School of Business and Management

Degree Program in Supply Management

Daria Minashkina

DEVELOPMENT OF THE FRAMEWORK FOR THE 3PL COMPANY FOR SELECTING WMS BASED ON CUSTOMERS’ OPERATIONAL CHARACTERISTICS

Master’s thesis

Supervisors: Professor Veli Matti Virolainen

Post-Doctoral Researcher Ari Happonen

Case company supervisor: Sami Ilvonen
ABSTRACT

Lappeenranta University of Technology
LUT School of Business and Management
Master's Programme in Supply Management
Daria Minashkina

Development of the framework for the 3PL company for selecting WMS based on customers’ operational characteristics

Master’s thesis
2017
131 pages, 19 figures, 14 tables and 14 appendices
Examiners: Professor Veli Matti Virolainen
Post-Doctoral Researcher Ari Happonen
Case company supervisor: Sami Ilvonen

Keywords: WMS, warehouse management system, 3PL, selection, customers’ characteristics

The current thesis has the exploratory and descriptive research purpose to develop a framework for the Finnish 3PL operator. While, this framework contains key customer’s characteristics essential for the 3PL to possess serving its customer with the most suitable WMS. The research validity is enhanced with the triangulation data analysis. The secondary data collected with a systematic literature review acknowledges a research gap in the amount of published research and indicates rarely studied phenomena in this topic direction. With underlined theoretical part evidences, the empirical part utilizes mixed research approaches to acquire the primary. These is the case company operations overview, semi-structured interview and benchmarking of WMS vendors responses to develop the framework for the 3PL company for selecting WMS for a customer and own operations most efficiently. The case company provided the WMS vendors names to interview and offered expert collaboration for the framework development. Finally, the five WMS framework topics for the 3PL to consider in a WMS choice for a customer are software types, vendor expertise, warehouse characteristics, technical criteria and sensitive deployment issues. Moreover, the resulted framework comprises key aspects for the 3PL to evaluate with questions to address for a customer. As the conclusion, the theoretical value and managerial implications are presented with future research steps in this area.
ACKNOWLEDGEMENTS

First of all, I would like to express gratitude to my first supervisor Veli Matti Virolainen for imparting his precious knowledge in guiding my thesis and shaping its content to enter the academic world.

Furthermore, I am thankful for my second thesis supervisor Ari Happonen to share his intelligence and expertise in this research project. I appreciate all the time devoted for discussion about the research directions.

My thanks are given to the case company for offering and developing such interesting and exciting topic, for devolving in its personnel field area expertise in our regular meeting and mentoring sessions. I would like to accord a thank to Sami Ilvonen for relaying knowledge and expertise as well as giving advices from the practical point of view. It was always a pleasure and unique opportunity to visit industrial sites of the case company and get involved into this business atmosphere and understand the research subject more. In addition, I thank all WMS vendors representatives interviewed in this study.

Last but not least, I thank my family who always astoundingly supports and encourages me in my live.

Lapeenranta 2017

Daria Minashkina
## TABLE OF CONTENT

### ABSTRACT

### ACKNOWLEDGEMENTS

### LIST OF FIGURES

### LIST OF TABLES

### LIST OF ABBREVIATIONS

1. Introduction ................................................................................................................. 10
2. Theoretical part ............................................................................................................. 28
3. Empirical part ................................................................................................................. 55

1.1. Background ................................................................................................................. 10
1.2. Research aim and questions ........................................................................................ 12
1.3. Research methodology and methods .......................................................................... 13
1.4. Limitations .................................................................................................................. 16
1.5. Research scope and gap .............................................................................................. 17
1.6. Thesis structure .......................................................................................................... 25
2. Theoretical part ............................................................................................................. 28
2.1. Warehouse characteristics for WMS functionality ..................................................... 28
2.2. WMS taxonomy .......................................................................................................... 34
2.3. WMS functions and features ....................................................................................... 38
2.4. WMS deployment considerations ................................................................................. 45
3. Empirical part ................................................................................................................. 55
3.1. Case company description ......................................................................................... 55
3.2. Research design ......................................................................................................... 57
3.3. Analysis of results ....................................................................................................... 60
3.3.1. WMS types ............................................................................................................ 60
3.3.2. WMS vendors’ expertise ....................................................................................... 61
3.3.3. WMS customer’s warehouse characteristics ....................................................... 68
3.3.4. WMS technical criteria ......................................................................................... 72
Appendix 13. The importance priorities classification. ......................................................... 127

Appendix 14. The framework for the 3PL company for selecting WMS for a customer and own operations most efficiently. ................................................................. 128
LIST OF FIGURES

Figure 1. Systematic literature review based on Siddaway (2014, 2) and Pejcinovic (2016). .......................................................... 18
Figure 2. Thesis structure scheme. .......................................................... 27
Figure 3. The 1st, 2nd and 3rd business cases. ........................................ 56
Figure 4. The 4th business case. ............................................................. 57
Figure 5. The 5th business case. ............................................................. 57
Figure 6. Benchmark process steps. ...................................................... 58
Figure 7. Vendors' business WMS path. .................................................... 62
Figure 8. Interrelation of WMS vendors software provision years and operating industry numbers. Industries: automotive, aviation, food, beverages, non-food consumer goods, healthcare & pharmacy, chemical, manufacturing products and electronics equipment. ... 64
Figure 9. WMS vendors customers' warehouses. ....................................... 68
Figure 10. WMS vendor experience in shipped order lines per day in customers' warehouses. ........................................................................ 69
Figure 11. Number of warehouse operators in WMS vendor customers' warehouses. .... 70
Figure 12. WMS vendors's 20 points distribution in terms of their software strength. .... 72
Figure 13. Each WMS integration times with ERP systems. ......................... 77
Figure 14. Time for WMS implementation for vendor’s customers. ................ 84
Figure 15. Comparison of WMSs deployment price ranges. .......................... 86
Figure 16. Total scores of WMSs according to types. .................................. 87
Figure 17. WMSs ranges of operating customer's warehouse size. ................. 98
Figure 18. Grouped number of order lines shipped per day on customers' warehouses with WMS. ................................................................. 99
Figure 19. Warehouse workers number using WMS. .................................... 99
LIST OF TABLES

Table 1. Systematic literature review results.................................................................24
Table 2. Warehouse characteristics for WMS set up....................................................33
Table 3. WMS taxonomy division................................................................................36
Table 4. WMS functions...............................................................................................45
Table 5. WMS selection criteria and installation issues..................................................47
Table 6. Operational warehouses types.........................................................................66
Table 7. Warehouse manual and automation characteristics of each WMS vendor........71
Table 8. WMS supported databases..............................................................................75
Table 9. Possibility to integrate WMS vendor software with other logistics execution systems................................................................................................................75
Table 10. WMS and integrated ERP systems.................................................................76
Table 11. WMS and ERP integration issues..................................................................79
Table 12. WMS user interface issues............................................................................80
Table 13. WMS user interface languages....................................................................80
Table 14. WMS installation...........................................................................................82
LIST OF ABBREVIATIONS

3PL - the third-party logistics

API - application programming interface

CRM - customer relationship management

e.g. - exempli gratia/for example

EDI - Electronic Data Interchange

ERP - Enterprise Resource Planning

et. al. - and others

etc. - et cetera

KPI - Key Performance Indicator

MRQ - Main Research Question

RSQ - Research Sub Question

SaaS - Software-as-a-Service

SCMS - Supply Chain Management System

SKU - Stock Keeping Unit

SME – Small Medium Enterprise

TMS - Transport Management System

WCS - Warehouse Control System

WES - Warehouse Execution System

XML - eXtensible Markup Language
1. INTRODUCTION

This chapter examines the actuality of the current thesis topic and proposes general research description prerequisites and procedures. Specifically, there is this thesis aim, derived research questions and relevant study limitations, which all orchestrate the current work.

1.1. Background

In today’s times of the globalization, fierce competition and innovation technologies race there is an urgent necessity for companies to hunt up additional opportunities for better resources utilization, further lowering the product costs level at the same time improving customers service to deliver substantial value. The current volatile business environment conditions dictate new ways of doing business for its market participants. Under this extraneous tremendous pressure companies are forced to change from their integrated hierarchal supply chains to strategic business partnerships with third party companies (Qing, et al. 2014, 32). Hereupon, outsourcing, which allows to do the following, has gained huge popularity among business from its first appearance.

Since the 80s and up till now, companies concentrate more in their core capabilities and outsourcing previously executed in-house logistics functions to third party logistics providers or also called logistic outsourcing operators (Marasco 2008, 128; Kotabe & Mudambi 2009, 122). Nowadays, between 30 to 60% of the final cost of the goods accrue to warehouse logistics and onward products transportation to end customers (Fieldstedt 2016). It is worth saying that one of the most frequently outsourced functions to third party logistic companies is warehouse rising in popularity nearly for 5 % of companies per year as noted in A.T. Kearney consulting report (2017, 3). This trend can be explained with more than just simple organizational and price reduction reasons, but with companies’ ability to free up resources for other investment purposes, increasing own flexibility, obtaining expertized skills and specialized technology. On top of everything else, an outsourcing company holds out an opportunity to gain admittance to third party’s network as well as to sharpen and grow own business in virtue of another company.

Along the time there is a dramatic shift in warehouse management merging inbound, inventory and outbound activities which has been developed hand-in-hand with escalating business processes awareness (Hamdan & Rogers 2008, 236). Warehouse functions have
been deviated from the passive role in the direction of the strategic importance in pursue of company’s vision (Bowersox et. al. 2013, 220-230). Historically, warehousing is a stone edge practice which through back to the famine times (Barcoding Inc. 2012). Later, people involved into trade perceived a warehouse as a standby and unavoidable costs storage premises (Faber 2002, 381). Nowadays, a warehouse comes into play not merely performing a role of the nod enhancing supply chain with distribution of the material flow (Ramaa et. al. 2012, 18; Faber 2015, 16), but also being a source of sustainable competitive advantage in innovations (Wagner & Sutter 2012, 955). Approximately 66% of warehouses are planning to increase investments in technology by 2018 (Lu 2014). Smartly organized warehouse operations become one of the priority tasks on the way of company's activities optimization.

Beyond this, a warehouse can become more productive equipped with Warehouse Management System (WMS hereinafter) which enables managing warehouse processes, working in real time and exchanging data and communicating with other company execution systems (Richards 2014, 138). WMS has made significant progress from its first implementation in 1975 from manual inventory account to mature functional application (Anonymous 2000). Now nearly 80% of the world largest revenue companies use WMS (Thompson 2010, 4).

There are numerous benefits which WMS can bring coming from higher quality information exchange resulting in more accurate stocking, picking, reporting, minimized return amounts and cycle times, unnecessary labour hours work and paper work, data traceability and visibility which results in enhanced customer satisfaction increased turnaround time. (Anonymous 2000, 42; Piasecki 2004, 60; Min 2006, 119; Richards 2014, 138)

Companies outsourcing warehouse related operations impose demand on technological capabilities and information processing technologies of 3PLs trusting more and more their competence in running automated systems such as WMS for managing customers’ warehouse operations (Wagner & Sutter 2012, 945). Referring to Capgemini Consulting report (2015, 5) more than a half of its research respondent company invested into WMS. Logistics outsourcing operators, in turn, accommodate their clients with “the right type of information and knowledge at the right time” (Faber 2015, 16, 33). Thus, 3PLs are
appreciated to have precious knowledge about these systems to satisfy customers demand quickly and to provide a glimpse of warehouse operations reality.

1.2. Research aim and questions
This thesis aims at determining customer’s characteristics which are the key elements for a WMS selection emphasizing parameters for the 3PL operator to elicit the most promising and suitable for a customer WMS system providers. Striving to fulfil this thesis aim, it is broken down into objectives that are:

1) to understand what customer’s characteristics are essential for the 3PL operator to be aware of
2) to know how to ask and weight these parameters
3) to filter WMS with the help of the created framework for the 3PL operator

The main research questions which address the current thesis topic and guide this thesis work can be formulated in the following way.

MRQ: What are the distinctive customers’ features for 3PL operator to select different WMS systems for different customer type categories?

The central research question is broken down into the three supported research sub questions related to different aspects of topic findings. The conclusion chapter is performed as answers to them

RSQ1: What are the WMS essential customer’s development prerequisite characteristics described in the academic literature related to 3PLs?

This question accentuates the most crucial aspects of WMS adoption which forms the backbone for creation empirical part findings.

RSQ2: What elements dictate that certain WMSs is suitable as a system for current and future customers of the Finnish case company 3PL operator?

This question is aimed at describing the scope of customers’ elements for given WMS systems and show the practicability of the defined characteristics in the framework applying them on current customers’ criteria which already have installed some WMSs what are studied with this framework.
RSQ3: What are the key elements for the Finnish case company 3PL operator provide its customers with efficient WMS operations?

The answer to this question implies the analysis of the empirical research part in the end of study in the subject of how the Finnish 3PL operator as the specialist in its own operational area can utilize the gained knowledge from the thesis the most efficiently and evaluate their importance based on its expertise.

1.3. Research methodology and methods

The purpose of this research has its nature as an exploratory and descriptive study because such study is meant, initially, to come with knowledge what WMS aspects guides 3PL in serving its customers and, afterwards, to portray these characteristics. According to Saunders et. al. (2009, 139) the exploratory study is used to "assess phenomena in a new light". By means of descriptive research accurate phenomena description can be accommodated (Russo 2014, 34).

For the theoretical part to discover the prominent nature of WMS the qualitative data research is applied with the help of systematic data review because of the interpretative and naturalistic approach of providing detailed descriptions (Jha 2008, 46). Thus, the qualitative approach is considered to yield more benefits for this research in order to retrieve the secondary data from various literature academic sources devoted to the studied topic such as journal articles and books and conference papers.

For the theoretical part to extract and acquire knowledge about WMSs and 3PLs topics the systematic literature review in the academic literature is chosen as the research method. The main primary reason for conducting a systematic literature review instead of a standard literature review resides in the nature of systematic literature review to study the topic of produced work by researches in depth using standardized scientific procedure compared to just providing topic summary (Okoli & Schabram 2010, 2-4). Moreover, Siddaway (2014, 1) claims that a standalone literature research can be placed "on the top of hierarchy of evidence" associated with other research methodologies because of its reasonable practicality. Whilst, according to Zurynski (2014, 1) with the help of systematic literature review it is possible to comprehensively observe the research topic scope and, consequently, identify research gaps, what fully correspond to the author's purposes concerning WMS. All abovementioned become a reason for making a standalone literature
review to demonstrate the actuality of WMS in the 3PLs context as a favourable ground to conduct the further thesis research. More deep explanation and guidance of the done systematic literature review is presented in the next subchapter to identify the research gap. Due to lack of existing literature on the researched topic, the thesis follows combination of deductive and inductive combination approach much more intrinsic to qualitative research, thorough understanding of the research context, gathering available literature sources development and developing empirical finding evidences (Saunders et. al. 2009, 41, 127; Williams 2011, 67).

For the empirical part to learn in the practice the truth about WMS and its contemporary state of art, three research methods are applied: a case study, semi structured in-depth interviews and benchmarking. The case company study of the 3PL Finnish logistic operator is used as a research methods choice help to gain richer understanding of WMS context from the perspective of the 3PL service provider since the main purpose of the proposed case study is to "investigates a contemporary phenomenon within its real-life context" (Yin, 2003, 13). Moreover, Stuart et. al. (2002, 423, 432) state that the case is in the great use in unmapped research areas such as operational management system of emerging integrated supply chains and e-commerce where there is a lack of the theory. In addition, a case study is used in exploratory research as this study is (Saunders et. al. 2009, 146). Additionally, richer empirical data about the current phenomenon can be got with the single case design (Kähkönen 2011, 34-35). The semi-structured interview is used as the second research method to acquire the primary data. Saunders et. al. (2009, 322-323) declares that a semi-structured interview is an attribute of the exploratory study. With the help of the designed list of 40 open ended questions (appendix 4) each WMS vendor representatives will be systematically interviewed "to get consistent answers to consistent questions" (Blaxter 2010, 79). One of interview questions follows the constant sum method where respondents are asked to distribute the certain number of points (Thomas 2013) among their WMS expertise in warehouse processes. Questions for interview is based on WMS aspects brought up in the thesis theoretical part. During the semi-structured interview author can manage the order of questions, e.g. skip already discussed, and stress the attention on a specific topic (Saunders et. al. 2009, 320). The aim of this interview is concerned with identifying the target customers scope characteristics of each WMS vendor.
The theoretical part of this thesis is supposed to serve the ground for creating interview questions which will be asked to the WMS vendors. The list of WMS vendors to research is given by the case company and its management team relying on their business interests. This WMS list as well as customers’ names obtained from the case company during the thesis project will remain confidential and will not be shared beyond the use of this thesis to any third parties unless otherwise agreed. Thus, the names of WMS vendors as well as their software products are changed accordingly and substituted with letters like Vendor-A (WMS-A), Vendor-B (WMS-B), Vendor-CE (WMS-C and WMS-E), Vendor-D (WMS-D), Vendor-F (WMS-F). For confidentiality reasons, the case company customers’ warehouse names are masked with warehouse 1, warehouse 2, warehouse 3, warehouse 4 and warehouse 5.

In order to utilize efficiently and effectively the empirical data, WMS vendors’ responses are benchmarked against each other. The fundamental idea behind benchmarking is in contrasting and comparing business practices to polish up business processes (Contractor 2008, M-5). From all four known types of benchmarking (competitive, internal, process, and generic), in this case the most suitable to apply is the generic benchmarking. Because according to Sefertzi (2000, 3-4) the generic benchmarking concentrates on consideration of aspects intrinsic for technology deployment and implementation. Keeping in mind the purpose of conducted interviews to get understanding of each WMS vendor’s customers scope, these WMS vendors can be perceived as supplier of the software product for the case company. What, in turn, verifies applicability of the generic benchmarking to determine and assess solid-state reliability measurements of suppliers (Bauld & McGuinnes 2006, 20). In addition, the great importance of benchmarking coming from its ability to identify best performance practices, strength and weaknesses of respondents by their true positioning and further areas for improvements (Sefertzi 2000, 4; Meek & van der Lee 2005, 7).

After getting answers to interviewed questions from WMS vendors all answers are grouped and monitored for similarities, herewith, their results are scored and weighed to find out the most promising WMS vendor for the case company 3PL operator in terms of the WMS vendors’ service range offering. With this in view monthly meetings and mentoring sessions with the case company are organized to align the direction of the research. This contributes to overall research concurrence with case company’s needs and later more
accurate recommendations composition. Meanwhile, the case company representatives are interviewed in the matter of what characteristics they are looking in their clients like preferable contract length, expected contract value and business amount of warehouse employees, systems integration and other relevant aspects to make deeper sense of the questions studied. To all the WMS aspects discussed in interview with vendors the case company has provided its own importance assessment criteria.

In order to contribute into the current research validity, the data analysis triangulation is applied. According to Jick (1979, 602-603) and Thurmond (2001, 253-254) the triangulation assumes the usage of multiple data sources to provide more comprehensive view and clear understanding of the phenomenon. In this sense, the systematic data review is used to examine the secondary data available on the researched topic, while the primary data is collected with the help of studying the 3PL company business cases, conducting semi-structured interview with WMS vendors, interviewing the case company to align the research direction with its expertise and asking its specialists to evaluate the get framework aspects.

1.4. Limitations
With this thesis research topic in mind, the author narrows down and attract attention to specific aspects of WMS within the 3PL context to acquire and deliver appropriate thesis findings. There are nine acknowledged limitations of this thesis. The first one concerns with drawing a line between warehouse and inventory management systems. To put it into nutshell, the former one is in the focus of this study, so WMS is about controlling and managing all space in warehouse, its recourse (SKUs, equipment and labour allocation) and processes, while the last one of inventory management refers to management of SKUs quantity Kappauf et. al. (2012, 8). So, inventory management system is not as complex as warehouse management system because the previous cope with only to physical management of material in warehouse. The second is that this research paper is not supposed to cover technical points of WMS such as software structure coding purchasing orders formation, programming controller logic and etc. It rather covers tactical and strategic elements of WMS itself, its selection and adoption. The third limitation to highlight is that this research is not going to observe WMS installation phases and provide guidance to each step, only issues relevant to WMS deployment is discussed. Besides, just WMS is analysed, not other SCMS such as TMS, ERP and etc. The last ones are mentioned
only in the integration manner with WMS. Further limitations are coming from research methods the author decides to apply in the thesis like own qualitative data interpretation, case study design for the special company no supposed generalization of findings to other companies because one size does not fit all and perhaps biased answers of interviewers. Herewith, this research centres around the analysis of responses got from five vendors about their six WMSs. One vendor supplies two WMSs. While the list of these WMS vendors to interview is given by Finnish case company 3PL operator agreed by its management team in the subject of business interest and further business operations. Moreover, this thesis does not concentrate on versatile versions of questions the 3PL company can address to its customers choosing WMS, but proposes the list of questions the 3PL company could ask a customer because the questions content varies from circumstances and situations to whom and how these questions are addressed.

1.5. Research scope and gap

For justifying the theory to be used in the current thesis it is decided by the author to apply a systematic literature review as one of available research methodologies to conduct a secondary data examination as it is declared previously.

Accordingly, as an informational source for this research the author makes the best use of the university informational seeking portal called LUT FINNA. There the research is conducted through both university inner library materials available and international e-materials extracted from different databases where the university has an access. Both inner library and international materials are reached through to assure the full-scale scope of researched literature. Thereafter, to make more structural reporting and sampling the PRISMA 2009 flow diagram is used in this thesis systematic literature review shown in the figure 1 which steps is described further in more details in the text.
Fundamentally, Petersen et. al. (2008, 1) in own research highlight that systematic literature review as well as studies systematic mapping starts with determining the right and most suitable research question(s) from which key words are used to search through databases. The appendix 1 shows detailed what key words combination were used and search terms results, while the main findings are described further in the text.

Taking into account the RSQ1, the purpose of conducting a systematic literature review to find evidences existing in the academia regarding a 3PL choosing a WMS for customers based on their characteristics and features. In this sense, the word “WMS” heads the list of the main key words in searching order because of this thesis focus in studying this system.

Figure 1. Systematic literature review based on Siddaway (2014, 2) and Pejcinovic (2016).
Moreover, it is crucial to expand WMS abbreviation and give a clarification of another keyword “warehouse management system” to assure that other WMS abbreviations such as wood material science, wavelength modulation spectroscopy and etc. will not be shown in searched results. However, these two words cannot be applied together in the inner library search, because this search results only in one study which cannot be due to its inaccessibility until 2019 and Finnish language. Moreover, searching for warehouse management system in inner library without parentheses gives more topic related studies because of more software synonyms like warehouse systems in some studies. Thus, this search is not limited only to “warehouse management system” to get any results there. Even though as it is stated in limitation the thesis concerns with WMS, not with inventory management system since the author decides not to include the word inventory into an excluded word because these two terms of warehouse and inventory go together in the literature. At this point, the search in the inner library is completed and, consequently, it is found out that there are 91 studies serving the topic from the LUT Academic Library collection. Because of the greater number of sources available in International scientific databases e-materials, both of these two key words can be used at the same time, what still produce quite a lot of results to narrow more the research. Another key word is the established term “third-party logistics” which comparing to its synonyms (“logistic service operator” and “3PL”) issued in more searching results in combination with previously mentioned words. Nevertheless, it is decided not to include any word related to “third party” as a searching criteria because in LUT inner library database this sort of filter eliminates to zero search results, and in international e-materials searching databases with these key words gives over 1,150 results and shifting the focus to different kind of logistics service providers and their activities from WMSs. For the search via e-materials, another key word for searching is “selection” applied instead for getting more results rather than its rated words and synonyms (“select”, “select*”, “choose”, “choice”). While, the author has tested other key words like “pick”, pick*, ”determine” and ”identify” to try this research direction but these words combination generates too much deviation in the research. The presents or absence of parenthesis in this and further key words usage does not influence on number of results get. To narrow down there is another word relates to WMS prerequisites since the research concentrates on customers’ important aspects in WMS. However, after searching with its synonyms and related words ("prerequisite*", "element*", "characteristic*") it is revealed that “characteristics” gives the most results.
Inclusion of the words related to 3PL scatter results to different spheres such as 3PL operational fields and indicators eliminating all valuable findings. This can already tell about unbridged concepts of WMS and logistics service providers and no study where a 3PL installed or choose a WMS for a customer. So, the most suitable set of keyword words for searching through e-material database is “wms”, “warehouse management system”, “selection”, “characteristics”. As it is explained above, the inclusion of the "third party" or "logistic service operator" or “3PL” curtail results significantly and leaves out all sensible information as well as the common search of these eight words of together. Finally, the Academic Library collection search gives 461 studies are from FINNA international e-materials, where the majority of the researches comes from (the full list is in the appendix 2):

- Scopus
- ABI/INFORM Global
- Engineering Research Database
- ScienceDirect Journals
- ProQuest Research Library
- Emerald
- Web of Science databases

It is decided to conduct systematic literature review through all databases available via LUT FINNA dataset to capture all versatile findings on WMS and 3PLs topics. The journals names covered the searching keywords are (the full list is in the appendix 3):

- Modern Materials Handling
- Industrial Management & Data Systems
- International Journal of Production Research
- International Journal of Production Economics
- European Journal of Operational Research
- Material Handling Management
- International Journal of Physical Distribution & Logistics Management

Siddaway (2014, 4) and Zurynski (2014, 2) advise to create a systematic review protocol with inclusion and exclusion criteria in advance. After removing duplications and limiting searching criteria to the full text available and to English language, the results from two
researched sources has dropped nearly to half. Referring to the history of WMS concept there are no limitations put into searching engines because all studies are dated not earlier than 90s. After first screening and later reading abstracts 230 sources are left out due to the research stated limitations in the subchapter before. Briefly, the exclusion criteria are to exclude those studies that are not concentrating on WMSs, but on Inventory Management Systems and other logistic executions systems, studies discussing technical WMS content and studies describing step-by-step WMS detailed installation phases. Meanwhile, also excluded studies do not open the topic of WMSs by just mentioning key words in papers abstracts, not inside a paper, all of this does not contribute to much towards understanding of keywords concepts. Then these studies are read in depth and the final amount of eligible studies shedding up light on the desirable topic of WMS and selection characteristics are 8 from home library and 43 from other databases.

Afterward, the relevant data from studies is extracted and synthesized accordant with the initial research aim (Okoli & Schabram 2010, 30). Consequently, there can be concluded that there is an evidence in literature of studied WMS and its customers (except 3PLs as a user of WMS), specifically, how 3PL can choose and what 3PL can take into account running this system.

In a couple of researches (Levans 2002; D/C Expo article 2004; Moberg & Speh 2004; Verwijmeren 2004; Richards 2014) appeared after the systematic literature review it is mentioned that logistics outsourcing operators deal with and are related in some way to warehousing logistics. However, all information about 3PL mentioned is not enough to fill one page and become a standalone subchapter. Thus, it is summed below in the text. Levans (2002, 24, 26-27) in the article to orchestrate supply chain execution processes notes the trend of leveraging warehousing and transportation outsourcing operations from 3PLs which the help of which outsourcing companies has greater access to technologies and avoid investments in infrastructure and equipment. Moberg & Speh (2004, 73) interview warehousing experts about their 3PL perception where they strongly agree that 3PLs cannot significantly succeed in warehousing logistics without deploying WMSs. Richards (2014, 256) just points that 3PLs takes warehousing under the authority of their customers. However, only in the article by Verwijmeren (2004, 168) about supply chain software, logistics service providers are skimmed as users of WMS. While in the D/C Expo article (2004, 49-50) it is mentioned that some WMS is specially created for 3PLs usage because
they contain clear data about warehouse processes hierarchy and easy access data via Web. While in other studies nothing is said not only about 3PL operators dealing with WMS, but also not about installing this system to 3PLs customers. This demonstrates the lack of researches done regarding the current thesis topic and a research gap to fill since there are no studies done with similar topic. All in all, this all information extracted from the academic sources referencing to 3PLs and WMSs is not that exhaustive to become a separate subchapter of the theory.

Other studies are classified on the common aspects served concerning WMS, while, in turn, these aspects are grouped to the four main topics highlighted in the WMS context. These four topics of warehouse characteristics, WMS taxonomy, functions and deployment considerations become subchapters of the theoretical part of this thesis. The table 1 depicts the most comprehensive grouping of the studies, precisely, each author study is analysed based on aspects brought up put into four beforementioned groups, authors are placed in the table in the alphabetical order. At this point it can be already noted that all four WMS related topics to a greater or lesser extent discussed by all authors, what can verify their actuality. Also, references to 3PL operators and WMS are summarized from the found literature source and shown as one of the last vertical columns there. In addition, two last horizontal lines of the table show the total sum of WMS aspects times in relation to the number of times those are mentioned and WMS topics actuality among authors according to sum of mentioned aspects times. For instance, the table four aspects of the topic of the warehouse characteristics for WMS mentioned 4, 12, 7 and 16 times in studies by authors while their sum showing the total topic actuality is 39. Beyond that, it is accounted how many aspects in each topic every author has covered what is shown in the four pre-last vertical columns coloured in accordant with topics. While, the last vertical column presents this author overall significance in providing insights into this thesis accounting all times aspects in each topic were mentioned. For instance, the first author in the table list named Anonymous (1998) in own works raises concerns about 4 aspects among all 5 topics not discussing other topics of 3PLs usage of WMSs and warehouse characteristics. Similarly, it can be seen that the last author Zapata (2012) reference only on 7 aspects in two topics, where this author heavily emphasizes the topic of WMS deployment issues (6) and cover one aspect in WMS taxonomy. In order to declare topics popularity in authors’ works the two horizontal rows of the last five vertical columns indicate how much summed
aspects mentioned in a topic and whether an author has touched this topic at all. About the last said as examples, it can be judged about topics mentions and their importance within the context. It is at once apparent that the two most heavily discussed topics by selected authors are WMS (30) deployment issues and WMS taxonomy (29) and in comparison with other topics mentioned in the literature. The description of WMS functions scores the second place of oft-reviewed topics (25). Meanwhile, a bit lesser authors (21) devoted their attention to warehouse characteristics outline as an element where WMS is implemented. Even at this stage it can be spot that only four out of 51 authors involve all WMS topics from the table in the high extent in their studies (their scores are coloured with dark grey in the last vertical column), other authors always do not write at least about one WMS topic (except the topic called WMS function where there is only one aspect). This fact can already tell about unexplored WMS theme and the degree to what it is studied among all presented authors. Stated differently, not so many authors consider the subject of WMS from the various angles.

Returning to these four studies, it can be pointed out that all of them look at more deployment aspects. What explains raised customers’ interest towards WMS. The first two of these studies are books (Hompel & Schmidt 2006, Manzini 2011) highlight the process of manual warehousing towards the one with more degree of automation, increasing number of technologies and methods available for storage and picking and integration with other IT systems. Whereas, Hompel & Schmidt (2006) draw more company attention as a WMS customer to the specific issues guiding and comparing specific WMS requirements and implications. So, the books start with simple warehouse operations handling and ends with design characteristics of a good WMS. Contrary, Manzini (2011) presents a WMS with a more general idea as an enhancer for supply chain effectiveness with bringing and maintaining its value for solving tasks with the mechanism of WMS functionality. Other two studies covering all WMS topics, especially, its adoption belong to Faber et. al. (2002) and Min (2006). Both explain boosted warehouse performance with a WMS. Unlike the previous two books, these articles are not about automation technologies precisely. The first authors underline more sharp difference existing between tailor-made and customized WMS associated with warehouse complexity functions. While the second author develops more recommended practical hints for WMS selection and implication. Even though all these four studies are different in focus, they make significant contribution into the thesis.
Table 1. Systematic literature review results.

<table>
<thead>
<tr>
<th>Reference to 3PL operators and WMS</th>
<th>WAREHOUSE CHARACTERISTICS FOR WMS FUNCTIONALITY</th>
<th>WAREHOUSE TAXONOMY</th>
<th>WMS FUNCTIONS AND FEATURES</th>
<th>WMS DEPLOYMENT CONSIDERATIONS</th>
<th>Number of aspects mentions (X) in topics by each author</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Moe (1996)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>39</td>
</tr>
<tr>
<td>A. Moe (1996)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>36</td>
</tr>
<tr>
<td>A. Zajac (2015)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85</td>
</tr>
<tr>
<td>A. Zapata (2012)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>A. Harter (2012)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>All WMS topics actuality as the sum of aspects time mentioned (X) in each topic</td>
<td>4 4 12 7 16 22 14 23 4 12 3 10 9 8 4 8 3 17 7 7</td>
<td>4 39 36 25</td>
<td>85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The actuality of topics is shown by the sum of all contained detailed aspects is in two last horizontal rows of the table. The first one topic in researches and the one which has become the first theoretical part subchapter is peculiar characteristics of warehouse scoring 39 mentions because it is rational in further design of WMS to take aspects of the warehouse into account. Otherwise, WMS can be either too weak to arrange warehouse logistics activities, or too technologically advanced for the certain warehouse causing incidental money and time expenses in terms of excessive information trainings and retrainings for usage. Both, in turn, will lead to WMS installation failure. The second common WMS point among studies concerns with understanding what WMS actuality is and its further division (36 mentions made). Thirdly, WMS basic and advance functions are discussed in the majority of studies (25 mentions). The last but not least, topic representing many interesting aspects and scoring the largest number of 85 mentions refers to WMS deployment and implementation issues, namely, with what companies should be familiar in WMS choice, its installation and further management. The more comprehensive and detailed discussion of the found academic literature sources according to mentioned WMS topics and aspects is presented in the corresponding subchapters of the thesis theoretical part.

1.6. Thesis structure
In the pursue of the consistency and accuracy of studied topic the current thesis is divided into four main chapters where, in turn, each one serves own purpose in bringing value to the thesis research context.

The introduction chapter is the starting point of the research. It comprises 6 subchapters which state study background and prerequisites, defined research aim and highlighted questions and research methodology applied. Also, there the research scope and constrains are discussed. Whilst, the literature to use in the theoretical part is derived from conducting the systematic literature review to reveal the current knowledge of the WMS and 3PL topics interrelation.

The theoretical chapter purpose is to be conducive to formulate questions to ask WMS vendors in the empirical thesis part. The theoretical part refers to in-depth studying of the literature ascertained with the help of the systematic literature review. Theory findings are grouped together into four subchapters to get a reader familiar with existent level of knowledge regarding WMS selection and applications. For instance, the warehouse
characteristics subchapter describes warehouse specificity, namely, how warehouses can differ depending on performed processes, SKUs stored, resources available and warehouse organization technologies. Meanwhile, the WMS taxonomy subchapter aims at providing a reader with the common WMS types and elements, actions scope and installation options mentioned in studied literature. In the end, the main issues to take into account during WMS deployment such as WMS technical attributes and WMS project management details influencing on a customer choice are examined too.

The empirical chapter utilizes all previously mentioned theory findings and apply them practically as asked interview questions to WMS vendors. Apart from that, this chapter summarizes and analyses interviewees’ responses to outline data overview for a reader. It starts with description of the thesis case company and research outcomes applicability. Afterward, research design plan is exactified with further explanation and systematic practical results application. Consequently, the subchapter called analysis of results contain WMS vendors answers to posed questions. For convenience, received responses are categorized according overarching themes which form subsections. Last but not least, a reader is presented with questions for the 3PL provider to define a WMS for a customer with further explanation.

The conclusion chapter answers to initially stated research questions and makes the total thesis summary by underling theoretical and empirical parts essentials at the same time giving recommendations for future researches. Plus, this chapter clarifies this research finding significance from practical standpoints.

To summarize above written and visually show a reader this thesis content, the figure 2 below illustrates the thesis structure scheme and research process.
After getting to know the thesis structure a reader can acquaint with the thesis outline and its main points overview and parts relation to each other. Moreover, the thesis outline can become a guide for a reader to interpret and navigate through the thesis insights.
2. THEORETICAL PART

This chapter gathers theoretical overview of previous researches revealed by the systematic literature review on topics relevant to WMS aspects. The organization of this chapter is as follows. In the beginning warehouse characteristics to consider in WMS setting are observed. Afterwards, the nature and taxonomy of WMSs is reviewed. Then WMS functions found in the selected literature studies are discussed. The last subchapter comprises in what elements a customer selecting a WMS is interested and what conditions should be met deploying a WMS. In this way, the most emphasized elements in the literature is intensively discussed to get acquainted with the basis for the empirical part content.

2.1. Warehouse characteristics for WMS functionality

Even though warehouse characteristics are not that much popular topic within the selected academic papers (only 21 authors write about it) in the systematic literature review, they are the starting point of WMS operations. This topic scores the second place on the actuality containing aspects mentioned 39 times by authors. All authors mention a warehouse as an element for further WMS operations in some way emphasising one or more warehouses aspects such as their types, operational and performance issues and automation equipment used. However, few authors (Rouwenhorst et. al. 2000, Magableh 2007, Roodbergen et. al. 2015) in their works of studying WMSs devote more attention than others to a warehouse. For instance, Rouwenhorst et. al. (2000, 516) in own article for designing a warehouse system enter extensive discussion of warehouse prerequisites as important ones for step-by-step creation of WMS design. Besides, Magableh (2007, 54) claims that a WMS is designed specifically for installation with customer's warehouse parameters. As reported by Roodbergen et. al. (2015, 3321) firstly a warehouse control policy should be taken into account prior to WMS implementation and be changed if it is needed. Other authors (Manzini 2011, Ramaa et. al. 2012, Trab et. al. 2015), consider a warehouse from supply chain management point of view where a warehouse with WMS leads to more efficient and smooth supply chain flows. In Ramaa et. al. (2012, 14) research a warehouse is defined as a middle way supply chain step to consolidate products. Interestingly, the mission of every warehouse can be compared to logistics one following the same soundness but it is about storing products "effectively in the right place, at the right time, and in the right quantity". Referring to Manzini (2011, xii) warehouses are nodes in supply chain arches of transportation networks. Trab et. al. (2015) make a study of WMS planning in which
designing and controlling of a warehouse cause reduction of supply chain costs and its increased throughput.

As it can be seen from the systematic literature review table only several authors (Min 2006, Ramaa 2012, Richards 2014, Faber et. al. 2002) state that WMSs aim at different warehouse types and, thus, can support much more particular processes there. As specified by Min (2006, 123) and Ramaa (2012, 14) all warehouses can be divided into distributional centres and production warehouses and their roles varies accounting warehouses of raw materials, finished goods, distribution and value-added service fulfilment. Faber et. al. (2002, 5) tell that a production warehouse can either store raw or semi-finished products sending them to a nearby production factory or receive finished goods and delivering to the next customer or warehouse, or manage all two previous mentioned activities. While Richards (2014, 7-11) expands more this distribution warehouses designed for collecting an order for a delivery to a customer. According to his book there are warehouses storing raw materials and finished goods, sort centres (for instance, of letters and parcels), fulfilment warehouses for e-commerce goods, cross-docking (of perishable items) and transhipment break-bulk centres and consolidation warehouses (for example, for automotive parts). He adds also reverse logistic centres which are popular now among companies to deal with all returned products, reusable packing and items sanitation before returning to supply chain.

The majority of authors discussing warehouse characteristics (Piasecki 2004, Rouwenhorst et. al. 2000, Manzini 2011, Faber et. al. 2013, Roodbergen et. al. 2015, Trab et. al. 2015) brings to notice warehouse operational issues as essential one for launching a WMS such as handling processes and committed assets. However, only Rouwenhorst et. al. (2000) unlike others provide meaningful examination of warehouse characterisation parameters. What is used later in this subchapter as the table basis for judging upon warehouse sides for WMS installation and describe them using other authors' findings. Rouwenhorst et. al. (2000, 516) in their article devoted to warehouse design highlight more comprehensively the importance of knowing own warehouse from the three angles: processes, resources and organization matter. More detailed findings made by authors from each study is examined later in the text and add to enhance this knowledge.

Common processes taken place in warehouse after goods/materials arrival are receiving, storage, order-picking and shipping. Hompel & Schmidt (2006, 3-4), Faber et. al. (2013,
1231) and Staudt et. al. (2015, 5527-5528) describe warehouse functions more comprehensively lengthening in after product handling assignment to location and phases the order-to-stock location allocation, order release and batch, packing orders and provision of value-added logistics activities before leaving a warehouse facility. Furthermore, warehouse organization documentation process flows play no little interest of warehouse controlling and management (Rouwenhorst et. al. 2000, 517). It is imperative to that warehouse zones are traced to each operation (Piasecki 2004, 62).

Another warehouse design criteria for a WMS concerns with its resources storage capacity (Rouwenhorst et. al. 2000, 519). Among all authors only Gu et. al. (2010, 540) and Roodbergen et. al. (2015, 3307) in warehouse designing tell that sizes and dimensions of a warehouse impose also own restrictions on its storage capacity for keeping inventory and products handling. Piasecki (2004, 60) pinpoints the significance of understanding SKUs characteristics, specifically, what are stored in the warehouse. SKUs handling is determined with its physical (units shape and weight) and environmental characteristics (frozen, flammable or hazardous material) (Manzini 2011, 6). Also, products stored in warehouse put additional requirements on WMS, for instance, the pharmacy hold temperature (Muehlbauer 2006, 48). Godin (1997, 28) introduces a flexible warehouse and describes it with the adequate storage capacity in order to place coming products with both efficient storage area utilization and equipment usage (Gu et. al. 2010, 540).

One more fundamental warehouse element concerns with its optimal layout decision combination (Rouwenhorst et. al. 2000, 515) to position product allocation, storage place, amount of parallel picking aisles, about product allocation, handling, storage area, input/output points (Manzini 2011, 56; Roodbergen et. al. 2015, 3310; Trab et. al. 2015, 291). Traditional warehouse layout, rectangular with straight aisles in parallel, can be found out in the majority of warehouses for racking areas and order-picking areas (Manzini 2011, 57-58). However, there are radical innovative warehouse layouts aim at the reduction of travelling for taking stored good and improvement of warehouse performance as Flying-V layout, V-shaped cross-aisles along all warehouse, Fishbone and Chevron aisles warehouses (Manzini 2011, 59; Roodbergen et. al. 2015, 3309). Warehouse layout is necessary to achieve willing warehouse performance (Roodbergen et. al. 2015, 3308). Faber et. al. (2013, 1249) set poor layout as warehouse physical constraints. Faber et. al. (2002, 388-389) refers to warehouse layout and size as warehouse performance complexity. Gu et. al. (2010, 541)
persuade that a wrong warehouse layout can cause challenges bearing additional costs in
construction and material handling as well as increasing travel distance and inefficient space
utilization.

Meantime, only two authors (Manzini 2011, Faber et. al. 2013) associate warehouse
performance with following aspects. The warehouse tasks complexity can be specified with
the number of SKUs (Stock Keeping Units), processes diversity, handled order lines per day
(Faber et. al. 2013, 1235). Manzini (2011, 4) justifies the term of an order line which contains
an item name and its quantity needed to be picked up, while order as a list includes in itself
one or more order lines assigned to a specific concrete customer or place. Both Manzini
(2011, 466) and Faber et. al. (2013) indicates with the help of the research about warehouse
utilized capacity that it is basically linked to in order lines number.

According to Rouwenhorst et. al. (2000, 517) warehouse recourses include all kinds of
equipment (storage unit and systems, material handling and pick equipment, computer
systems) and warehouse staff - everything as determinants of the warehouse performance.
Roodbergen et. al. (2015, 3307) denotes assigning of the right amount of employees as a
warehouse tactical decision.

Another extensively discussed issue of warehouse topic by 16 authors concerns with the
Hompel et. al. 2015, Staudt et. al. 2015, Trab et. al 2015). Within these authors there are new
names which have not been mentioned in the text before in the relation to warehouse
characteristics. What, in turn, can tell about the focus of researcher more on studying
automated subsystems in a warehouse. In addition, there is the fast-emerging trend for
installing more and more high automation in warehouses (Faber et. al. 2002, 382, 388).
What, in turn, means the integration of material and informational flows with different
technologies levels such as WMS, barcoding (Godin 1997, 28) and robots (Staudt et. al. 2015,
5535-5536). The degree of warehouse automation significantly influences on processes
performance in a warehouse. Speaking about warehouse automation, it is essential to
understand what is meant with automation, namely, physical handling systems and
information handling system (Manzini 2012, 8). The last one concern with WMS systems
which will be discussed later in the next chapter, but physical handling systems should be
given attention before.

Manzini (2012, 9) and Staudt et. al. (2015, 5530) claim that there are a lot of automation
going on in the warehouse order picking process, in which 60% of operating costs are either
labour intensive or capitalize technologies intensive. The traditional paper picking list takes
a back seat to technologies (Richards 2014, 138) to eliminate mistakes associated with data
entry (Hill 1997, W14). Hompel et. al. (2015, 40) tell that now in usage there are not only
stationary terminals where a picker can see information online on monitor, but also mobile
 terminals with information where a picker is not obliged to sit in one place. There are light
directed systems such as pick-to-light and put-to-light, both consist of lights indicator and
displays. The idea behind is that picking/putting location is shown to a picker with light as
well as items quantity to be picked/put. The picking/putting light indicators can be either
integrated into shelves, racks or portable. Pick-to-voice systems become popular recently
providing a picker with real-time instruction. Virtual display-directed picking systems show
the direction to picker and give guidance. (Manzini 2011, 8-9) Rouwenhorst et. al. (2000,
517) refers to previously mentioned equipment as "order pick auxiliaries". Referring to
statistics for eliminating error rates, pick-by-voice system (0,08%) shows the best results in
comparison to pick-by-light system (0,40%) and just mobile terminals plus labels usage
(0,94%) (Hompel et. al. 2015, 41). Moreover, with this technology equipment an order
picker can manage high volume picking with free hands. Van Den Berg (1999,752)
distinguishes three kinds of warehouse automated systems used for picking, namely, picker-
to-product which includes all vehicles and machines with the help of which a picker can
reach the picking destination or place, product-to-picker that are automated storage and
retrieval systems such as automated crane shelves performing picking and sorting and
different conveyers and picker-less systems such robotics or automated dispensers.

According to Rouwenhorst et. al. (2000, 519) and Kappauf et. al. (2012, 102) the desired
throughput can be achieved via deployment of technical automated solution in a warehouse
like automated racks, horizontal/vertical carousels, a-frame dispenser systems and so on.

Another warehouse process scoring popularity in implementation of automated solutions
with the combination between the Internet of Things infrastructure and cloud computing is
the inventory management with either Radio Frequency Identification (for inventory
tracking (Hill 1997, W8), bar coding and radio frequency data-communications (Hill 1998, W24)), or bar coding, or robotics (Richards 2014, 151; Staudt et. al. 2015, 5535; Trab et. al. 2015, 292). Bar coding can be linear, 2-dimensions or directly marked parts (Anonymous 2011, 8). Hompel & Schmidt (2006, 23) tell not only bout pick-to-light system integration with WMS, but also about automatic measuring devices such as handheld equipment and scanning gates with which goods articles can be scanned and proceed respectively with WMS. Piasecki (2004, 62) addresses all abovementioned as Automated Data Collection hardware which should be all applicable to integrate with WMS software to ensure the perfect combination without unnecessary programming later. Autry et. al. (2005) underline warehouse automation to add value also to increased customer service level via stock depletion reduction, delivery reliability and backorder decrease. The abovementioned IT intelligent system has become popular because of more complex tasks in warehouse (Kappauf et. al. 2012, 102).

The key conclusions figured out from this chapter about warehouse parameters to acknowledge in WMS setting are encapsulated in the table 2.

Table 2. Warehouse characteristics for WMS set up.

<table>
<thead>
<tr>
<th>warehouse type:</th>
<th>production</th>
<th>distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>processes diversity:</td>
<td>receiving</td>
<td>storage</td>
</tr>
<tr>
<td></td>
<td>packing</td>
<td>value-added logistics</td>
</tr>
<tr>
<td></td>
<td>order-picking</td>
<td>shipping</td>
</tr>
<tr>
<td></td>
<td>order batch</td>
<td></td>
</tr>
<tr>
<td>resources:</td>
<td>warehouse parameters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- dimensions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>number of order lines per day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>layout</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SKU's characteristics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>physical</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- unit shape</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- weight</td>
<td></td>
</tr>
<tr>
<td></td>
<td>environmental</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- frozen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- hazardous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SKU's number</td>
<td></td>
</tr>
<tr>
<td></td>
<td>number of warehouse personnel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>automation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- physical handling systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- pick-to-light</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- pick-to-voice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- put-to-light</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- virtual display</td>
<td></td>
</tr>
<tr>
<td></td>
<td>automated racks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>horizontal/vertical carousels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a-frame dispenser systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- ADC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- RFID</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- bar code</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- robotics</td>
<td></td>
</tr>
</tbody>
</table>

In summary, it can be said that all warehouse characteristics mentioned in the table above are tightly bound to each other and to WMS selection. Thus, one of the key elements for...
WMS assortment is a warehouse type determining not only further warehouse operations purposes and its place in supply chain, but also the way of handling both processes and SKUs. In turn, SKUs peculiarities as physical characteristics and attributes dictate certain requirement for warehouse, process management and number of warehouse personnel resources. Warehouse infrastructure and equipment can significantly influence warehouse throughput and operation time.

2.2. WMS taxonomy

The following WMS issue is discussed a bit more within the authors' works as the result of the systematic literature review compared to the previous subchapter. This topic is mentioned by 29 authors in their studies. There are two aspects that can become evident after analysing these studies. More authors deliberate WMS definitions than WMS existing categorization based on aspects mentioned times (22 vs 14).

Before beginning the further discussion of WMS, it is useful to put wise how WMS perceived generally in some studies. A warehouse furnished with IT and automated services to support warehouse logistic tasks becomes WMS which is able to exchange information about resources and inventory in the real time supporting continuous communication (Min 2006, 112). Gunter & Byham (2000, 60) claim that WMS brings warehousing on the next level. However, looking more precisely at a WMS definition each author proposes there are two opinions towards WMSs are explicit. Some authors deal with WMS as a purely electronic software while others do not fully agree with this interpretation and argue that a WMS is not only a product, but it assumes even more another special way. Both of these authors' different points of view are discussed below in the text.

The first group includes the majority of authors (16). Gu et. al. (2010, 546) writing mainly about enhancing warehouse design mention WMS as a computational system which screens material, storage space, personnel, equipment and support protocol and policies of handling storage, order completing and dispatching. Faber et. al. (2002, 382) and Son et. al. (2015, 1435) simply call a WMS a software meant to order management. Manzini (2011, 466) adds that a WMS can help in monitoring good on the way from receiving prior to shipment even focusing on picking and storage technologies in a warehouse. Complementary, Faber (2015, 7) notes that WMS is a complex software package aiming at providing high service level and efficient use of warehouse equipment, workforce and space. Staudt et.al. (2015, 5539)
shortly judge about WMS as an information system to manage resources inside a warehouse. Muehlbauer (2006, 1) supports this definition saying that WMS is a computer program assemblage targeted at encouraging a company in dealing with warehouse operations faster and more accurately. According to Kappauf et. al. (2012, 101) WMS is a system which optimize internal warehouse subsystems. This information system is designed to manage warehouse data (Vaisman & Zimanyi 2014, 53) and to detect problems in warehouse activities (Lam et. al. 2010, 635). WMS also collects data about warehouse inventory level, cross-docking logistics and customer's order patterns (Magableh 2007, 54). The last one happens because a WMS can provide algorithms and rules for performing warehouse tasks such as goods allocations, route picking lists, orders division and etc. (Zajac 2015, 26). Two authors Friedman (2010) and Son et. al. (2016) assume that the true value definition of WMS can be seen easily in comparison with other logistic execution systems. Friedman (2010, 42-43) shows that a WMS outperforms an ERP system being specially designed to manage "physical activities and arrangements" in a warehouse. Son et. al. (2016, 980) as the previous author draw a parallel between WMS and WCS concluding that WMS is more about order management and documentation rather than automating handling equipment and machines control in a warehouse.

The second group of eight authors does not treat a WMS as just an IT product but shed up the light more on this issue. WMS is a way more than a software decision, it assumes changing of warehouse operations and installation of intelligent systems (Anonymous 1998, A6). Finkel (1996, 1, 16) in own article argues that WMS is just not an electronic software tool put off from the shelf, it is about project management because WMS installation takes place in the real world not only with technology, but also with human interactions where a special team should be assigned for WMS. Hill (1997, W7-W10) and Anonymous (1998, A2) claim that a WMS is not simply a system package which can be implemented mindlessly, instead of this they suggest a customer to create a project management team and proceed with stepwise guidance. Hompel & Schmidt (2006, 287-304) in their study devoted to WMS believe that optimized, structured and transparent warehouse logistic activities can be achieved only with WMS. Plus, they also provide a checklist how to select the suitable WMS for company’s needs. Supporting so, Richards (2014, 141) advises to create a documented list of functions a company needs called a request for information and send it to a vendor for further checking their availability. Gunter & Byham (2000, 60) confirm this
decision of the written document with required warehouse functionality scope description. The authors mentioned above do not limit technical functionality of a WMS. Thus, WMS encapsulates in itself both information and material flows (Finkel 1996, 2). Since the existent warehouse performs a huge number of logistics operations. It is said that WMS is a mini enterprise system responsible for managing key operational functions of a warehouse such as material receiving, putting away, picking, packing, shipping and warehouse administration (Anonymous 1998, A2). Verwijmeren (2004, 168) accounts typical WMS users can account such as wholesalers and logistic service companies.

When it has become clear with WMS definition it is time to understand the natural division of WMS. The table 3 gathers in itself the key divisions of WMS from the literature, while each WMS variations are discussed in further details.

Table 3. WMS taxonomy division.

<table>
<thead>
<tr>
<th>WMS TAXONOMY</th>
<th>system type</th>
<th>functionality scope</th>
<th>software provision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- customized</td>
<td>- basic</td>
<td>- standalone WMS</td>
</tr>
<tr>
<td></td>
<td>tailor-made</td>
<td>- advanced</td>
<td>- SaaS WMS</td>
</tr>
<tr>
<td></td>
<td>- standard box</td>
<td>- complex</td>
<td>- WMS via cloud computing</td>
</tr>
<tr>
<td></td>
<td>solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- ERP module</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The appearance of warehouse management varies sizeably since it can act from electronic work sheets to a purpose-built application such as WMS. In the literature observed it can be concluded that WMS taxonomy has three kinds. Commonly, authors judge among different commercial WMS can be classified according to types.

WMS can come either as a tailor-made system which are developed and according to company needs or standard not customised off shelf system configured with same functionalities and designated to fix the same issue in several companies (Levans 2002, Faber et. al. 2002; Verwijmeren 2004, 168; Min 2006, 118; Faber 2015, 8). Tailor made WMS systems are built from zero because of their special design, while standard comes as a complete package which should be changed to customized WMS if future business dictates these conditions (Faber 2015, 8). Companies interested in a tailor-made WMS should decide whether it will be done by this company's IT department in-house or outsourced (Faber et. al. 2002, 385). Particularly, complicated business activities in warehouse in product/material
mix, order lines, processes diversity, supply chain uncertainty require a great deal of highly customized WMS (Manzini 2011, 466). Hompel & Schmidt (2006, 1) discuss that a tailormade WMS should consist of three elements which are technical structure, operational framework and system control. Levans (2002, 24) claims that from the beginning WMSs has been highly customised and designed each per a warehouse, however, several years ago another thought about creating a WMS to be run in several warehouses has appeared. According to Faber (2015, 7) standardized WMS has become more popular among companies rather than customized systems as years passed. It should be emphasized that an erroneous choice of either a customized or standard WMS type can result in competitive disadvantage requiring additional costs and time (Faber et. al. 2002, 382).

Plus, there is the escalating trend within ERP system vendors to develop WMS modules in their software product to perform some of WMS functions but not the ones for boosting productivity, eliminating errors, storing more space cubes in a warehouse (Friedman 2010, 42). And it was like this since ERP is the first generation of logistic execution systems (Mahendrawathi et. al. 2015, 116). WMS module in ERP system can work with some warehouse requirements, but not unlock the high warehouse potential (Hill 1998, W5; Mahendrawathi et. al. 2015, 117). WMS can be interfaced with communication and automatic dentification systems (Manzini 2011, 466).

Treibilcock (2009, 26) also divide WMS coming as a package of simple warehouse functioned described previously and advanced supporting more automation of warehouse activities, integration capabilities and reporting. However, authors such as (Faber et. al. 2002) and (Ramaa et. al. 2012) the other side of WMS classification which is connected to WMS scope of activities. There are three kinds of WMS: basic (to register information about inventory and its location), advanced (besides basic ones to plan and monitor resource and activities happening in warehouse) and complex (to fully optimize warehouse activities with value-added planning). (Faber et. al. 2002, 385; Ramaa et. al. 2012, 14-15)

Richards (2014) in in book concentrating on warehouse management as only one author fully mentioned about existing a division of provision software to users. A company can implement WMS as a standalone system, what means a software is hosted, installed and maintained on premise on companies’ costs for long term operations vision. Whilst Software-as-Service (SaaS) means that a vendor holds and rents/lease to different customers
its server, there WMS is presented as internet based application. Such solution is mostly
good in the short term - pay as modules for start-ups and SMEs because of low entry costs.
However, data security and strength of internet connection stays questionable. (Richards
2014,147) To keep it short, customers are run on the same software with this option but this
software is for every customer who pays subscription fees (Levans 2002, 24). Making WMS
via cloud computing means that software and hardware infrastructure is run by vendor only
for its clients, where a customer can access WMS via web and gain benefits without upfront
logistics supports more cloud based WMS information management and sharing because it
allows standardization of processes, remote control, reduction of operational costs.

2.3. WMS functions and features

By interpreting table 1 results, the topic of WMS functionality is the lesser researched topic
than the previous subchapters topics of warehouse characteristics and WMS taxonomy
among authors scoring mentions in 25 studies. All studies there can be divided to the ones
saying explicitly and implicitly about WMS functions. The common ideas of each grouped
studies are presented below.

There are eight literature sources of Hill (1997), Piasecki (2004), Hompel & Schmidt (2006),
and Hompel et. al. (2015) which aim at designing or studying available WMS functions.
Even within these eight studies it is possible to draw common patterns. For example, both
Hill (1997) and Piasecki (2004) define comprehensively WMS functions in own articles, the
first one by assisting a customer what to look for during WMS installation and the second
one by posing concerns to a customer to figure out a need of the WMS. Other authors
(Hompe and Schmidt 2006, Manzini 2011) has thoroughly researched and devoted their
books to the topic of WMS. Hosp and Schmidt (2006) do this from the point of design
storing and order picking WMS functions. Manzini (2011) via studying warehouse logistics
gives attention to WMS functions for storage and picking automation capabilities. Min
(2006) in own research explores the current practice of companies implementing WMS with
naming acquired functionality and factors of their choice towards this software. Kappauf et.
al. (2012) also study warehouse logistics functionality with SAP WMS and WM module in
SAP ERP system. The rest three studies of Trebilcock (2009), Friedman (2010) and Hompel
et. al. (2015) document and compare several logistics software systems.
The majority of authors (17) in this topic judges about benefits which WMS can bring or provides assistance for future WMS customers defining generally WMS functions, but not going too deep into details, in addition, some papers put as an aim to describe the certain situation or solve this case with WMS implementation (Godin 1997, Anonymous 1998, Van Den Berg 1999, Barry 2001, Anonymous 2000, Hackman et. al. 2001, Faber et. al. 2002, Magableh 2007, Lam et. al. 2010, Faber et. al. 2013, Faber 2015, Golinska 2015, Liu et. al. 2015, Roodbergen et. al. 2015, Zajac 2015, Bond 2016). For instance, Roodbergen et. al. (2015) in the article more speak about warehouse design and layout and new warehouse allocation SKUs policy as core components to be fulfilled prior WMS set up rather than about WMS functions. Furthermore, Godin (1997) claims that an organized flexible warehouse can allow later to enjoy more benefits from WMS functionality, for example, agreed exchange information method such as barcoding with suppliers. Barry (2001) says other way around that WMS operability can give greater flexibility to warehouse operations because of advantages coming from facilitated warehouse processes. Anonymous (2000) describes the general idea what companies should look for WMS where advanced planning and WMS integration software synthesis abilities are essential to achieve. Supporting WMS technology functions, Trab et. al. (2015) address product allocation mechanism via IoT abilities for exchange of information. Magableh (2007) developing integrating model of supply chain combine both data which can be get from generalized TMS and WMS functionalities. Golinska (2014) does not mention any specific WMS functions, but about usual inventory management software capabilities of minimizing inventory level as the result of the analysis of cloud based WMSs potential in Japanese fashion market for supply chain operations optimization and customers service improvement. Likewise, Faber et. al. (2002, 385, 393-395) does not consider any specific function belonging to WMS, but provide their three functionality classification known in the literature regarding functions scope, namely, associated with inventory analysis information such as quantity and documentation and tracing, another is warehouse management meaning warehouse organization processes and resources management as well as inside reporting, and the last id warehouse execution functions that make available the continuous and smooth materials flow inside the warehouse giving employees guidance what, when and how to do. The same way, Van Den Berg (1999) describes warehouse automation systems and does not give exact details about WMS. Anonymous (1998) withdraws statistics of WMS implementation and also its positive influence on supply chain operation such as labour costs
reduction, inventory decrease and ROI increase mentioning WMS functions for data exchange. Bond (2016) explains the WMS implementation case of and some benefit derived from using this system. Lam et. al. (2010) limit WMS capabilities by blaming it for focus on managing warehouse operation rather than warehouse resources management. Both Faber et. al. (2013) and Faber (2015) generally describe operations in a warehouse while the first one more concern about WMS types according to warehouse task complexity and the second one presents more comprehensive study about warehouse performance and the common scope of WMS functions. Continuing the topic of warehouse performance Hackman et. al. (2001) propose the input and output data for warehousing system. Zajac (2015) in the book evaluates sustainability and energy consumptions of a warehouse with WMS and this system impact. Liu et. al. (2015) speak about functions available via browser mode with WMS. After discussing the context in which WMS functions are mentioned in the selected academic literature, the more extensive analysis of studies is described more deeply further in the text.

From general overview of studies to more specific one, it is unarguable that WMS is designed to steer warehouse processes and operations as noted in chapters before, consequently, WMS should support and enhance all functions in warehouse. Hence, WMS functions cover warehouse functions mentioned in early chapter simply can be distinguished between goods receiving, storing and issuing (Hompel & Schmidt 2006, 4). Friedman (2010, 42) believes that WMS manages all physical arrangements in warehouse. In other words, WMS control all processes from receiving to shipment (Golinska 2014, 570). Afterward, WMS functions description acquired from the academic literature are given according to defined warehouse processes.

Starting from the process of goods receiving, WMS fortifies warehouse operations (e.g. incoming goods quality acceptance, labelling, inclusion and completing purchasing order) (Manzini 2011, 429). By applying a WMS companies can unload coming material to receipt area, verify those receipts and split incoming units for future loading lots (Kappauf et. al. 2012, 101).

About the storage process, Trab et. al. (2015, 291) pinpoints optimal product allocation as the one of critical in WMS. Here slotting as a standard function of WMS comes for great usage to optimize product zoning storage allocation according to velocity like ABC goods.
categorization (Friedman 2010, 112). Hompel & Schmidt (2006, 27-28) make examples of varied warehouse operational storage types, namely, fixed or random storage bins, shortest driveways, cross distribution, clustering, pre-buffers in front of storage areas. The same authors state that WMS should be assigned with technical characteristics to storage types, for example, goods storage on ground (floor directly sometimes stacked) or on shelves, storage type as one block (on the top of another) or line (side by side with aisles), goods location type can be static (goods remain on the same location before retrieval) and dynamic (goods are moved after storage) (Hompel & Schmidt 2006, 92). Barry (2001, 60) and Zajac (2015, 20) include in WMS obligatory inventory SKUs management and replenishment. For this, the majority of WMS offers the cycle counting function to count inventory SKUs (Hill 1997, W22; Piasecki 2004, 62). Trebilcock (2009, 24) refer to replenishment and cycle accounting as functions of advanced WMS. Faber (2015, 1) describes WMS in mixing inventory level to be consistent with customers’ expectations keeping it to a minimum. In this way, WMS reduces redundant buffer stock (Hompel & Schmidt 2006, 6).

For order picking operations in a warehouse, WMS assists the variety of picking strategies such as single order picking (Van den Berg 1999, 752), batch wave (several orders at a time), zone picking depending on operations volume (Piasecki 2004, 63). Manzini (2011, 429) distinguishes order-picking leveraged either by human labour (man-to-goods, parts-to-picker, with the help of put systems), or with machines (robots and automated picking machines. For goods retrieval strategies, commonly FIFO (First-In First-Out), the first stored loading unit of an article is retrieved, or conversely LIFO (Last-In-First-Out), retrievals according to presumable time period or sequenced according to route path (Hompel & Schmidt 2006, 29). Friedman (2010, 112-113) pinpoints to not-typical picking such as mini-wave picking where same pick tickets given as to picking orders via labour tracking and pick to truck. The module of routes optimization which assists a picker in setting picking and delivery routes and so on is usually absented in standard WMS, but belongs to advanced WMS function requiring for more customization and coding (Roodbergen et. al. 2015, 3322). For instance, a pull-down function in WMS in bulk overflow storage determines when an item should be lifted down and moved to pick zone (Friedman 2010, 112). In addition, with cross-docking function of WMS incoming product are simultaneously sent to output points skipping unnecessary storage, however, pure cross docking function in WMS is less common because of the large space utilization to sort out goods on place. WMS supports
traditionally tasks interleaving in which various tasks happening in one place are combined together to maximize productivity. For instance, in case when there is some place left during pallet loading a warehouse worker can prepare there goods for the next pick in route (Piasecki 2004, 62).

Before actual shipment WMS can prepare consolidated items for loading and do quality checking to dispatch right amount of items (Hompel & Schmidt 2006 45). During this process, Godin (1997, 28) adds that WMS supports sorting and packaging of goods. Kappauf et. al. (2012, 101) adds to WMS capabilities forming units for shipment loading. Thereto, WMS supports pack verification what means just scanning goods in a pack pallet before loading to examine accuracy (Barry 2001, 60).

WMS administers warehouse operations on daily basis providing relevant documentation (Piasecki 2004, 60). During the loading process WMS can print and design pick tickets and loading reports for shipping items (Barry 2001, 60; Friedman 2010, 112, 114). WMS works with complex warehouse data (Kappauf et. al. 2012, 101). Hompel & Schmidt (2006, 4, 6) highlight the most valuable feature of WMS as trust and security feeling by comprehensive and transparent data and processes handling. Lam et. al. (2010, 635) announces the main function of WMS to track, store products and share accurate information about those to customers like material storage, movement and receipt. WMS comprise easy-to-access data from suppliers’ or customers’ stock position and pattern (Magableh 2007, 54). Document and information in intensified documents accompanying goods and warehouse product design becomes more complex in warehouse logistics what highlights the actuality of WMS in merging this data (Lam et. al. 2010, 634-635). WMS can also show equipment utilization, labour and work processes statistics (Hackman et. al. 2001, 83). Hompel & Schmidt (2006, 6) argue that WMS makes warehouse logistic more transparent, moreover, database become more accessible and secure since WMS aims at comprehensive data handling. WMS possess knowledge about mistakes and damages in real time (Golinska 2014, 536). In case of WMS implementation offered by it is said that nature of errors in afterwards warehouse operations relate to human factor, not software faults (Bond 2016, 62). WMS records data about damaged goods, for instance, if information about materials is kept with bar codes and this bar code is missed on a product, WNS can print new barcode to substitute lost one (Friedman 2010, 112). The core function of WMS is to guarantee that necessary product number are ready for customers leverage when they are requested. WMS is able to analyse customers’
orders and inform as reports to expand SKUs because of their growing requirements and vice versa. (Magableh 2007, 54) So WMS does a warehouse replenishment using, for instance, bar coding to track an order to a customer and maintain productivity generating reports for this (Barry 2001, 60). According to Kappauf et. al. (2012, 101) WMS functions are presented basically not just in controlling, supervising and optimizing warehouse distribution subsystems such as SKUs amount and location and conveyance management, but also in mode detailed system monitoring and strategies optimization. Min (2006, 117, 124) states that among secondary functions of WMS there are quality measurement, inspection and audits and labour management reporting to check the WMS status. Friedman (2010, 112) notifies about a possibility to produce performance reports.

There is a shift from direct manual entering data into WMS terminal to network structure mode. Whereas, a user does not have to physically stand near the client station, but rather can access the system and use its functions via web app. Aside from the previous, because of system layers it is possible to securely distribute data and documentation for different authority level users from warehouse operational workers to strategic management people. There is a possibility to log into WMS also with mobile terminals via web based interface even with own client devices and custom made terminal software. (Liu et. al. 2015, 147)

Value added logistic activities can be add into WMS to bring competitiveness through supply chain (Anonymous 2000, 42; Hompel & Schmidt 2006, 285). There is a growing emphasize on Advanced Shipment Notice for WMS, what enables electronic data interchange about goods or materials from a sender to a receiver (Min 2006, 122). This function is beneficial for bother upstream and downstream warehouse logistic activities increasing the overall supply chain excellence (Friedman 2010, 110) because more accurate information can facilitate receiving processes (Piasecki 2004, 62). Advanced administrative function pointed out by Piasecki (2004, 64) is 3PL billing or activity based costing which gives a possibility to assign fees in bills based on the certain activities conducted, for example, for each unit shipment or value-added activities performed. Besides, ASN (Advanced Shipment Notice) can be delivered to industry customers (Anonymous 1998, A/7). Pick-to-cartoon as an advanced function can be useful for parcel shippers to determine shipping carton with SKU dimensions such as its weight and size (Piasecki 2004, 63). Yard management as advanced function refers to management of trucks space outside the warehouse logic are the same as in cross docking activity (Piasecki 2004, 62). For instance, there is no need in yard
management function for small warehouse because of close good allocation there (Hompel & Schmidt 2006, 22). Additional module of labour management or capacity planning can be introduced to WMS where the system identifies work capacity and staff load, assign each time for task completion and help to efficient utilize labour (Piasecki 2004, 63). In this way, a WMS can trace each worker labour efficiency rate and see progress of completed tasks (Golinska 2014, 536). Hence, WMS helps management staff to optimize warehouse work (Min 2006, 119).

As Hompel et. al. (2015) rightly emphasize the scope of WMS functions has quite expanded from early times since customers are demanding more warehouse functions in pursue of costs reduction. Hereupon, up-to-date WMS obtains their functions roots in ERP, TMS and SCM systems, examples of which are processes assistance from receiving to dispatching, complete order fulfilment, routes planning, billing and other value-added services. (Hompel et. al. 2015, 5)

It is worth to stress that optimisation is the core of WMS. As it is seen from the above text, this system allocates at the best place for inbound materials to be kept and to be picked later, the right time, person and route (reducing to minimum travel time to assemble order line), regroup and reclassify warehouse content to guarantee outcoming goods velocity and cycle accounting and so forth (Min 2006, 115; Manzini 2011, 466).

With the help of automated communication equipment, a WMS can become a powerful tool. Min (2006, 119) exclaims that WMS encompassed with automated technologies can boost warehouse throughput. Kappauf et. al. (2012, 101) say that WMS focuses on internal warehouse subsystems optimization. Paperless storing allows online and on time data exchange between a warehouse worker and a WMS application gains a lot with paperless technologies (Faber et. al. 2013, 1250; Faber 2015, 7). WMS is not developed in the isolation because of existence of warehouse physical labour and material handling equipment (Hill 1997, W10).

The table 4 reports WMS functions discussed in this chapter and distribute them among warehouse processes supported by WMS.
Table 4. WMS functions.

<table>
<thead>
<tr>
<th>materials/goods receiving</th>
<th>storage</th>
<th>order-picking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloading</td>
<td>Slotting</td>
<td>Human labour / machines picking</td>
</tr>
<tr>
<td>Scanning</td>
<td>Fixed, random or hybrid storage</td>
<td>Batch wave, mini wave, zone, volume picking</td>
</tr>
<tr>
<td>Goods acceptance</td>
<td>Inventory management &amp; replenishment</td>
<td>Sequence picking</td>
</tr>
<tr>
<td>Labelling</td>
<td>FIFO</td>
<td>Tasks interleaving</td>
</tr>
<tr>
<td>Purchasing order update</td>
<td>LIPO</td>
<td></td>
</tr>
<tr>
<td>Quality checking</td>
<td>Pull down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle Counting</td>
<td></td>
</tr>
<tr>
<td>shipping</td>
<td>warehouse administration documentation</td>
<td>value-added logistics activities</td>
</tr>
<tr>
<td>Lots formation</td>
<td>Customer service reports</td>
<td>Dock/Yard management</td>
</tr>
<tr>
<td>Load sequencing</td>
<td>Storing instructions</td>
<td>3PL billing</td>
</tr>
<tr>
<td>Packing</td>
<td>Picking instructions</td>
<td>Cross-docking</td>
</tr>
<tr>
<td>Quality checking before shipment</td>
<td>Inventory reports</td>
<td>Pick-to-cartoon</td>
</tr>
<tr>
<td></td>
<td>Loading reports</td>
<td>Advanced Shipment Notice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labour management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity Planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Routes optimisation</td>
</tr>
</tbody>
</table>

The table above shows observed WMS functions in covered literature studies which are spread along the six processes taking place in a warehouse. The biggest variety of functions are linked with WMS ability to manage SKU’s, assemble picking orders and provide additional value of warehouse activities.

2.4. WMS deployment considerations

The most actual topic discussed in studies concern with WMS implementation raised in 30 studies. Besides, this topic includes the biggest number of aspects (total topic actuality is 85) from authors considering WMS implementation issues from various angles. Alongside this, there are no evidences revealed in the literature about the installation of WMS by 3PL companies and there is no guidance at this point designed for 3PLs installing or choosing a WMS for its customers. The findings gathered in this chapter comes in several ways as frameworks of aspects to look for in software (Sahay & Gupta 2003, Min 2006, Zapata 2012), designed advices and guidance for choosing a WMS for succeeding in warehouse logistics (Finkel 1996, Hill 1997, Hill 1998, Benefield 1998, Gunter & Byham (2000), Manzini 2011, Bond 2016, Hompel & Schmidt 2006, Richards 2014) and other addition

During the systematic literature review, as it is said there are only few articles found out in which valuable models for WMS software and vendor selection (Min 2006, 118; Zapata 2012, 96) and overall drivers in logistics execution software selection (Sahay & Gupta 2003, 102) are presented. In contrast to two previous Sahay & Gupta (2003, 101-103) propose the framework with overwhelming selecting criteria of six supply chain software such as Supply Chain Planning, ERP, Order Management System, Manufacturing Execution System, WMS and TMS. In this framework Sahay & Gupta 2003, 102) distinguish factors influencing of software choice on primary (technology software attributes and features as well as customization need, finance aspects and vendor’s software support for continuous running) and secondary drivers (vendor’s business vision, experience, strength and other small factors). Even though this framework is all-encompassing regarding software selection, it is too comprehensive including lots of general technical details and issues being as a drawback in orienting precisely on WMS selection, for instance, nothing is said about any specific WMS interface, integration devices, quality and realisation time requirements. Next, Min (2006, 117-118) suggests generic criteria for a customer to decide upon a logistic execution system, what criteria (technical features, cost issues, service aspects and vendor description) later this author uses for interviewing companies about WMS choice to form after practical guidance for future customers of a WMS. Because this model is quite generic there is no that much description available of including elements into WMS criteria. Zapata (2012) goes further and present a hierarchical structure a customer should follow to select WMS and evaluate the preferences of respondents participating in this research. Zapata (2012), in turn, classifies WMS selection in administrative (vendor characteristics, costs, realization time) and product (design, performance, adaptivity) aspects. However, this author does not provide
neither any integration with databases, communication systems and execution software, nor any exact figures for realisation time. In order to address all possible issues relevant for a customer in WMS selection and installation and bring more validity into this research, these models complement each other. Afterwards, they are enriched with details gathered from other topic related academic sources covered in the systematic literature review. So, conjunction points of these models are intersected and other information is strung like beads. The table 5 with these findings summary is presented below.

Table 5. WMS selection criteria and installation issues.

<table>
<thead>
<tr>
<th>WMS SELECTION CRITERIA AND INSTALLATION ISSUES</th>
<th>costs</th>
<th>WMS replacement</th>
<th>WMS vendor reputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>technical</td>
<td>- functions range</td>
<td>- software and hardware integrate compatibility (open vs standardized)</td>
<td>- system customization (if needed)</td>
</tr>
<tr>
<td></td>
<td>- software installation</td>
<td>- user interface (easy to access, remote access, language)</td>
<td>- layout</td>
</tr>
<tr>
<td></td>
<td>- system customization (if needed)</td>
<td>- system customization (if needed)</td>
<td>- SKUs</td>
</tr>
<tr>
<td></td>
<td>- license software basis: annual, month, user and etc.</td>
<td>- systems intergration</td>
<td>- automated/manual</td>
</tr>
<tr>
<td></td>
<td>- systems intergration</td>
<td>- MHE hardware</td>
<td>- labour</td>
</tr>
<tr>
<td></td>
<td>- MHE hardware</td>
<td>- maintenance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>warehouse physical characteristics</th>
<th>implementation time</th>
</tr>
</thead>
<tbody>
<tr>
<td>- type</td>
<td>- installation (standard vs tailor made WMS)</td>
</tr>
<tr>
<td>- layout</td>
<td>- systems intergration</td>
</tr>
<tr>
<td>- SKUs</td>
<td>- testing</td>
</tr>
<tr>
<td>- automated/manual</td>
<td>installation assistance and project management:</td>
</tr>
<tr>
<td>- labour</td>
<td>-training</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>support</th>
</tr>
</thead>
<tbody>
<tr>
<td>installation assistance and project management:</td>
</tr>
<tr>
<td>-training</td>
</tr>
<tr>
<td>- instructions</td>
</tr>
<tr>
<td>-professional service</td>
</tr>
<tr>
<td>-after-sale support:</td>
</tr>
<tr>
<td>-maintinance</td>
</tr>
<tr>
<td>-regular updates</td>
</tr>
<tr>
<td>-quality verification</td>
</tr>
<tr>
<td>-help desk</td>
</tr>
<tr>
<td>-warranty duration</td>
</tr>
</tbody>
</table>

When a company selects WMS, everything starts with understanding own business processes and needs and matching these requirements with the WMS choice (Anonymous 1998, A/8). Levans (2002, 25) proposes the list of question a warehouse manager should
address before going with WMS which concern with warehouse process flow and requirement operational capabilities. As Richards (2014, 145-146) declares that a WMS provider should fully understand its client’s requirements and be able to fulfil them. Faber et. al. (2013, 1249) in their multi-variable conceptual model declare that warehousing logistics tasks complexity is the main driver of WMS choice because of faster decision-making accounting all complexity, required more extensive planning and control. Min's (2006, 123) survey shows that more staff there are in a warehouse higher sense a company has in WMS adoption. Even though WMS is one of the best tools for managing warehouse activities is a blot on landscape because WMS does not guide what warehouse material handling equipment to choose and how to allocate resource and labour, all of this is left for warehouse manager to decide (Lam et. al. 2010, 634-636). Gunter & Byham (2000, 60) give an advice to choose such WMS that meet a company business needs rather than become persuade by a vendor to change so much warehouse activities and operations to match its WMS.

Keeping this in mind, Sahay & Gupta (2003, 101), Zapata (2012, 96) and Min (2006, 117-118) recommend looking firstly at technical software components such as functions range, user interface operability characteristics, software platform compatibility with other subsystems and devices, customization design.

Furthermore, Hompel & Schmidt (2006, 290) advice to look for WMS scalability. Namely, vendors' products should be compared based on their diversity and multiplicity of WMS modules offered, because software significant functions should align with company's business operations. The special focus should be put on formed list of specification requirement function to state not only day-to-day warehouse processes, but also on functions necessary for administration like generating performance reports. A company can inquire WMS vendor how many employees should be allocated in a warehouse for system running. (Hompel & Schmidt 2006, 291-294) Richards (2014, 144) also states that it is wise to select such modular WMS, to which it will be possible to add modules, to keep the path of growing business, for example, in case of acquisitions, WMS can manage multiple sites, at the same time, it is crucial not to overestimate functionalities of new WMS because such software can trigger more cost and time spent in its implementation. Min (2006, 118) puts in into the choice of the right WMS type according to business needs because standard box WMS solutions are clearly unfit for heavy modifications and customization.
In the book of Hompel et. al. (2015, 10) it is advised for companies deciding to implement WMS to look at the interface of WMS whether it is open or standardized to share information and interconnect with other systems and subsystems easily in order not to waste integration efforts in doing this. Continuing the discussion about WMS compatibility, Hill (1998, W25-W27) notes that a WMS should be able to transfer data and messages in the common format and content with other systems. Kappauf et. al. (2012, 102) specify that WMS is commonly interplayed with company’s ERP what can help to achieve outstanding performance. It is rational to choose a WMS software that has already integrated with certain ERP in order to avoid spending more money on integration (Piasecki 2004, 66). A couple of authors (Faber et. al. 2002, 384; Friedman 2010, 42) endorse this on pointing out that ERP sends transaction to WMS concerning company’s operations long-term horizon planning while WMS is, in turn, responsible for short-term warehouse shop-floor planning and cross docking. Indeed, this can be explained that ERP transfers customers’ orders queue to WMS to perform (Hompel et. al. (2015, 1-2; Hompel & Schmidt 2006, 332). Faber et. al. (2002, 384) denotes more WMS and ERP communicate with AS/RS control, Programmable Logic Controllers and radio frequency systems for material handling. Son et. al. (2016, 981) attributes that WMS can join together efforts not only with ERP, but also Supply Chain System. Autry et. al. (2005, 167) and Hompel et. al. (2015, 2) refer to another integration of WMS and TMS logistics information systems to exchange the core data. Magableh (2007, 56) supports this WMS integration with TMS indicating an access to the right information comprising from optimising warehouse operations and transport activities respectively. Because all these three systems working together can generate accurate on-time information essential for business (Helo 2006, 1064). Verwijmeren (2004, 169) insists on creating supply chain engine architecture to become an umbrella for ERP, WMS and TMS to manage supply chain dynamics and unite information extracted to different layers, where using of EDI interface is not enough for exchanging information.

Whereupon, it is valued if WMS can integrate not only with other systems, but also with subordinate and superordinate systems (Hompel & Schmidt 2006, 286, Faber 2015, 26). Sahay & Gupta (2013, 101) recommend checking technical feature of hardware integration compatibility. Other planning subsystems to communicate with in a warehouse are material planning and manufacturing execution systems with advanced planning and scheduling computerized maintenance management systems (Anonymous 2000, 42), account systems
and material handling equipment such as order-picking control systems and automation technologies (Schmidt 2013, 28; Richards 2014, 143-144). For example, to heighten productivity WMS interfaced with automated systems such as voice picking technologies can cut errors to two thirds and late picking by a half, decrease out-of-stock rate to 4%, logistics costs and inventory to 0.5% (Min 2006, 122). Generally, a WMS is interfaced with peripheral devices such as label printers, RFID scanners (Faber et. al. 2002, 384), barcodes readers, forklifts and other handheld terminals (computers and wireless terminals) (Hompel et. al. 2015, 16). Finkel (1996, 18) suggests asking how many barcode and radio frequency places can vendors’ WMS handle. For operation WMS needs Manzini (2011, 9) makes examples of communication systems used to set connections between WMS and information and physical handling systems they are RFID, networks and also voice/based systems, while barcoding, radio frequency and vision systems are automatic identification systems to collect data for WMS. Hompel & Schmidt (2006, 7-9) provide too the list of different systems with what WMS can be integrated. Among not mentioned there is management/execution information systems, merchandise management systems, product resource planning and control and material flow calculators. Moreover, WMS can advance from integration with WCS because the later has focus on controlling automated system machines status (movements management, communication equipment interface etc.) in warehouse not about execution orders in warehouse as WMS does (Son et. al. 2015, 1435, 1438; Son et. al. 2016, 980-981).

Speaking about practical issues, namely, operational suitability of user interface, Hompel & Schmidt (2006, 246-248) highlight to stand assured of the control protocols and access man-machine interface to be in the user's mother tongue or at least at to be in the language native for processes handled in the warehouse. At the same time, Richards (2014, 144) names an accessibility as one of characteristic features of WMS meaning its ability to be accessed easily and remotely via the web, for instance. Sahay & Gupta (2013, 103) denotes that in today’s time of the Internet a software must have web access configuration as a technology feature. With the help of WMS interface, a user can go into inner database and coordinate tasks there (Verwijmeren 2004, 169).

For execution systems working together with WMS a customer should make sure to have a common main database (Sahay & Gupta (2013, 102, Min 2006, 124; Langer 2012, 223) and if a company already uses some database, it is good if a WMS can support it (Hill 1998, W8-
The data model dictating operational behaviour, data operation flows and stock management is in the heart of each WMS (Vaisman & Zimanyi 2014, 52-53). A customer should upload in WMS a master data configured in such way to maintain all warehouse activities (Levans 2002, 24-25). WMS document exchanged and transferred data protocols such as item number, location, quantity and other value-added description (set storage length, age and other related aspects) (Hompel & Schmidt 2006, 53). It is ought to be remarked, that in case of replacing old WMS with new one, it is the inevitable question to make sure that database is supported. The data transfer might take up much of time what should be accounted in data stocks transfer. (Hompel & Schmidt 2006, 285, 286, 301, 307)

It is worth remembering that each WMS has features what suit more to one warehouse type than another (Faber 2015 27, 66; Hompel et. al. 2015, 14). WMS should maintain the capacity of warehouse operation function and processes (Hompel & Schmidt 2006, 286). Also, products characteristics combination stored in warehouse such as quantity, size, weight, size put additional requirements on WMS leading to warehouse complexity. For instance, Muehlbauer (2006, 48) mentions about handling conditions as hold temperature for the pharmacy. All other warehouse characteristics to refer to in WMS installation are mentioned in the earlier chapter.

Literature shows that companies implementing WMS should take into account implementation run time and money investment as crucial ones (Finkel 1996, 2; Min 2006, 124; Ramaa et. al. 2012,17; Sahay & Gupta 2013, 101; Bond 2016, 62). To explain this likewise, Zapata (2012, 97) launches WMS experts study in which cost and set up time scale the most weight as administrative aspects of WMS analytical hierarchy selection. Faber et. al. (2002, 389) and Faber (2015, 22) say that set up of customized and tailor-made WMS takes more time and require more costs.

Initially, Min (2006, 124) credits with creation and stepwise following contingency plan of WMS implementation as a good practice. Hompel et. al. (2015, 17-28) tells that nowadays implementation time period of logistic systems exceeds the usage time of these systems because this system needs to be continuously develop and improved to keep up with requirements and advantages. Richards (2014, 146) characterizes the right time of WMS installation as the one with the quietest time of a warehouse handled operations and as one when the crucial people are on their working places not having holidays. Because usually
the installation of WMS, integration with other logistic system including all testing and adjustments takes several months (Zapata 2012, 96). Hill (1997, W26, W28) insists on continues pre-installation performance testing after system development. According to Hompel & Schmidt (2006, 303) these tests should be done in conditions close to real with full operational load and the continuous operations without interruptions (e.g. several days) to stress WMS maximum setting. Hompel, et. al. (2015, 17) assume that the average WMS software launch time between 12 to 24 months. In Ramaa et. al. (2012, 17) research the average time of WMS implementation is 6 to 12 months. Whilst Hompel & Schmidt (2006, 283) proposes different figures for the average WMS realisation time up to 9 months. As opposed to other authors before, Hill (1997, W22) judges based on companies’ experience in WMS installation that implementation cycle depends on system complexity, consequently, for small system it takes from 3 to 6 months, for medium 1 year and for high complexity software up to 15-30 months. Following, WMS implementation time is connected to its complexity. If a customer is going to have some modifications in standard WMS package, which is not supposed for customization, it might cause some difficulties resulted in more time and money to spent (Min 2006, 118). Faber et. al. (2002, 389) exemplify that realisation of standard WMS is to the utmost 6 months, whilst initiation of tailor made system is longer in time and, consistently, requires more costs.

WMS costs are viewed as a barrier for companies to install this software. WMS vendors “forgot” to inscribe to customers all cost behind WMS installation, which include annual software costs, cost of devices like barcode readers and integration with other systems like ERP and etc. (Friedman 2010, 114). Thereto, Min 2006 (117-118) gives a few pointers on costs consideration in software selection such as the actual price of software installation, maintenance and training costs. WMS implementation can account costs in system running licence (measured in PC user/radio data terminal user, paying per transaction paying on annual or monthly base), in addition, maintenance and trainings costs should be planned, system customization, professional service and integration costs, hardware costs including infrastructure (Zapata 2012, 96). Benefield (1998, 47), Sahay & Gupta (2013, 103) and Richards (2014, 143) adds here system development and update costs. By reference of Hill (1997, W16) to companies adopted WMS, the biggest cost shares coming from WMS installation and services, label application, material handling equipment and terminals, while a bit lower spending from software licence and host interface design. Hompel & Schmidt
consult companies interested in WMS purchase to examine what licence server model and client software costs offered by a WMS vendor. Hompel et. al. (2015, 33-34) says that SMEs prefer to install logistic software on cloud because this option can offer cost saving potential to them. Anonymous (1998, A/6, A/8) tells that a WMS will pay back as the decrease of labour costs.

In addition to guidance for customers installing WMS, Hompel & Schmidt (2006, 283,302) observe two ways of old WMS replacement, the first is a direct substitution of old system with new, the second is running new WMS along with old one. It is worth saying that with the last approach a company can avoid malfunctions. Moreover, in order to guarantee steady flow of materials in a warehouse Richards (2014, 147) instructs to deploy new WMS with execution of current WMS to go without extensive buffer until the new WMS will be stabilized.

Reputation of WMS vendor becomes by no mean important in choice of WMS vendor. It is highly recommended to look at its reputation which comes from its experience of already installed WMSs and industry where it has already worked and installed (Zapata 2012, 96; Richards 2014, 145-146). Hompel & Schmidt (2006, 294) offer a checklist of WMS vendor requirements, in which there are done WMS projects in terms of warehouse automation or manual degree, goods category involved, warehouse type. Benefield (1998) and Hill (1997 W19, W22) encourage companies participated in WMS search to scrutinize not only into a vendor's experience, but into company WMS success factor. Vendor's operations stability description like past installed industries (in the form of feedbacks from its clients) and business operations years should be appreciated there (Min 2006, 117-118). Moreover, software worldwide presence can give creditworthiness Sahay & Gupta (2013, 103).

WMS installation and after sales service is important component in this logistics software implementation. Benefield (1998, 47) as a cogent argument to vendor selection in his research proposes to give attention to training and documentation supplied as well as overall support vendor capabilities. According to Min (2006, 117-118) customer service from a vendor imply installation and training facilitation, plus, guaranty duration. Consequently, attention should be given to WMS vendor service contract and warranty. It is critically to organize trainings for the purpose of introducing to warehouse personnel new WMS system and how to deal with it (Min 2006, 124). Hompel & Schmidt (2006, 302) emphasise advance
timing and the actuality of comprehensive trainings which should be in advance scheduled to ensure that everyone can attend if training is organized work over time or on weekends or if someone gets ill. During testing of WMS, it is possible and necessary to check training digestion (Hill 1998, W26). In the WMS implementation case issued by Bond (2016, 62), he admires that the WMS installed in his company is easy to get started to work with because it takes less than 15 minutes to warehouse personnel to learn it how to use it. Moreover, vendor compulsively should deliver training manuals and handbooks (Hill 1997, W25). Hompel & Schmidt (2006, 299) and Hill (1997, W14) set a requirement of document with machine interface guidance too. In responses of interviewed warehouse managers by Faber et. al. (2002, 389) there is a complain about poor after-sale service, unattainability during help desk opening hours. Richards (2014, 145) sums to seek for WMS provider who supplies not only software alone, but also its installation, maintenance and help desk support service. It is good to look at vendor who offers regular updates and quality checks to its WMS (Richards 2014, 144) and quality international software standards (Zapata 2012, 96). Manzini (2011, 11) refers to system quality which is defined by measurement relevant to customer service. Zapata (2012, 96) considers WMS support as a part of vendor evaluation.
3. EMPIRICAL PART

The empirical part acknowledges the theoretical part evidences in the practice. On top of this empirical deliverables redound to advantage of describing the current gap in knowledge between WMS selection and the 3PL service provider. Principally, based on what customer’s parameters the 3PL can pick a certain WMS. Inasmuch as there is no exploration or touch on the WMS topic in the content of logistic outsourcing operators in covered literature studies in this thesis. This chapter, firstly, provides the case company description and needed WMS models. Afterwards, the research design is observed in more details. All of abovementioned is followed by the analysis of WMS vendors’ interview results and discussion of questions for the 3PL to predefine customer’s WMS following on from its characteristics and their importance from the 3PL point of view.

3.1. Case company description

The case company for this thesis is a Finnish originated 3PL logistics service operator offering customized solutions in managing material, information and capital flows. Its expertise dates back to 1990’s, when the case company provided the quality systems consultation. Whilst, in contrast with the past the current time scope of company’s operations has changes and expanded to provision of own logistics services. During the 25 years, the company has expanded to 25 offices not only in Finland, but also abroad and its personnel account over 650 people. The case company serves customers from diverse industries such as industrial, chemical, e-commerce and healthcare products. The case company service model can be divided into three spheres of consultant services, logistics outsourcing and capital solutions and packages and packing services. The case company provides customers with consultancy in their supply chain development processes such as purchasing, production, warehousing, inspection and packaging. Logistics outsourcing and capital solutions include all activities starting from simple and complex warehousing, workforce leasing and ending with entire outsourcing and procurement logistics to enlarge customers’ assets leverage. With packaging and packing services the case company deploys customized wood and plywood packaging. The case company underlies excellence and quality as its business cornerstones using cutting edge technologies and following top technology trends to keep value added services to its clients. Regarding warehousing logistics, the Finnish 3PL operator runs customers’ warehouses and work with WMS being involved into its installation, customisation and implementation.
Thesis practical purpose is to assist the 3PL case company to determine how to precategories future customers’ needs of WMS and choose a WMS to offer based on these customers’ description offering better service. More precisely after visiting the 3PL operator business sites, it is found out 3 peculiar concerns bases of WMS capabilities needed to manage customer’s operations happening in and around warehouse activities. The current typical business situations are illustrated in figures 3, 4 and 5 where the case company operation area is blue coloured and activities held by other parties are in the gray colour. The first case is named warehouse 1 which is a big warehouse what the 3PL owns and where the 3PL company carries out simultaneously high-volume warehouse activities for multiple clients with different ERP systems, so a WMS system deployed there should be so strong to be able to offer wide range of appropriate processes features as well as to satisfy the scalability of future needs. Contrary, there is the second and the third case of warehouse 2 and warehouse 3 shown in the scheme of the lightweight WMS when a customer holds a warehouse with and the 3PLs runs all operations happening in warehouse as well as WMS there. The two cases are grouped together in the figure 3. The fourth case of warehouse 4 where the case company is engaged in cargo business warehouse which is highly automated and has one ERP system (the figure 4). Warehouse 5 illustrates the last fifth case of a lightweight WMS need, when a 3PL company is only involved into inbound operations coming to a customer’s warehouse such as materials receiving and outbound flows going out a customer’s warehouse such as goods packing. In this way, the case company does not run operations inside the warehouse, but rather operations happening around this customer’s manufacturing operations (the figure 5).

Figure 3. The 1st, 2nd and 3rd business cases.
In sum, all five cases show that the case company should distinguish versions of light and advance WMS solutions to be able to meet current customers’ needs and their business operations scope as well as to satisfy future customers’ ones.

3.2. Research design

The empirical part is also executed with the help of generic benchmarking. In this sense, the author follows generally accepted benchmarking stages in the literature. Even though there are various existing studies interpreting techniques stages in details how to perform benchmarking, it is decided with the case company that developing own model with guidance for conducting the empirical part steers and orient the research more towards the case study needs for this thesis. Followingly, the author comes up with and creates five phases of the benchmarking process adopted from several research method studies (Elmuti & Kathawala 1997, 233-234; Sefertzi 2000, 3; Hart 2003, 32-33; O’Rourke 2012, 10-11). The benchmarking process for this study is performed and illustrated with the figure 6. Essentially, the author focuses on processes from 1 to 3 being responsible for the planning, analysis and integration stages. Since the actual implementation of benchmarking results and
its further monitoring with steps 4 and 5 remain with the case company, however, in order to make it possible and sure these benchmarking finding applicability the author can put forward a plan and ideas.

1) Planning

- Select processes & functions to benchmark in the context of the Finnish 3PL operator
- Identify benchmarking performance variables
- Decide on benchmarked organizations
- Determine data collection methods
- Time planning

2) Analysis

- Acquire the data
- Measure performance
- Compare results to identify gap in performance levels

3) Integration

- Communicate and interpret findings
- Develop and proposing plan for improvements

4) Action

- Execute & implement actions

5) Maturity

- Continuous mitorere
- Recalibrate

Figure 6. Benchmark process steps.

To start with planning as the 1st stage of benchmarking, it is declared previously the aim of conducting WMS vendors interview is to come up with scope characteristics of target customers of each WMS vendor to recognise on what customers groups these vendors focus having the most experience to work with and what are their development efforts in the near future. Consequently, WMS vendors benchmarking helps to reveal strengths and weaknesses of each WMSs by comparing them.

Next, the aspects discussed in theoretical subchapters has provided the author with WMS benchmarking criteria from the literature that a customer as interested in and judge weighting different WMS options for own warehouse. Concisely, the literature findings and insights from the theoretical thesis part contribute to the creation of 40 interview questions as shown in the appendix 4 to address for WMS vendors. In addition, meetings with the case company has helped to consider questions with practical matters not mentioned in the theory part before. These questions are about technical aspects (such as API communication, point-to-points and middleware integration) of WMS integration with other software. Because in the
theoretical thesis part there is no evidence or mention in the got academic literature about 3PLs running a WMS for a customer. Especially, the case company has provided its expertise in logistics for this work to design the interview questions in the way that the literature study materials could be applied efficiently and effectively into the practical context. Thus, on the one hand, the academic literature has given the basis to build the WMS criteria for the framework, on the other hand, the 3PL operator with its long history and field experience has validated that the selected points are good grounds for framework enrichment.

The list of the chosen WMS vendor to interview is given by the case company. Totally, there five vendors and six software products. One vendor provides two WMS solutions. WMS vendors names and their products are masked and dovetail into one another like WMS-A (Vendor-A), WMS-B (Vendor-B), WMS-C and WMS-E (Vendor-CE), WMS-D (Vendor-D), WMS-F (Vendor-F).

As the primary data collection methods for the analysis step of benchmarking, the author organizes phone interview with all vendor representatives. To some of the questions, it is more convenient for WMS vendors to give answers via email, e.g. more detailed description of functions, integrated ERP system names and times. Because these interviews are conducted with WMS vendors representatives coming from projects implementation teams of each software the time period for gathering interview responses accounts 4 months get their answers because due to high workload and involvement of these people in projects. In order to ensure the responsible scientific study and interview data descriptive validity, all interviews with vendors are recorded along with written down observations made by the author. In this way, the author can easily come back into given responses and does not miss out any details at the same time. To obtain the most of vendors responses, the author addresses some questions about WMS technical limitations by converting them into the experience a WMS vendor can tell about regarding its software products. An example of such questions is like not enquiring about the biggest warehouse size where this WMS can work but is requesting about the biggest customer’s warehouse where this WMS is deployed. In order to allocate WMSs differences and performance gaps, all vendors answers are put into the framework with corresponding scores of + and – where these scores depend on the answers of vendors and scores ranges are based on vendors’ answers scope. The next subchapter presents vendors’ responses analysis.
For the further work with the empirical findings interpretation, interview questions are put together to form brought up topics in groups which has become subchapters for the chapter devoted to WMS vendors’ responses analysis. After collecting the answers from interviewees to questions describing their customers, they are analysed and structured by the author in this way applying the benchmarking process discussed in the research methodology. To make the navigation within questions more convenient, there is a map in the appendix 5 presenting questions order numbers together with touched common topics. Precisely, WMS types are discussed because not all interviewed vendors’ warehouse solutions present a standalone WMS. WMS vendor expertise can be reflected in years spent in business, geographical activity spread, focus industries and products operations, customers description. Warehouse characteristics call for current customers’ warehouses dimensions, operations capacity and warehouse automation features. The subchapter devoted to technical characteristics discusses each vendor functions capabilities and other systems operability moment. While the last subchapter amplifies WMS non-technical sensitive deployment considerations like installation types, project management, software set up time period, contract and finance elements.

As a part of results communication, the author suggests various scenarios with designed list of questions when and what WMS the 3PL operator can select based on customer’s characteristics and its current and future business needs. In addition, the Finnish 3PL operator is asked to put rating scales on WMS aspects importance (from the less important 0 to 3 the most important) in the framework to make easy its use and understanding the aspects importance consideration in the 3PL context.

3.3. Analysis of results

The following chapter examines WMS vendors’ responses in the reasonable order for further discussion. There are several rough answers from WMS vendors on interview questions because some WMS vendors mention the exact information as confidential one to be shared only within their clients’ operational environment.

3.3.1. WMS types

Before continuing the further analysis of WMS vendors, it is essential to set record straight and say that WMS-A is not an independent system in own application. What, in turn, means that a customer cannot just install WMS-A separately because it can be installed only as a
component of the ERP Lean System. WMS-A is out of shell solution coming as a standardized module of the ERP Lean system. In brief terms, WMS-A cannot be installed on a customer’s case if this customer has not purchased ERP Lean System built by Vendor-A. Especially, because of this there are two columns in the table of interview results evaluation WMS-A in the context of its implementation. In one column WMS-A is considered as a component module of its ERP Lean System and as a solution for 3PL usage as long as other WMS, for these reasons the last column is completely in the red colour. This visualisation is done to remind a reader that WMS-A is not 100% directly comparable solution to other WMS system options. Thuswise, the ERP Lean System with WMS-A module is assembled by the vendor and a customer only set parameters (do parametrization) to system to work smoothly. Contradictory, only five WMS-B, WMS-C, WMS-D, WMS-E and WMS-F are the real WMSs. WMS-B up till now is a highly tailor-made WMS because every project handling built around customer’s warehouse work. Moreover, WMS-C is offered to customers a standard WMS (with pre-study and implementation) with some degree of customization (such as customized interface to other systems regarding interfaces with other systems ERP, TMS and other automated systems). In the same way, WMS-D is mainly supplied as a standard WMS with some customization. The vendor of Vendor-F underlines the discernible trend of offering more and more out of box WMS in recent years. WMS-F is a standardized platform with some customization like processes modification and qualification, integration and additional features according to a customer’s needs. WMS-E is a WMS, but not a typical WMS because it is a mobile front-end system for smart warehousing and production logistics. To keep it shortly, it is designed for companies which do not need the complete functionality of a WMS.

3.3.2. WMS vendors’ expertise

The WMS vendor years spent in the particular business sphere can already tell a lot about its potential to future customers. Before continuing the further acquaintance with WMS vendors, it is interesting to trace the history of each software company, especially, from what product it has started operations to provide own WMS solution. To give visual imaginary
for a reader, the figure 7 demonstrates each vendors’ original and WMS products. This shift in more details is discussed in the text below.

Figure 7. Vendors' business WMS path.

After the interview respondents, there are two the most experienced vendors in warehouse management functionalities provision systems, namely, Vendor-CE and Vendor-D, 30 and 24 years respectively. Indeed, Vendor-D has firstly developed own ERP system which included a WMS module in it and only after this company decided to launch the separate WMS-D. WMS-C and WMS-E are software products of the same company Vendor-CE. WMS-E replaced an old company product 7 years ago. Vendor-A has offered Lean Systems for roughly 25 years since the beginning of 90s and only 4 years ago it included this WMS-A module in its ERP Lean System provision. Vendor-F started own business growth from developing voice picking solutions, and then only developed own WMS. WMS-A and WMS-F are quite the same in years, 4 and 5 respectively. WMS-B as the youngest WMS
solution among others appeared in last 2 years because initially Vendor-B set up business designing WES.

Giving references to key customers, WMS vendor can demonstrate their WMS successful delivery and scope. For instance, the following can be related to Vendor-CE as the vendor supplying two WMS. WMS-C key reference customers are IKEA, Arla Foods, SCA, REXEL and PostNord what, in turn, can already tell about this WMS system possibilities. WMS-C as a big WMS vendor has customers in 30 countries located around the world, particularly, in Europe, North America, Dubai, Singapore and Australia. While the majority of its customers coming from North and Western Europe. Another WMS of this vendor has smaller sphere of influence, WMS-E serves customers mainly located in Nordic countries and its customer references are Cloetta and Lantmännen. WMS-E has approximately 50 customers in 10 countries. Whereas, Vendor-D clients have been distributed worldwide including Dansk Supermarket, Ferrero, Hilti and Uniliver. Some of the reference customers from Vendor-F are Pelican Rouge Group (coffee company) and PostNord Logistics (postal organization) and Mediq Suomi. On Vendor-A website there are more than 15 references to customers implemented their ERP Lean System solutions among its clients chosen WMS-A module are Sandvik (Tampere and Turku) factories, Murata Electronics, VAK and LKI Käldman.

It is explainable that software vendors who has started business not from a pure WMS product have on their websites the majority of case story regarding another company’s product. Likewise, on Vendor-F website there a lot references to customers using Vendor-F pick by voice technologies rather than deploying WMS-F. For example, some company names given as references during the interview Vendor-F voice picking are Itella Posti, DHL and Intersport Finland Ltd. Besides, not all information about WMS customers is publicly available. Vendor-F has customers mainly in the North Europe Scandinavian area (Finland, Sweden, Denmark), Russia and some in Baltic countries (Estonia, Latvia, Lithuania). Up till now Vendor-B with its WMS serves only Polish SMEs and has only 4 WMS deployment such as Amex, Polango, tezeusz. In addition, there are 2 installations of WMS-B coming soon. The same cannot be said about its WES customers accounting above 20 companies in Poland.
Moreover, the industry where a customer operate can influence the choice of the certain WMS vendor previously worked in a warehouse with same activities held. Regarding the industry, the two most experienced WMS vendors again are Vendor-CE with WMS-C and Vendor-D working in every industry from predefined answers. Noticeably, Vendor-D investigates in-depth industry-specific processes functions, at a time when Vendor-CE in WMS-C places a greater focus on development of e-commerce and 3PLs functions needs. Other WMS vendors orient on a lesser number of industries. WMS-E customers belong to manufacturing industries, such as paper and pulp, wood and furniture, automotive parts, food and beverages. Vendor-B installs its WMS projects in spheres of office stationary supply, bookstore e-commerce and frozen food distribution. There are more about kitchenware shop e-commerce, stainless steel metal parts distribution in progress. Vendor-A has its WMS customers in machines, metal technology and some food industries. Vendor-F WMS prevalently carries out warehouses activity in grocery industries such as food and beverages (the most experienced are for this WMS), besides, others are automotive parts, electronic equipment and pharmacy.

![Figure 8. Interrelation of WMS vendors software provision years and operating industry numbers.](image)

Figure 8. Interrelation of WMS vendors software provision years and operating industry numbers. Industries: automotive, aviation, food, beverages, non-food consumer goods, healthcare & pharmacy, chemical, manufacturing products and electronics equipment.

With regards to previous information given by vendors of their years devoted to WMS development and operating industries, the figure 8 presents graphically that with increasing WMS operating years the variety of industries served increased as well. This trend is
common for all WMS vendors, however, the vendor of WMS-B conducts operations in bigger industry range in spite of its WMS recent development.

The industries of different WMS are tightly connected with SKUs characteristics a WMS customer can store using this system. Neither of interviewed WMS vendors has any special limitations concerning SKUs technical restrictions. All six WMS-A, WMS-B, WMS-C, WMS-D, WMS-E and WMS-F can work in warehouses with different temperature, with SKUs which has temperature requirement and the best before (expiry) date. However, the most of WMS-A customers do not need these features. Based on huge installation experience WMS-C can handle different kind of SKU’s, e.g. mixed and large amounts pallets which should be picked or broken into smaller parts, it can multiple articles into one piece or to one article when goods are in the shipping area. WMS-C allows to create new articles for warehouse goods, while WMS-E can add some products require extra adaptation.

WMS-E presently does not have any operations with fashion and cosmetics goods, but with other SKUs categories it has worked. Vendor-B has not carried any pharmaceutical goods as well as some dangerous flammable goods so far because WMS-B requires some additional certificates for such SKUs. WMS-A points also the need of such certificates. Even though Vendor-F can deal with some medical products, it should get FDA (Food and Drug Administration) approval for stronger medic supplies. Vendor-F says that the software can manage flammable and hazardous materials, but restrictions apply more for specific hardware like handheld devices and computers. Whereas in contrast, Vendor-D underlines its WMS-D abilities in handling of hazardous substance and dangerous goods and integrate with environmental health and safety SKUs characteristics. WMS-C can administer dangerous goods as well.

Systems vendors design their WMS to suits processes taken place in warehouses. Generally, all six WMSs can support both production and distributional warehouses operations, despite previously mentioned the extent to which these WMS vendors designate their system to deal with various kinds of warehouses differs. The table 6 displays in what various types of customers’ warehouse different WMS solutions are used in. Initially, WMS vendors are asked in what type of warehouse they specialize, in accordance with their response WMS are given more pluses for target customers’ warehouses. Operating warehouses can already tell about WMS experience corresponding to customers’ environment.
Table 6. Operational warehouses types.

<table>
<thead>
<tr>
<th>Warehouse type:</th>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WMS-A</td>
<td>WMS-B</td>
</tr>
<tr>
<td>production</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>distribution</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• Raw materials &amp; finished goods</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• Sort centres</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Fulfilment warehouses for e-commerce</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Cross-docking</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Transshipment break-bulk centers</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• Consolidation warehouses</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

For example, WMS-A mainly specialises on production warehouses, like factories, companies who have production and need to get the right product on the right place at right time compared to distributional warehouses because this system cannot take on the high-volume goods. Nevertheless, WMS-A can assist in a couple of warehouses involved into distribution activities such as consolidation and break-bulk centres. The opposite story is with WMS-B which is constructed primary for distributional warehouses. WMS-B can be run in all distribution warehouses subtypes. Currently it does not have any sorting centres warehouses because of the company’s vision not to expand business there. However, there is still one WMS-B customer (Amex) which uses simple production on its warehouse premise like packaging. Also, Vendor-F key activities lie in distributional rather than production warehouses, only the last it has about prefabricated components for production. It has operations in all distributional warehouses types, except sorting and transhipment centres. WMS-C as one of the most powerful WMSs analysed in this research can be installed in both production and distributional warehouses. According to this WMS vendor history records, 5 years ago it concentrated only on distribution warehouses and then applied a distributional warehouse module for production warehouses like supplying raw material to production lines. From then onward, Vendor-CE started its WMS-C development of distributional warehouses as its target customers and now WMS-C covers all of customers’
warehouses types. The similar situation is with Vendor-D which started offering own WMS-D for shippers to control warehouse distributional centres and expanded to production warehouses functions. Vendor-CE typical customers of WMS-E are middle-sized producing companies receiving raw material and sending finished goods both to distribution centres and directly to customers. Also, it has some storage warehouses with maintenance equipment like tools, maintenance and lubricant liquids and measurement equipment. In addition, WMS-E customers do not use this WMS for sorting and e-commerce goods warehouse. WMS-E does not have customers with pure transhipment break-bulk centres operations, but its customers do this as part of their production, namely, send goods straightway to another manufacturer to add on its products range. There is a good moment to keep into mind that all WMS-A, WMS-B, WMS-C, WMS-D, WMS-E and WMS-F supervise as a common practice of 3PLs running customer’s warehouse using these vendors WMS, but so far from six only WMS-A, WMS-C, WMS-D and WMS-F have worked with 3PLs. Yet, only vendors of WMS-C, WMS-D and WMS-F consider 3PLs as its target customer types and now concentrates on developing this segment. According to vendor of WMS-C response amount of 3PL customers purchased WMS has increased by 30-40% in recent years.

All WMS support multiple warehouses, however, WMS-B can coordinate and support picking from one or another warehouse, but does not have a possibility for balancing stock at the same time. So, nothing can be said about it is ability to control warehouses in several countries, because it has no experience up till now concentrating on SMEs. WMS-A is designed for production warehouses with supported stock transactions, storing of raw materials within one warehouse or different number of warehouses to send raw materials to production in warehouse sites areas and even picking queues there. Vendor-CE, Vendor-D and Vendor-F have customers with coordinated operations in warehouses in several countries running with their WMS. WMS-C system does not have any limitations there, only the coordination depends on complexity of warehouse and its size, capacity of server and network. This vendor gives as an example, a customer who has two warehouses: one in Sweden and one in Poland operating from the same sale systems, then has one server and one system, so that they can use it for different divisions.
3.3.3. WMS customer’s warehouse characteristics

Asking different WMS vendors about their customers’ actual warehouses physical parameters can help to determine the right WMS selection. The figure 9 illustrates their current customers’ warehouses sizes. This information gives understanding of the scope customers and the ability of WMS to run different warehouses sizes.

<table>
<thead>
<tr>
<th>WMS</th>
<th>Operating customers’ warehouses surface in m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>120 - 50,000</td>
</tr>
<tr>
<td>F</td>
<td>5,000 - 70,000</td>
</tr>
<tr>
<td>D</td>
<td>2,000 - 400,000</td>
</tr>
<tr>
<td>C</td>
<td>5,000 - 375,000</td>
</tr>
<tr>
<td>B</td>
<td>≤5,000</td>
</tr>
</tbody>
</table>

Figure 9. WMS vendors customers' warehouses.

With WMS-A a customer’s warehouse size is not taken into account by the system because it has not met any limitation but they are more about goods volume level, this vendor has not given any exact figures to be put into the figure above. However, Vendor-A representative pinpoints that WMS-A could be useful for small warehouses because the main value of this system is in its mobility. The same is for WMS-E since it does not depend on warehouse size. Yet, WMS-E has data for its smallest and largest customer’s warehouses which are 120 m² and 50,000 m² respectively. WMS-B serves small warehouses up to 5,000 m², what can be explained with its main focus on SMEs. Whereas, WMS-F serves customers having no less than 5,000 m² and up to 70,000 m². WMS-C nowadays as distinct from previous having a huge customers range operates in warehouses from 5,000 to 375,000 m². However, the figure above does not mean that WMS-C cannot run due to technical software limitations warehouses lesser than 5,000 m², but in the most cases customers apply this WMS in large warehouses. WMS-D has huge range of customers applied this software, for instance, the smaller warehouse is 2,000 m², while the biggest is approximately 400,000 m².

A customer’s warehouse layout does not matter for deploying all vendors’ WMSs. WMS-A does not need to have any warehouse visualisation, only stock location like A, B, C put into the system is enough for performing picking process in a warehouse. The WMS vendor of WMS-C tries to find a solution for existing customer’s warehouse layout, but in case if layout
is not effective, this vendor proposes new one for customers. This vendor states that it is not that much convenient when a customer has different size of place locations in racks because it is not so quick to set in the software optimal SKUs locations. In WMS-B case a warehouse layout influences the WMS solution because for every distant location in the system the system should assign the importance order which is useful for creating a picking list where to go first. All vendors tell that nowadays customers have standard rectangular warehouses are

Another a customer’s warehouse characteristic to refer to is the number of order lines shipped per day represented in the figure 10. WMS-A states that it can handle only low or middle volume goods up to 1,000 daily order lines because the system is not engineered as a real WMS. WMS-E is quite equal to this parameter of customers from 1 to 800 order lines performed on daily basis. The smallest and biggest amount of order lines processed per day WMS-B manages is 200 and 2,000 respectively. Customers applying WMS-F perform more order lines per day rather than customers using WMS-A and WMS-B, namely, from 2,000 to 50,000. WMS-C operates with bigger range of 600 to 200,000 order lines per day. WMS-D outperforming other WMSs providers has customers with warehouses from 1,000 to 250,000 order lines.

<table>
<thead>
<tr>
<th>WMS</th>
<th>Shipped order lines per day in customers’ warehouses</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMS-E</td>
<td>1 - 800</td>
</tr>
<tr>
<td>WMS-F</td>
<td>2,000 - 50,000</td>
</tr>
<tr>
<td>WMS-A</td>
<td>≤1,000</td>
</tr>
<tr>
<td>WMS-D</td>
<td>1,000 - 250,000</td>
</tr>
<tr>
<td>WMS-C</td>
<td>600 - 200,000</td>
</tr>
<tr>
<td>WMS-B</td>
<td>200 - 2,000</td>
</tr>
</tbody>
</table>

Figure 10. WMS vendor experience in shipped order lines per day in customers’ warehouses.

It is fair to look at the amount of warehouse personnel in a customer’s warehouse too where a WMS is set. In the case of ERP Lean System together with WMS-A customers operate their warehouses with a small number of warehouse workers approximately from 2 to 10. WMS-B for now has developed its WMS solution for warehouses from 5 up to 50 operators.
Compared to the previous WMS, WMS-E can demonstrate experience working from 2 to 200 warehouse personnel in its customers’ warehouses. While WMS-C has the depth of experience working with 2 staff in a small customer’s warehouses and with 750 operators in another large customer’s warehouse working in the same shift and at same time. WMS-F and WMS-D have been implemented in small warehouses of 10 users, but the largest amount of users working at the same shift differs for the first one is 120, while for the second one it is up till 900 users. For visual clarity, the figure 11 illustrates findings.

![Figure 11](image-url)

Figure 11. Number of warehouse operators in WMS vendor customers' warehouses.

Herewith, even though these two software vendors are one of the most powerful in own software markets, it does not mean that they are able to work only with large customers and only with their specific industries function requirements. Alternatively, looking at customers’ warehouses characteristics installed WMS-D and WMS-C such as a warehouse size, personnel number and shipped order lines per day these vendors cover all groups of customers, namely, in small, medium and large sizes. WMS-D has a bit more advantage there over WMS-C being implemented in larger warehouses with higher production characteristics and more employees. All vendors have experience in working with different types of layout, however, their preferred option of a warehouse to have a traditional rectangle layout with parallel aisles between shelf racks what is common nowadays.
Table 7. Warehouse manual and automation characteristics of each WMS vendor.

<table>
<thead>
<tr>
<th>SKUs information exchange:</th>
<th>WMS Solutions for 3PL</th>
<th>Automation integration in warehouse:</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMS-A</td>
<td>WMS-B</td>
<td>WMS-C</td>
</tr>
<tr>
<td>RFID</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Bar Coding</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Printers</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Automatic scales</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Horizontal/ vertical carousels</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>A-frame dispensers</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Robotics</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pick-to-light</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Put-to-light</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pick-by-voice</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Virtual display-directed picking</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

All vendors’ WMS can be installed in warehouses previously with full manual operations. Nevertheless, WMS-B has not been installed so far in any warehouses with lots of automation except automated scales and printers, what is different for other WMS systems which work not only with previous mentioned but with even more. WMS-E additionally works with pick-to-voice technologies. WMS-A has integrated previously not only with basic automation such as labels printing support and scale integration in customers’ specific solution, but also with horizontal Cardex carousels. WMS-F has integrated not only with vertical/horizontal carousels, but also one with automated forklift robot racks. However, WMS-F has not done any integration with picking robots, because for this WMS the core functionality relies on people doing the work. Furthermore, this software vendor actually competes with pick to light systems considering pick by voice to be more effective. One trend this company shows an interest in is the augmented reality technology. WMS-F vendor evaluates current market hardware as poor and not mature enough to provide all required functions so some laboratory inner company testing is conducted to make a ready production technology. That is the reason why the cell responding for virtual display automation is in yellow colour. WMS-C and WMS-D have been in lots of integration with warehouse automation types referred in the table 7. All WMS system support information exchange via RFID and barcoding.
3.3.4. WMS technical criteria

The most important issue why companies turn to using a WMS is revealing its advantages of using WMS functions. Interviewed WMS vendors offer different WMS scale possibilities. Initiating the discussion about WMS general functions, WMS vendors is asked to split 20 points among 6 processes in warehouse to see where the certain WMS is most powerful in. From the figure 12 it can be emphasized that WMS-A is purely aimed at inventory management in a warehouse, while WMS-B, WMS-C and WMS-D has expanded their influence to be able to handle more activities associated with warehouse management. The interesting pattern can be observed with WMS-F who points more the process of picking bring more value to customer. This is not a surprise referring back to company history as it started with voice picking technologies. Nowadays, WMS-F is sold together with the module of voice picking. There is no fixed answer with points distribution in the WMS-E case because the system strength lies in the ability of the system to tune processes according to a customer’s requirements. For one customer a key process is supply of materials to run smooth production and for another customer - a reversed pick distribution orders which does not optimize the actual picking route, but eliminates deviation reporting when loading a truck.

Figure 12. WMS vendors's 20 points distribution in terms of their software strength.
Starting from less to more powerful vendors in terms of WMS functions, it can be said that WMS-A along with normal ERP functionalities fulfils all warehouse basic supporting activities. It includes simplified functions to manage inventory in the simplest way, namely, SKUs counting, reconciliation and replenishment and to pick and ship warehouse goods. The main strength of this system is in its mobility allowing a warehouse worker to use configurable mobile user interface to get a parcel, mark and send it to another track. So, this WMS does not support sequential picking and routes optimization. Specifically, if a warehouse operator has a picking list with a number of goods in mixed locations order, it is up to a worker to decide in what sequence to assemble order relying on own knowledge about SKUs location. Furthermore, WMS-A cannot assist in time efficient task interleaving and notify about pulling down goods in warehouse in advance. In WMS-A a customer can enter parameters how the system will work and, hence, do the allocation of goods manually. Additionally, WMS-A supports 3PL billing like in the case of warehouse 2 like the 3PL is paid for working hours, which are invoiced. WMS-A is not designed to handle as many parcels in a minute as possible, it is better for this system to store components and final goods and to send for production. No WMS-A customers do checking before goods shipments, because neither of current customers require this, nor the system does not have this function because it aims at more simple activities for warehouse management. Basic modules supported by WMS-E are quite the same as WMS-A has, however, it poses more in system administration and inventory management. However, WMS-E can be installed in different modules functions: basic, advanced and extended (appendix 6). And here it exceeds WMS-A because of different options in stocks moving, reclassifications of SKUs. According to the interviewee’s words about WMS-E, its foremost advantage is in its ability to design WMS processes according to customer’s requirements. For instance, a quality function is not mention in the WMS-E functions in the appendix 6, but an ERP’s quality module or other external quality system can be integrated in WMS-E system can be integrated in WMS-E system to meet customer’s needs. In WMS-A there are also quality modules for labour management, capacity planning tools.

In the case of WMS-B functions, unfortunately, the description of WMS functions is not translated into the English language during the research times. In order to solve this issue, the table from the thesis theoretical part of WMS functions is sent to vendor for answering. This list is in the appendix 7. WMS-B has not yet developed 3PL billing due to the fact that
it has not operated with 3PLs yet. In contract with previous, WMS-B can do cross docking and now develop partial crossdocking of joining cross docking and part order picking in picking zones. WMS-B has two stages check when an order is assembled by one person and checked by another before dispatching. Also, compared to abovementioned, it has not been adopted in automated warehouses with machines picking technologies. Analogically to WMS-B approach, WMS-F vendor marks in the similar table of functions what of them the software possesses. The table can be seen in the appendix 8. WMS-F offers more advanced functioned compared to WMS-A, and it support more automation tools in warehouse unlike WMS-A and WMS-B. What makes WMS-F equal with WMS-E. Neither WMS-A, WMS-B, WMS-F and WMS-E support dock and yard management.

The rest two WMSs of WMS-C and WMS-D significantly outdo their preceding WMS in managing warehouse processes. The first one includes more functions of capacity and resources planning, tasks interleaving, order picking strategies alignment, tracking, performance monitoring, transport management and even more. Functions are also divided among basic, advanced and extended, the separate module support automation processes in warehouse. WMS-D can do more in goods tracing and tracking, quality control and documentation planning. Comparing the list of functions from two WMS (appendixes 9 and 10 respectively) it can be said that WMS-D addresses more comprehensively functions among warehouses processes, what can be explained with its huge operating years in business, wide customers scope and detailed industries requirements development. Both WMS-C and WMS-D can deal with returning goods because of being engaged in running e-commerce warehouses. Quality control modules can be added into WMS-C. Especially, WMS-C can set the way how to deal with damage goods like sent back to supplier or receive and put in quality area. In WMS-D it is possible to designate in the system quality checks of a certain supplier or put in compulsory checking or a supplier or every 10th or 15th pallet arrived from it.

Commonly all interviewed WMS vendor’s software are built in and can be run in Microsoft SQL database. However, more database-friendly WMS is WMS-D supporting all 5 databases in the table 8. WMS-B main database is MS SQL while the additional database for configuration purposes is PostgreSQL. WMS-F has a software layer that separates their software logic from database one, so it is database undependable with the ability to be installed in any database customer likes, but recommended is PostgreSQL. Currently, it does
not have any customers using any DB2 database. Not a single WMS vendor expresses any difficulty of own software to transfer data from other database if a customer changes one WMS to another. For example, WMS-B cannot use ORACLE as a database engine but it can take easily data out from it. WMS-C has a couple of tools to migrate data and it can export data from the old database system into excel or some kind of a text file and easily import into new supported database which for this WMS are ORACLE and Microsoft SQL. In WMS-A case the old database can be kept as info warehouse for a customer, but it is not usual practice.

Table 8. WMS supported databases.

<table>
<thead>
<tr>
<th>Database:</th>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WMS-A</td>
<td>WMS-B</td>
</tr>
<tr>
<td>• Microsoft SQL</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Postgre SQL</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• ORACLE</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• DB2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• SAP HANA</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Generally speaking, WMS vendors claim their software compatibility and operability with the following logistic execution systems shown in the table 9.

Table 9. Possibility to integrate WMS vendor software with other logistics execution systems.

<table>
<thead>
<tr>
<th>Integration with logistic execution systems:</th>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WMS-A</td>
<td>WMS-B</td>
</tr>
<tr>
<td>• ERP</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• TMS</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• WCS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• WES</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• CRM</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• Courier system</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

75
The most developed systems in this context are WMS-C and WMS-D with its ability to communicate with all mentioned logistic execution systems. For instance, WMS-C can communicate with this company own WCS and with other suppliers’ one. WMS-E has as well experience in integration nearly with all systems, except a courier system. WMS-B has lesser experience there, but still more than WMS-A. WMS-B WES is the part of its WMS. Also, WMS-B has integrated with courier shipment systems, but not with TMS. The strong point of WMS-F system that it can easy integrate with multiple logistic execution systems. Also, it can integrate to customer’s reporting, invoicing, automation systems, payroll, use courier system brokers.

Table 10. WMS and integrated ERP systems.

<table>
<thead>
<tr>
<th>Ability to integrate with several ERP systems of a customer</th>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to integrate with several ERP systems of a customer</td>
<td>WMS-A</td>
<td>WMS-B</td>
</tr>
<tr>
<td>Ability to integrate with several ERP systems of a customer</td>
<td>WMS-A</td>
<td>WMS-B</td>
</tr>
</tbody>
</table>

The name of ERP systems with which vendors has completed integration are presented above in the table 10. It is challenging for some WMS vendors to give the exact number of ERP systems so they provide with rough one. The number of times each WMS has integrated with ERP is displayed on the figure 13. All WMS can be integrated with several ERP systems of a customer, however, only WMS-C, WMS-D, WMS-E and WMS-F have experience in doing so. WMS-E also supports multiple nodes of integration, for instance, it can interface at the same time with an ERP and a quality control system. Currently there is not so many WMS-A users using some other ERP system than this Vendor-A ERP Lean System, whereas this system has integrated with various other logistics execution systems. However, Vendor-A has several customers who has deployed not only this vendor ERP Lean system together
with WMS-A, but also SAP ERP performing financial tasks, while WMS-A is responsible for performing warehouse tasks. WMS-C and WMS-D are the most practiced in own software interface with different ERP systems, however, it is hard for these WMS vendor representatives to say the exact number. WMS-C says that the number of integration exceeds 50, while for WMS-D there is no exact records only the approximate number from this vendor. So, it can be assumed that the number of times this vendor WMS has been integrated with ERP systems and somehow equals to WMS-C since these two software products are quite powerful in terms of functions and popular among companies and have geographically spread WMS customers. Without any doubts WMS-D has been integrated with the most well-known ERP systems. WMS-B has been integrated with the most popular ERP systems in Poland and with some big ERP providers and Vendor-B does not limit the ability of its software to support multiple ERP systems integration. According to Vendor-B, WMS-B integration with ERPs is different every time because difficulty is not in problem is not in technology but in deciding what information and how to send it to ERP. WMS-F has 25-35 different ERP system it manages to connect to. Practically, ERP sends orders which appeal in WMS-F as warehouse tasks. WMS-F tries to keep itself ERP neutral so it can be integrated into everything a customer has. There a lot of WMS-F customers using SAP ERP in Finland, while in Sweden its customers prefer local ERP systems. This could explain the high number of different supported ERP systems. All WMS vendors has done integration with SAP ERP as one of the most popular.

![Times WMS integrated with ERP system(s)](image)

Figure 13. Each WMS integration times with ERP systems.
Concerning interface of ERP systems both WMS-A and WMS-C use XML standard interface language for transactions (for WMS-A it is called LeanWML), whereas WMS-D, WMS-C, WMS-E and WMS-F can transfer messages into ERP both as XML and EDI formats. In WMS-B case a customer cannot use by himself any given API in the table 11. In every case WMS-B took part integration requirement set by customer were so demanding that interface was built by this vendor since a customer did not want to take any responsibility there. WMS-E works otherwise around since offers an in-house built integration API which this vendor uses to integrate with the major ERP systems. Quite the same situation is with WMS-F which has standard interface that can be used to provide a customer with integration. However, it depends on the case, because WMS-F can be also adapted for a customer system. WMS-F can support both XML and EDI, but the last one according to vendor is not so much popular at least in Finland. WMS-E uses Streamserve as a middle ware, for instance. WMS-C, WMS-D and WMS-A have both customers with point-to-point interface and with middle ware. In case of WMS-A as a module of ERP lean system am Enterprise Application Integration such as Unifaun middle ware technology is used, moreover, depending on a customer’s situation point-to-point can be applied. In WMS-C case their quantity of customers applying point-to-point integration spread like 70 to 30 percent respectively. However, the opposite trend is with customers’ size, large companies prefer to use middle ware and small – point-to-point integration. WMS-D states that building a middleware for the 3rd party integration is more common because the share of customers utilizing point-to point integration is decreasing with years. WMS-B does not use neither point-to-point, nor middleware for ERP integration because they are too expensive for its target customers. WMS-F offers a middleware called ESB built into its WMS solution which is a flexible integration platform used to integrate into one or several systems with high integration logic.
Table 11. WMS and ERP integration issues.

<table>
<thead>
<tr>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMS-A</td>
<td>WMS-B</td>
</tr>
<tr>
<td>XML</td>
<td>+</td>
</tr>
<tr>
<td>EDI</td>
<td>-</td>
</tr>
</tbody>
</table>

The way of ERP integration with WMS:

- **XML**: Supported (+) or not supported (-)
- **EDI**: Supported (+) or not supported (-)
- **point-to-point**: Supported (+) or not supported (-)
- **middleware**: Supported (+) or not supported (-)

In terms of user interface shown, WMS-A is design is the web portal solution for warehouse operators to assess out of office. In the way that this system streamlines picking processes moving away from paper to tablets usage. WMS-A, WMS-C, WMS-D and WMS-E and WMS-F can work both on Windows and Android devices, while WMS-B can be run on Windows CE and normal windows operational devices only. Vendor-B can build a communication layer for devices with some components from other party, design and implementation from itself. Concerning warehouse workers operational systems interface, WMS-F main focus now is on Android rather than Windows which is not so commonly used today but it can be run on both. There is neither support, nor customers’ demand for iOSs. WMS-F also can work with forklift PCs such as industrial standardized computers based on Windows.

WMS-D can work together with nearly all devices mentioned in the table 12, plus, it can be accessed via web browsers such as Google Chrome, Safari, Firefox and Microsoft Explorer. While WMS-B interface is not web based, so mobile devices use native application. WMS-C uses Aix or Windows server side operating system for its implementation. Currently this WMS does not provide web based interface, but consider this in the next software release in March. For another WMS of this vendor, Web based interface of WMS-E is under the development Since Vendor-CE already has announced its web interface for the next WMS-C release, so, probably, WMS-E will soon have it too as another software product of the same vendor. WMS-F has also a web based user interface which warehouse supervisor managers can use. If a warehouse worker fulfils voice based operations with picking by voice, voice based interface can be used in WMS-F and WMS-E. All six WMSs provide reporting platforms with KPIs and dashboards for a quick look and processes visualization,
however, the extent to which it is comprehensive and detailed in terms of different results varies for different WMS.

Table 12. WMS user interface issues.

<table>
<thead>
<tr>
<th></th>
<th>WMS-1</th>
<th>WMS-2</th>
<th>WMS-3</th>
<th>WMS-4</th>
<th>WMS-5</th>
<th>WMS-6</th>
<th>WMS-7</th>
<th>WMS-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web based user interface</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>KPIs and dashboard visualisation</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Operational systems native device applications:

- Android: + - - + + + +
- Windows: + - + + + + +
- iOS: - - - - - - -

WMS system should communicate in the same language or language familiar to warehouse operators. Followingly, the table 13 present languages of operations in interviewed vendors’ WMS interfaces. Only English, Finnish, Polish and German languages are given pluses because they bring value for the case company from its operational business point of view.

In case if there are more languages offered by a WMS, they are marked just with green colour.

Table 13. WMS user interface languages.

<table>
<thead>
<tr>
<th></th>
<th>WMS-1</th>
<th>WMS-2</th>
<th>WMS-3</th>
<th>WMS-4</th>
<th>WMS-5</th>
<th>WMS-6</th>
<th>WMS-7</th>
<th>WMS-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>User interface language available:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Finnish</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• Swedish</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• English</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• Polish</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Danish</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Dutch</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• German</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Norwegian</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Interface language translation tool</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
The richest software in terms of the language interface range is WMS-D supporting 30 languages, more comprehensive list is in the appendix 11. WMS-C has 9 languages which customer can use and considered to add even more in the future such as some customers want to have French, Italian, Spanish. WMS-A has available Finnish, Swedish and English for all functionalities as basic languages. The least system adapted interface belongs to WMS-B having only 2 languages available. In WMS-E English is set as default language. Both WMS-A and WMS-E have an embedded language tool for translation which a customer can do. In WMS-F case there are only three languages available but its customer can also translate the system in any language basically uploading a file into the system with translation.

3.3.5. WMS sensitive deployment issues

All WMS of interviewed vendors can be installed as a standalone system what means a software is hosted, installed and maintained on a customer’s premise. Technically, two other installing options of SaaS and in Cloud possible for WMS-E, but they do not go as a current package offer. While in some cases WMS-A customer outsources server to some other server company which runs a server from its premises, so this WMS vendor can install the system on the Cloud of another company. WMS-A is currently developing SaaS option installation that is why it is in yellow colour in the table 14. WMS-C can be provided in two previously mentioned options and SaaS installation too in sales contracts. Initially, WMS-C vendor offered for its software only cloud option and it was quite hard to convince its customers to use those, but now it has expanded installation modules. Currently there are its 4-6 WMS-C customers who use cloud computing and who can easily switch to own servers in case if they want to. There are a lot of installation of WMS-C as a standalone server on the customers’ sites, only problem pointed out is if a customer does not have a backup in some other place rather than on own premise because if everything goes down or fails, a customer is not able to run after immediately and continue warehouse operations. This is more about infrastructure and how to handle problems what is more in customer side rather than in WMS-C vendor’s. Shortly, in order to avoid difficulties WMS associated with a change over from one server to another, WMS should be carefully designed and implemented. Among WMS-F customers popular options are installation on either a customer’s premise or on cloud, while the majority of clients and new deployments go to the cloud. This vendor can
also provide SaaS, but it is not feasible package and the system is not designed for multi tenants holding. WMS-D approaches all three installation options.

Table 14. WMS installation.

<table>
<thead>
<tr>
<th>Software installation:</th>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>• As Standalone system</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• As SaaS</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• As Cloud Computing</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Touching the subject of WMS project implementation, WMS-B vendor starts with implementation and deployment consultancy with optimising a customer’s warehouses processes and logistic flows. The vendor can advise a customer to rearrange warehouse like moving racks, using another storage system and changing some processes to pursue efficiency. Afterwards, WMS customization is done. So, the system is adjusted to a customer’s warehouse not another way around like bringing the system and a customer should work with it. Managing a project of WMS-F looks similar to a certain degree, this vendor, firstly, organizes warehouse work through visits to observe a customer’s warehouse operations. Then a couple of workshops with software specialists and customer people to go into and through step by step all sites processes and trainings before WMS goes live. Taking into account of WMS-A supplied as a standard solution, the vendor is not so much involved into project management except initial acquaintance with processes in warehouse, educating a customer to enter parameters into the system, while exact process instructions (the way of use) is usually written by customers key users. WMS-C vendor provides customers with comprehensive project management. Specifically, its sale department investigates what are request for quotations from a customer manage its warehouse requirements and conducts a pre-sale study. When a project is ordered by a customer, the operational department takes the wheel developing a scope of WMS, then project planning begins with appointing a key account manager who plans project details, further meeting discussions with a customer and provision of functionalities description solutions. Before launching WMS-C project is
presented for a customer for approval. All WMS vendors are involved into trainings of end users delivering all trainings and handbooks to a customer, testing on a customer premise and after sales support. Also, this vendor unlike other WMS vendors tells that in this WMS-C project management the installation team present into a customer’s site when WMS goes live. In addition, it has the term train to trainer what means that training is usually not given to end users, but to key users or project members from a customer side. For WMS-E as well as for WMS-C the vendor usually starts with a pre-study design and then follow its project model for implementation. However, WMS-E project management depends in integration not only on its customer, but also on its other software suppliers, for example ERP vendor. WMS-F also have the installation support from the vendor. About WMS-D project handling, it can be said that it is proceeded from developing requirement and checklist for a customer followed kick off workshop before deploying.

As a part of after sales service WMS-A and WMS-B vendors both provide upgrades once a year, before a new version release companies do always new system checks. Likewise, WMS-F has one major upgrade per year, also WMS upgrades can be installed in customer’s maintenance windows in case if, for instance, a customer has a standard project with no customization. What is different for WMS-C and WMS-E coming as new releases 2 times in a year and it is recommended to their customers to upgrade every 2nd year. This vendor can also collect all updates and install them in maintenance windows in customers’ premises as well. About warranty, WMS-A as a module of ERP Lean system goes with 6 months of warranty, maintenance service after warranty ends is agreed when a contract with a customer is made. In the case of WMS-C and WMS-E every customer contract is signed for 1 year for license and support. For WMS-B the warranty period is 12 months too. For customers of WMS-C and WMS-D a customer can decide upon the warranty period since there are different options available in systems installation agreements,

For WMS-C the average implementation time varies from 3 to 9 months. The quickest set up time is 3 months (from pre-study before the Christmas to end live in the middle March), the longest is 1.5 year with lots of integration with SAP ERP and specific customer’s demands. Coming to WMS-D, there is the rapid development solution from this vendor to set the system in 5 weeks, while the total set up time can be up to 1.5 year as well. In WMS-B case the fastest deployment is in 6 weeks, meanwhile, the longest is 6 months. WMS-A (together with ERP Lean System) can be implemented with the strict schedule in 3 or 4
months. Usually, its average realisation period is from a half of year to 1 year. The complexity of working with large clients can explain the long time needed for WMS-C implementation. The shortest WMS-F implementation is 2 months and the longest from the project start to go life is a 1 year. For this vendor the progress of implementation depends on customer’s overall needs and specific features and functionalities development. WMS-E has the fastest implementation experience accounting 4 days and for the longest there is no some fixed number. This is explained by continuous calendar development in several years. In addition, WMS-E notes that its customers always modify and develop the system with their business needs. In order to align WMS-E with other WMSs its longest time of implementation is set to 1,5 year. For convenience, the figure 14 compares setting WMS time in same dimensions of interviewed vendors taking into account their fasters and longest deployments in a customer’s case.

![WMS set up time range in months from the shortest to longest](image)

Figure 14. Time for WMS implementation for vendor’s customers.

Required WMS implementation time depends whether there will be needed to interface with a customer’s ERP. In some cases, this also can put some constraints on integration time requirements. Unfortunately, nothing can be said about WMS-A because it has not so much other ERP integration experience, except the ERP Lean System it is installed together with, so rough figure is given by this vendor. For WMS-B integration takes 3 months so nearly a half of the WMS implementation time contingent upon information volume. While for WMS-C the average integration time varies from 2 weeks to 2,5 months depending on two factors, how experienced a customer’s ERP provider of doing interface and something has to be changed in systems transactions. For WMS-F vendor integration time with ERP is one
of the key elements in delivering project solution. If it is a standard integration between WMS and ERP so modification should be done only on the customer’s ERP side 2 weeks are needed, but in case of full interface creation and customization, it is 5 months. Relying on WMS-E customers, the time spent for ERP integration nearly varies from 1 day to 3 weeks. For WMS-D the integration in shortest and longest time typically ranges from 3 weeks to 4 months. As it can be seen nearly for all vendors a half of the WMS implementation time is given for an ERP system integration.

Nearly each WMS vendor has disclosed the rough price of software installation. The figure 15 illustrates WMSs deployment price comparison. In the view of WMS-A as only a module of ERP Lean System, there is no price available because it is not sold as a standalone WMS. The total price of ERP Lean System together with WMS-A is considered as confidential and not communicated by this vendor, however, Vendor-A representative shared the price of 25,000 euros for adding WMS-A module to already purchased its ERP Lean System by a customer. From here it can be assumed that minimum costs of this ERP Lean System implementation should be more than 25,000 euros. At the same time looking through some statistics of deployment an ERP for small and medium businesses on which WMS-A module focuses these costs are around 50,000 up to 100,000 euros (EASYERP, 2016). Speaking about standalone WMSs, for WMS-B it is near 25,000 - 50,000 euros. WMS-E price range is between 35,000 euros to 200,000 euros what, in turns, depends on a customer’s choice of software options. In the case if a customer selects WMS-C, a company should pay 100,000 – 150,000 euros for the full deployment, however, depending on the fact whether the customer has some automation already done in warehouse and the price will be lower. WMS-F only approximate project costs range from 100,000 to 500,000 euros. WMS-D deployment costs ranges from 120,000 euros to 550,000 euros being the most expensive WMS shown in the figure. The cost structure of WMS vendors is quite the same all of them have monthly licence fees which depend on WMS modules installed, integration and deployment costs. A customer makes a maintenance contract with Vendor-A where the times of maintenance and costs are set as well as price include licence and work. Vendor-B, Vendor-CE and Vendor-F also can include there hardware devices they supply for a customer, while others two Vendor-A and Vendor-D do not provide this option.
Asking WMS vendors about their customers’ contract length it can be noted that only WMS-B provides fix terms contracts for one year, whilst other WMS providers offer customers a possibility to cancel their contract whenever they want. WMS-F normal contracts are 1 or 3 years. WMS-C claim that for customers it is not beneficial to have contract for shorter time period, rather than on the long run. What it is true because in this case all expenditures cannot be repaid and disbursements exceed advantages got from WMS installation on the short run.

3.4. Framework for the 3PL to select WMS for a customer
This subchapter examines the content of the framework designed for the 3PL to select WMS for a customer and own operations most efficiently. This subchapter starts with gathered measured scores of responses about each WMS, especially, what conclusions can be made from these score numbers. Afterwards, there is explained guidance for the 3PL in the framework in the form of aspects importance and questions explanation. The full framework is placed in the appendix 14.

3.4.1. WMSs classification according to final scores
In order to determine when the certain WMS is a good fit for the 3PL’s customer, each software vendors’ answers influencing positively on this WMS choice are scaled (framework indicators in the appendix 12) and summarized in the framework (appendix 14) as it is discussed in the research design chapter.
To recapitulate what is evaluated, the figure 16 sketches out WMSs scores according to WMS capabilities solution in two extremes as advance and light WMS. For better illustration, in this figure all boxes with WMSs names are in the same colours as ones used for their identification in the course of the thesis. Overviewing further WMS scores and assigning them to customers groups, the interesting picture is emerging that WMS-A as a part of ERP Lean System and WMS-B comprise the list of lightweight WMSs, whilst, WMS-D and WMS-C both can be referred as advance WMS solutions competing against each other for the first place in the total WMS scores. However, WMS-F and WMS-E are only WMSs located half way along these two groups of light and advance WMSs.

Figure 16. Total scores of WMSs according to types.

Based on final scores WMS-C and WMS-D can be put together into the highest category of WMS opening up a lot of opportunities for usage. Their scores are 98 and 91 respectively. For instance, they can serve both small, medium and large companies, possess extensive functions scope, technical compatibility and operability with other systems. In the concise form, these two WMSs offer extensive set of features and support and assistance for multitude work environments.
Whereas, the rest four WMSs of WMS-B and WMS-E, WMS-A and WMS-F seem to be allocated down in this categorisation. Consequently, WMS-F and WMS-E together are higher in scores compared to both WMS-B and WMS-A.

Looking in more details, it can be said that WMS-F to be one jump ahead of WMS-E, but not that much (4 points), so both of these WMSs is in the middle group of warehouse solutions. WMS-F score is 61 and WMS-E is 57. The first one is highly customized with some standard function, while the second one is different because it comes as standard box solution offering a customer to choose from bulk of modules to customize own business. These two WMS specializes on different types of warehouses, WMS-E – production ones, while WMS-F – distribution ones, What, in turn, influence their customers operating industries and warehouse parameters such as warehouses surfaces and order lines performed per day. More warehouse staff work in warehouses with WMS-E rather than WMS-F. In automation tools and databases integration and software installation WMS-F is more advanced than WMS-E. However, WMS-E gains the upper hand in interface with various logistic systems. Both of these WMSs provide similar level of functions. From the standpoint of non-technical issues, WMS-F has higher deployment costs and longer installation time in comparison with WMS-E that can be set up quite fast.

WMS-B and WMS-A (47 vs 39) with quite similar scores falls into the same category. From this pair of WMSs WMS-B is considered as a tailor-made WMS adjusted to customer’s needs. However, WMS-A can be compared poorly with other WMS because it is not sold a standalone module, but together with the ERP Lean System. The total price of the Vendor-A ERP Lean System together with WMS-A is not disclosed by this vendor, but with the further analysis of this ERP Lean System with WMS-A module is in the same price category with WMS-D, WMS-C, WMS-E and WMS-F). What, in turn, limits its applicability. Regarding deployment, WMS-B is quicker in implementation and less costly than WMS-A with ERP Lean System. Speaking about WMS-A as a module of the Lean ERP system it does a good job as an inventory management system fulfilling basic warehouse activities. While WMS-B, in turn, serves more than just basic, but also advanced WMS functions. This two WMS has also different customer’s warehouses focus. WMS-B has more customers with distribution warehouses, while WMS-A deals mainly with production warehouses. In terms of automation, WMS-A as WMS-B interfaces with basic automation such as printers and automatic scales, but also WMS-A has customers with automated racks in warehouses.
Coming to vendors’ expertise, it can be pointed out that more years a WMS product is in business, more functions it has developed as well as more customers it has originated from more industries. However, WMS-B being the youngest WMS solution from all does not follow the common path where more operating years equals to higher industries range. WMS-B has developed operations to more industry types rather it should be then. These could be explained with its niche focusing only on SMEs and only on Polish market. Notwithstanding, WMS-B should not be disregarded because of young ages, it can even show better results in functionality and technical performance details in comparison with WMS-A. WMS-D and WMS-C are the most experienced WMS followed by WMS-E, WMS-F and WMS-A in this matter. All WMSs except WMS-B have worked with 3PL.

Furthermore, technical characteristics of a customer’s warehouse with which each WMS has experience in running can already tell about this WMS target customers group scope. The attention can be turned that WMS-D and WMS-C have captured quite significant customers’ warehouses surface ranges from small to big ones. However, WMS-D has a bit better records in this dimension because it works with bigger customers’ warehouse characteristics such as warehouse size, workers and performed order lines on daily basis. Yet, WMS-C specializes more than WMS-D on serving customers with smaller amount of warehouse employees and shipped order lines per day. WMS-B specializes on small warehouses according to the vendor business focus. Among all WMS-F and WMS-E fall in the middle exceeding WMS-B operations and being in the figure 16 in the beginning of advance WMSs’ customers sizes. Consequently, WMS-F and WMS-E can serve middle group customers. Taking a look at technical customers’ warehouses parameters, it can be noted that WMS-F outperforms WMS-E in all customers’ warehouse operational parameters. Interestingly, with these figures WMS-E overlaps with WMS-B in both warehouse size and users amount working at the same time. While with the first WMS-E serves bigger warehouse sizes and with the second WMS-E widen warehouse worker range in both smaller and larger dimensions compared to WMS-B. With this two WMS-E is in the middle group too. However, for order lines shipped per day WMS-B scores more which could be explained with WMS-B focus on distribution warehouses in comparison with production ones as WMS-E does. Quite the same order of priorities regarding shipped order lines per day, and in this dimension both WMS-A and WMS-E can support their small number. With shipped order lines the same pattern can be observed where WMS-F overcomes WMS-E and significantly WMS-A and
WMS-B. Succinctly, WMS-A and WMS-B concentrate on small customers, WMS-E serves both small and medium customers, WMS-F with all results support medium companies having no small customers’ warehouse parameters and WMS-D and WMS-C in all two previous types, plus, large clients.

3.4.2. Question for the 3PL to address to a customer selecting a WMS

The collected WMS vendors’ responses help to compose the list of questions that the 3PL can address to a customer to select the right WMS. These questions are inserted into the framework in the appendix 14. To start with, a selected WMS for a customer should serve its business needs and requirements. Because of this questions that a 3PL can ask are sorted to start from common questions followed by more specific deeper questions. These questions are bellow with short comments why these questions should be asked by the 3PL from a customer wishing to implement a WMS.

• What type of WMS does a customer need?

This question helps to identify the 3PL operator whether its customer wants a real WMS or just an ERP module.

• How experienced is a WMS vendor in business?

This question adds points towards the selection of the vendor who has the certain business years experience. Meanwhile, as responses demonstrate vendors who are more years in business have more customers.

• What is a customer's industry of operations?
• Is a WMS ready to handle SKUs restriction if a customer has any?

These two next questions the 3PL provider serving its future customer should know what industry this customer is coming from what is tightly linked to customer’s SKUs characteristics and operations performed in a warehouse. Industries of vendor operation can already tell about SKUs characteristics for the particular WMS system.

• What type of warehouse does a customer have?

Starting discussion with customer about WMS application, it is imperative for the 3PL to raise the question whether a customer has a production or distribution warehouse, namely, whether a customer’s warehouse purpose is to store products in different production stages
or to dispose goods. In case of distributional warehouses a customer should be asked about its specific categories types.

- If a customer has several warehouses, can this WMS coordinate and run them together?

A customer and 3PL should have clear understanding about a customer’s future business plans.

- What is customer's warehouse premise surface where a WMS will work?
- What is expected/current amount of order lines shipped per day in a customer's warehouse?
- How many warehouse operators should be able to work simultaneous with the certain WMS in a warehouse?

These three questions above are useful for 3PL to determine the right WMS scope selection because a customer’s WMS will be linked to actual physical warehouse of a customer. It is of interest to note that a customers’ answers on these questions are positively correlated with each other. In other words, if a WMS runs on the customer’s warehouse operating surface it is meant to be able to serve corresponding number of order lines shipped per day range and to use by a number of warehouse operators.

- How information about SKUs should be exchanged in a customer's warehouse like via RFID or barcoding tags?
- What should be the level of automation in a customer’s warehouse such as basic (printer and scales) or more advanced (e.g. automated racks, picking support technologies and robotics)?

With the help of this system the 3PL can choose a WMS which responds to technical requirements proposed a customer. More detailed kind of automation tools are presented in the framework for the 3PLs.

- What kind of functions should a WMS accord assistance and facilitate in a customer’s warehouse?

This one of the most essential questions the 3PL should be aware of choosing a WMS for a customer.

- What are the technical requirements for databases for a future customer's WMS?
This question helps to understand a customer’s technical requirements regarding databases if there are any, namely, database technical connectivity to other systems and ability to integrate into the available databases.

- With what customer's logistic execution systems WMS should be able to integrate?
- Can vendor's software be integrated with several customer's ERP systems?
- With what ERP system(s) that a customer might have a vendor has already completed integration?

There should be a match between a customer’s logistic systems and WMS integration abilities.

- What kind of integration of a customer's ERP with WMS is used?
- In what way messages from a customer's ERP can be exchanged with WMS?

The last two questions are useful for the 3PL to know how the integration will be done in a customer’s case.

- Does a customer need WMS with web based interface?
- What are customer’s preferable platforms and operational systems to work with WMS?
- What should be the interface operating language in a customer’s warehouse?

Questions above present a customer’s requirement for a WMS and with what the 3PL will work running a warehouse.

- What is the preferred way for a customer to install WMS?

With this question the 3PL can know about a customer’s intent to have own server infrastructure or run it on behalf of another company.

- How long should a customer be ready to wait for WMS deployment?
- How much time does WMS require from a customer for ERP integration?

It is wise to ask a customer in what time range this customer is going to devote for WMS implementation or whether there are any time requirements for installing the system and running in warehouse. Because this influence also on 3PLs project planning.

- What deployment costs is customer ready to pay for WMS?
Regarding financial aspect, a customer should be ready to pay the all project costs of WMS deployment.

- When can a customer cancel contract with WMS provider?

Asking a customer about its WMS contract length expectations is also important to the 3PL provider because it can already tell about their working time together.

3.4.3. Framework aspects importance classification

An additional issue to turn this framework into the efficient tool is its aspects importance classification. This way, the case company representative is asked to evaluate each WMS elements which a customer consider in WMS implementation and selection according to the rating scores distribution. The following, firstly, guarantees wise exploitation of the framework by the Finnish 3PL because it makes the further usage of framework easier for the user who is not familiar with this research content, but knows where to look in the beginning. Secondly, this classification provides practical insights to shed up the light in the topic of 3PLs choosing a WMS for a customer. Following, there is a points scales importance from low (0) to high (3) presented in the appendix 13. In the framework in the appendix 14 the majority of aspects (54) are given the high priority of 3 where the 3PL has more expertise and more interested in working with. This fact validate that the author has rightly extracted and highlighted parameters from the literature to bring more value of this research.

There are two sections of framework of warehouse characteristics and sensitive deployment issues racking up purely 3s in all aspects. Especially, attention should be given to study customer’s warehouse characteristics prior to WMS implementation as its physical parameters and operational performance as well as the automation deployed in the warehouse to communicate with WMS to increase warehouse logistics output. All WMS sensitive deployment issues, namely, realisation time, price and contract length are scored with 3 too as important one to consider before stepping up into WMS set up. Also, 3s given there can tell about the experience of 3PL operator dealing with various customer warehouses and contract related issues. Other aspects scaling 3s are distributed in different framework topics. Referring to the importance aspects they are industries and warehouse types supported by a WMS, all functions level divisions, a WMS ability to interface with logistic execution systems, and ERP integration matters (communication and integration with WMS), web user interface and WMS KPIs and dashboard performance metrics.
In the framework 12 aspects have the next categorisation of 2 for parameters less importance for the case company to have, but still with enough experience. There is no full section of the framework having purely 2s, because they are always put in the mix with 3s. For example, more 2s are in the part of the technical WMS characteristics. For instance, there are Postgre SQL, DB2 and WMS-D HANA are less frequently used databases of the 3PL customer. In addition, 3PLs shows that iOS is not that popular device system used in a warehouse. Furthermore, 2s are mainly given for all languages and its translation tool, except Finnish, English and Polish which only ones there scoring 3s. In addition, the 3PL gives less preference for WMS installed as a Cloud Computing option. There are some parts of table having not similar scoring, take the first topic of WMS types. the 3PL emphasises there own experience in working with systems requiring a lot of customisation to align WMS to customer’s warehouse processes. Also, the case company gives preference in installation of box WMS systems. Another type of WMS as an ERP module seems to be not in the interests of the 3PL to work with at the same time it does not have that much experience, because the primary business focus of the case company is on standalone WMS installation. There is an element of SKUs restrictions having 1 as the importance score from the case company. What, in turns, means that the 3PL company does not currently have customers with any special SKUs restrictions and does not evaluate it as the first priority aspect in WMS selection.
4. CONCLUSION

The following chapter starts with answering the initially stated research sub questions to support the overall aim of the current research work. Afterwards, this chapter synthesizes findings that can be inferred from both theoretical and empirical parts of this thesis and addresses the further research recommendations.

4.1. Answers to research questions

**RSQ1: What are the WMS essential development prerequisite characteristics described in the academic literature?**

The theoretical part of this thesis places the primary emphasis upon investigating and discussing key aspects of WMS adoption. As it is previously shown there exists the research gap between WMS and 3PLs because in the academic literature studied during the systematic literature review there is no mentioned connection of these two concepts. No evidences of 3PLs engaged in installation of WMS can already tell about this phenomenon. Followingly, this study can bring up a novel dialog into academia. The study of literature demonstrates on what aspects customers focuses getting involved into WMS initiatives. In the logical sense, WMS aspects what a customer interested in and what it demands from a vendor’s system are the same as these aspects with which this customer challenges and refer to a 3PL as an intermediate between a customer and a WMS vendor company to improve own warehouse logistics. The theoretical part helps to form the basis for creation of the list of questions for interview for WMS vendors to describe their target customers scope.

In the first place, WMS is run on warehouse premises, hence, wheres and whens are crucially important. As demonstrated with findings, warehouse characteristics put some constraints into WMS setting and capacity. Specifically, WMS becomes a tipping point in conducting warehouse operations. In case if a warehouse cannot respond to or guarantee preconditions for WMS, all efforts fail miserably. Warehouse can be described with its handled processes determining its operational role, resources employed such as physical warehouse parameters, SKUs and warehouse personnel and organisational structure warehouse manual or automated structure.

Secondly, it is essential for companies to understand the mission of the WMS in their warehouses and its possible variations. WMS system can be an independent (tailor made or box solution) systems or module of ERP. In addition, WMS can appear for a variety of ends
satisfying different customers’ needs such as basic, advanced and complex warehouse logistics operations. Yet another option is how customer can implement and rent this system influencing on WMS types (e.g. standalone, SaaS or cloud computing).

Nowadays, customers are demanding more and more activities from WMS, consequently, some of its functionality are derived from other logistics executions systems. Moreover, there is no clear boarder in the observed literature drawn of WMS functions available. Since WMS functions is extended with the time according customers’ requirements so previously advanced functions become standard in WMSs. All functions in WMS can be grouped into six processes happening in every warehouse: receiving, storage, order picking, warehouse administration documentation and value-added logistics services.

The key elements of what customers are aware installing WMS are observed in the literature. These WMS aspects are studied and taken into account designing further interview question for WMS vendors. Apart from earlier examined warehouse characteristics, there are other WMS selection sides. The fundamental factor of selecting WMS system is flexibility for growth to comply with future business growth. To be concise, in WMS deployment process attention should be given to its technical side as functionality diversity, other systems compatibility, design modifiability and user interface quality. If a customer switches from one to another WMS system technical features interoperability and implementation ways should be considered. WMS total cost components and set up time should be also reviewed in advance. Pre- and after- sale WMS vendor support add value into software decision. Last but not least, a WMS vendor who has more experience of previously installed industries software and good reputation is more trusted.

**RSQ2: What elements dictate that certain WMSs is suitable as system for current and future customers of the Finnish case company 3PL operator in the future?**

After conducting the empirical part interview and analysing its results, there are several patterns and dependencies in WMS vendors’ responses to the certain questions. The factor which goes to the first place considering WMS is its vendor business year expertise of supplying especially this software solution. As the framework with answers (appendix 14) shows that vendor’s provision years of WMS influence positively not only on served customer’s industries ranges and types, but also on functions quantity and diversity and total WMS technical capabilities. Consequently, if a customer wants to have more of the
parameters mentioned previously, it is wise to look at large WMS vendors of WMS-D and WMS-C. Both of these vendors offer all basic, extended and advanced WMS functions specializing on both production and distribution warehouses. Moreover, it is relevant for a customer to choose such a WMS vendor that has developed a real-life application customer range to what a customer belongs and among the certain customers’ warehouse types. This fact can impact on elaborated WMS features and functions too. All vendors can work in all warehouses types but each vendor except WMS-D and WMS-C has more focus on either customers’ production or distribution warehouses. In this way, WMS-E and ERP Lean System with WMS-A concentrate more on production customers’ premises rather than other two WMS-B and WMS-F working for distributional warehouses purposes. Such element as a customer’s intention to store a particular type of SKUs in a warehouse can influence on whether a WMS vendor has all required certificates. Mostly all vendors except WMS-D and WMS-C have some SKU’s restrictions.

Regarding the overall customers’ warehouse technical characteristics as it has been already discussed in this thesis that there is the dependency among all three warehouses parameters questions about warehouse surface, throughput and workforce. What, in turns, means that a customer can be importantly asked, for example, about actual warehouse parameters such as its warehouse surface and fall into the same group category of answer with the rest two question.

In order to demonstrate previously said and test the WMS framework, the current customer cases named the 1st, 2nd, 3rd, 4th and 5th of the Finnish 3PL provider are used presented previously in figures 3, 4 and 5. So, their parameters such as its size, throughput results on order lines shipped per day and warehouse workers number are taken. The actual values to define number ranges are taken from the empirical part data from vendors’ answers (figures 9, 10 and 11). In order to define numbers for dimension of light to advance WMS solutions these figures are deeply analysed in the matter of intersections and gaps. Particularly, with what customers having a certain warehouse size, order lines and workers some WMSs have already worked and with what they have not. Compared WMS results are combined in the respective figures 17, 18 and 19. To illustrate practically and actuality of findings for selecting a WMS bases on a customer’s characteristics, the dimensions of 3PLs’ warehouses are drawn with coloured lines in all these figures.
Whereas, a large column of the gray colour responds for the most powerful WMS running all customers’ dimensions mentioned by WMS because this category of WMS can operate even with the bigger number indicated with arrow the total view of this part of the bar chart is aligned in size with others, the pink colour shows medium metrics up to which middle WMS can work, while the light blue-green colour responds in light WMS performance figures. For convenience, each graph has labels with numbers.

In all figures all three customers’ warehouse parameters are supported with WMS-D and WMS-C, WMS-F works with middle and small dimensions warehouses, while WMS-A orients on small customers warehouses. With WMS-B the situation is quite mixed because only in customers’ warehouse sizes and operational customers’ warehouse characteristics it is purely in the light WMS solution group, while in rest case of personnel it partly touches medium characteristics.

Figure 17. WMSs ranges of operating customer's warehouse size.
Figure 18. Grouped number of order lines shipped per day on customers' warehouses with WMS.

Figure 19. Warehouse workers number using WMS.
At the first few, the line associated with warehouse 4 belongs mainly to the highest column, so only two WMS-C and WMS-D should be considered for this customer not only on customers parameters, but also because of the highly automated robotic racks deployed. The line associated with warehouse 1 joins the medium customers’ warehouse sizes. What, in turn, means that this warehouse can be run only with either WMS-D, or WMS-C or WMS-F. Even though WMS-B can manage medium number of warehouse staff for warehouse 1, this WMS other performance characteristics are still not enough because this vendor currently does not have experience with large customers’ warehouses. Moreover, other mentioned WMSs offer more advanced functions required for running such big warehouse with multiple clients. WMS-C and WMS-D as powerful WMS for operations can handle all three warehouses left (warehouse 2, warehouse 3 and warehouse 5). Additionally, WMS-F, WMS-B, WMS-E and WMS-A can run these three warehouses. At the same time, a 3PL company is unhappy with some done WMS projects of WMS-F. WMS-A is also not suitable for warehouse 3 and warehouse 5 because these customers already have their ERP systems, so these customers do not need to buy a new one where WMS-A will be a module. So, WMS-F and WMS-A are crossed away and WMSs got for these warehouses type are WMS-B and WMS-E. In warehouse 3 a customer has Vendor-A ERP where WMS-A module can be easily added. Coming to another issue for this customer to consider, if a customer wants to facilitate warehouse flows with automation, it is better to look at automation tools integrated with WMSs. All WMS support basic automation such as printed and automated scales, however for advanced automation a customer should look at WMS-D and WMS-C, followed by WMS-F interface abilities and WMS-E ones. WMS-B supports basic automation while WMS-A does only some more. Referring to warehouse 1, there are installed picking robots, pick and put to light system equipment used simultaneously. So, this automation only WMS-C and WMS-D support. What, in turn, narrow the suitable WMSs for these warehouses.

A customer’s wish to install a WMS on premise or on Cloud or outsourcing it to another company can be explained with customers’ infrastructure capabilities. All WMSs can be installed as standalone, other vendors’ WMSs such as WMS-C and WMS-F support various customers’ choice.

User interface can be an element a customer could look whether it is conveniently can accessed from web to supervise warehouse operations and what languages can be used. Importantly, all vendors support English and Finish.
All WMSs are experienced enough with integration with multiple logistics executions systems, all specificities come with a customer choice.

In the meantime, it is essential to look at non-technical issues of the new WMS project such as deployment costs and time and contract length (more precise information will be received from vendors later). A more popular WMS vendor on the market and wider functions range it has developed such as WMS-D and WMS-C, a higher price it has.

**RSQ3: What are the key elements for the Finnish case company 3PL operator provide its customers with efficient WMS operations?**

The answer to this question implies the additional analysis of the empirical data from the subject of the applicability by the Finnish 3PL operator as the specialist in its own operational area. Pursuing this validation, the Finnish 3PL company representative evaluates and assesses the importance of framework elements as it is described earlier. This, consequently, increases the framework further usage and guidance. Moreover, with the help of this endorsement the case company can comprehend for itself what framework elements are seen as important ones and where the case company expertise lies. This, consequently, increases the empirical value of the framework and e.g. allows it to be used development and guidance tasks. As the results, it becomes empirically evident that all defined aspects within the framework present a value for the 3PL company in consideration for a WMS for a customer. This happens because, particularly, almost all aspects have nonzero scores, while their majority has the highest score given. It can be observed that two sections of the framework responsible for customer’s warehouse characteristics for WMS and WMS sensitive non-technical deployment issues are exclusively rated with the highest scores. What, in turn, can tell about the cruciality of these aspects for the 3PL operator providing a customer with a WMS. It is essential for the 3PL to take into account a customer’s warehouse as an actual platform for running a WMS software. So, there should be a match of warehouse working parameters and WMS abilities because the wrong choice of too weak or too advance WMS can lead to negatives consequences in the future warehouse operations. Customer’s warehouse characteristics are reflected in warehouse size, monthly shipped order lines as performance measurement, labour force available and automation tools deployed in a warehouse from simple to advance to exchange SKUs information and facilitate the warehouse logistics. WMS sensitive deployment issues not related to technical software
parameters have the prominent role too because the 3PL takes on the role of an intermediate between a WMS vendor and a customer. This clarifies why aspects of WMS implementation such as set up time and cost and contract length should be delivered explicitly. There are also some other aspects scaling the high importance in different framework sections, they are concerned with WMS vendors industry proficiency (spheres not number of years) and warehouse types background. In addition, WMS integrational issues regarding the software interface and other systems interface as well as methods used there are the points to be highly relevant for the 3PL company. Yet, other framework sections deserve attention, even though there is some variation of the case company responses in the degree of the aspects importance. For instance, some databases and languages (except Finnish, English and Polish) as well as WMS cloud computing installation option are not given the top priority in the WMS selection. These could be explained with the practical expertise of the 3PL company gained during working years and its customers’ demand, that these are not the first thing to look into. There is a readable pattern shaped in WMS types importance classification for the 3PL service operator. The 3PL company shows its interests and expertise working more with a standalone WMS rather than a WMS module implemented as a part of ERP. This could tell about customer willingness to have more just WMS system, might be, because of already having ERP which is not enough to run warehouse operations. The 3PL have many experience in WMSs customization toward WMS need. What can be considered as one of important factors for the 3PL to align software according to customers’ needs. Moreover, this classification of priorities importance done by the experts of the case company brings more insights into the intersection of 3PLs and WMSs topics.

4.2. Theoretical contributions

The study has found and validated the current knowledge gap existing in the academic literature resulting from conducting the systematic literature review in LUT FINNA database. As the result of which 51 literature sources are more comprehensive studied and classified according to common topics discussed by authors. The lack of knowledge in collected literature concerns with no evidences found about a 3PL running, choosing and advising a WMS for its customer. 3PLs are only just mentioned in the context of WMS users (four studies), not of the ones who install them to customers’ warehouse premises. After the analysis of all 51 studies the common four themes discussed are placed emphasis. All four topics are equally mentioned by authors, what can already tell about their actuality, however,
there is still some deviations in in number of authors mentioned them, namely, warehouse characteristics (by 21 author) lay as the basis for a WMS operations and the place where a WMS starts working, WMS divisions and types are discussed (in 29 studies), WMS functionalities scope, while not that many studies (25) are concerned with study available WMS functions which can tell scarcity of programmatic studies done. The majority of authors (30) mentions characteristics a customer should look for implementing WMS. Moreover, the last topic of the WMS deployment contains the biggest amount of aspects in it such as WMS software technical characteristics, integrational manners, vendors expertise and reputation. What, in turn, could tell about the topic total actuality of 85 aspects mentions by its extensive study and importance for a customer in the WMS context. Other two topics of WMS warehouse characteristics and taxonomy have the equal actuality in terms of aspects mentions scores, 39 and 36 respectively. Whilst, there are more aspects looking at a warehouse from different angles and discussing its significance as a place for WMS set up. Contrary, less discussed topic is about WMS functions where is only one aspect raised. However, no studies found within the systematic literature review providing any guidance or assistant for 3PLs implementing WMS for a customer. Only in five studies found 3PLs and WMSs discussed shortly. Nevertheless, all 51 studies are deeply analysed while the main aspects about WMS set up for a customer are excerpted and constitute a ground and basis for forming interview questions. The case company has approved the list of aspects found in literature. However, there is a lack of studies about components important for the 3PL in installation of WMS. Followingly, the case company has provided their business insights to make these interview questions more oriented toward the content of the 3PL.

4.3. Managerial implications

As the thesis practical output there is the framework created for the Finnish 3PL company for selecting WMS for its customer based on customers’ characteristics. This framework is driven by both the case company and customer needs. Poling this work applicability, there are versatile ways how this framework can be used by the case company:

- Informativity

This framework gathers in itself comprehensive and approved WMS characteristics according to customers’ interests and requirements both by the literature study and Finnish 3PL operator. Thus, it can already show the aspects actuality.
• Software-descriptiveness

This framework contains description of six different WMSs from the perspective of target customer’s characteristics served with this software. At the first view, an idea about each WMS activities and operational elements can be acknowledged. In addition, the framework shows that five out of six vendors software products standalone WMSs are WMS-C, WMS-D, WMS-B, WMS-E and WMS-F, while WMS-A is only installed as a module together with ERP Lean System and cannot be considered as a WMS.

• WMSs comparison and benchmarking based on responses

This framework analyses and compares six different WMS under different aspects defined in the academic literature. Moreover, these WMS are not simply compared by words, but benchmarked between each other by giving a weight as pluses for supporting certain features in the WMS context. Moreover, WMSs comparison for some aspects are based on vendors’ responses range e.g. operating years, warehouse surface, workers, daily shipped order lines and etc. These scores directly correlated and connected with WMS abilities scope. Thus, looking at the final scores of each WMS it can be concluded that WMS-D and WMS-C are the most advanced and powerful WMS in terms of their activities and fitness of working with different conditions, where WMS-D a bit outperforms WMS-C, but still they have quite the same score. WMS-B and ERP Lean System with WMS-A module can be seen as lightweight WMSs with equal scores. In spite of being not real WMS WMS-A as a module ERP Lean System can compete with WMS. Whilst, WMS-F and WMS-E go in the middle of these two extremes, whereas, WMS-F earns a few points more.

• Target customers’ characteristics of each WMS

The WMS scores got in the framework not only tell about the level of each WMS activity, but also about its covered characteristics belonging to their target customers groups. What, in turn, mean that WMS-D and WMS-C being the most experienced can work with all categories of customers’ warehouses from all industries with various processes and SKUs and from the smallest to the biggest one in terms of surface, workers, order lines shipped per day. However, a client’s choice depends such issues as price where WMS-D is a more expensive solution. While WMS-A as a module of ERP Lean System focuses only on small warehouses bringing the mobility into warehouse logistics. WMS-B aims at SMEs.
warehouse operations, however, it only touches medium warehouses in the initial parameters because WMS-F and WMS-E can serve all mediums ones until the big warehouses.

- Aspects for selecting a WMS for future customers

With the intersection of both the first left vertical column of WMS aspects and first upper horizontal column of WMS names, the 3PL operator gets parameter values where future customers fit in for choosing a certain WMS.

- Aspects for analysing a current customer WMS operability

With this framework the 3PL operator can judge about current customers operations. The same can be done with current 3PL customers using a WMS, whether this WMS is able whether they use the system to fulfil later their capabilities

- Customer’s WMS efficiency consultation validation

The current framework can be used as a part of consultation service offering. Especially, any customer can ask the case company to do the consultation and verify whether this customer use the right WMS to bring the most efficiency.

- Education matters

The same way this model can be used for inner company’s purpose to teach sales and operating people about presented WMS and their aspects.

- Pointable guidance

One of the columns in the framework concern with WMS aspects importance. This scaling of questions with rates is provided by the 3PL operator. With the help of this categorisation this framework can be used for inner-company educational purposes e.g. the case company’s internal workforce training and education program, sales & management trainings. Also, this number scale shows where a user of this framework should look firstly secondly and so on, namely, what aspects more important and in what aspects the 3PL case company has more expertise.

- Questions supportiveness e.g. for sales people

Consequently, whenever the 3PL company gets a customer, its sales team can use this framework in further discussion about customer’s characteristics and consulting this
customer to match these key characteristics and to choose one or another WMS and the same time the 3PL company shows own experience working with this system vendor. Moreover, for easier use of the case company personnel each related WMS aspect is provided with the right explanation question which should be addressed to a customer to get an answer for this WMS aspect. In addition, with answering these questions the 3PL service provider can select a WMS for a customer which not only suit to the current warehouse operations, but also fulfil and meet the future customer’s business growth targets, because it is crucial to choose such WMS that not only fulfils the present needs, but also not too weak for future customer’s business.

- **Easy-to-WMSs-extend framework**

In addition, this framework can be easily extended and other WMSs can be added for the analysis within the defined scope of WMS aspects.

- **Negotiation with WMS suppliers**

The results from this framework can be used to negotiate a certain WMS vendor capabilities and conditions with another WMS vendor.

- **Setting WMS performance indicators**

This framework gives an idea about the performance of each WMS systems both based on WMS aspects and vendors’ responses.

- **Developing a WMS**

Moreover, with this model 3PL can to orient on best WMS suppliers and compare, benchmark the rest, possible to use this framework for development of own WMS. Because it makes visible the criteria to pursuit for continuous improvement of WMS performance.

- **Request information offer from a new WMS vendors**

Whenever the 3PL operator has offer from a new vendor whose WMS product is not in the framework, this vendor can be asked to fill the information about own software based on this WMS criteria. So, the 3PL provider can get new information already in the needed format.
4.4. Findings summary

The current thesis has examined the customers characteristics which are significant for the Finnish 3PL company in selection of a WMS for this customer. These characteristics are not composed together into the framework in the end of the thesis, but also evaluated and weighed to reveal the most powerful WMSs. In addition, each aspect of the framework is given priorities by the case company and accompanied by the question for a customer. This framework provides a glimpse of the reality for the 3PL regarding a customer’s WMS choice. As it is found in the literature there is no similar studies done on this topic drawing the intersection of these two concepts like a 3PL choosing and installing WMS on a customer’s premise. Because of this, the research takes look on the issue from a customer’s perspective selecting and assessing WMSs what, in turn, is important for the 3PL serving this customers with WMSs. In addition, the case company has shaped this research highlighting some aspects the 3PL provider is interested in installing WMS. Reported findings from the interview verify WMS aspects emphasized in the literature studied such as WMSs division, WMS vendors experience, customer’s warehouse characteristics as determinants for this software operability, WMS technical parameters and further implementation issues. In order to contribute to the research validity and increase confidence of the research data, the triangulation data analysis is applied in the multiple form of acquiring data, namely, the systematic literature review, case company study, semi-structured WMS vendors interviews and evaluation of the framework component by the 3PL company. To demonstrate the actuality and applicability of this framework, the current customers cases of the 3PL company are reflected as cases in this framework exercising.

4.5. Recommendations for future research

The limitations stated in the beginning of this thesis lay as a basis for further research to conduct in this direction.

As the systematic literature review has showed that there is lack of academic literature on the topic of WMS and 3PL, namely, issues important for the 3PL in installation and selection of a WMS for a customer. For instance, more research about WMS functions available nowadays and, namely, WMS function for a 3PL can be done. Also, it would be interesting to get to know which WMS functions a 3PL value more in running with this solution own and a customer warehouse. On the other way around, it is noteworthy also to ask customers what WMS functions they value when a 3PL operate their warehouse. Also, these customers
can be asked what they appreciate outsourcing warehousing operations to a 3PL, namely, not general knowledge and benefits as saving for own business outsourcing to a 3PL what is known already in the literature but when this 3PL runs these customer’s warehouse especially with WMS. One more point to make this framework proposed more 3PL oriented is to ask this 3PL with what automated suppliers it has already worked and with what of these suppliers has a certain WMS already been integrated. So, all abovementioned can make the aspect of this framework more comprehensive and give profound knowledge to judge about elements suitability of WMS and 3PLs.

Moreover, along the interviews every WMS vendor has mentioned above the ability of software to generate KPI’s and dashboard. Consequently, it would be interesting to study those in details and aligning their importance to 3PL business needs. For instance, whether a 3PL can use these KPIs from WMS labour modules as an assessment of trainings effectiveness. Additionally, whether a 3PL can utilize these indicators efficiently for example for accounting bonus salary resulted from individual warehouse worker performance. As the result, each of the six WMS system chosen by the 3PL provider is closely examined in this research with the created framework. This framework can be extended and include, for example, more WMS software vendors of WMS to interview. The bigger number of responses can become more intrinsic to drawing more well-defined and common patterns, what, in turn, can bring even more research value into the topic of WMSs and 3PLs intersection. Furthermore, the author proposes the list of questions the 3PL company can address to a customer to select a WMS system from the given in the framework. These questions could be researched and re-aligned when the environment changes where these 3PL operators work.
LIST OF REFERENCE


https://www.slideshare.net/ImplementConsultingGroup/warehouse-and-distribution-footprint


O'Rourke, L. (2012). Handbook on Applying Environmental Benchmarking in Freight Transportation (Vol. 21). Transportation Research Board


APPENDIXES

Appendix 1. Searched keywords sets with results.

The dark gray colour indicates the combination of words chosen, while the semi gray indicates words scoring more results in their category search.

<table>
<thead>
<tr>
<th>KEYWORDS COMBINATION USED IN SLR</th>
<th>NUMBER OF SEARCH RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Academic Library's collections</td>
</tr>
<tr>
<td>wms</td>
<td>321</td>
</tr>
<tr>
<td>&quot;wms&quot;</td>
<td>298</td>
</tr>
<tr>
<td>warehouse management system</td>
<td>91</td>
</tr>
<tr>
<td>&quot;warehouse management system&quot;</td>
<td>8</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system</td>
<td>1</td>
</tr>
<tr>
<td>&quot;wms&quot; AND &quot;warehouse management system&quot;</td>
<td>1</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;logistics service provider&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;3pl&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;third-party logistics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;third-party logistics&quot; OR &quot;3pl&quot; OR &quot;logistics service provider&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND selection</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;select&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;select*&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND select*</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;pick&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND pick</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;pick**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;pick**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;choose&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND choose</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;choice&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND choice</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;determine&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND determine</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;identify&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND identify</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;characteristics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;characteristics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;prerequisite**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND prerequisite**</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;element**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND element**</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;select**&quot; AND &quot;characteristic**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND select** AND &quot;characteristic**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND select* AND &quot;characteristics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND select* AND characteristics</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND pick* AND &quot;characteristic**&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND pick* AND characteristic** AND &quot;third-party logistics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND select* AND characteristic*AND &quot;third-party logistics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;characteristics&quot; AND &quot;third-party logistics&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;characteristics&quot; AND &quot;logistics service provider&quot;</td>
<td>0</td>
</tr>
<tr>
<td>&quot;wms&quot; AND warehouse management system AND &quot;selection&quot; AND &quot;characteristics&quot; AND &quot;3pl&quot;</td>
<td>0</td>
</tr>
</tbody>
</table>
Appendix 2. The list of databases used in systematic literature review.

Appendix 3. The list of journal titles used in systematic literature review.

Appendix 4. The list of interview questions.
1) What is the scope of systems (what systems) that your company supplies except WMS?
   a) or also some order-picking systems?
   b) or some storage technologies?
   c) or something else?
2) How long have you been offering WMS systems?
3) In what geographical regions do you (as a WMS vendor) supply/ operates/in what countries are your customers’ warehouses located? (Where is the majority/the biggest share of customers coming from?)
4) Does your WMS support coordination of operations in several warehouses + in several countries?

5) Who are your key customers to whom you can give a reference?

6) From what industries are your WMS customers coming from? (the question with predefined answers)

Automotive / Aviation / Food / Beverages/ Non-food consumer goods/ Healthcare & pharmacy/ Chemical/ Steel/ Manufacturing/ Electronics equipment

7) What products can be stored in a customer warehouse with your WMS? any SKUs restrictions (physical (units shape and weight) and environmental characteristics (frozen, flammable, or hazardous material)?

Automotive / Aviation / Food / Frozen goods/ Non-food consumer goods/ Healthcare & pharmaceuticals/ Chemical/ Printed materials/ Office stationery / Fashion goods / Cosmetics / Electronics & mobile phones & computer equipment and etc / Industrial products / Spare parts

8) In what industries do you have the most experience in installation your WMS? & what industries are newly developed/new for you?

9) What kind of customers do you have/serve with WMS? / How would you describe your customer segment there? / What are the most typical customers? Has the amount of 3PL customers of your WMS increased (how)?

10) What types of warehouses should your customer have? Any limitations? (the question with predefined answers)

a. production warehouse

b. distribution warehouses: raw materials and finished goods, sort centres, e-commerce fulfilment warehouses, cross-docking and transhipment break-bulk centres, consolidation warehouses.

11) Do you offer a customized WMS or a standard out of box WMS as box system (is any customization allowed)? Who does this customization? How do you understand each of this (tailor made vs off shelf WMS)?
12) In what sizes of warehouses your WMS has already worked (min. & max. warehouse surface in m²)?

13) How warehouse does layout influence your WMS?

14) What is a minimum & maximum number of warehouse staff in a customers’ warehouses where your WMS operates?

15) What are your customers’ warehouses current experience in order lines shipped per day? The smallest & biggest warehouse where you operate has what number of order lines shipped per day?

16) If a customer has a warehouse where all operations are done manually, will be a problem for you as a WMS vendor to install your system? or does it require some degree of warehouse automation?

17) What are subsystems (order-picking + communication) supported with your vendor WMS/ it is possible to use? some names?
   a) like Automated Data Collection hardware such as Radio Frequency Identification, bar coding?
   b) like order picking process systems (supporting human labour or machines) such as pick-to-light, put-to-light, pick-to-voice, virtual display-directed, automated racks - horizontal/vertical carousels, a-frame, robotics?

18) Processes in warehouse can be divided into six spheres as follows.
1. materials/goods receiving
2. storage (putting away/product allocation/SKU’s management)
3. order-picking
4. shipping
5. warehouse administration/generated documentation output
6. other value-added logistics activities
Could you tell, please, in what processes, according to your mind, your WMS is the most powerful/ where your WMS has the most strength in? there are 6 processes and there are 20 points to distribute/split.

19) What are your WMS standard functions? What are advanced functions your WMS offers? Is it possible to send the list of these?

20) How information got from your WMS can be used for supporting for administrative functions/ what are documents outputs? / What kind of information/documentation can be generated by WMS to support warehouse administrative function?

21) What are new features in WMS your company designing currently?

22) What are database management systems to work with?

23) Will be there any problem with supporting a database your company replace some old WMS system with yours?

24) With what kind of logistics execution systems (like ERP, TMS, CSR and etc.) your WMS can be integrated?

25) If a customer has several ERP, is it doable for your WMS to coordinate with all of them?

26) With what ERP systems have you already completed the integration, please, name:
   a) many times/ is there the best integration? + preferable or costly with a lot of challenges?
   b) with which a few?
   c) with which you haven’t done any integration (you do not know whether they are supported or not)?
   d) or if it is not possible could you name, please, with that ERP systems and how many times have completed integration

27) For ERP system integration, do you offer documented API (Application programming interface), so can your customers use for integrations (by themselves) e.g. EDI-messages, XML etc.?

28) Do you have customers who have implemented (or have you done implementation for them) for a middle ware that translates multiple ERP messages into messages your WMS system is accepting? Or point-to-point has better place?
29) Does WMS support a web based interface?

30) Does your company supply an integration layer to interface with customer’s platforms and operational systems (like Windows NT, Linux and etc)? If not, what outside layer do you use?

31) What languages (customer warehouse language) are supported with vendor’s WMS?

32) About the installation of software, you are familiar with implementation of WMS as a standalone system (what means a software is hosted, installed and maintained on a customer’s premise) on Software-as-a-Service model (vendor holds and rents/lease to different customers its server), WMS via cloud computing (software and hardware infrastructure is run by vendor only for its clients, where a customer can access WMS via web), what option do you offer?

33) What is the implementation time of your WMS on average? On what factors, from your mind, does it depend?

34) How much time on average does it take to integrate with ERP systems?

35) How WMS project management is supported? (e.g. do you handle the implementation of your WMS as a project to your customer’s warehouse like, for example, you start with the visit a customers’ warehouse to do some consultation firstly, like what actions do you do?)

36) Can your WMS customer choose/set the length of contract? If not, do you have some fixed contract periods?

37) What cost structure and price components of your WMS? Any average price of deployment? software cost (system running licence measured in what? for example, PC user/radio data terminal user (varies from users number?), paying per transaction, paying on annual or monthly base

a) actual price of software installation

b) system customization/ integration costs

c) devices costs

d) maintenance
e) training cost

38) Does your company provide any presale & implementation support?

39) Does your company give any after sales service?

40) How often do you provide your system upgrades?

Appendix 5. The topics map of interview questions.

<table>
<thead>
<tr>
<th>QUESTION(S) №</th>
<th>INTERVIEW TOPICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>WMS types</td>
</tr>
<tr>
<td>1 - 16</td>
<td>WMS vendor expertise</td>
</tr>
<tr>
<td>22 - 31</td>
<td>WMS customers’ warehouse characteristics</td>
</tr>
<tr>
<td>17 - 21</td>
<td>WMS technical criteria</td>
</tr>
<tr>
<td>33 - 40</td>
<td>WMS sensitive deployment issues</td>
</tr>
</tbody>
</table>

Appendix 6. WMS-E list of functions.
Appendix 7. WMS-B list of functions observed in literature and chosen by WMS representative.

<table>
<thead>
<tr>
<th>WMS FUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>materials/goods receiving</strong></td>
</tr>
<tr>
<td>Unloading</td>
</tr>
<tr>
<td>Scanning</td>
</tr>
<tr>
<td>Goods acceptance</td>
</tr>
<tr>
<td>Labelling</td>
</tr>
<tr>
<td>Purchasing order update</td>
</tr>
<tr>
<td>Quality checking</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>shipping</strong></td>
</tr>
<tr>
<td>Lots formation</td>
</tr>
<tr>
<td>Load sequencing</td>
</tr>
<tr>
<td>Packing</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Appendix 8. WMS-F list of functions observed in literature and chosen by WMS representative.

<table>
<thead>
<tr>
<th>WMS FUNCTIONS</th>
<th>materials/goods receiving</th>
<th>storage</th>
<th>order-picking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloading</td>
<td>Slotting</td>
<td>Fixed, random or hybrid storage</td>
<td>Human labour / machines picking</td>
</tr>
<tr>
<td>Scanning</td>
<td>Inventory management &amp; replenishment</td>
<td>Batch wave, mini wave, zone, multi order picking, batch picking, volume picking</td>
<td></td>
</tr>
<tr>
<td>Goods acceptance</td>
<td>FIFO</td>
<td>Sequence picking</td>
<td></td>
</tr>
<tr>
<td>Labelling</td>
<td>LIFO</td>
<td>Tasks interleaving</td>
<td></td>
</tr>
<tr>
<td>Purchasing order update</td>
<td>Pull down</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle Counting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shipping</td>
<td>warehouse administration documentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lots formation</td>
<td>Customer service reports</td>
<td></td>
<td>Dock/Yard management</td>
</tr>
<tr>
<td>Load sequencing</td>
<td>Storing instructions</td>
<td></td>
<td>3PL billing</td>
</tr>
<tr>
<td>Packing</td>
<td>Picking instructions</td>
<td></td>
<td>Cross-docking</td>
</tr>
<tr>
<td>Quality checking before shipment</td>
<td>Inventory reports</td>
<td></td>
<td>Pick-to-cartoon</td>
</tr>
<tr>
<td></td>
<td>Loading reports</td>
<td></td>
<td>Advanced Shipment Notice</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Labour management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Capacity Planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Routes optimisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Process Analysis</td>
</tr>
</tbody>
</table>


Appendix 9. WMS-C list of functions.

<table>
<thead>
<tr>
<th>Base Modules</th>
<th>Advanced Modules</th>
<th>Extended Modules</th>
<th>Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warehouse Layout &amp; Logic</td>
<td>Adaptive Task Interleaving</td>
<td>Collect YMS</td>
<td>SattMate WCS</td>
</tr>
<tr>
<td>Goods Receiving</td>
<td>Dispatch Area Planning</td>
<td>Detect/Early Warning System</td>
<td></td>
</tr>
<tr>
<td>Putaway</td>
<td>Gate Area Time Scheduler</td>
<td>OpView</td>
<td></td>
</tr>
<tr>
<td>Dispatch Order Planning</td>
<td>Goods to Man Picking</td>
<td>RetroSpect</td>
<td></td>
</tr>
<tr>
<td>Picking</td>
<td>Issue Tracking</td>
<td>SattMate WCS</td>
<td></td>
</tr>
<tr>
<td>Packing</td>
<td>Kitting/BOM</td>
<td>System Health Check</td>
<td></td>
</tr>
<tr>
<td>Dispatch</td>
<td>Long Term Storage</td>
<td>Voice</td>
<td></td>
</tr>
<tr>
<td>Supporting Functions</td>
<td>Material Supply</td>
<td>Warehouse 3D</td>
<td></td>
</tr>
<tr>
<td>Basic Functions</td>
<td>Pallet Pool</td>
<td>WorkForce Planner</td>
<td></td>
</tr>
<tr>
<td>System Environment Administration</td>
<td>Paper Based Tasks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring</td>
<td>Performance Manager</td>
<td></td>
<td></td>
</tr>
<tr>
<td>User Clients</td>
<td>Preplan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>Serial Number Handling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Slotting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automation Equipment</td>
<td>TMS WebServices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference Documentation</td>
<td>Web Order Entry</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix 10. WMS-D list of functions.

- **Inbound Processing**
  - ASN data receiving, validation
  - Transportation unit mgmt.
  - Goods receipt
  - Putaway bin determination
  - Internal routing
  - Deconsolidation
  - Putaway
  - Returns / reverse logistics
  - Goods receipt optimization
  - Advanced returns mgmt.
  - Receipt from production
  - FIORI Apps

- **Storage & Operations**
  - Rearrangement
  - Slotting
  - Inventory counts / record accuracy
  - Replenishment
  - Freight order management
  - Scraping
  - KIt-to stock
  - Warehouse Billing
  - Transit warehousing
  - Transportation cross docking
  - Pick from goods receipt
  - Push deployment
  - Yard management

- **Outbound Processing**
  - Order deployment
  - Route determination
  - Transportation unit management and Shipping cockpit
  - Wave management and Work assignment
  - Picking bin determination
  - Warehouse order creation
  - Picking, packing, staging
  - Loading & goods issue
  - KIt-to-order
  - Direct outbound delivery
  - Production supply
  - Production staging and consumption

- **FIORI Apps for Lean Warehouse Clerk**
  - Graphical warehouse layout
  - Transp. integration (LESS)
  - Claims & Returns
  - Multiple EAN
  - Cartonization
  - Rapid deployment package
  - KPIs, Performance dashboard
  - Retail enhancements
  - Batch on Plant level
  - Direct PLC Communication
Appendix 11. WMS-D interface languages.
Interface language: Arabic, Bulgarian, Catalan, Chinese (Simplified), Chinese (Traditional), Croatian, Czech, Danish, Dutch, English, Finnish, French, German, Greek, Hebrew, Hungarian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Romanian, Russian, Slovak, Slovenian, Spanish, Swedish, Turkish, Ukrainian.

Appendix 12. Indicators meaning in the framework.

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>WMS support this option</td>
</tr>
<tr>
<td>-</td>
<td>WMS does not support this option</td>
</tr>
<tr>
<td>+</td>
<td>WMS vendor is developing this option</td>
</tr>
<tr>
<td></td>
<td>Available WMS feature if needed</td>
</tr>
</tbody>
</table>

Appendix 13. The importance priorities classification.

<table>
<thead>
<tr>
<th>PRIORITIES</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>very important to look firstly, because of the 3PL company the most experienced in</td>
</tr>
<tr>
<td>2</td>
<td>less essential, but nice to have</td>
</tr>
<tr>
<td>1</td>
<td>look at the last moment</td>
</tr>
<tr>
<td>0</td>
<td>does not matter at all, neutral</td>
</tr>
</tbody>
</table>
### Appendix 14. The framework for the 3PL company for selecting WMS for a customer and own operations most efficiently.

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>PARAMETERS IMPORATANCE CLASSIFICATION FOR THE 3PL OPERATOR</th>
<th>WMS AS A MODULE OF ERP/LEAN SYSTEM</th>
<th>WMSSOLUTIONS FOR 3PL</th>
<th>QUESTIONS THE 3PL OPERATOR CAN ADDRESS TO A CUSTOMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMS</td>
<td>WMSES</td>
<td>WMSC</td>
<td>WMSE</td>
<td>WMSF</td>
</tr>
<tr>
<td>Customised value module</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Standardised box solution</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>ERP module</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operational year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- up to 15 years</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td>- over 15 years</td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Industry supported</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>- up to 3</td>
<td>3</td>
<td>metal parts, food</td>
<td>paper &amp; pulp, wood &amp; furniture, automotive parts, food &amp; beverages</td>
<td>++</td>
</tr>
<tr>
<td>- 4 over 3, but under 10</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>- all</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>SKUs restrictions</td>
<td>1</td>
<td>require additional certificate for pharmaceuticals, diagnosics, flammable goods</td>
<td>require additional certificate for pharmaceuticals, diagnosics, flammable goods</td>
<td>no</td>
</tr>
<tr>
<td>Warehouse type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- production</td>
<td>3</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>- distribution</td>
<td>3</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>- raw materials and finished goods</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>- Sort centers</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>- Fulfillment warehouses for e-commerce</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>- Cross-docking</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>- Transshipment break-lack centers</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>- Consolidation warehouses</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>- Several warehouse coordination</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>TOPICS</td>
<td>PARAMETERS</td>
<td>WMS A AS A MODULE OF ERPLANN SYSTEM</td>
<td>WMS B</td>
<td>WMS C</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>WMS size experience (the smallest biggest warehouse at surface operated)</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Skipped-order then per day</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Current number of warehouse personnel</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SKU’s information exchange</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Automation integration in warehouse</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

| Parameters of Automation |
|---|---|---|---|---|---|---|---|---|
| Pickers | 3 | X | X | X | X | X | X | X |
| Automatics | 3 | X | X | X | X | X | X | X |
| Horizontal/vertical carousels | 3 | X | X | X | X | X | X | X |
| A-frame dispensers | 3 | X | X | X | X | X | X | X |
| Robots | 3 | X | X | X | X | X | X | X |
| Pick to light | 3 | X | X | X | X | X | X | X |
| Put to light | 3 | X | X | X | X | X | X | X |
| Pick by voice | 3 | X | X | X | X | X | X | X |
| Virtual display-directed picking | 3 | X | X | X | X | X | X | X |
## Topics

<table>
<thead>
<tr>
<th>Function range:</th>
<th>WMS-A</th>
<th>WMS-B</th>
<th>WMS-C</th>
<th>WMS-D</th>
<th>WMS-E</th>
<th>WMS-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>• basic</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• advanced</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>• complex</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Database:</th>
<th>WMS-A</th>
<th>WMS-B</th>
<th>WMS-C</th>
<th>WMS-D</th>
<th>WMS-E</th>
<th>WMS-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Microsoft SQL</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• PostgreSQL</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>• ORACLE</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• DB2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• SAP HANA</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Questions the 3PL Operator Can Address to a Customer

- **What kind of functions should a WMS accord assistance and facilitate in a customer’s warehouse?**
- **What are the technical requirements for databases for a future customer’s WMS?**
- **What should be the level of automation in a customer’s warehouse such as basic (printer and scales) or more advanced (e.g. automated racks, picking support technologies and robotics)?**
- **Can vendor’s software be integrated with several customer’s ERP systems?**
- **With what ERP system(s) that a customer might have a vendor has already completed integration?**
- **With which ERP system(s) that a customer might have a vendor has already completed integration?**

### Parameters Importance Classification for the 3PL Operator

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>WMS-A AS A MODULE OF ERP LEAN SYSTEM</th>
<th>WMS SOLUTIONS FOR 3PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function range:</td>
<td></td>
<td>WMS-A</td>
</tr>
<tr>
<td>• basic</td>
<td>3</td>
<td>+</td>
</tr>
<tr>
<td>• advanced</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>• complex</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Database:</th>
<th>WMS-A</th>
<th>WMS-B</th>
<th>WMS-C</th>
<th>WMS-D</th>
<th>WMS-E</th>
<th>WMS-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Microsoft SQL</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• PostgreSQL</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>• ORACLE</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• DB2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>• SAP HANA</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Technical Criteria

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>WMS-A</th>
<th>WMS-B</th>
<th>WMS-C</th>
<th>WMS-D</th>
<th>WMS-E</th>
<th>WMS-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>• ERP</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• TMS</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• WCS</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• WES</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• CRM</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• Courier system</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

### Ability to Integrate with Several Customer’s ERP Systems

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>WMS-A</th>
<th>WMS-B</th>
<th>WMS-C</th>
<th>WMS-D</th>
<th>WMS-E</th>
<th>WMS-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>• IFS, JDE, SAP, SAP Business One, CDI XI, and another Polish ERP</td>
<td>SAP</td>
<td>-</td>
<td>IFS, JDE, SAP, SAP Business One, CDI XI, and another Polish ERP</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS, Pyramid</td>
</tr>
<tr>
<td>• MS Dynamics, MS Navision, Movex, M3, IFS, IBS, Pyramid</td>
<td>SAP</td>
<td>-</td>
<td>IFS, JDE, SAP, SAP Business One, CDI XI, and another Polish ERP</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS, Pyramid</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS, Pyramid</td>
</tr>
<tr>
<td>• Movex M3, Microsoft Dynamics AX, iScala, SAP, Pyramid</td>
<td>SAP</td>
<td>-</td>
<td>IFS, JDE, SAP, SAP Business One, CDI XI, and another Polish ERP</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS, Pyramid</td>
<td>SAP, MS Dynamics, MS Navision, Movex, M3, IFS, IBS, Pyramid</td>
</tr>
</tbody>
</table>

### Integrated ERP Systems Experience

<table>
<thead>
<tr>
<th>TOPICS</th>
<th>WMS-A</th>
<th>WMS-B</th>
<th>WMS-C</th>
<th>WMS-D</th>
<th>WMS-E</th>
<th>WMS-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Times WMS integrated with ERP</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>+ up to 5 times</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>+ 5 - 40</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>+ over 50</td>
<td>3</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
</tbody>
</table>
### The way of ERP integration with WMS:
- **XML**: 3 + - - + + + +
- **EDI**: 3 - - - - + + +

### ERP API transactions supported:
- **point-to-point**: 3 + - - + + - -
- **middleware**: 3 + - - - + + +

### Web based user interface
- **Android**: 3 + - - - + + +
- **Windows**: 3 + - * + + + +
- **iOS**: 2 - - - - + + -

### KPIs and dashboard visualization
- **Finnish**: 3 + - - - + + +
- **Swedish**: 2 - - - - + + -
- **English**: 3 + - - - + + +
- **Polish**: 3 - - * + + - -
- **German**: 3 - - - - + + -
- **French**: 2 - - - - + + -
- **Netherlands**: 2 - - - - + + -
- **Norwegian**: 2 - - - - + + -

### Operational systems native device applications:
- **Android**: 3 + - - - + + +
- **Windows**: 3 + - * + + + +
- **iOS**: 2 - - - - + + -

### User interface language available:
- **Finnish**: 3 + - - - + + +
- **Swedish**: 2 - - - - + + -
- **English**: 3 + - - - + + +
- **Polish**: 3 - - * + + - -
- **German**: 3 - - - - + + -
- **French**: 2 - - - - + + -
- **Netherlands**: 2 - - - - + + -
- **Norwegian**: 2 - - - - + + -

### Interface language translation tool
- **Finnish**: 3 + - - - + + +
- **Swedish**: 2 - - - - + + -
- **English**: 3 + - - - + + +
- **Polish**: 3 - - * + + - -
- **German**: 3 - - - - + + -
- **French**: 2 - - - - + + -
- **Netherlands**: 2 - - - - + + -
- **Norwegian**: 2 - - - - + + -

### Software installation:
- **As Standalone system**: 3 + - - - + + +
- **As Saas**: 3 + - - - + + +
- **As Cloud Computing**: 3 + - - - + + +

### Implementation time (the shortest - longest)
- **6 months - 1 year**: 3 - - - - - -
- **6 weeks - 6 months**: 3 - - - - - -
- **3 months - 1.5 years**: 3 - - - - - -
- **5 weeks - 1.5 years**: 3 - - - - - -
- **4 days - 1.5 years**: 3 - - - - - -
- **2 months - 1 year**: 3 - - - - - -

### Average integration time with ERP system
- **3 months - 6 months**: 3 - - - - - -
- **3 weeks - 3 months**: 3 - - - - - -
- **2 weeks - 2.5 months**: 3 - - - - - -
- **5 weeks - 6 months**: 3 - - - - - -
- **1 day - 3 weeks**: 3 - - - - - -
- **2 weeks - 5 months**: 3 - - - - - -

### Deployment costs
- **(50,000 - 100,000) + 25,000**: 3 - - - - - -
- **25,000 - 50,000**: 3 - - - - - -
- **50,000 - 100,000**: 3 - - - - - -
- **100,000 - 150,000**: 3 - - - - - -
- **150,000 - 200,000**: 3 - - - - - -
- **200,000 - 250,000**: 3 - - - - - -
- **250,000 - 300,000**: 3 - - - - - -

### Contract length
- **Upon request**: 3 - - - - - -
- **1 year**: 3 - - - - - -
- **Upon request**: 3 - - - - - -
- **Upon request**: 3 - - - - - -
- **1 year**: 3 - - - - - -
- **1 or 3 years**: 3 - - - - - -

### Deployment costs (€)
- **Upon request**: 3 - - - - - -
- **1 year**: 3 - - - - - -
- **Upon request**: 3 - - - - - -
- **Upon request**: 3 - - - - - -
- **1 year**: 3 - - - - - -
- **1 or 3 years**: 3 - - - - - -

### TOTAL SCORE (SUM OF +)
- **WMS-A**: 39
- **WMS-B**: 0
- **WMS-C**: 47
- **WMS-D**: 91
- **WMS-E**: 98
- **WMS-F**: 57
- **61**