---|
| 11.5. Forecasting | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | An extra that could increase DSV's ability to prepare for orders and increase effectiveness |
| 11.6. KPI | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | An extra that could increase DSV's ability to understand how the warehouse is performing |
| 12. Possibility of Future Integration with New Technologies | Yes | No | N/A | Comments |
| 12.1. Integration with e-commerce platform | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance but a good option for further improvement |
| 12.2. Integration with artificial intelligence | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance but a good option for further improvement |
| 12.3. Interface voice or visual picking | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance but a good option for further improvement |
| 12.4. Interface with RFID | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Small relevance but a good option for further improvement |
| 12.5. Interconnection with transportation/distribution system | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Relevant for DSV to improve information exchange |

From the results attained from the checklist it was confirmed that the WMS solution can perform the fundamental operations for managing a warehouse. It is able to provide support for the activities by managing and creating inbound and outbound orders, creates picking lists and storage assignment lists providing the operation with an automatic suggestion of locations for storage and picking, respectively, from a user defined criterion, tracks stocks and all operations performed with the system. It also allows for the integration and use of barcode scanners on the outbound orders and possesses the capability of spatial recognition of each location meaning that it does not make store suggestions that are impossible to meet (ex: suggest storing three pallets in a location where it is only physically possible to store two)

Still, it was also verified that some functionalities are not supported by the solution. Functionalities that limit the improvements that can be made onto the processes. For instance, the solution does not support any type of EDI connection such as having the orders (inbound and outbound) received on DSV's booking platform entering directly to the solution speeding up the process or informing the customer about the state of the order (arrived, right quantities and quality, picked, shipped etc..) in real time.

The solution is also not capable of scheduling orders (saying which order should be picked first), does not allow for scanning on the inbound like it happens on the outbound. The whole inbound process is only possible using a computer and a sheet of paper. Even if it were possible, the solution does not generate labels for the scanner to read, if such system was to be implemented the labels for the articles would have to be made externally, with another tool unrelated to the WMS.

The WMS does not manage additional logistical services such as unboxings, special palettization or others, nor generates shipping documents. The necessary documents must be made with a specific transport software. This is a software that relies very much on the operator assertiveness since it does not have a way to prevent operational mistakes, for example it does not give an alert when a worker picks only three boxes when the order is four allowing for that mistake to go through unchecked. It is also a very limited software in terms of operations besides the ones already specified, not being able to handle invoicing and returns. Its reporting and analysis capabilities are

very limited as well. The solution is not capable of optimizing the warehouse and its processes, does not possess the intelligence for space or routing optimization nor to make analysis on the articles to detect products with high turnover. The perspectives for future developments are also non-existent since the WMS does not contemplate the possibility of integration with new technologies (e-commerce platform, RFID, voice picking, etc..)

The support team is good but very unwilling to make changes or add non-existent features. Nonetheless, the fact that the software dictates where to pick and store goods, following a criterion that can be user defined is something that, along with the other existent functionalities, has showed to be very beneficial and allowed for changes in warehouse processes.

4.1.2. New Process Flow

The addition of the WMS solution, in managing inbound and outbound operations resulted in the process flow of the warehouse for these activities being changed by including, at some stages, the use of the software to create documentation and in some cases to replace operator's tasks or decisions.

These results were accomplished throughout the testing phase and, for the inbound and outbound operations. In this case, since these changes were performed in a testing phase, the role of the warehouse manager belonged to the implementation team, more specifically the author of this project.

By the end of the testing phase new schemes for the operations were drafted, reflecting the changes made to optimize the process flow. For the inbound process, the new scheme after the implementation of the warehouse management system is presented in Figure 25.

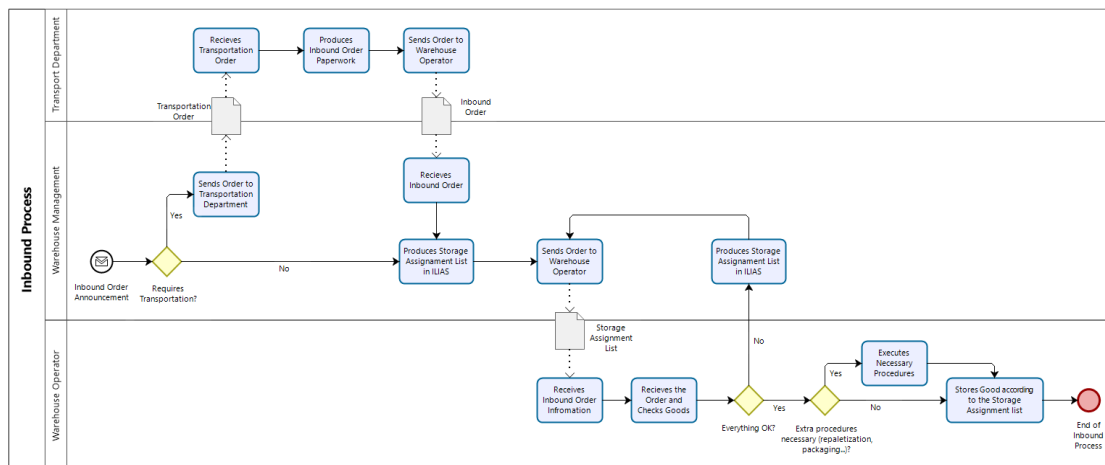


Figure 25 - New Inbound Process

The major differences can be found on the type of documentation used. In the original process, only raw untreated papers were used that provided little information for the worker to perform its task.

With the addition of ILIAS, storage assignment lists are created adding information such as where to store the goods that are arriving to the warehouse. It aids the workers by allowing them to know which locations are free for storing and removes the decision time and responsibility from the

worker's hand. This can also lead to an extra step of altering the inbound order and the storage assignment list in case the order is different from what is really being inbounded to the warehouse. In the previous scheme, if such situation presented itself all that it would be done is warning the customer, informing about the situation and ask how to proceed. Now, the warehouse also has to make changes to the system to make sure what is being inbounded is correct.

For the outbound process, changes were also made due to the involvement of the software in the process, as can be seen on Figure 26.

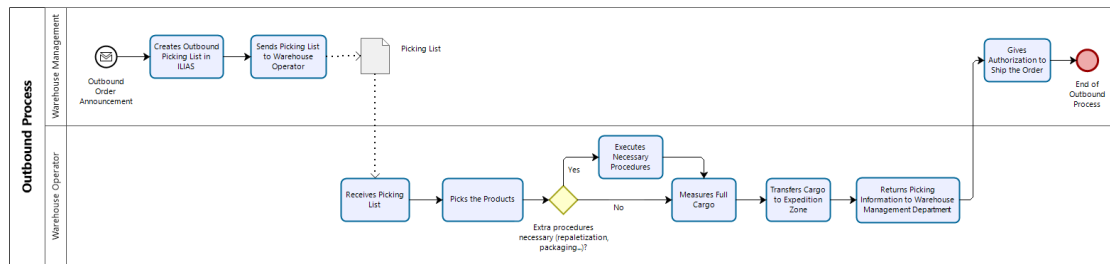


Figure 26 - New Outbound Process

For the outbound process, the introduction of a picking list passes to the system, the task of finding the storage place of each product that needs to be picked. Still, this list has to be made which adds a new task to the warehouse management team. There is also changes as to how the information necessary for picking is returned to warehouse management. In this case, through ILIAS, using the scanner, all necessary information is available on the WMS making unnecessary the use of sheets of paper to exchange information.

The changes made to both processes (inbound and outbound), have consequences that can be counted and collected. Variables such as the time goods stay in the reception zone before being stored, time it takes to perform picking activities and others are changed because of the alteration in the process flow.

4.1.3. Picking Time Reduction

As a quantitative analysis on the effects caused by the changes made in the process and the implementation of the WMS in the testing phase, a comparison between the time needed for picking before and after performing said changes was made to access how much improvement was achieved with those changes. For this analysis, data was gathered from two different months, "Month 1" and "Month 2". The data collected in the first month represents results obtained before any change or intervention was performed and before utilizing the software tool for warehouse management. The data collected in the second month results from changes in the process and the use of the WMS. The goal is to access the improvement gained with the implementation of the WMS solution.

The data gathered on the number of inbound and outbound orders along with the monthly movements recorded for each month can be consulted in table 8. In this case, the concept of movement refers to a trip that an operator makes to a different storage location. From the first set of data mentioned, an average of movements per order was calculated and it is also presented on the same table.

Table 8 - Inbound and Outbound Orders, Monthly Movements and Avg. Movements per Order

| Clients | Inbound Orders | | Outbound Orders | | Monthly Movements | | Avg. Movements per Order | |
|--------------|----------------|-----------|-----------------|------------|-------------------|------------|--------------------------|---------|
| | Month 1 | Month 2 | Month 1 | Month 2 | Month 1 | Month 2 | Month 1 | Month 2 |
| Client A | 0 | 0 | 4 | 3 | 10 | 7 | 2.50 | 2.33 |
| Client B | 2 | 1 | 9 | 9 | 53 | 46 | 4.82 | 4.60 |
| Client C | 9 | 8 | 81 | 134 | 291 | 470 | 3.23 | 3.31 |
| Client D | 2 | 2 | 24 | 21 | 40 | 36 | 1.54 | 1.57 |
| Total | 13 | 11 | 118 | 167 | 394 | 559 | | |

By analyzing table 8, one can infer that the number of orders and subsequently movements differ from client to client. In either month, clients A and B do not surpass 10 orders a month, client D stays at the 20 to 25 range while client C tops the scales with more than 100 orders in month two and close to that number in month one. The number of monthly movements follow a similar trend, however, client B has, in average, a larger amount of movements per order comparing to client D which results in a higher number of monthly movements for this client comparing with client D. One can infer that Client B's orders are few but each one has a high number of requests.

While gathering the data previously mentioned about orders and movements made by the operator, was also possible to analyze and obtain concrete data from each order. The focus was on the outbound orders that required picking activities. As such, it was decided to study the improvements achieved with the changes on the outbound process. The outbound process was divided into more specific actions (dislocation warehouse-office, dislocation office-warehouse, product searching, order picking, shipping preparation, transport of goods to the expedition zone and dislocation warehouse-office again), the actions were timed, those times were collected and an average time for each action was calculated. This was done for the four clients and for each one, times were collected before (orders from Month 1) and after changes (orders from month 2). These results are expressed in table 9, along with a calculation of the total picking time for each situation, a calculation of the time reduction after applying the process changes mentioned in the previous chapter and a calculation of what that reduction translates to in terms of percentage of improvement.

Table 9 - Percentage of Time Gained from the Implementation

| Action | Average Time in Seconds (by order) | | | | | | | |
|--|------------------------------------|-------|-----------|-------|------------|-------|------------|-------|
| | Client A | | Client B | | Client C | | Client D | |
| | Before | After | Before | After | Before | After | Before | After |
| Dislocation – Retrieval of outbound order sheet/picking list (Warehouse -> Office) | 79 | 77 | 80 | 80 | 92 | 98 | 66 | 63 |
| Dislocation – Return to the warehouse (Office -> Warehouse) | 79 | 77 | 80 | 80 | 92 | 98 | 66 | 63 |
| Product Searching | 58 | 0 | 47 | 0 | 151 | 0 | 80 | 0 |
| Order Picking | 31 | 28 | 31 | 27 | 177 | 165 | 90 | 84 |
| Shipping Preparation | 120 | 124 | 112 | 110 | 198 | 206 | 144 | 139 |
| Transport to Expedition Zone | 158 | 158 | 158 | 157 | 189 | 189 | 142 | 141 |
| Dislocation – Delivery of Cargo Information (Warehouse -> Office) | 64 | 62 | 66 | 68 | 74 | 75 | 53 | 52 |
| Total Picking Time in seconds (by order) | 589 | 526 | 574 | 522 | 973 | 831 | 641 | 542 |
| Total Picking Time in minutes (by order) | 9.82 | 8.77 | 9.60 | 8.70 | 16.00 | 13.85 | 10.68 | 9.03 |
| Reduction Time in minutes (by order) | 1.05 | | 0.87 | | 2.37 | | 1.65 | |
| Reduction Time in seconds (by order) | 63 | | 52 | | 142 | | 99 | |
| Percentage of Time Gained | 11% | | 9% | | 15% | | 15% | |

The evidence collected on table 9, show that there are not major differences in the time it takes to perform most actions between the before and after the introduction of the software. However, in one of those actions the differences were very noticeable. With the addition of the WMS to the outbound process, the action of “Product Searching”, was completely eliminated from the process since with the help of the WMS no time is wasted looking for the location where the necessary goods are stored. The software indicates on the picking list the place where the operator should perform the picking activity of each article. This change resulted in a considerable amount of time saved from this activity (time went to zero), while in most actions only subtle differences were found. This was, possibly, also due to the removal of “Product Searching”, which makes the operators less tired while performing other activities which contributes to a small increase in the pace other actions are being executed and the introduction of a barcode scanner in picking activities improving confirmation speed.

The results show that for every client, the introduction of changes in the process with the implementation of the WMS decreased the total picking time per order. The differences in the picking time were different for every customer, client A experienced a reduction of one minute, client B experienced a reduction of about 52 seconds, client C’s reduction surpassed the two minutes per order and client D reached a 99 second reduction. This corresponded to a percentage of time gained between 9% and 15% for each client.

Considering the number of outbound orders shown on table 1, a monthly statistic that can be consulted on table 10 that shows an overall reduction of about 363 minutes in the picking time for a whole month (6.05 hours).

Table 10 - Monthly Picking Time Statistics

| Measurement | Client A | Client B | Client C | Client D | Total |
|----------------------------------|----------|----------|----------|----------|---------------|
| Total Minutes Reduced (by month) | 3.15 | 7.80 | 317.13 | 34.65 | 362.73 |
| Total Hours Reduced (by month) | 0.05 | 0.13 | 5.29 | 0.58 | 6.05 |

4.1.4. Key Performance Indicators

In addition to the picking time reduction, and to evaluate the solution's performance as well as the improvements it brought to the warehouse, performance indicators were calculated. The KPI's were selected in terms of what was possible to collect throughout the project with the help of the software or without it through direct observation, counting and timekeeping. Table 11 shows, the six analyzed performance indicators: Storage Utilization (%), Dock to Stock Time, Order Accuracy, Orders per Hour, Movements per Hour, and Inventory Accuracy.

In table 11 it was also registered the values of each indicator from before and after the implementation of the warehouse management system in order to calculate the improvement brought by the applied changes to the warehouse processes.

Table 11 - Key Performance Indicators

| KPI | | Client A | Client B | Client C | Client D | Total /Average | Improvement (%) |
|-------------------------|--------|----------|----------|----------|----------|----------------|-----------------|
| Storage Utilization (%) | Before | 3% | 4% | 22% | 8% | 37% | 3% |
| | After | 3% | 4% | 20% | 7% | 34% | |
| Dock to Stock Time | Before | 0.00 | 0.00 | 5.33 | 1.20 | 6.53 | 68% |
| | After | 0.00 | 0.00 | 1.80 | 0.30 | 2.1 | |
| Order Accuracy | Before | 100% | 78.88% | 76.54% | 91.66% | 87% | 12% |
| | After | 100% | 100% | 93.35% | 100% | 98% | |
| Orders per Hour | Before | 0.03 | 0.07 | 0.56 | 0.16 | 0.82 | 26% |
| | After | 0.02 | 0.06 | 0.89 | 0.14 | 1.11 | |
| Movements per Hour | Before | 0.06 | 0.33 | 1.82 | 0.25 | 2.46 | 30% |
| | After | 0.04 | 0.29 | 2.94 | 0.23 | 3.49 | |
| Inventory Accuracy | Before | N/A | | | | N/A | N/A |
| | After | 100% | 100% | 96% | 99% | 99% | |

From the collected results one can observe, in a broad perspective, a general improvement in the performance of the warehouse.

Analyzing client by client, it can be perceived that, mostly due to its small frequency of inbound and outbound orders as well as a low number of items per order, client A was, even before the solution's implementation, in an almost optimal situation regarding the evaluated performance indicators.

Therefore, the introduction of changes in the process and the implementation of the WMS had no effect on the table results of this client. For instance, the dock to stock time of client A and also client B, stayed at zero. For client A the same happened with the order accuracy, the values were already at 100% and after the implementation it stayed at 100%. For the other clients, quantitative improvements were achieved. Client C had the largest issue with the number of days goods usually stayed in the reception zone before being stored (dock to stock time) and, with the introduction of the WMS, that number decreased from 5.33 days to 1.8 days. Overall, this indicator sustained an improvement of 68%. The overall order accuracy registered an improvement of 12%, going from an accuracy of 87% before the implementation, to 98%.

In terms of productivity, the warehouse improved in 26% and 30% in orders per hour and items per hour respectively, going from 0.82 orders per hour to 1.11 and from 2.46 item movements per hour to 3.49.

The inventory accuracy is a comparison between the stock that is kept in the system and the real stock present in the warehouse. For the inventory accuracy, since there was no stock management system in place before the implementation of the WMS solution, no data was gathered. There was nothing to be used to compare to the real warehouse stock. Therefore, one is left only with the inventory accuracy after the implementation which, upon comparison of the stock existent in the system with the real stock, resulted in an overall accuracy of 99%.

As previously stated, these results were achieved throughout the testing stage where only four clients were implemented. These clients represented 37% of the occupation in the warehouse in the first month (before the WMS implementation) and that percentage decreased to 34% in the second month (after the WMS implementation) which corresponds to about a third of the total amount of storage locations.

4.2. Discussion of Results

The logistics and supply chain based markets are highly competitive, the high diversity of products, and customer demand put a great deal of pressure on organizations to provide a high service level to their clients and obtain advantage over the competition (Pereira et al., 2019). In this regard, warehouses play a vital role, they function as nodes that direct the flow of materials within a distribution network influencing the performance of an entire supply chain (Ramaa et al., 2012). As such, the incorporation of an effective warehouse management process has become very much essential and unavoidable to achieve a sustainable competitive advantage (Shashidharan and Anwar, 2021). The results presented in this research have shown a possibility for improvement regarding the overall performance of the warehouse, after the implementation of a warehouse management system, which allows the company to boost its competitiveness. It is possible to analyze these results.

The assessment of the viability of a warehouse management system followed a method similar to the one used in the work of Assis and Sagawa (2018). In this research a functionality checklist presented on table 7 was constructed to determine the capabilities of the software in regard to the warehousing process necessities. The results confirmed that the WMS solution can perform the fundamental operations for managing a warehouse such as, handling and creating inbound and outbound orders, creating picking lists and storage assignment lists, tracking stocks and all

operations performed with the system. However, from the collected results it was found that, of the 63 checked functionalities, the implemented software only possessed 27 (about 43%).

Most functionalities that involve integration with different software, improvements in technology or customization are not supported by ILIAS. Also, some situations, that can be classified as micro functionalities were detected that can prevent a good management of the stock and the warehouse processes. For example, throughout testing it was discovered that ILIAS would not consider, for the calculation of the available space in a location, the fact that some pallets could be stacked on top of each other. This means that a single pallet is enough to fill the area (square meters) availability of the location, not allowing more pallets to be inserted, when in fact, more than one pallet be placed into the location. The calculation for this field (area availability) should result from the multiplication of the length of the pallet by the width by the value of the location's allowed quantity (QTY ME1). A solution for this was asked, to the ILIAS support team, but the response was that it was not possible to change a feature like that. Other examples include the fact that ILIAS does not allow for pallets multi article (more than one reference in the same pallet) nor multi batch which decreases the possibilities for optimization of space, customer IDs cannot be user defined (ILIAS creates one randomly) which makes any attempt of information exchange between ILIAS and other software namely Cargo Link (DSV's TMS – transport management system) more difficult. The inability to scan the batch can also be an issue, although the scanning of the article number and the customer number helped improve picking, not being able to scan batches makes the improvement feel incomplete and slower than it should, also, problems with future customer implementations would rise since some customers have specific traits to their operations such as having items (articles) with variable weight meaning that for example, boxes of the same article (same reference) can have different weights amongst themselves, which is something that ILIAS cannot deal with.

Still, for this testing phase and regarding the characteristics of the implemented customers, the available functionalities permitted the subsequent changes to the warehousing processes that led to an improvement in performance. These changes were manifested in the process flow for the inbound (Figure 25) and the outbound (Figure 26).

For the inbound process, the changes in the flow are essentially the inclusion of a storage assignment list made in the software that removes the decision time and responsibility of choosing where to store a product, from the worker and places it on the software itself. Still, due to the software characteristics it does not remove the necessity of creating, printing, and handling a sheet of paper. On the outbound, the changes were similar but this time with a picking list instead of an assignment list. This picking list removed the product searching activity that used to be executed by the workers on the outbound process, making it faster. The picking list by having barcodes identifying the customer and the articles, that can be read with a scanner also improves the process.

These results manifested in changes in the process are in accord with the ones achieved in the works of Pereira et al. (2019) and Ramaa et al. (2012) that provided improvements to the process. This work becomes different from the previously mentioned research due to the uniqueness of the software implemented.

As mentioned, changes in the process led to improvements in the outbound process. This research focused on quantifying those improvements, specifically, in the picking time reduction. For that, data was gathered concerning the number of inbound orders, outbound orders, and monthly movements for the period of two months. At the same time, the picking activity was divided into

several actions and the necessary time to execute each action was collected. The results showed that the average picking time suffered a reduction for every client after the implementation of the WMS. The percentage of time gained was between 9% and 15% for each client that corresponds to a total reduction of 363 minutes (6.05 hours) in picking time for a whole month. The most determining factors for this reduction are the elimination of the “Product Searching” activity and the increase in the “Order Picking” speed due to the introduction of the barcode scanner.

In addition to the picking time reduction, KPIs were measured, namely the storage utilization, dock to stock time, order accuracy, orders per hour, movements per hour and inventory accuracy. The selection of these KPIs for measurement of the warehouse performance is supported by the literature of Frazelle (2002), Liviu et al. (2009), Perera and Kumarage (2013), Assis and Sagawa (2018), Pereira et al. (2019) among others. The results for the measurement of the KPI’s showed an improvement of 3% for the storage utilization, 68% for the average dock to stock time, 12% for the order accuracy, 26% on the number of orders picked per hour and 30% for the movements executed per hour. The inventory accuracy had no term of comparison but with the implementation of the presented solution the KPI’s reached an accuracy of 99%.

The KPI results, despite being collected over a relatively small sample size, point to the evidence that there were improvements in the warehouse performance. Some KPIs might have even been favored by the increase in orders and movements from month one to month two for some clients.

Nonetheless, the results achieved are in accord with what was consulted on other studied WMS implementations ((Pereira et al., 2019), (Assis and Sagawa, 2018), (Ramaa et al., 2012), (Caridade et al., 2017), (Liviu et al., 2009), (Perera and Kumarage, 2013), (Istiqomah et al., 2020), (Shashidharan and Anwar, 2021), etc.) in the sense that the overall efficiency of warehouse operations was increased. In this implementation, however, the improvement numbers were, at times, not as high as the ones found on the literature. It is believed that the lack of capabilities of the software and its inability to adapt or simplify the processes even further, hindered the accomplishment of higher improvement numbers.

This work aimed to answer a question. Can the implementation of a warehouse management system in the DSV warehouse lead to improvements in its performance? After analyzing and discussing the results of this research it is considered that the answer is affirmative. The final results indicate that improvements in warehouse performance were achieved through changes in the warehousing process which can be proven by the previously mentioned analysis of the KPI’s and the picking time reduction. These results were made possible only because of the implementation of the WMS which answers this investigation’s initial question.

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5. CONCLUSION

In this chapter, the conclusions of the dissertation are presented along with a description of the limitations encountered throughout the investigation and the suggestions made for future work.

5.1. Final Considerations

This study aimed to achieve improvements to the performance of the DSV warehouse in Porto through the implementation of the warehouse management system ILIAS. This objective was achieved.

This study focused, firstly, on a detailed literature review in chapter two, that allowed for an understanding of relevant subjects for the study, namely logistics and supply chain management, information and warehouse management, warehousing operations, information exchange technologies (RFID and EDI), WMS concept, relevance and implementation and warehouse performance indicators.

Chapter three detailed how the methods were used in order to try and achieve a better warehouse performance. The method utilized was the implementation of the warehouse management system ILIAS. Therefore, this chapter, explained in a detailed manner how the system was implemented. The implementation was divided into four phases: business requirements, configuration, testing and deployment. The first phase is the “Business Requirements” phase where it was researched the initial state of affairs, the methods used by DSV to manage the warehouse before any implementation, as well as a presentation of the warehouse itself, its dynamics, clients, layout, and improvement opportunities.

The next phase was the “Configuration” phase where the various software applications and connections that were configured on the solution were presented, namely the application Intra-Sys which was meant to run as a terminal and desktop frontend application along with WILIAS. WILIAS is a web application that works in a frontend capacity only.

The third phase is the “Testing” phase. This study described how to establish information about the warehouse, articles, and the customers, in the WMS, as well as an extensive explanation of the basic operations (inbound and outbound) that were tested. In the end of this phase, data was collected in order to assess the improvements resulting from the implementation and to decide if it should continue to the deployment stage.

The mentioned results were presented in chapter four along with a discussion about them. The results were composed of a functionality checklist to assess the viability of the WMS, a new scheme for the process flow within the warehouse for inbound and outbound operations and a comparison between the values of the warehouse performance indicators from before the implementation and after the implementation.

The analysis of the functionality checklist led to the conclusion that the WMS solution can perform the fundamental operations for managing a warehouse. It can provide support for the activities by managing and creating inbound and outbound orders, creates picking lists and storage assignment lists providing the operation with an automatic suggestion of locations for storage and picking from a user defined criterion and tracks stocks as well as all operations performed with the system. It

also allows for the integration and use of barcode scanners on the outbound orders and possesses the capability of spatial recognition of each location meaning that it does not make store suggestions that are impossible to meet.

Still, from the collected results it was found that, of the 63 checked functionalities, the implemented software only possessed 27 (about 43%).

It was verified that some functionalities are not supported by the solution. Functionalities that limit the improvements that can be made onto the processes, for instance, the solution does not support any type of EDI connection. The WMS does not manage additional logistical services such as unboxings, special palettization or others, nor generates shipping documents. It was found to be a software that relies very much on the operator assertiveness since it does not have a way to prevent operational mistakes. It is very limited, not being able to handle invoicing and returns and has a very small capacity for making reports and analysis. The perspectives for future developments are also non-existent since the WMS does not contemplate the possibility of integration with new technologies (e-commerce platform, RFID, voice picking, etc..).

Nonetheless, the fact that the software dictates where to pick and store goods, following a criterion that can be user defined is something that, along with the other existent functionalities, has showed to be very beneficial and allowed for changes in warehouse processes.

The addition of the WMS solution, in managing inbound and outbound operations resulted in the process flow of the warehouse for these activities being changed by including, at some stages, the use of the software to create documentation and in some cases to replace operator's tasks or decisions.

For the inbound process, with the addition of ILIAS, storage assignment lists are created adding information such as where to store the goods that are arriving to the warehouse. It aids the workers by allowing them to know which locations are free for storing and removes the decision time and responsibility from the worker's hand. For the outbound process, the introduction of a picking list passes to the system the task of finding the storage place of each product that needs to be picked. There is also changes as to how the information necessary for picking is returned to warehouse management. In this case, through ILIAS, using the scanner, information is made available on the WMS.

After the process changes, the improvements achieved were measured. Starting with the reduction in the picking time, the results showed that the average picking time suffered a reduction for every client after the implementation of the WMS. The percentage of time gained was between 9% and 15% for each client that corresponds to a total reduction of 363 minutes (6.05 hours) in picking time for a whole month. The most determining factors for this reduction are the elimination of the "Product Searching" activity and the increase in the "Order Picking" speed due to the introduction of the barcode scanner.

In addition to the picking time reduction, KPIs were measured, namely the storage utilization, dock to stock time, order accuracy, orders per hour, movements per hour and inventory accuracy. The results for the measurement of the KPI's showed an improvement of 3% for the storage utilization, 68% for the average dock to stock time, 12% for the order accuracy, 26% on the number of orders picked per hour and 30% for the movements executed per hour. The inventory accuracy had no

term of comparison but with the implementation of the presented solution the KPI's reached an accuracy of 99%.

The appreciation of the gathered results led to the conclusion that the introduction of ILIAS as a warehouse management system generated improvements to the warehousing process for the DSV warehouse. This ends up answering this study's investigation question.

However, the results also showed that the implemented software (ILIAS) is a very limited tool. Specifically, for DSV, ILIAS does not possess the ability to adapt to most client operations and does not allow for further integration with other software that support the remaining DSV activities. In this sense, through the conclusions that were reached about the software and, considering the investment that would have to be made not only financially but also in terms of time, DSV decided to not pursue the implementation further into the deployment stage. It was concluded that the software would not be capable of providing the benefits that were expected.

Still, in an overall analysis, the goals initially set were achieved, this research added relevant literature on a pertinent topic, contributing to the scientific community. It was also a great contribution to DSV since, despite the discovered limitations of the software, this work showed the improvements that can be achieved with the implementation of a WMS which led DSV to maintain in its plans the idea of implementing a WMS in its warehouse but with another software. As an ultimate assessment one can conclude that the present investigation was successful.

5.2. Limitations and Future Work

The biggest limitation of this project was the software itself. Throughout this work it was found that the software was limited and did not possess the needed functionalities to complete a full implementation in the warehouse. Not only that but the simplicity of the WMS led to an inability to study other relevant aspects for warehouse improvement such as route planning, picking waves, RFID inclusion and others.

Another limitation was the difficulty in obtaining accurate data regarding the weight and dimensions of the products of each client. All data was collected directly by the author's weighing and measuring of the products. This process took a long time to complete and made the implementation a lot more time-consuming than anticipated. Also, if other clients had to be implemented, this process would have to be done for each of them.

The future work that can be considered relevant to mention is, naturally, the implementation of a new WMS. DSV still wants to implement a solution to manage its warehouse and even though it was concluded that ILIAS was too limited, this research showed that even with an inadequate software, significant improvements can be achieved. Therefore, even more significant improvements can be obtained with a software that has more functionalities that can develop operation's efficiency and is able to adjust conveniently to the operations performed in the warehouse.

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APPENDIX A – WAREHOUSE TEMPLATE

| Branch | Storage type | Storage place | description | length | width | height | kind of utilization | storage place utilization | allowed QTY ME1 | max weight | distance inbound | distance outbound | re-filling | different article allowed | general use |
|--------|--------------|---------------|---------------|--------|-------|--------|---------------------|---------------------------|-----------------|------------|------------------|-------------------|------------|---------------------------|-------------|
| 3511 | RBLK | 9060A | General Floor | 10 | 10 | 5 | S | 100 | 9999 | 99999 | 99 | 99 | J | J | J |
| 3511 | RSMP | A0100 | Floor | 1.2 | 2.7 | 1.2 | S | 0 | 999 | 10000 | 4 | 4 | J | J | J |
| 3511 | RPAL | A0101 | First Level | 1.2 | 2.7 | 0.77 | S | 0 | 3 | 3000 | 4 | 4 | J | J | J |
| 3511 | RPAL | A0102 | Second Level | 1.2 | 2.7 | 2.25 | S | 0 | 3 | 3000 | 14 | 14 | J | J | J |
| 3511 | RPAL | A0103 | Third Level | 1.2 | 2.7 | 2 | S | 0 | 3 | 2000 | 19 | 19 | J | J | J |
| 3511 | RSMP | A0200 | Floor | 1.2 | 2.7 | 1.2 | S | 0 | 999 | 10000 | 4 | 4 | J | J | J |
| 3511 | RPAL | A0201 | First Level | 1.2 | 2.7 | 1.36 | S | 0 | 3 | 3000 | 4 | 4 | J | J | J |
| 3511 | RPAL | A0202 | Second Level | 1.2 | 2.7 | 2.25 | S | 0 | 3 | 3000 | 14 | 14 | J | J | J |
| 3511 | RPAL | A0203 | Third Level | 1.2 | 2.7 | 2 | S | 0 | 3 | 2000 | 19 | 19 | J | J | J |
| 3511 | RSMP | A0300 | Floor | 1.2 | 2.7 | 1.2 | S | 0 | 999 | 10000 | 3 | 3 | J | J | J |
| 3511 | RPAL | A0301 | First Level | 1.2 | 2.7 | 1.36 | S | 0 | 3 | 3000 | 3 | 3 | J | J | J |
| 3511 | RPAL | A0302 | Second Level | 1.2 | 2.7 | 2.25 | S | 0 | 3 | 3000 | 13 | 13 | J | J | J |
| 3511 | RPAL | A0303 | Third Level | 1.2 | 2.7 | 2 | S | 0 | 3 | 2000 | 18 | 18 | J | J | J |
| 3511 | RSMP | A0400 | Floor | 1.2 | 2.7 | 1.2 | S | 0 | 999 | 10000 | 3 | 3 | J | J | J |
| 3511 | RPAL | A0401 | First Level | 1.2 | 2.7 | 1.36 | S | 0 | 3 | 3000 | 3 | 3 | J | J | J |
| 3511 | RPAL | A0402 | Second Level | 1.2 | 2.7 | 2.25 | S | 0 | 3 | 3000 | 13 | 13 | J | J | J |
| 3511 | RPAL | A0403 | Third Level | 1.2 | 2.7 | 2 | S | 0 | 3 | 2000 | 18 | 18 | J | J | J |
| 3511 | RSMP | A0500 | Floor | 1.2 | 2.7 | 1.2 | S | 0 | 999 | 10000 | 3 | 3 | J | J | J |
| 3511 | RPAL | A0501 | First Level | 1.2 | 2.7 | 1.66 | S | 0 | 3 | 3000 | 3 | 3 | J | J | J |
| 3511 | RPAL | A0502 | Second Level | 1.2 | 2.7 | 1.95 | S | 0 | 3 | 3000 | 13 | 13 | J | J | J |
| 3511 | RPAL | A0503 | Third Level | 1.2 | 2.7 | 2 | S | 0 | 3 | 2000 | 18 | 18 | J | J | J |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

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APPENDIX B – STORAGE PLACE ILIAS

Log out

System

Master Data

System

Branch

Storage Place

Storage Type

SP-Blocked

Outbound Strategy

Customer

Item

Accounting

Scanning

Inbound

Actual Stock

Outbound

Scanning

Statistic

DSV Own

L1400 3511
Display type management

F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12

Storage type * Palett shelf

Storage place * Second Level

Basic data

Connections

Length m Width m Height m

Storage place utilization

The Storage place is full

Special definition

Distance priority Fill-in number

Outbound priority Standard

Restorage allowed Different article allowed

| | whole | occupied | reserved |
|--------------|----------|----------|----------|
| Amount | 3.00 | 0.00 | 0.00 |
| Kilogram | 3000.00 | 0.00 | 0.00 |
| Cubic meter | 6.318000 | 0.000000 | 0.000000 |
| Square meter | 3.2400 | 0.0000 | 0.0000 |

Spezial bis

© ILIAS 01.01.10-WL1400W 10.06.01.0002 COPYRIGHT (C) 2006-2017 BY DSV M2917525

Geändert von ILIUEB09 am 15.02.21 um 08:15:55

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APPENDIX C – SET CUSTOMER TEMPLATE

| <u>Set customer in ILIAS</u> | | |
|---|----------|--|
| If you want to set a new customer in Ilias, please send an E-Mail to BCM with following informations: | | |
| <p>Please set the following customer in Ilias:</p> | | |
| Customer | xxxxxx | |
| Street | xxxxxx | |
| House number | | |
| Zip Code | xxxx-xxx | |
| Place | xxxxxx | |
| Branch | 3511 | |
| <p>Thanks in advance, best regards</p> | | |
| | | New Customer fits Road Plus standard: |
| | | <input type="radio"/> YES <input type="radio"/> O |
| BCM approved by: | | |
| <hr/> | | |
| | | <input type="radio"/> YES <input type="radio"/> NO |
| IT approved by: | | |
| <hr/> | | |

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APPENDIX D – MASTERDATA ARTICLES I

| Branch | customer number | article number | description | Category of products | goods properties | Qtu1 | Qtu1 length | Qtu1 width | Qtu1 height | Qtu1 gross weight | Qtu1 net weight | ... |
|--------|-----------------|-----------------|-------------|----------------------|------------------|------|-------------|------------|-------------|-------------------|-----------------|-----|
| 3511 | 1092454 | AACSCMP0002 | x | CHE | COR | FP | 00120 | 00080 | 00105 | 01150000 | 01125000 | ... |
| 3511 | 1092454 | AZD35001 | x | CHE | CHE | FP | 00120 | 00080 | 00089 | 01025000 | 01000000 | ... |
| 3511 | 1092454 | BERZNOGS001 | x | CHE | CHE | FP | 00120 | 00080 | 00110 | 01025000 | 01000000 | ... |
| 3511 | 1092454 | BIOSANBIT20 | x | CHE | COR | FP | 00120 | 00080 | 00106 | 00625000 | 00600000 | ... |
| 3511 | 1092454 | BIOSANDB20 | x | CHE | COR | FP | 00120 | 00080 | 00106 | 00625000 | 00600000 | ... |
| 3511 | 1092454 | GULTPKGC20EX001 | x | GEN | GEN | FP | 00120 | 00080 | 00094 | 00625000 | 00600000 | ... |
| 3511 | 1092454 | GULTPKGC30EX001 | x | GEN | GEN | FP | 00120 | 00080 | 00094 | 00625000 | 00600000 | ... |
| 3511 | 1092454 | IZLO63W70002 | x | CHE | FLA | FP | 00120 | 00080 | 00103 | 00805000 | 00780000 | ... |
| 3511 | 1092454 | IZRAP27X60001 | x | CHE | FLA | FP | 00120 | 00080 | 00103 | 00825000 | 00800000 | ... |
| 3511 | 1092454 | IZRAP38X60HV001 | x | CHE | FLA | FP | 00120 | 00080 | 00103 | 00825000 | 00800000 | ... |
| 3511 | 1092454 | IZRAP28X61001 | x | CHE | FLA | FP | 00120 | 00080 | 00103 | 00825000 | 00800000 | ... |
| 3511 | 1092454 | IZRAP28X61002 | x | CHE | FLA | IC | 00120 | 00100 | 00116 | 01025000 | 01000000 | ... |
| 3511 | 1092454 | IZRAP45X60001 | x | CHE | FLA | FP | 00120 | 00080 | 00103 | 00825000 | 00800000 | ... |
| 3511 | 1092454 | IZRAP45X60002 | x | CHE | FLA | IC | 00120 | 00100 | 00116 | 01025000 | 01000000 | ... |
| 3511 | 1092454 | IZSO40X65001 | x | CHE | FLA | FP | 00120 | 00080 | 00103 | 00825000 | 00800000 | ... |
| 3511 | 1092454 | JAN101 | x | CHE | CHE | FP | 00120 | 00080 | 00103 | 00985000 | 00960000 | ... |
| 3511 | 1092454 | JAN130 | x | CHE | COR | FP | 00120 | 00080 | 00103 | 00905000 | 00880000 | ... |
| 3511 | 1092454 | JAN131 | x | CHE | CHE | FP | 00120 | 00080 | 00103 | 00905000 | 00880000 | ... |
| 3511 | 1092454 | JAN132 | x | CHE | CHE | IC | 00120 | 00100 | 00116 | 01025000 | 01000000 | ... |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

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APPENDIX E – MASTERDATA ARTICLES II

| ... | Qtu2 | Qtu2 quantity | Qtu2 length | Qtu2 width | Qtu2 height | Qtu2 gross weight | Qtu2 net weight | Qtu3 | Qtu3 quantity | Qtu3 length | Qtu3 width | Qtu3 height | Qtu3 gross weight | Qtu3 net weight |
|-----|------|---------------|-------------|------------|-------------|-------------------|-----------------|------|---------------|-------------|------------|-------------|-------------------|-----------------|
| ... | BG | 45 | 00060 | 00040 | 00010 | 00025000 | 00025000 | KG | 25 | | | | 00001000 | 00001000 |
| ... | BG | 2 | 00060 | 00060 | 00075 | 00500000 | 00500000 | SB | 20 | 00003 | 00003 | 00003 | 00025000 | 00025000 |
| ... | BG | 40 | 00060 | 00040 | 00012 | 00025000 | 00025000 | KG | 25 | | | | 00001000 | 00001000 |
| ... | JC | 24 | 00030 | 00024 | 00046 | 00025000 | 00025000 | LT | 25 | | | | 00001000 | 00001000 |
| ... | JC | 24 | 00030 | 00024 | 00046 | 00025000 | 00025000 | LT | 25 | | | | 00001000 | 00001000 |
| ... | BG | 40 | 00060 | 00040 | 00010 | 00015000 | 00015000 | KG | 15 | | | | 00001000 | 00001000 |
| ... | BG | 40 | 00060 | 00040 | 00010 | 00015000 | 00015000 | KG | 15 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00195000 | 00195000 | LT | 195 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00200000 | 00200000 | LT | 200 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00200000 | 00200000 | LT | 200 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00200000 | 00200000 | LT | 200 | | | | 00001000 | 00001000 |
| ... | UN | 1 | 00120 | 00100 | 00116 | 01000000 | 01000000 | LT | 1000 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00200000 | 00200000 | LT | 200 | | | | 00001000 | 00001000 |
| ... | UN | 1 | 00120 | 00100 | 00116 | 01000000 | 01000000 | LT | 1000 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00200000 | 00200000 | LT | 200 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00240000 | 00240000 | LT | 240 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00220000 | 00220000 | LT | 220 | | | | 00001000 | 00001000 |
| ... | DR | 4 | 00060 | 00060 | 00089 | 00220000 | 00220000 | LT | 220 | | | | 00001000 | 00001000 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

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APPENDIX F – CUSTOMER MENU WILIAS

The screenshot displays the WILIAS Customer Menu interface. On the left is a vertical navigation menu with options such as Log out, System, Master Data, System, Branch, Customer, Confirmation, Booking reason, BR-Controlling, Number Ranges, Packing, Dispatch Def, WCC, Shippingdata Cost, implement. Shipping type, Special Order, Item, Accounting, Scanning, Inbound, Actual Stock, Outbound, Scanning, Statistic, and DSV Own.

The main content area is titled "Display data" and includes a header with function keys F1 through F12. Below this, the "Customer" field is populated with "1092452" and "Renolt Portugal".

Navigation tabs include "Basic data", "Billing Data", "Storage criteria", "Serial Number", "Batchinput", and "Setarticle". The "Basic data" tab is active, showing the following fields:

- Cco./Pco./Loc: P 2626 Póvoa de Santa Iria
- Dispatch Pco/Location: 4485 Porto
- ILN-Number: 99999999
- external SSCC allocation: No
- Report: Single Delivery per File

The "Criteria - Stock book" section includes:

- Report rhythm: None
- last Report: (empty)
- Output medium: Printer
- Print preparation: Article ingoing and outgoing unseperats

At the bottom right, a timestamp reads "Geändert von s0310 am 25.02.21 um 13:17:33". At the bottom left, the copyright notice states "WILIAS 01 01 10-WL1150W 20.05.01.0000 COPYRIGHT (C) 2006-2017 BY DSV M26170327".

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APPENDIX G – WILIAS ITEM DATA

Log out

System

Master Data

System

Branch

Customer

Item

Item data

EAN's

Duplicate

Accounting

Scanning

Inbound

Actual Stock

Outbound

Scanning

Statistic

DSV Own

L1300
3511
Display

F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12

Send
New
Change
Cancel
QTY/Label
Item-version
Select
List
Delete
Duplicate
Refresh
Printed

Partner number *

Item number *

Item version

Cat. of products * Generic Prod. Goods property * Generic Prod.

| Unit | Quantity | Length | Width | Height | Gross weight | Net weight | Stacking factor |
|-----------------------------------|-------------------------------------|----------------------------------|----------------------------------|---------------------------------|--|--|-------------------------------|
| * <input type="text" value="PL"/> | | <input type="text" value="100"/> | <input type="text" value="175"/> | <input type="text" value="70"/> | * <input type="text" value="670.830"/> | * <input type="text" value="670.830"/> | <input type="text" value=""/> |
| <input type="text" value="RL"/> | * <input type="text" value="8"/> | <input type="text" value="25"/> | <input type="text" value="175"/> | <input type="text" value="25"/> | * <input type="text" value="76.354"/> | * <input type="text" value="76.354"/> | <input type="text" value=""/> |
| <input type="text" value="SD"/> | * <input type="text" value="4125"/> | <input type="text" value="10"/> | <input type="text" value="10"/> | | * <input type="text" value="0.018"/> | * <input type="text" value="0.018"/> | <input type="text" value=""/> |

Value of goods

Overwidth pallet Pallet consists of pos

Nestbar

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APPENDIX H – INITIAL STOCK TEMPLATE

| Customer no. | article no. | storage type | storage place | ME1 qty | ME2 qty | ME3 qty | handling type | date of inbound | Charge | Order |
|--------------|-------------|--------------|---------------|---------|---------|---------|---------------|-----------------|--------|---------------|
| 1092452 | 00328001 | RPAL | M0801 | 1 | 8 | 32800 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 00328003 | RPAL | M1201 | 1 | 5 | 20600 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 00328004 | RPAL | M0601 | 1 | 7 | 28980 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 02329Z06 | RPAL | M0203 | 1 | 6 | 24600 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35052GG2 | RPAL | M0302 | 1 | 2 | 10750 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35052GG2 | RPAL | M0303 | 1 | 9 | 48375 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35052GG2 | RPAL | M0304 | 1 | 9 | 48375 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35052JGC | RPAL | M0200 | 2 | 21 | 67725 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35052JGC | RPAL | M0201 | 1 | 11 | 35475 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35066201 | RPAL | L0104 | 1 | 8 | 33000 | ST | 31.12.2020 | W15132 | INITIAL_STOCK |
| 1092452 | 35066201 | RPAL | L0104 | 1 | 8 | 33000 | ST | 31.12.2020 | W15250 | INITIAL_STOCK |
| 1092452 | 35066201 | RPAL | L0104 | 1 | 1 | 4125 | ST | 31.12.2020 | W14969 | INITIAL_STOCK |
| 1092452 | 35066206 | RPAL | L0103 | 1 | 8 | 33000 | ST | 31.12.2020 | W14889 | INITIAL_STOCK |
| 1092452 | 35066206 | RPAL | L0103 | 1 | 4 | 16500 | ST | 31.12.2020 | W14501 | INITIAL_STOCK |
| 1092452 | 35066213 | RPAL | L0401 | 1 | 1 | 4125 | ST | 31.12.2020 | W14970 | INITIAL_STOCK |
| 1092452 | 35066213 | RPAL | L0402 | 1 | 8 | 33000 | ST | 31.12.2020 | W14970 | INITIAL_STOCK |
| 1092452 | 35080100 | RPAL | M1200 | 1 | 1 | 48000 | ST | 31.12.2020 | | INITIAL_STOCK |
| 1092452 | 35086101 | RPAL | LM0104 | 1 | 16 | 30000 | ST | 31.12.2020 | | INITIAL_STOCK |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

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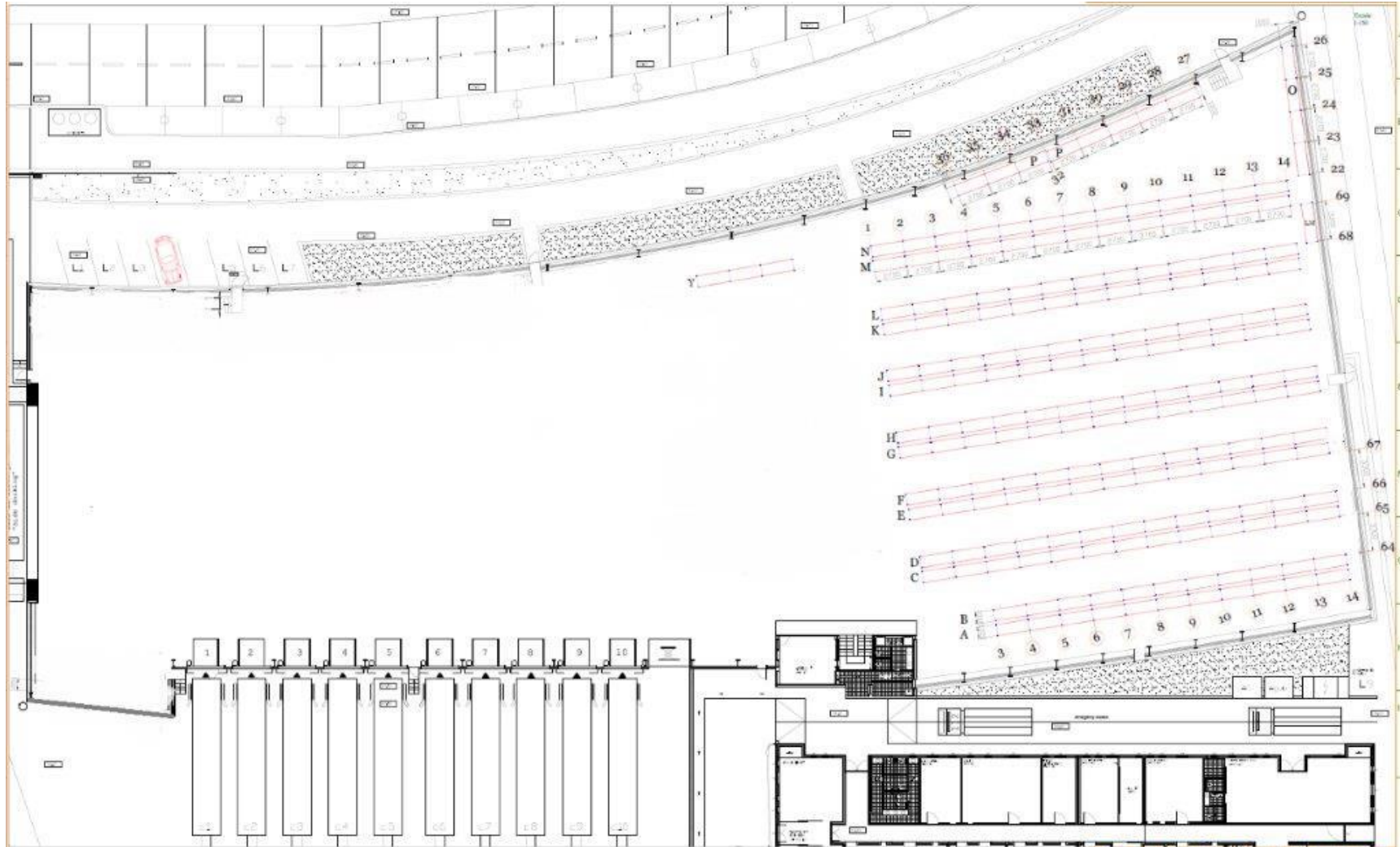
APPENDIX I – WILIAS STATISTIC STATION

| E6900 | | 3511 | | Statistiken | | | | | | | | | | | | | | | | | inseam 22.04.21 12:12:43 | | | |
|--------|--------------|-------------|---------|---------------|---------------|-------------|------------|------|-------------|--------------|--------------|---------------|----------|----------|----------|----------|----------|----------|-----------------|----------|--------------------------|----------|-----------------|----------|
| F1 | | F2 | | F3 | | F4 | | F5 | | F6 | | F7 | | F8 | | F9 | | F10 | | F11 | | F12 | | |
| | | DSV | | Mail | | | | | | | | | | | | | | Refresh | | | | | | |
| Branch | Customer no. | Article no. | Variant | Inbound order | Delivery note | Size | Charge no. | Stof | Goods state | Inbound date | Storage type | Storage place | Qty. ma1 | Type ma1 | Qty. ma2 | Type ma2 | Qty. ma3 | Type ma3 | Avail. qty. ma1 | Type ma1 | Avail. qty. ma2 | Type ma2 | Avail. qty. ma3 | Type ma3 |
| 3511 | 1092452 | 81122401 | 001 | UPL0AD | STOCK | 99999999000 | W15068 | 0 | | 20201231 | RPAL | L0901 | 1 | D1 | 1 | RL | 1650 | SD | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81122401 | 001 | UPL0AD | STOCK | 99999999000 | W15068 | 0 | | 20201231 | RPAL | L0901 | 2 | D1 | 2 | RL | 3300 | SD | 2 | D1 | 2 | | | |
| 3511 | 1092452 | 81516242 | 001 | UPL0AD | STOCK | 99999999000 | W13215 | 0 | | 20201231 | RPAL | L0901 | 1 | PL | 1 | RL | 1650 | SD | 1 | PL | 1 | | | |
| 3511 | 1092452 | 35216206 | 001 | UPL0AD | STOCK | 99999999000 | W14692 | 0 | | 20201231 | RPAL | L0903 | 1 | PL | 4 | RL | 20500 | SD | 1 | PL | 4 | | | |
| 3511 | 1092452 | 35216206 | 001 | UPL0AD | STOCK | 99999999000 | W14692 | 0 | | 20201231 | RPAL | L0903 | 1 | PL | 7 | RL | 35875 | SD | 1 | PL | 7 | | | |
| 3511 | 1092452 | 35216206 | 001 | UPL0AD | STOCK | 99999999000 | W14290 | 0 | | 20201231 | RPAL | L0903 | 1 | PL | 1 | RL | 5125 | SD | 1 | PL | 1 | | | |
| 3511 | 1092452 | 35417503 | 001 | UPL0AD | STOCK | 99999999000 | LS80996807 | 0 | | 20201231 | RPAL | L0904 | 1 | PL | 6 | RL | 20625 | SD | 1 | PL | 6 | | | |
| 3511 | 1092452 | 81122317 | 001 | UPL0AD | STOCK | 99999999000 | W14511 | 0 | | 20201231 | RPAL | L1002 | 1 | D1 | 1 | RL | 2079 | SD | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 35417504 | 001 | UPL0AD | STOCK | 99999999000 | S2696601 | 0 | | 20201231 | RPAL | L1004 | 1 | PL | 2 | RL | 8250 | SD | 1 | PL | 2 | | | |
| 3511 | 1092452 | 35417505 | 001 | UPL0AD | STOCK | 99999999000 | PS1296501 | 0 | | 20201231 | RPAL | L1004 | 1 | PL | 3 | RL | 12375 | SD | 1 | PL | 3 | | | |
| 3511 | 1092452 | 81052P02 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RPAL | L1101 | 4 | D1 | 4 | CT | 24 | UN | 4 | D1 | 4 | | | |
| 3511 | 1092452 | 81445001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RPAL | L1101 | 1 | D1 | 1 | D2 | 1 | BG | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81516244 | 001 | UPL0AD | STOCK | 99999999000 | W14642 | 0 | | 20201231 | RPAL | L1101 | 1 | PL | 6 | RL | 8250 | SD | 1 | PL | 6 | | | |
| 3511 | 1092452 | 81122607 | 001 | UPL0AD | STOCK | 99999999000 | W14850 | 0 | | 20201231 | RPAL | L1102 | 1 | D1 | 1 | RL | 2079 | SD | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81516244 | 001 | UPL0AD | STOCK | 99999999000 | W13216 | 0 | | 20201231 | RPAL | L1102 | 1 | PL | 1 | RL | 1650 | SD | 1 | PL | 1 | | | |
| 3511 | 1092452 | 81516243 | 001 | UPL0AD | STOCK | 99999999000 | W14877 | 0 | | 20201231 | RPAL | L1103 | 1 | PL | 1 | RL | 1650 | SD | 1 | PL | 1 | | | |
| 3511 | 1092452 | 35417501 | 001 | UPL0AD | STOCK | 99999999000 | LS70110324 | 0 | | 20201231 | RPAL | L1104 | 1 | PL | 4 | RL | 16500 | SD | 1 | PL | 4 | | | |
| 3511 | 1092452 | 81088002 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RPAL | L1104 | 13 | D1 | 13 | CT | 78 | UN | 13 | D1 | 13 | | | |
| 3511 | 1092452 | 81043002 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 9 | D1 | 9 | UN | 45 | LT | 9 | D1 | 9 | | | |
| 3511 | 1092452 | 81051100 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 1 | CT | 1 | CT | 100 | UN | 1 | CT | 1 | | | |
| 3511 | 1092452 | 81057003 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 1 | D1 | 1 | D2 | 1 | CT | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81057003 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 1 | D1 | 1 | D2 | 1 | CT | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81060R14 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 5 | D1 | 5 | CT | 100 | UN | 5 | D1 | 5 | | | |
| 3511 | 1092452 | 81061003 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 13 | D1 | 13 | CT | 260 | UN | 13 | D1 | 13 | | | |
| 3511 | 1092452 | 81061014 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 2 | D1 | 2 | CT | 40 | UN | 2 | D1 | 2 | | | |
| 3511 | 1092452 | 81061P16 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 1 | D1 | 1 | CT | 8 | UN | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81602R01 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 3 | D1 | 3 | CT | 1500 | UN | 3 | D1 | 3 | | | |
| 3511 | 1092452 | 81602R01 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1200 | 26 | D1 | 26 | CT | 12900 | UN | 26 | D1 | 26 | | | |
| 3511 | 1092452 | 81116504 | 001 | UPL0AD | STOCK | 99999999000 | W14874 | 0 | | 20201231 | RPAL | L1201 | 1 | PL | 8 | RL | 16632 | SD | 1 | PL | 8 | | | |
| 3511 | 1092452 | 81116506 | 001 | UPL0AD | STOCK | 99999999000 | W14848 | 0 | | 20201231 | RPAL | L1202 | 1 | PL | 1 | RL | 2079 | SD | 1 | PL | 1 | | | |
| 3511 | 1092452 | 81088001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RPAL | L1204 | 25 | D1 | 25 | CT | 150 | UN | 25 | D1 | 25 | | | |
| 3511 | 1092452 | 81116502 | 001 | UPL0AD | STOCK | 99999999000 | W14262 | 0 | | 20201231 | RPAL | L1204 | 1 | PL | 1 | RL | 2079 | SD | 1 | PL | 1 | | | |
| 3511 | 1092452 | 81116502 | 001 | UPL0AD | STOCK | 99999999000 | W14846 | 0 | | 20201231 | RPAL | L1204 | 1 | PL | 5 | RL | 10395 | SD | 1 | PL | 5 | | | |
| 3511 | 1092452 | 81025001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 1 | D1 | 1 | CT | 3 | UN | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81026001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 4 | D1 | 4 | CT | 22 | UN | 4 | D1 | 4 | | | |
| 3511 | 1092452 | 81026001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 1 | D1 | 1 | CT | 2 | UN | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81037001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 4 | D1 | 4 | CT | 19 | UN | 4 | D1 | 4 | | | |
| 3511 | 1092452 | 81037001 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 1 | D1 | 1 | CT | 1 | UN | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81038004 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 6 | D1 | 6 | CT | 34 | UN | 6 | D1 | 6 | | | |
| 3511 | 1092452 | 81038004 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 1 | D1 | 1 | CT | 2 | UN | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81038024 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 1 | D1 | 1 | CT | 5 | UN | 1 | D1 | 1 | | | |
| 3511 | 1092452 | 81038024 | 001 | UPL0AD | STOCK | 99999999000 | | 0 | | 20201231 | RSMP | L1300 | 1 | D1 | 1 | CT | 5 | UN | 1 | D1 | 1 | | | |

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ANNEX A – LAYOUT – (DSV PANALPINA A/S, 2021)



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ANNEX B – PROCESS OVEVIEW WITH ILIAS - (DSV PANALPINA A/S, 2021)

