

ANALYSING WHETHER COMPANY X SHOULD IMPLEMENT A WAREHOUSE MANAGEMENT SYSTEM



Author:

Kushtrim Kycyku

LTH staff:

Supervisor – Andreas Norrman

Examinator – Joakim Kembro

Acknowledgements

This master's thesis is the final project of my Master of Science in Industrial Engineering and Management at the Faculty of Engineering at Lund University. The period in which this project was written has been challenging and filled with hard work, so I would like to seize this opportunity to extend my gratitude and appreciation to everyone who contributed to bringing this thesis into fruition.

First, I would like to thank Andreas Norrman, my supervisor at the Institution for Department of Mechanical Engineering Sciences (Division of Engineering Logistics), for his continuous support and guidance throughout my thesis.

Second, I would like to give thanks to Company X and my supervisor at Company X for the opportunity to do this thesis, the freedom to choose the topic, as well as their help and support when gathering data at their warehouse.

I would also like to thank Ongoing WMS, Apport Systems, and Noventus for agreeing to interviews, for their support in reaching their customers (Company Y & Z), and for their profound answers.

Lastly, I would like to thank my family for their unending support and love.

Kushtrim Kycyku

Lund, March 2024

Abstract

Title: Analysing Whether Company X Should Implement A Warehouse Management System

Author: Kushtrim Kycyku

Supervisor: Andreas Norrman, Professor Engineering Logistics, Division of Engineering Logistics, the Faculty of Engineering at Lund University

Examiner: Joakim Kembro, Professor Engineering Logistics, Division of Engineering Logistics, the Faculty of Engineering at Lund University

Background: A Warehouse Management System (WMS) is a software that tracks and manages warehouse activities. The first WMS was introduced in 1975 and today the WMS market is valued at over USD 3 billion. Most warehouses use one as quality assurance becomes unlikely plausible without software support. This thesis focuses on Company X, who are the third-largest manufacturer by revenue in their industry and are active in more than 150 countries. Company X has existed for more than 200 years, and since the 19th century in City X, and predate the creation of the warehouse management system. Combined with an overall focus on the production part of the site, they have not implemented a WMS (Warehouse Management System) for their warehouse yet.

Problem definition and purpose: Company X believes that it would be difficult to make warehouse improvements without a WMS as it would be too time consuming to plan everything manually at the scale of their warehouse. Company X currently use an ERP from SAP and with this they have an internal policy to not use any external software. The policy also prevents them from using external companies to make an analysis regarding a WMS implementation. Therefore, the purpose of this thesis is to increase understanding of how to analyse whether a company should implement a WMS or not. The purpose is answered by researching the benefits and problems of different WMS features, how external factors influence the warehouse performance and the WMS features, and how a WMS implementation is translated into financial gain.

Theoretical framework and methodology: The theoretical framework consists of four sections: warehouse operations, core WMS features, KPIs (Key Performance indicators), and lastly a section briefly explaining ABC-classification and path-optimizations since they were brought up a lot in the findings. The method used in this thesis was an abductive holistic multiple-case study, with inspiration from Yin's (2018) method of how to do case study research. Data based on 15 KPIs related to warehouse efficiency was gathered at Company X and then three WMS vendors were interviewed along with two customer companies to the vendors, in order to compare and generalize the findings rather than optimizing one specific case. The cases were analysed with cross-case

synthesis, where they were compared to each other, and analysed with the literature using pattern matching, where the results were compared to the literature.

Result and conclusion: The case interviews showed that all 15 KPIs were likely to be positively impacted by a WMS implementation. The impact depends on many influencing factors. A WMS gives full visibility and control of goods in a warehouse and the opportunity to improve the flow-speed of the warehouse. It also eliminates most human error related problems in warehouses. There are many benefits and very few problems with implementing a WMS. Company X can benefit from implementing a WMS; in Company X's case the benefits would mostly be found in picking and put-away through optimised pathways, ABC-classification, and multi-picking. The optimised picking and put-away can also impact their storage positively.

Keywords: Warehouse management system, WMS, Key performance indicators, KPI, warehouse efficiency, ABC classification, influencing factors.

Table of Content

1. Introduction.....	1
1.1 Warehouse Management System	1
1.2 Company X	3
1.3 Problem	3
1.4 Purpose.....	4
1.5 Focus and delimitations	4
1.6 Structure of thesis	5
1.6.1 Literature.....	6
1.6.2 Methodology & Method	6
1.6.3 Findings.....	6
1.6.4 Cross Case Analysis.....	6
1.6.5 Reflections & Recommendation.....	6
1.6.6 Conclusion	6
2. Literature.....	7
2.1 Warehouse operations.....	7
2.1.1 Receiving.....	8
2.1.2 Put-away	9
2.1.3 Storage.....	9
2.1.4 Picking	10
2.1.5 Shipping	10
2.2 Core WMS Features.....	10
2.2.1 Appointment Scheduling	11
2.2.2 Receiving.....	12
2.2.3 Quality Assurance	12
2.2.4 Put-Away	13
2.2.5 Location Tracking	13
2.2.6 Work-Order Management	14
2.2.7 Picking	15
2.2.8 Packing and Consolidation	16
2.2.9 Shipping	17
2.3 KPIs	18
2.3.1 KPIs gathered from literature.....	18
2.3.2 Consolidating KPIs into one table.....	21
2.4 Added features after the findings.....	23
2.4.1 ABC-classifications.....	23
2.4.2 Route optimization	24
2.5 conclusion on the literature	24
3. Methodology.....	27
3.1 Choosing the method	27
3.2 Plan	30
3.3 Design.....	30

3.3.1 Theory	31
3.3.2 Types of case study design	31
3.3.3 The design	32
3.4 Prepare	35
3.4.1 How to prepare	36
3.4.2 What to do	36
3.4.3 Protecting human subjects	37
3.4.4 Case Study Protocol	37
3.4.4.1 Section A. Overview of the Case Study	37
3.4.4.2 Section B. Data Collection Procedures	37
3.4.4.3 Section C. Protocol Questions	38
3.4.4.4 Section D. Tentative Outline for the Case Study Report	38
3.5 Collect	38
3.6 Analyze	40
3.7 Share	43
3.8 Trustworthiness	44
4. Findings.....	45
4.1 Company X	45
4.1.1 Company X warehouse	45
4.1.2 Receiving Operation and Receiving KPIs	46
4.1.2.1 KPI 1 Receiving time.	47
4.1.2.2 KPI 2 Dock door utilization.	49
4.1.2.3 KPI 3 Documentation processed accurately.	50
4.1.3 Put-Away Operation and Put-away KPIs	50
4.1.3.1 Put-away time.	50
4.1.3.2 Put-away utilization of labour and equipment.....	51
4.1.3.3 Correct put-away.....	51
4.1.4 Storage Operations and Storage KPIs.....	52
4.1.4.1 Inventory days on hand	52
4.1.4.2 Storage space utilization.....	53
4.1.4.3 Storage accuracy.....	53
4.1.5 Picking Operations and Picking KPIs	54
4.1.5.1 Company X current problem with picking.....	54
4.1.5.2 Picking time	56
4.1.5.3 Picking utilization of labour and equipment.....	57
4.1.5.4 Picking accuracy	58
4.1.6 Shipping Operations and Shipping KPIs	59
4.1.6.1 Shipping time	59
4.1.6.2 Dock door utilization.....	59
4.1.6.3 Orders shipped on time	61
4.1.7 Conclusion of the Company X empirical data	61
4.2 Multiple cases	62
4.2.1 The Cases.....	63
4.2.1.1 Company background and context	63
4.2.1.1.1 Ongoing Warehouse AB.....	63
4.2.1.1.2 Apport Systems	64
4.2.1.1.3 Noventus Systems AB	65
4.2.1.1.4 Company Y.....	65

4.2.1.1.5 Company Z.....	65
4.2.1.1.6 Customer reviews online.....	66
4.2.2 KPIs related to Time.....	67
4.2.2.1 Receiving Time.....	67
4.2.2.2 Put-away Time.....	68
4.2.2.3 Inventory Days on Hand.....	69
4.2.2.4 Picking Time.....	69
4.2.2.5 Shipping Time.....	70
4.2.2.6 Summary on Time related KPIs.....	71
4.2.3 KPIs related to Utilization.....	72
4.2.3.1 Receiving Dock Door Utilization.....	72
4.2.3.2 Put-away Utilization of Labour and Equipment.....	72
4.2.3.3 Storage Space Utilization.....	73
4.2.3.4 Picking Utilization of Labour and Equipment.....	73
4.2.3.5 Shipping Dock Door Utilization.....	74
4.2.3.6 Summary on Utilization related KPIs.....	74
4.2.4 KPIs related to Quality.....	75
4.2.4.1 Documentation Processed Accurately (at Receiving).....	75
4.2.4.2 Correct Put-aways.....	75
4.2.4.3 Storage Accuracy.....	76
4.2.4.4 Picking Accuracy.....	76
4.2.4.5 Orders Shipped on Time/on Schedule.....	77
4.2.4.6 Summary on Quality related KPIs.....	78
5. Cross Case Analysis.....	79
5.1 Time.....	79
5.1.1 Receiving time.....	79
5.1.1.1 Cross-case analysis.....	79
5.1.1.2 Company X analysis.....	80
5.1.2 Put-away time.....	80
5.1.2.1 Cross-case analysis.....	80
5.1.2.2 Company X analysis.....	81
5.1.3 Inventory days on hand.....	81
5.1.3.1 Cross-case analysis.....	81
5.1.3.2 Company X analysis.....	81
5.1.4 Picking time.....	82
5.1.4.1 Cross-case analysis.....	82
5.1.4.2 Company X analysis.....	83
5.1.5 Shipping time.....	84
5.1.5.1 Cross-case analysis.....	84
5.1.5.2 Company X analysis.....	84
5.1.6 Conclusion on time.....	85
5.2 Utilization.....	85
5.2.1 Dock door utilization (receiving).....	85
5.2.1.1 Cross-case analysis.....	85
5.2.1.2 Company X analysis.....	86
5.2.2 Put-away utilization of labour and equipment.....	86
5.2.2.1 Cross-case analysis.....	86
5.2.2.2 Company X analysis.....	86
5.2.3 Storage space utilization.....	86
5.2.3.1 Cross-case analysis.....	86
5.2.3.2 Company X analysis.....	86

5.2.4 Picking utilization of labour and equipment	87
5.2.4.1 Cross-case analysis	87
5.2.4.2 Company X analysis	87
5.2.5 Dock door utilization (shipping).....	87
5.2.5.1 Cross-case analysis	87
5.2.5.2 Company X analysis	87
5.2.6 Conclusion on utilization	88
5.3 Quality	88
5.3.1 Documentation processed accurately	88
5.3.1.1 Cross-case analysis	88
5.3.1.2 Company X analysis	88
5.3.2 Correct put-aways	88
5.3.2.1 Cross-case analysis	88
5.3.2.2 Company X analysis	89
5.3.3 Storage accuracy	89
5.3.3.1 Cross-case analysis	89
5.3.3.2 Company X analysis	89
5.3.4 Picking accuracy	90
5.3.4.1 Cross-case analysis	90
5.3.4.2 Company X analysis	90
5.3.5 Orders shipped on time	90
5.3.5.1 Cross-case analysis	90
5.3.5.2 Company X analysis	91
5.3.6 Conclusion	91
5.4 Summary of cross-case analysis	91
5.4.1 Benefits and Problems	91
5.4.1.1 Benefits	91
5.4.1.2 Problems	92
5.4.3 Influencing factors	94
5.4.4 KPI results	95
6. Reflections & Recommendation	99
6.1 Reflections on the findings	99
6.1.1 Unexpected outcomes	99
6.1.2 Results from the cross-case analysis	100
6.2 Recommendation to Company X	100
7. Conclusion	103
7.1 Purpose and Research Questions	103
7.1.1 RQ1: What are the benefits and problems of different WMS features?	104
7.1.2 RQ2: What external factors influence the warehouse performance and the WMS features effects?	107
7.1.3 RQ3: How would implementing a WMS impact warehouse performance and how is this translated into financial gain?	109
7.1.4 RQ4: How would this impact Company X specifically?	110
7.1.5 Fulfilment of the Purpose.....	113
7.2 Contribution	115
7.3 Limitations and future research	115
Appendices	125

Appendix A – Interview Questions	125
Appendix B	129
Appendix C	131
Section A. Overview of the Case Study.....	131
A.1 Mission and goals reflecting the interest of the Company X.....	131
A.2 Case Study Questions	131
A.3 Key readings	131
A.4 Protocol role in guiding case study researcher	131
Section B. Data Collection Procedures	132
B.1 Fieldwork contact persons.....	132
B.2 Data collection plan	132
B.3 Preparation prior to fieldwork	133
Section C. Protocol Questions	133
C.1 Company X questions	133
C.2 Multiple Cases questions	133
Section D. Tentative Outline for the Case Study Report	133
D.1 Audience for the report.....	133
D.2 Extent of documentation and how to ensure secondary visits don't occur.....	133
D.3 Length of report (estimate)	134

List of Figures

Figure 1.1: plan to answer the problem	4
Figure 1.2: Company X's warehouse layout	5
Figure 1.3: The structure of the thesis	6
Figure 2.1: Why the topics were chosen	7
Figure 2.2: The Warehouse Operations	8
Figure 2.3: Depiction of warehouse operations interacting and passing each other	8
Figure 2.4: A figure showing which KPIs were chosen, and from where.	22
Figure 2.5: ABC-classification example	23
Figure 2.6: Example of Route optimization on a single location and on multiple locations, green is the optimal route.	24
Figure 2.7: Visualization of the theory	26
Figure 3.1: The research onion from Saunders et al. (2016).	27
Figure 3.2: Example of how abduction affected the concept	28
Figure 3.3: Case Study Method Sequence (Yin 2018) p.31	29
Figure 3.4: Conditions to choose methodology. (Yin 2018)	29
Figure 3.5: Types of design, redrawn from (Yin, 2018) p.84.	32
Figure 3.6: Difference between Unit of Analysis and Unit of Data Collection	33
Figure 3.7: How the cases will be documented	35
Figure 3.8: Example illustration of the structure of the data-base	39
Figure 3.9: Visualization of where Table 3.3 is used.	42
Figure 4.1: Vertical layout of the warehouse	46
Figure 4.2: Two receiving areas marked on the warehouse layout	47
Figure 4.3: Visualization of pallets being received at the conveyor belt	48
Figure 4.4: Graph showing pallets received from the conveyor belt for 47 weeks	49
Figure 4.5: Left: how it can look at Company X right now, Right: how it could look with a WMS	50
Figure 4.6: A graph showing the days on hand for 9 pallets, and an average of them	52
Figure 4.7: A graph showing the fill rate over 10 weeks	53
Figure 4.8: Four instances of how the picking routes can look if the pickers follow their orders.	55
Figure 4.9: A visualization of how the route for bringing down items could be shortened	57
Figure 4.10: A graph of the total number of shipments over a period of 23 months	60
Figure 4.11: A graph of the dock door utilization	60
Figure 5.1: Layout of the Company X warehouse with the route of a single-pick order drawn in red	84
Figure 5.2: Illustration of put-away simplicity with a WMS	89
Figure 5.3: Illustration of picking simplicity with a WMS	90
Figure 5.4: The benefits and problems from the empirical data	93
Figure 5.5: External influencing factors from the empirical data	95
Figure 5.6: The change of the scenario table from the left to the right due to the empirical findings	95
Figure 7.1: Research questions visualised in the purpose-plan figure	103
Figure 7.2: The benefits and problems	106
Figure 7.3: External influencing factors from the empirical data	107
Figure 7.4: Example of how Company X's warehouse (left) could use	

ABC classification (on the right)	111
Figure 7.5: An example of how the route would change for eight one-piece orders with multi-picking	112
Figure 7.6: Complete figure explaining benefits, problems, influencing factors, and effect on warehouse performance through 15 KPIs.	114

List of Tables

Table 2.1 25 KPIs from Kusrini et al. (2017), Pajic et al. (2021).	20
Table 2.2 Warehouse measurement KPIs Staudt et al. (2015).	20
Table 2.3 Warehouse measurement KPIs gathered and condensed from Faveto et al. (2021).	21
Table 2.4 KPIs for a WMS based on the literature for the warehouse operations, divided in time, utilization, and quality.	22
Table 2.5 Benefits, problems and influencing factors from the theory.	24
Table 3.1 List of vendors considered, which were contacted, and which agreed to interview	34
Table 3.2 Final list of relevant vendors and their customers that were interviewed	34
Table 3.3 Before and after table to showcase findings	42
Table 3.4 Four Criterion for assessing the trustworthiness of a qualitative research according to Guba & Lincoln (1989)	44
Table 4.1 Company X's current values for the before and after scenario	62
Table 4.2 The KPIs chosen, with the types of KPIs highlighted	63
Table 4.3 KPIs measured at Company Z	66
Table 4.4 Collection of answers on the Time related KPIs	71
Table 4.5 Collection of answers on the Utilization related KPIs	74
Table 4.6 Collection of answers on the Quality related KPIs 5	78
Table 5.1 Table showcasing expected result of implementing a WMS based on the study findings.	96
Table 5.2 Expected results for Company X	97
Table 7.1 Table showcasing expected result of implementing a WMS based on the study findings	109
Table 7.2 Expected results for Company X	110
Table B Data from customer cases of Ongoing WMS, Apport WMS, SAP WMS, and Vendor X All taken from their websites.	129
Table C.1 Important readings	131
Table C.2 Type of data that needs to be collected.	132

List of Acronyms

WMS	Warehouse Management System
ERP	Enterprise Resource Planning
SKU	Stock Keeping Unit
KPI	Key Performance Indicator
FIFO	First In First Out
RFID	Radio Frequency Identification
GPS	Global Positioning System
QR	Quick-Response
SEK	Swedish Krona
3PL	Third Party Logistics
API	Application Programming Interface

1. Introduction

In this section, a brief introduction to the topic of the thesis, Warehouse Management Systems (WMS), and of the company will be given.

1.1 Warehouse Management System

A WMS is software that tracks and manages warehouse activities. Since the creation of WMS's, 1975, warehouse logistics have improved tremendously. Especially with the introduction of the ERP (Enterprise Resource Planning) systems in the 1990's, which allowed the WMSs to utilize the drastic improvement of data availability. Year after year the WMS's have been improved with new features, faster features, and a more holistic connection to the rest of the supply chain. The modern WMSs are very fast and provide very accurate information (Zimmerman, 2020).

There are many WMS suppliers, with ERP WMSs being the most popular form according to Forger (2018). The majority of new users pick mega-suite supplier (large software companies with software for the entire enterprise such as Microsoft or SAP) including a WMS (Forger, 2018). The complexity of WMS's varies from company to company, but the core is the same. At the foundation of its existence, a WMS tracks all products when they arrive and all products that are shipped out from the warehouse. A WMS would allow a company to automate the logical parts of the warehouse activities through an organized database and a stock locator system, which manages an inventory of storage locations and an inventory of products. A good WMS will not only track the storage locations but every place a product can be in, including fine details such as forks of individual forklift trucks. It also allows for directed put-away and picking (Bartholdi & Hackman, 2019). These details allow for very easy and sometimes automated warehouse optimizations, which in turn provides less effort, more efficient warehouse, and reliable results when compared to manually handled systems. A WMS often works by having material identified by a barcode which is then transmitted using a radio frequency terminal, most often in the form of a scanner, to the company server, thus allowing for computerized solutions (Kučera, 2017).

A WMS could be categorized in basic (core), advanced, and complex (Bartholdi & Hackman, 2019; Raama et al., 2012). According to Raama et al. (2012) the basic system supports stock and location control while the advanced WMS can plan resources and activities as well as synchronizing the flow of goods in the warehouse. The complex WMS allows also for tracking and tracing, planning, control, and execution. The features of a complex WMS allow for a real time optimization of a warehouse that is able to adapt to change both in demand and supply patterns as well as in physical changes to the warehouse and new SKUs (stock keeping unit; Raama et al., 2012).

The features of a WMS will vary depending on the developer and the user's needs, but most WMS's share the same set of core features (Bartholdi & Hackman, 2019):

- Appointment scheduling
- Receiving
- Quality assurance

- Put-Away
- Location tracking
- Work-order management
- Picking
- Packing and consolidation
- Shipping

These core features give significant opportunities to benefits such as reducing labour, and in turn reduce capital.

There are many problems and key factors to handle when implementing a WMS. Some of these factors include making sure that the WMS can be integrated into the companies ERP system (Afolabi, n.d; Andiyappillai, 2020), selecting the right WMS for the company, having good internet connection (Ahmed, 2023), making sure to acquire hardware such as handheld devices (F.Curtis Barry & Company, n.d), and making sure that the system requirements are met to handle the software (Trinidad, 2021). If there are problems integrating the ERP system with the WMS (if the ERP does not already have a WMS) or if the hardware cannot run the WMS software as it should, then the WMS might have a negative impact. This was the case for Adidas in 1996, where they under-shipped by 80% due to system failures (Supply Chain Digest, 2006).

For implementation, the total cost of the WMS is also important. Another very important factor is training the employees, including training them to scan barcodes and use the new equipment, setting new rules, and teaching the employees how to use the software (Ahmed, 2023). Changing the entire work process and training the staff is very important, as only implementing a WMS without any process change will not lead to cost savings. A WMS implementation will only reduce errors made due to human factors if there are no changes made in the work processes (Raama et al. 2012).

The key factors needed for a successful WMS implementation can be narrowed down to the following 6 (ScanTexas, n.d; Inbound Logistics, 2017):

1. Preparedness: this includes training staff and acquiring hardware and equipment.
2. Specificity/complexity of operations: making sure to get at WMS tailored for your warehouse.
3. Patience: not rushing the implementation of the WMS
4. Capability: make sure the WMS can meet the demands
5. Expenses: Make sure its profitable
6. Long-term planning: consider where the needs of the customers are going and plan the WMS to include future demand also.

Another very important factor after the implementation is to review the WMS for success. This is done to make sure that aspects that did not work in the initial implementation get fixed, or just reviewing the WMS for changes in the company that can result in further profit (Whiting, 2023).

There are many different types of WMS products and many different WMS vendors. Combined with integration compatibility between the WMS's and the other software's, this makes for a difficult decision when choosing which WMS to use.

1.2 Company X

Company X is a multinational company with their headquarters in Country Y, with activities in more than 150 countries. Company X is the world's third-largest manufacturer by revenue in their industry. The department of Company X that this master thesis will be based on is their regional headquarters in City X. Their manufacturing principles are a mix of MTS (make to stock) and MTO (make to order) for both industrial and smaller clients. Company X in City X has two warehouses, one for each of the two different types of clients. When Company X is mentioned throughout the study, it will refer to the regional headquarters and not the entire company.

Company X uses an ERP (Enterprise Resource Planning) from SAP to handle their enterprise, but the current software version does not include a WMS. The software they currently use includes some features that a WMS provides. These are features such as using barcodes and scanners to transmit information and tracking inventory numbers and locations.

1.3 Problem

Company X has existed for more than 200 years under different names, and in Country X since 18xx. As Company X in City X is a production focused company, they have focused on making money on the production part of the site, as the greatest profits would be generated there. This has led to their logistical department not being up to par with modern technology and theory, and they lack a WMS. Company X in City X predates the creation of the WMS and has kept their traditional ways of keeping the warehouse. This has, according to Company X's logistics department, lead to a potential ineffectiveness in the picking and in the material flow of the warehouse and thus lower profit. Picking is the physical process where individual items are picked to satisfy the customer's order.

Company X believes, that without a WMS it would be difficult to implement any changes for warehouse improvement, as it would be too time consuming to determine where items should be placed and what pick paths should be used. Optimizing a warehouse without a WMS would further only work for the very same data that is used currently and not consider future demand patterns or company changes.

Company X has a contract with SAP for their ERP. With this contract is an internal policy that prevents them from using any external WMS. This policy prevents them from paying any external companies to make an analysis regarding a WMS implementation. But Company X wants an analysis on WMS benefits and problems to help determine if they should implement a WMS or not.

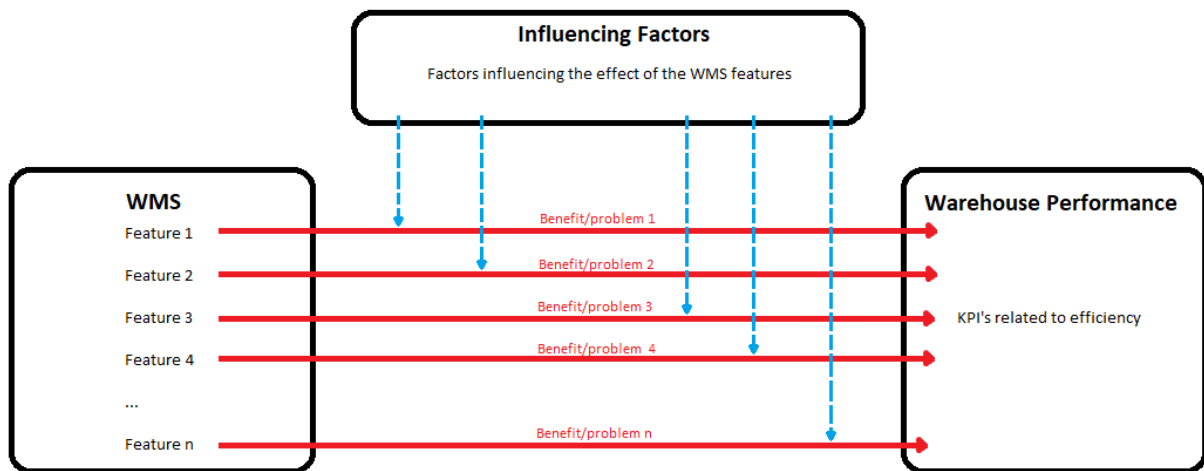


Figure 1.1: Plan to answer the problem.

1.4 Purpose

The purpose of this thesis is to increase understanding of how to analyse whether a company should implement a WMS or not.

To fulfil the purpose, the following research questions will be investigated:

RQ1: What are the benefits and problems of different WMS features?

RQ2: What external factors influence the warehouse performance and the WMS features effects?

RQ3: How would implementing a WMS impact warehouse performance and how is this translated into financial gain?

RQ4: How would implementing a WMS impact Company X specifically?

1.5 Focus and delimitations

Among the two warehouses at Company X, the company only believe one of them could need a WMS. This is because one of the warehouses get their orders days in advance and orders mostly are full EU-pallets, while the other warehouse gets their orders at the requested shipping-day and the orders are much smaller which make the warehousing activities more complex. The current software is sufficient to handle the first warehouse without problems, and Company X do not think a WMS would improve much. Thus Company X will only focus the other warehouse, illustrated in figure 1.2.

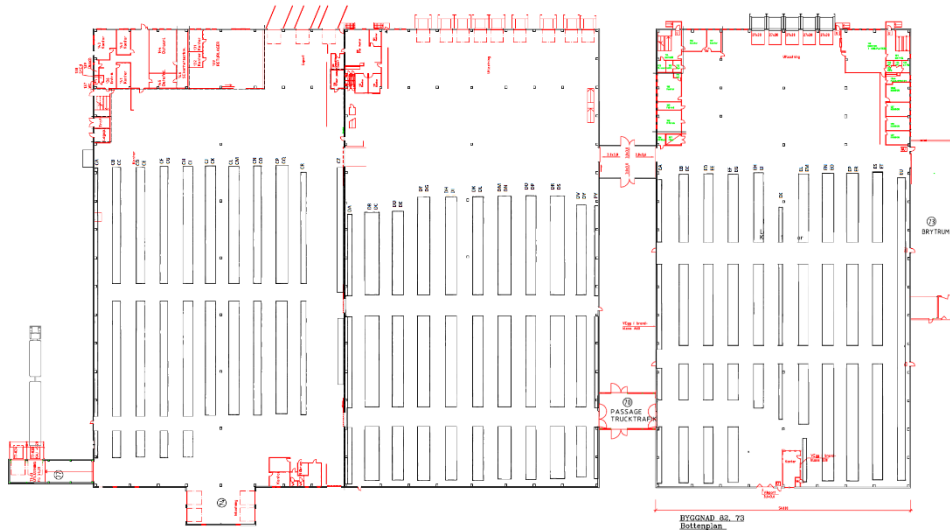


Figure 1.2: Company X's warehouse layout

The thesis will learn from multiple cases of WMS implementations, and data from companies before and after implementing a WMS. However, experimental and hypothetical implementation of a WMS for company X will not be made due to time limitations.

Another delimitation is that the focus of the thesis will be on operational aspects, such as Key Performance Indicators (KPI), benefits, and functionality of a WMS, instead of on the strategic aspects. This is mainly due to WMS vendors having different payment plans and different costs, so it would be difficult to generalize profit from a strategic point of view. Which is why RQ3 deliberately is phrased as the financial gain from WMS impact on warehouse performance, and not the financial gain of a WMS implementation as a whole.

1.6 Structure of thesis

The structure of the thesis is split into 7 sections, presented in figure 1.3 with different colours. The following sections are the theoretical framework, the methodology & method, the empirical study, the analysis, the discussion, and the conclusion and contributions.

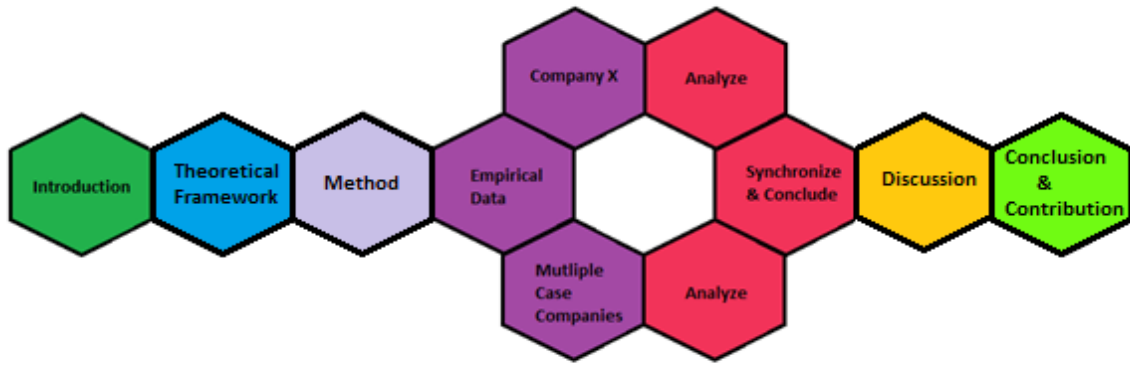


Figure 1.3: The structure of the thesis

1.6.1 Literature

The theoretical framework describes four main topics of literature, Warehouse Operations, Warehouse Management Systems, core functions, and their KPIs. Lastly a section will explain some specific features that often occurred in the findings.

1.6.2 Methodology & Method

Methodology & Method will explain and motivate the chosen research design and the method. The method will explain how data was collected and analysed in an effective way.

1.6.3 Findings

The empirical data is described in two parts. The first part pertains the gathering of the empirical data at Company X, and their warehouse will be explained in more detail. The other part will show the data gathered from other companies.

1.6.4 Cross Case Analysis

This part will analyse Company X and the other case companies, compared to the theory. The Company X analysis will describe a before implementing WMS scenario, while the case studies will serve as an after to-be scenario. These analyses will be combined to get a holistic analysis.

1.6.5 Reflections & Recommendation

A brief discussion of the findings follows that will include recommendations for Company X.

1.6.6 Conclusion

The final chapter presents conclusions and answers to the research questions. Recommendations will be given to Company X based on these conclusions. The chapter will also position the contributions of this study and suggest further research.

2. Literature

The literature was studied during the first phase of the thesis, which represents the planning and design phase. In order to fulfil the purpose, warehouses in general have to be understood, thus the literature will start with Warehouse operations, then the core WMS features, the KPIs, and a section explaining ABC-classification and path-optimization since these were brought up a lot in the findings. The sections were chosen based on the purpose and plan to answer the problem (figure 2.1)

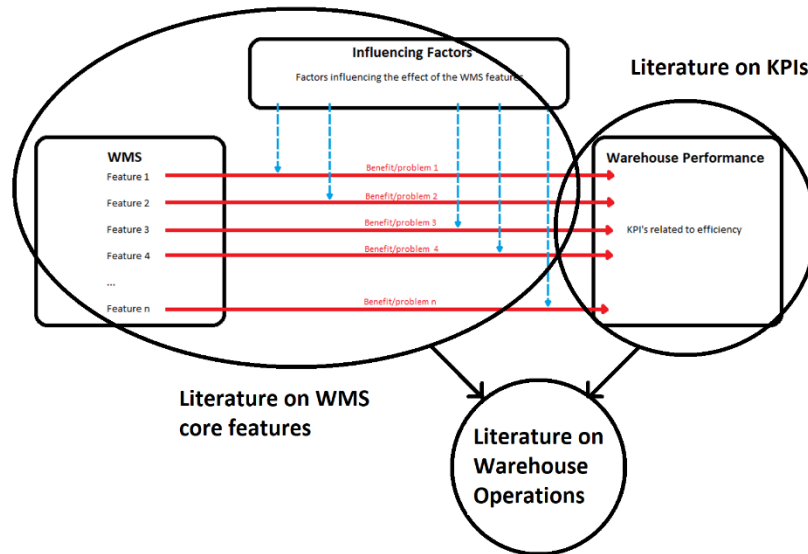


Figure 2.1: Why the topics were chosen

2.1 Warehouse operations

The purpose of a warehouse is, according to Bartholdi & Hackman (2019), to reorganize and repack products. In a warehouse goods are typically arrived in bulk and are shipped in smaller scale; one important function of a warehouse is to break down shipments of goods into smaller quantities so that they can be redistributed (Bartholdi & Hackman, 2019).

Warehouses usually consist of 5 operations, these are receive, put-away, storage, picking, and shipping. The order which goods go through the warehouse is usually in the order shown in figure 2.2.

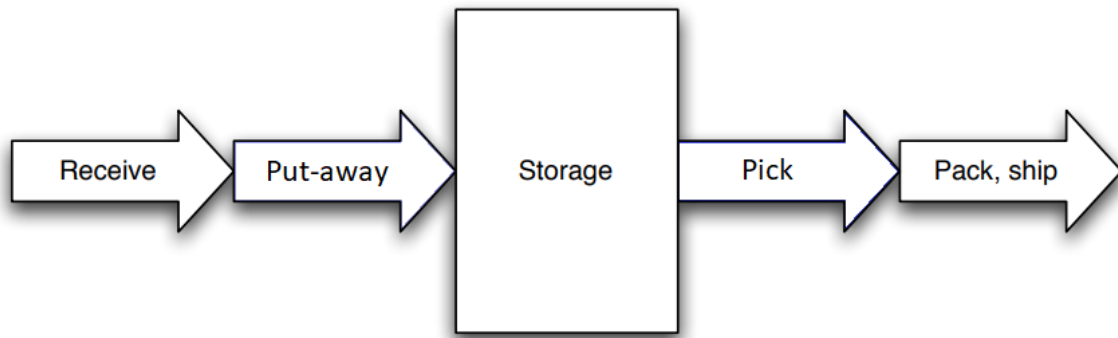


Figure 2.2: The Warehouse Operations

But depending on multiple variables such as the size of the warehouse, the type of product, the customer orders and many more, certain steps can be skipped (figure 2.3). An item can for example be sent to shipping immediately after it is received if there's an order that includes that item. Thus, skipping the entire steps of put-away and storage (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005).

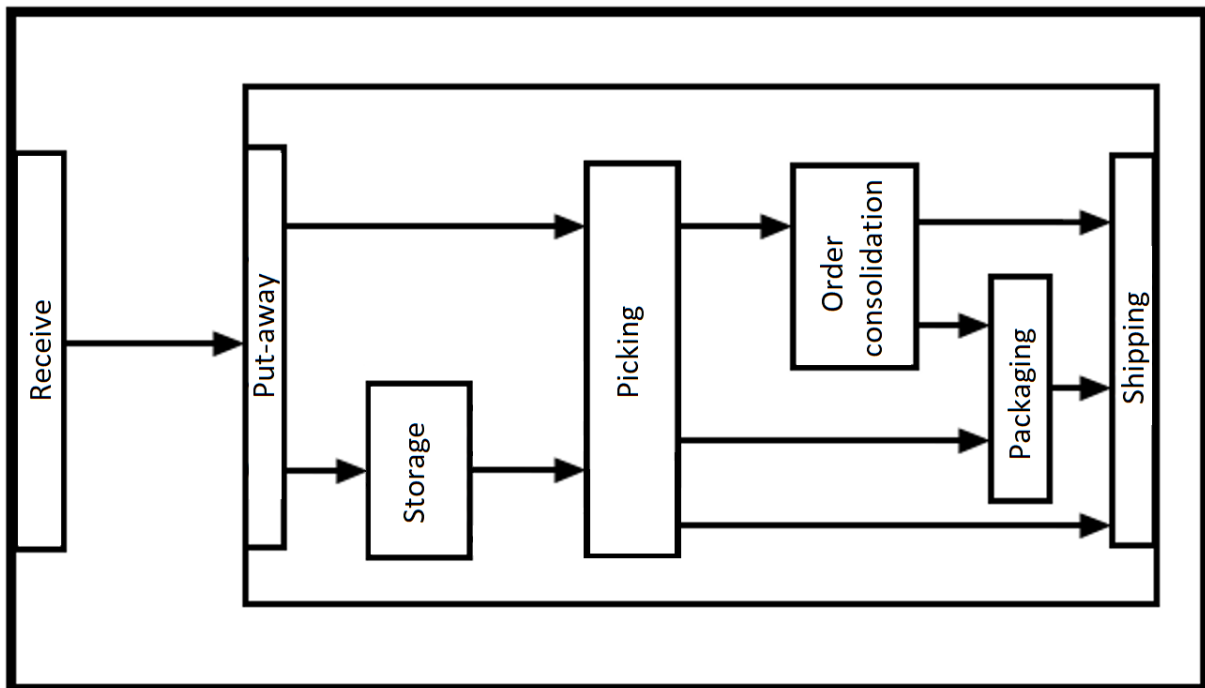


Figure 2.3: Depiction of warehouse operations interacting and steps being skipped

2.1.1 Receiving

The receiving operation can start when the warehouse is notified of the arrival of goods. This allows the warehouse to plan the unloading and handling of receipts efficiently as to not interfere with the other operations (Bartholdi & Hackman, 2019). But since this requires some sort of planning, small warehouses might not do this. The physical activity of the receiving is the actual unloading and documenting of the arrived goods. This step often includes goods inspections as well (Bartholdi & Hackman, 2019; Hompel

& Schmidt, 2005). The receiving sections usually don't require a lot of labour since products typically come in larger units.

2.1.2 Put-away

The put-away is the actual moving of goods from the receiving area to the storage. It is important that the storage location is well thought as the location of the storage will affect the traveling distance during put-away, and thus determining the cost of the entire operation (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005). When a product is put away it is important to also document the storage location.

Put-away is basically the in-between process of placing goods in the storage area, for example a warehouse may put their products on a pallet then that pallet is taken to a storage area. There are three kinds of put-away, one is called free flow, or dynamic put-away, and is when the entire warehouse space is regarded as a put-away area, and goods are stacked wherever possible. Free flow has the advantage of the warehouse being able to be used optimally but the disadvantage is both the lack of structure and that all locations may not be well suited for put-away. A second type of put-away is called fixed put-away and is when there is a dedicated area used for put-away. The advantage is that goods can be sorted more neatly, and this makes it easier for the workers to pick the items as they know where to look for them (Istiqomah et al. 2020; Extensiv, 2022). A third method is called direct put-away and is a method of storing where goods are scanned and go directly into storage with no criteria for the location. While this method is faster, it lacks flexibility for organising (Extensiv, 2022).

2.1.3 Storage

A storage is where goods are stored and plays a vital role to lower both costs and time for bringing an item to the customer. It sounds counterintuitive that an extra activity, that costs money, would reduce costs. But since demand uncertainties in volume and time exist, the storage serves to anticipate customer demand. Customers don't have to wait for production, instead goods can be sent from the storage. The reduced leadtime usually allows for more products to be sold and the accumulated profit is greater (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005).

Most warehouses use shelves as storing mechanisms and use forklifts to move pallets full of goods to and from the shelf positions. For smaller products and for smaller warehouses, items could also be stored on ground level at designated spots. The storage itself does not cost much, but it is pivotal for both the put-away and the picking costs. These costs are based on employee's time to move to storage locations, and from storage locations to their next operation. With good storage layout the distances and the time for picking and put-away decrease, with less workforce needed (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005; Ackerman, 1997).

2.1.4 Picking

Picking, or order picking, is the consolidation of a customized quantity of one or several articles. This includes the checking of availability of raw materials and/or products, the assembling of essential documents, and the defining of the schedule for the preparation of orders and transportation. Order-picking is a labour intensive and expensive part of the warehouse (Hompel, 2007). The order-picking typically accounts for 55% of the warehouse operating costs, and most of the activity is spent on the traveling that the picker does (Bartholdi & Hackman, 2019; Zhang & Jiang, 2022; Moeller, 2011). Furthermore, the operating costs of warehouses represents around 22-25% of the entire logistics cost (Baker & Canessa, 2009). Half the pickers time is spent traveling, this means that reducing the pick-flow can lead to major savings in the operating costs, making it one of the most important activities in the warehouse (Moeller, 2011).

2.1.5 Shipping

In shipping the products are shipped out of the warehouse. Shipping handles larger units than picking because picking has consolidated the products into fewer cases or pallets (Bartholdi & Hackman, 2019). Shipping also includes the operation packing which is when the consolidated products gets packed together. Packing is needed for orders with more than one product (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005).

2.2 Core WMS Features

To understand the benefits of a WMS it is crucial to understand which the core WMS features are, what the features do, and how they influence the warehouse performance. This section is a literature review of the core WMS feature. The features of a WMS are very interactive with each other, and the full effect of a WMS is hardly perceived from a single feature. Some features are also not so much 'a feature' but more explain how a WMS through combining many features will affect a certain warehouse operation. Thus, some features are named for example, picking and put-away, even though these are operations in the warehouse. The core WMS features, and the structure of this section, are these:

- Appointment scheduling
- Receiving (first operation in a warehouse)
- Quality assurance
- Put-Away (second operation in a warehouse)
- Location tracking
- Work-order management
- Picking (fourth operation in a warehouse)
- Packing and consolidation
- Shipping (fifth operation in a warehouse)

2.2.1 Appointment Scheduling

Appointment scheduling makes it possible for the warehouse manager to reduce waiting time through scheduling only when they know the specific times required for each element of each activity, as well as the likelihood of delay or interruptions. Through the measuring of the elapsed time, it can be estimated when one task can be completed, and another started. This estimate translates into the needed knowledge for reducing waiting time and congestion through scheduled truck appointments (Ackerman, 1997).

Appointment systems pre-specify the quotas for the number of truck arrivals, in time periods, and will choose to accept or reject the applications. Appointment systems are among the most important management tools for improving resource usage in the terminal. The only downside is that it's difficult to predict what will happen when it is deployed to real situations, and it is a big risk to implement in a real system without any precautions and preparation (Duong et al, 2016).

An appointment scheduling system is a key component in intelligent warehouse management. A scheduling system schedules both incoming and outgoing tasks in an intelligent way, maximizing the usage of equipment and improving the efficiency of warehouse personnel. There are many scheduling algorithms for different types of inventory valuation methods such as FIFO (first in first out). A good scheduling algorithm can improve waiting efficiency and execution efficiency of scheduling processes as well as help avoiding scheduling traps (Jin & Yu, 2022).

Sometimes scheduling problems occur due to uneven demand, for example at Christmas when the demand for practically everything increases. If a warehouse is set up for normal demand, it might be overwhelmed during the Christmas season demand. In a case like this, one possible solution is to advance some activities and delay others. This would lead to some penalties due to holding costs, but Ackerman (1997) argues it could be worth the cost of hiring extra warehouse workers for the season.

Ackerman (1997) describes that most carriers like the precision of a scheduled dock and would gladly cooperate with warehouse operators with unloading appointments. But this also means that the warehouse must expect to being penalized if the promised time is not met. This goes both ways and is not only on the warehouses part (Ackerman, 1997).

WMS providers often call this feature Dock Appointment Scheduling as it deals with the scheduling at the warehouse docks. A WMS would allow for the management of appointments for both inbound and outbound shipments making the processes easier, faster, and more efficient. Some features of the appointment scheduling are the searching of dock appointments, viewing dock schedule details, making, modifying, and cancelling appointments, documentation, and the ability to collaborate with carriers by including them into the system, allowing them to book scheduling times as well (SAP, n.d; IMB Sterling Warehouse Management System, 2021; Descartes, n.d).

2.2.2 Receiving

When unloading it is common for warehouses to register the products arrival, check for any errors, and dispatch payments. When the products are inspected the exceptions get noted down. Receiving stands for about 10% of operating costs in a typical distribution centre (Bartholdi & Hackman, 2010).

The accuracy of the material information is paralleled with how the data is recorded at the receiving operations. Most warehouses still enter receiving data manually which can cause a lot of human errors and data entry issues which may lead to data inaccuracy (Yang et al. 2020). A faulty receiving process can create a lot of problems further down the stream of operations, especially in order picking and shipping operations (Ackerman, 1997).

There are many risks involved with receiving, a lot of them are due to human errors. Some human risk factors are the incorrect identification of goods, incorrect sorting of goods, incorrect labelling of good, and incorrect delivery of goods. Other risks at the receiving operations are the delivery of unsolicited goods, the receiving of incorrect quantity of goods, receiving of damaged goods, hidden defects of goods, the damaging of good when receiving them for storage, and the receiving of goods that are incorrectly documented (Kulinska & Giera, 2019).

Except for problems caused outside of the warehouse, such as goods getting damaged on the truck ride, most of the risks can be lowered by a lot, as shown by Harb et al. (2016). Some risks could quite possibly even be completely eliminated using a WMS. A WMS will offer proper documentation and a lot of tools for the receiving and unloading operation. The effects of a WMS on the receiving operations are essentially more accurate stock counts, fewer stockouts and dead stock, and overall, more efficient inventory storage (Shipbob, 2023; Hopstack, 2023).

2.2.3 Quality Assurance

Quality Assurance is all the planned and systematic activities in the quality management system. It's required to create an adequate trust of the unit's ability to fulfil quality requirements (Hompel & Schmidt, 2005). In other words, the quality management identifies the potential for improvement while the assurance checks potential negative influences that activities may have on the quality. If there is a great number of combinations possible for storage, then quality assurance becomes very unlikely plausible without any software support, such as a WMS (Lubandy, 2016).

Poor quality control decisions in the warehouse can lead to a high level of defective products which in turn can lead to poor customer satisfaction. Traditionally, the decision-making process when selecting the necessitate quality control operation, is determined by the operators and their experience and skills. This makes the risk of human errors more likely. Human based quality assurance is believed to be lacking in imagination and can often be arduous. This means that human observation is not enough systematic or enough reliable (Lao et al. 2012). A WMS removes this obstacle by

computing the assurance for the warehouse. This improves time spent for the workers as well as the effectivity of the quality.

A WMS will include functions such as a step-by-step guide on how each part of a warehouse operation should be performed in order to ensure the orders are correctly processed, instructions on how to operate machines or how to interact with materials, information on what kind of supplies or tools are needed, keeping documents up to date, and measuring the quality of products. The information will help preventing problems from occurring. A WMS could also include functions such as flagging SKUs or pallets for quality control during the receiving process. Once flagged the system will allocate work around these items to ensure faulty products don't get stored (Extensiv, 2022; Oracle, n.d).

2.2.4 Put-Away

The put-away operation is the second “physical” operation in a warehouse. Put-away is important as it can reduce travel time for picking if used carefully. Before an item can be put-away, storage location must be allocated. When the product is put away then the storage location should be scanned to record the location where the product has been placed. Typically, the put-away accounts for 15% of the warehouse operating expenses (Batholdi & Hackman, 2010).

A good put-away strategy leads to these benefits (Cin7 Core, 2022):

- Knowledge about the details of every item in the warehouse
- Organized warehouse without worrying of lost or misplaced goods.
- Faster order fulfilment process as the warehouse workers knows the location of the products better
- Avoid stockout as your team knows when the stock is running low
- More efficient storage space

One mistake that warehouses usually do are that items are put-away at wrong locations. Another is the inaccurate tracking and quantity of goods. There is also the risk of delays in the put-away to the location. These errors are all caused by human error or due to lack of proper software, or both (Prasad Ramesh, 2021).

A WMS can help the optimization of the put-away operations with real-time data insight, always keeping track of your stock, saving time and reducing errors, and overall optimisation of the process flow (Extensiv, 2022; Cin7 Core, 2022).

2.2.5 Location Tracking

WMS location tracking allows for the tracking of all goods and provides location-based information. It also tracks the condition of goods and real time shipment shifting (Jarasuniene et al. 2023). Tracking is often done with some kind of scannable code like a barcode or QR-codes (Quick-Response). Another way to track goods or objects is by using radio-frequency identification (RFID) tags. (Fjodorov et al. 2023).

To track a product at a precise timespan is not easy, especially when a certain product changes location and environment. If a product is moved outside of the warehouse, and outside of the warehouse locations, then it becomes much more difficult to track it. In some cases where this type of tracking is needed it could be tracked with a GPS (Global positioning system). Combined with the WMS software tracking, or with an RFID system and with an easy-to-use user interface, the products can be tracked without any effort at all (Tejesh & Neeraja, 2017).

Another problem is that it can be difficult to track the locations of specific vehicles in the warehouse as they may move during the storage operations. If the warehouse is big the walking distances can be long, especially if the workers do not know where to search. A WMS reduces these negative impacts by also allowing the tracking of vehicles and not only goods (Jarasuniene et al. 2023; Fjodorov et al. 2023). Inside buildings Bluetooth technology and Wi-Fi technology can also be used aside from RFID.

According to Zhao et al. (2018) a WMS equips the operators with mobile or desktop apps so that they can track equipment and goods easily. Instead of sending many people to find the location of the needed goods, or to find for example a forklift, the location is readily shown on the devices which saves a lot of time. A good tracking system can help to significantly reduce manpower, searching time, picking time, and paper costs (Zhao et al. 2018).

But RFID has some negative limitations. Halawa et al (2020) finds that it is hard to track 3D movement, there is a likelihood of reader and tag collisions to happen, RFID technology can be costly. For a WMS to include, and for the warehouse to implement it, the WMS solution might be more expensive than with scanner-barcode tracking. Further the localization accuracy is not precise enough for some applications, so usability differs between industries (Halawa et al. 2020).

2.2.6 Work-Order Management

The previously mentioned location tracking feature of a WMS provides full information on goods-in-transit, which allows a holistic view of where the goods are. Furthermore, a WMS also shows to what work-orders goods are attached. A WMS allows the operations manager to allocate the workers to attend any work-order by a simple drag on a system interface, or automatically by the WMS system (Assis & Sagawa, 2018).

Work-order management is the systematic processing and completing of work order maintenance done to minimize asset downtime. Traditionally operating managers have done this by paper-based orders. This can lead to problems such as slow time, labour intensive work, human errors in the form of bad handwriting, incorrect documentation, misplacement of physical documents, and more. Another problem is that the documentation becomes a hassle as this can lead to stacks of paper, making it very difficult to find historical work orders (FTMaintenance, 2019).

Work-order management will be handled by the WMS software, the human errors will be reduced, at least the errors for the work that is replaced by the WMS. Some benefits of

implementing a WMS are reduced downtime and maintenance backlog, extended and improved asset life and reliability, and capital expenditures shifted to operational expenditures. For the work order management, an example of features a WMS can provide are (SAP, n.d):

- Manage work orders and notifications. Recording of problems, actions, time, parts, measurement readings, and attachments
- Enable geographic information system integration.
- Simplify integration with the SAP multisource Scheduling application.

2.2.7 Picking

The performances of the warehouse operations are dependent on the efficiency and effectiveness of the supply chain network, and each company in the supply chain should strive to reduce order-picking time and to improve order-picking efficiency. Order-picking is important as it is the most customer-sensitive and requires most resources in the warehouse operation (Anđelković & Radosavljević, 2018).

The main factors determining the efficiency of order-picking are the demand for raw materials and/or products, the warehouse layout, the location of the items, the picking method used in combination with the routing methods, the knowledge of the employees, and the level of automation of the warehouse.

The objectives of order-picking are:

- Minimising the total costs
- Minimising the throughput time of an order
- Minimising the overall throughput time
- Maximizing the level of service quality
- Maximizing the use of space
- Maximizing the use of equipment
- Maximizing the use of labour
- Maximizing the accessibility of all items

The optimisation of the process includes the optimisation of the travel time required, the search time required, the optimization of the retrieval time, and the optimization of the return time. The overall goal is to make the process faster and more efficient (Anđelković & Radosavljević, 2018).

The overall efficiency of the picking process is also determined by the size of the warehouse, since the size of a warehouse determines the storage policy (Lorenc & Burinskience, 2021). Reducing the distance travelled for a non-productive activity can also reduce the order-picking time (Zhang & Jiang, 2022). It is however important to not try to achieve a 100% efficient work rate. Humans are not capable of working nonstop without any breaks, even if theoretically it is possible to set up a system with near 100% efficiency.

It is unpractical to stock and pick orders efficiently without using a WMS as the picking process will be too tedious to optimize manually (Lorenc & Burinskience, 2021). The benefits of implementing a WMS for the order-picking process are thus many. These benefits can be divided into informational, operational, and raw materials/product related benefits. When it comes to information sharing benefits, a WMS will benefit the order-picking due to factors such as increased data accuracy, improved information sharing throughout the supply chain, better planning of arrival and dispatch times (Lim et al. 2013).

The advantages of implementing a WMS in the order picking operations is that the warehouse will have cost savings in the form of fewer picking errors and shorter flow time. The warehouse will have up-to-date and digital stock information, and overall increased productivity (Mecalux, 2022).

On the operational level a WMS will improve the order-picking through reduced material handling, faster exception management, quality control, supply and production continuity, better customer services, reduced labour, and overall reduced costs (Lim et al. 2013).

The order-picking in relation to the raw materials/products, will be improved through reduced shrinkages, tracking of products and raw materials, better utilisation of the space, reduced stockouts, and an overall lower inventory (Lim et al. 2013) as well as fewer picking errors and shorter flow time.

One problem with the WMS controlled order picking is that it may not work when orders are arriving in real time and when shipping schedule times are very short (Bartholdi & Hackman, 2019).

2.2.8 Packing and Consolidation

Packing and consolidation is when one order is completed with multiple items; consolidation is when an order requires more than one item, and thus sometimes needing more than one picker or being located more than one warehouse (Karasek, 2013; Red Stag Fulfillment, 2023). Consolidation has many advantages for a company, both for cost efficiency and for customer satisfaction. For example, if a customer wants to buy a set of golf clubs and golf balls, then it would be cheaper to package all the clubs and the balls together rather than send each club and ball as a separate package.

The benefits of packing and consolidation are:

- Reduction of transportation costs as less deliveries are made.
- Lower fuel emissions for the same reason.
- Minimizing shipping costs through the sharing of trucks and less amounts of fees as every package usually gets a fee.
- Increasing customer satisfaction as they get all their goods at the same time.
- Increased employee productivity

- Optimization of the storage space

Consolidation is good when certain items are sold together regularly, or if small accessories can be shipped in a box with a bulky product for free, or most importantly if the shipping charge for consolidated options is cheaper than the cost of separate shipping.

Setbacks of consolidating, first are that it calls for a perfect synchronization between suppliers and transportation agencies and it is tedious to do manually. Then, consolidation does not fit for situations resulting in dimensional weight charges, with cost driven by the package volume. It can cause the cost to be higher if the dimensional weight is higher than the actual weight. Third, if the combined packages actual weight reach over certain thresholds as there can be higher fees for packages over certain limits. Lastly, consolidation is not good if the items are at risk of being damaged, such as if a ceramic bowl is shipped together with a crowbar. (Modula, 2022; Mecalux, 2022; Red Stag Fulfillment, 2023).

A WMS can handle the consolidation planning, making sure that all the benefits are made possible but also smooth and easy. A WMS system can even calculate what and where to store goods based on if goods are bought together and consolidated often to make sure that the picking time is optimal. A single warehouse package consolidation has the potential to lower the order fulfilment cost if applied correctly, but WMS's also make the next step possible; with a WMS the possibility of multiple warehouse consolidation gets realised. If a company has multiple warehouses, or if the supply chain of a purchase has multiple warehouses and all warehouses communicate with the same WMS system, then it becomes possible for consolidation across warehouses. Cross warehouse consolidation is when one item is picked and packed at one warehouse and then at the next warehouse stop another item is picked, added, and repacked. Cross warehouse consolidation has the possibility to reduce the number of shipments caused by split orders. Not only can the fulfilment cost be reduced greatly, but also an environmental impact will come out of consolidation (Zhang et al. 2021).

2.2.9 Shipping

The sole task of the shipping operations is to consolidate units for shipping in accordance with customer orders, and to load the goods into transport means. For shipping to be cost-optimized it requires an exact study of shipping quantities, both in volume and height (Hompel & Schmidt, 2005).

Ackerman (1997) argues that the ideal routine for shipping is roughly the reverse routine for receiving. It's a good idea to keep track of the quantities and content of what is shipped by using shipping labels or tags (Ackerman, 1997).

According to Ackerman (1997), a complaint from most operations managers is that a warehouse does not have enough doors/docks. This is often due to scheduling errors, as bad scheduling can lead to many trucks coming at the same time. This leads to a lot of

excessive waiting and stress for the receiving and shipping employees. Another issue is the loading and unloading time, as different industries take different amount of time to load, and unload based on their products sizes and how many boxes and pallets they need. Most often the problem is not the number of doors/docks, but that doors/docks are not used at peak efficiency. In most cases the problem is not there all day but only during certain times when trucks come all at once. Good scheduling would distribute trucks throughout the day and fix this problem (Ackerman, 1997).

A WMS would facilitate the inventory and efficiently locate items for onward shipping and assembly, which typically increases a warehouses shipping accuracy to 99% (Badwi, n.d). A WMS would reduce errors and returns, optimize picking and packing (which leads to faster and more accurate shipping), track and trace shipments throughout the supply chain, automate shipping documents, and analyse and improve performance. A WMS is often also compatible with other systems and can through their communications lead to further improvements in the shipping operations (AI & linked in community, 2023; SAP, n.d).

With the help of tracking, automatic documentation work, and all the above-mentioned features, it's possible to reduce the time of all data documentation to less than a second. This would save a tremendous time otherwise spent on documenting, but also remove the risks of errors from documenting. For certain companies it's possible to lower the complete processing time of data transmission by almost 99.9%. Chen et al. (2013), shows a reduction in time from 91 minutes to 12 seconds for the entire documentation process (Chen et al., 2013). Another positive impact is that in case of backorders, a WMS may also dictate that a received item is directly prepared for shipping, skipping time spend on sending it to storage (Nee, 2019).

2.3 KPIs

To be able to understand how a WMS and its features impacts warehouse performance it is important to set up working performance measurements. To get functional and effective measurements, it's important to base them on good and useful KPIs (Lam et al. 2010). Raama et al. (2012) identifies order fulfilment, inventory management, and warehouse productivity as good metrics for measuring performance in a warehouse.

2.3.1 KPIs gathered from literature

Planning and allocation of warehouse resources is a critical factor when increasing operation efficiency. Improving the operation performance can lead to increases in customer satisfaction, which is why it is important to measure the warehouse operation performance (Lam et al. 2010).

Performance can be divided into two measure groups, which both then can be divided into two types of measures. These are result indicators and performance indicators. When looking at the whole of a company, Frost & Gustafsson (2018) argue that result

indicators deal with measures as a summation of more than one company team's input, while performance indicators are measures that can be connected to a specific team or one goal or purpose. The four measures are thus key result indicators, key performance indicators, result indicators, and performance indicators. The difference between key indicators and non-key indicators are that key indicators summarize the measure on an organizational level while the regular indicators deal with individual teams (Frost & Gustafsson, 2018).

KPIs measure the performance level of a process. The focus of the KPI is on how a process affects the performance of an activity. The so-called SMART criteria can be used when defining a KPI. Smart stands for specific, measurable, achievable, realistic, and timely (Marziali et al. 2021). KPIs can be both good and bad tools to use depending on how they are used. The most common mistakes that businesses do when implementing KPIs are that they don't focus enough on the KPIs, and that they fail to connect the KPIs to the business model (Frost & Gustafsson, 2018). Without an overall holistic view of the organisation, it is easy to use KPIs that look useful for a certain activity, but not very useful for the overall scope of the business. This leads to a lot of money spent to improve an activity that won't yield in much overall improvements.

To be able to use KPIs it's important to understand the different activities it should measure. Warehouse activities generally consists of receiving, put away, storage, picking and shipping. Four studies discussing KPIs in warehouses were found: Kusrini et al. (2017), Pajic et al. (2021), Staudt et al. (2015), and Faveto et al. (2021). Kusrini et al. (2017) and Pajic et al. (2021) present the same table in their papers.

According to Kusrini et al. (2017), performance measurement can be divided in 4 categories, and these are: input, output, efficiency, and effectiveness. In traditional logistics these are further divided into soft and hard metrics. Hard metrics entail quantitative measures such as order cycle time, fill rates and costs, while soft metrics deals with qualitative measures like the corporation's perceptions of customer satisfaction and loyalty (Kusrini et al. 2017).

It is evident that the performance measurements and the KPIs are not universal, and that it depends on the industry and the needs of the companies. Kusrini et al. (2017), presents 25 KPIs for warehousing that they have arranged in two dimensions (table 2.1).

Table 2.1 25 KPIs from Kusrini et al. (2017), Pajic et al. (2021). (Coloured numbers to see similarities with Tables 2.2 and 2.3, where the colour red indicates similarities with the KPIs from Staudt et al. (2015), and the blue are the similarities with Faveto et al. (2021).)

	2 Financial 7	Productivity 8	Utilization	Quality 6	1 Cycle Time 5
Receiving 1	Receiving cost per line 3	Receipts per man-hour 13	% Dock door utilization	% Receipts processed accurately	Receipt processing time per receipts
Putaway	Putaway cost per line	Putaways per man-hour	% Utilization of putaway labor and equipment	% Perfect putaways	Putaways cycle time (per putaway)
2 Storage	Storage space cost per item 4	Inventory per square foot	% Locations and cube occupied	% Locations without inventory discrepancies 10	Inventory days on hand 8
3 Order picking	Picking cost per order line	Order lines picked per man-hour	% Utilization of picking labor 5 and equipment	6 % Perfect 11 picking lines	Order picking cycle time (per order) 9
4 Shipping	Shipping cost per customer order	Orders prepared for shipment per man-hour	% Utilization of shipping docks	% Perfect shipments 12	Warehouse order cycle time 9

Kusrini et al. (2017) then tried these KPIs importance with senior managers of construction materials warehouses. The five most important KPIs were found to be receipts per man-hour, locations and cube occupied, put-aways cycle time (per put-away), order picking cycle time (per order), and orders prepared for shipment per man-hour.

Staudt et al. (2015) also presents KPIs for warehouses using two similar dimensions as Kusrini et al. (2017). One dimension focuses on time, quality, cost, and productivity while the other dimension focuses on the warehouse activities receiving, storage, inventory, picking, shipping, and delivery. Based on a thorough analysis on articles, Staudt et al. (2015), found 16 KPIs to be the most important (table 2.2).

Table 2.2 Warehouse measurement KPIs Staudt et al. (2015). (Coloured numbers to see similarities with Tables 2.1 and 2.3, where the colour red indicates similarities with the KPIs from Kusrini et al. (2017), and the green are the similarities with Faveto et al. (2021).)

	Receiving 1	Storage 2	Inventory	Picking 3	Shipping 4	Delivery
Time 5 1	Receiving time 3	Putaway time		Order 9 picking time 4	Shipping time	Delivery lead time
Quality 6		Storage accuracy 10	Physical inventory accuracy; stock-out rate	Picking accuracy 11 5	Shipping accuracy; orders shipped on time 12	Delivery accuracy; on-time delivery; cargo damage rate
Cost 7 2			Inventory cost 6			Distribution cost
Productivity 8	Receiving productivity 13		Inventory space utilization; turnover		shipping productivity	Transport utilization

Faveto et al. (2021), divide the KPIs into subclusters (table 2.3), these being generic performances, time related performances, cost performances, information system performances, warehouse measures, emission, and labour practise. Warehouse measures, information system and emission have to do with the automated systems they are researching and some of the KPIs in each of the subclusters deal with automation as well and cannot be used as a generic KPI for any warehouse (Faveto et al. 2021).

Table 2.3 Warehouse measurement KPIs gathered and condensed from Faveto et al. (2021). (Coloured numbers to see similarities with Tables 2.1 and 2.2, where the colour red are the similarities with the KPIs from Kusri et al. (2017), and the blue indicates similarities with Staudt et al. (2015).)

Subcluster							
Generic Performance	Throughput	Area	Receptivity	Travel distance	Resource utilization	Picking accuracy ⁵ ₆	Peak utilization
¹ Time Related Performances ¹	Cycle time ⁹	Picking time ⁴ ₇	Travel time	Planning time	Packing time	Retrieval time ³	Inventory time ⁸
² Cost Performances ²	Management cost	Storage cost	Retrieval cost ³	Inventory cost ⁶	Holding cost ⁴	Direct labour cost	Indirect labour cost
Labour Practise	Human Utilization ⁵	Human error	Human activity time	Employee per area			

One important KPI that was not brought up by the previous three tables is, according to Chytlova et al. (2019), Customer satisfaction.

2.3.2 Consolidating KPIs into one table

The previous reviews show that there are many different KPIs for warehouse performance, even if excluding special KPIs relevant only to specific situations. In order to make the study more general, the KPIs are consolidated (table 2.4).

Table 2.4 is proposed, it includes each of the five warehouse operations, suggesting the three most relevant KPIs, per operation, for a WMS based on the reviewed literature. The proposed table includes 3 KPIs for each of the five warehouse operations to effectively show the impact of a WMS throughout the entire warehouse. The KPIs all origin from tables 2.1-2.3 and are then consolidated into one table. First, the KPIs were chosen focusing on different warehouse operations. Then KPI's were chosen based on how frequently they appeared in the previous studies. Coincidentally this resulted in KPIs for the dimensions of time, utilization, and quality. The KPIs chosen for table 2.4 from tables 2.1-2.3 are shown in figure 2.4.

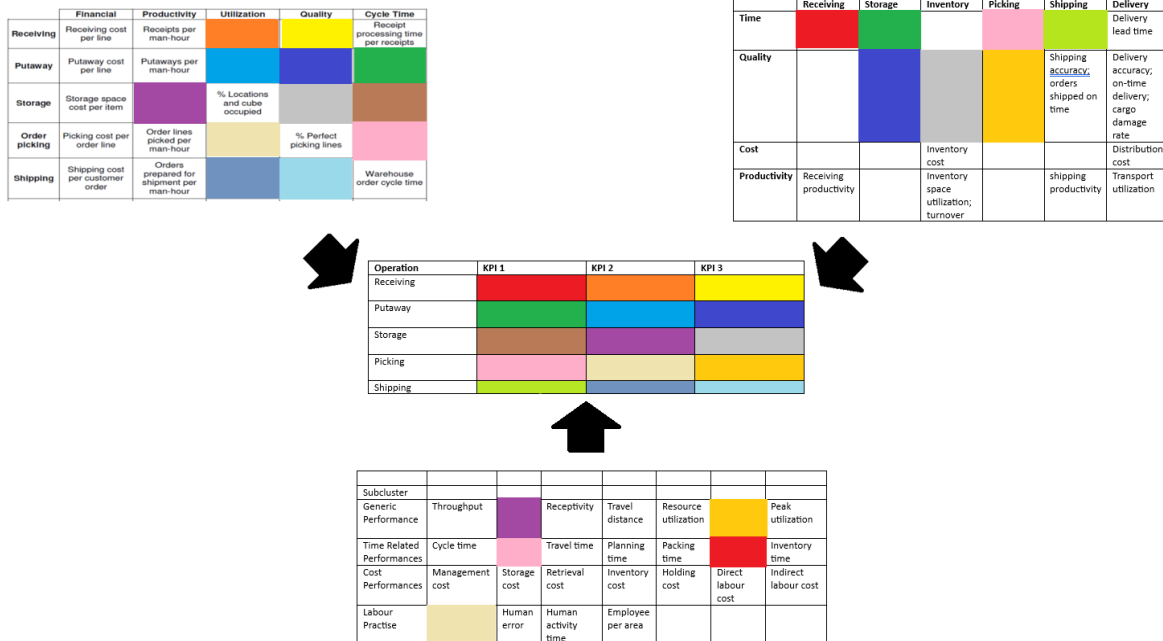


Figure 2.4: A figure showing which KPIs were chosen, and from where.

Table 2.4 KPIs for a WMS based on the literature for the warehouse operations, divided in time, utilization, and quality.

Operation	Time	Utilization	Quality
Receiving	Receiving time	Dock door utilization	Documentation processed accurately
Put-away	Put-away time	Put-away utilization of labour and equipment	Correct put-aways (no errors)
Storage	Inventory days on hand	Storage space utilization	Storage accuracy
Picking	Picking Time	Picking utilization of labour and equipment	Picking accuracy
Shipping	Shipping time	Dock door utilization	Orders shipped on time

It's important to note that all these KPIs affect the operation costs for a warehouse. Some of them, like the storage space utilization, directly affects the cost while others, like the time, utilization, and accuracy KPIs cost-effects become visible when the entire warehouse operations are looked at from a holistic perspective. These all imply that if these KPIs are done correctly, then for example personnel and equipment can be utilized for other purposes or be laid off.

2.4 Added features after the findings.

After the findings of the studies were drawn, two features not explained in the theory stood out as very important: the ABC classifications and the route optimization. These were not listed as core-features but due to them being mentioned a lot they are now briefly explained.

2.4.1 ABC-classifications

An ABC-classification is an analysis of SKUs in a warehouse that is similar to the 80-20 rule, which states that twenty percent of the SKUs normally account for 80% of the activity. In ABC the three letters are used to rank SKUs by the following criteria (Bartholdi & Hackman, 2019).

- A: A small fraction of SKUs that account for most of the activity
- B: A moderate amount of SKUs that account for a moderate activity
- C: The bulk of the SKUs that account for a fraction of the activity

The ABC-classification doesn't have to be based on money and volume as this might not always be the most optimal solution. The ABC-classification can instead be based on how frequent items move through the warehouse, how often certain SKUs are picked, how many pieces are sold, or any configuration that is of use to the warehouse (Bartholdi & Hackman, 2019). The classification can also take into account items that often are sold together, and bundles of items that belong to each other. Once the classification is made, the warehouse locations can be optimized so that A-class goods are stored closer to the relative stations, and C-class goods are stored further from the stations, this is exemplified in figure 2.5.

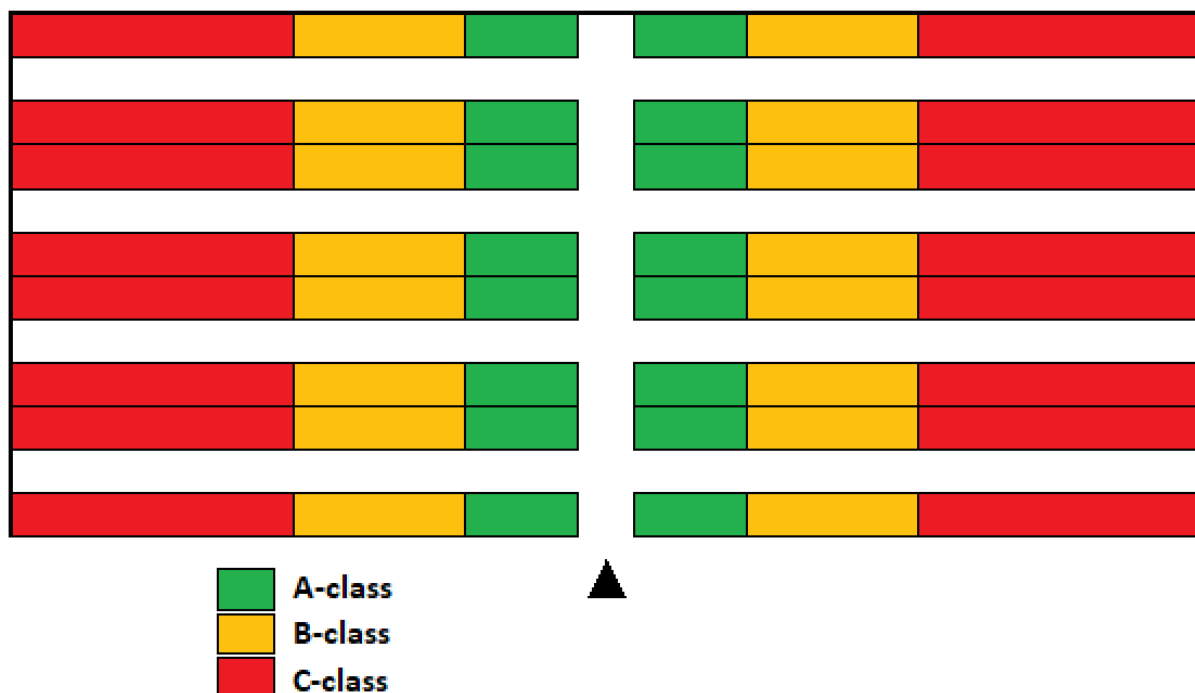


Figure 2.5: ABC-classification example

2.4.2 Route optimization

The purpose of route optimization (or trip/path optimization) is to determine the shortest/fastest route to get to a location. This is useful when there are several possibilities of paths to take (Hompel & Schmidt, 2005). For the best outcome, the WMS should include a geometric model of the warehouse layout and compute the shortest paths between pairs of locations, but this is not always done. For some WMS's the route optimization is done by defining path-outlines, giving operators local rules to help them adapt the path outlines, and by placing products to work with the outlines. (Bartholdi & Hackman, 2019).

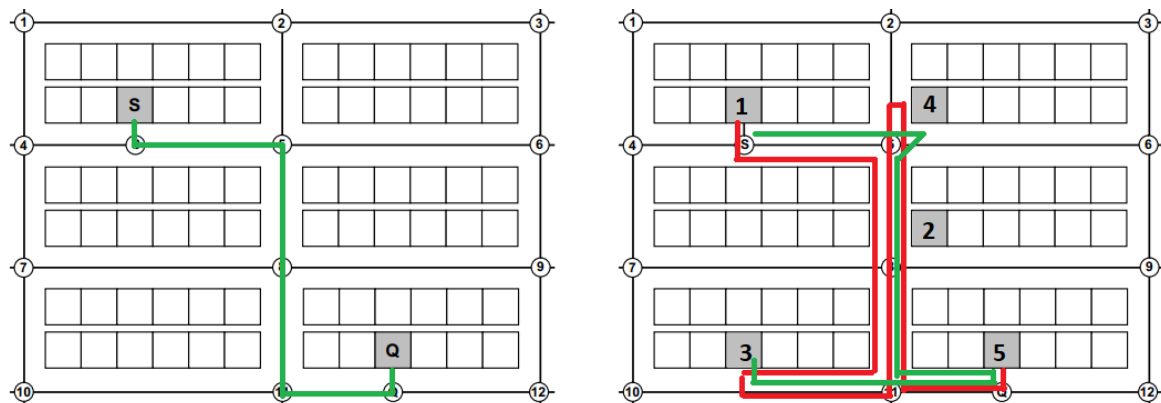


Figure 2.6: Example of Route optimization on a single location and on multiple locations, green is the optimal route.

2.5 conclusion on the literature

The benefits, problems, and influencing factors mentioned in the theory are gathered in Table 2.5.

Table 2.5 Benefits, problems and influencing factors from the theory.

Feature	Benefits	problems	Influencing factors
Appointment scheduling	Reduce waiting time. Maximize usage of equipment and warehouse personnel Gives more control		Needs information, uneven demand can affect the WH
Receiving	Lowers risks from human errors. Proper documentation Accurate stock count, fewer stockouts, more efficient inventory storage		Human errors: incorrect identification, sorting, labelling, and delivery of goods. Damaged goods from transport
Quality assurance	Becomes possible for large numbers of goods combinations. Step-by-step guide on how operations should be performed		Human errors
Put-away	Save time/better flow. Reduce errors		Human errors: wrong locations, inaccurate

			tracking, and quantity of goods
Location tracking	Allows tracking of all goods	Items tracked are confined to tracking space, more control = less freedom	
Work-order management	Gives visibility on which work-orders goods are attached to. More control over orders		Human errors: bad handwriting, incorrect documentation, misplacement of physical documents, and more.
Picking	Fewer picking errors Shorter flow time Reduced material handling	May not work when orders arrive in real time and shipping schedule times are very short.	Overall efficiency is determined by size of warehouse.
Packing and consolidation	Optimization of storage space Reduced transportation costs Increased employee productivity	Can cost more if weight exceeds threshold for shipment. Does not work if items are at risk of being damaged.	Weight of products influence if it's possible or not
shipping	Reduce time of data transmission for documentation to less than a second. Shipping accuracy increased to around 99%.		Warehouse size: lacks enough doors/docks Industry/product types affect loading and unloading.

Only few problems were found that comes with a WMS. The influencing factors on the other hand can be condensed into human errors, warehouse size, knowledge, and industry/product types.

The external influencing factors, the benefits, and the problems are combined with the WMS core features and the KPIs into a figure similar to figure 1.1 (figure 2.7).

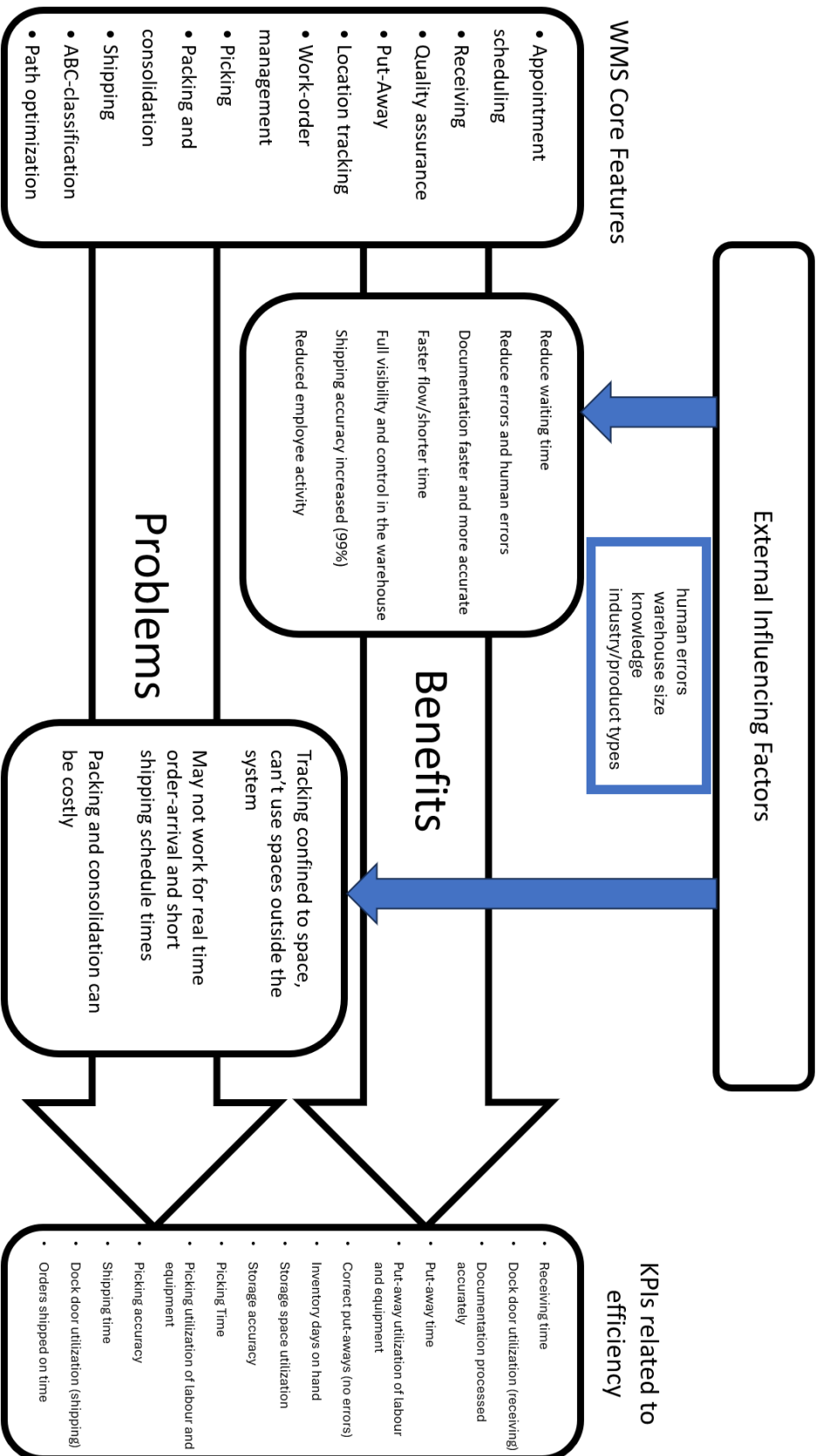


Figure 2.7: Visualization of the theory

3. Methodology

This chapter first introduce and explain how the method was chosen and then it delves into the details of the method.

3.1 Choosing the method

One widely used concept for discussing methodology is the research onion (figure 3.1) proposed by Saunders et al. (2016). This concept with six layers supports the user to develop a method that suits them. It starts with research philosophy, which reflects the ontological and epistemological assumptions of the researcher (Saunders et al, 2016). Saunders et al. (2016) exemplify some philosophical positions. This thesis will be based on Critical realism, a branch of philosophy that distinguishes the observable from the real, which in this study translates to wanting to understand the underlying reasons (the real) which lead to visible changes (the observable).

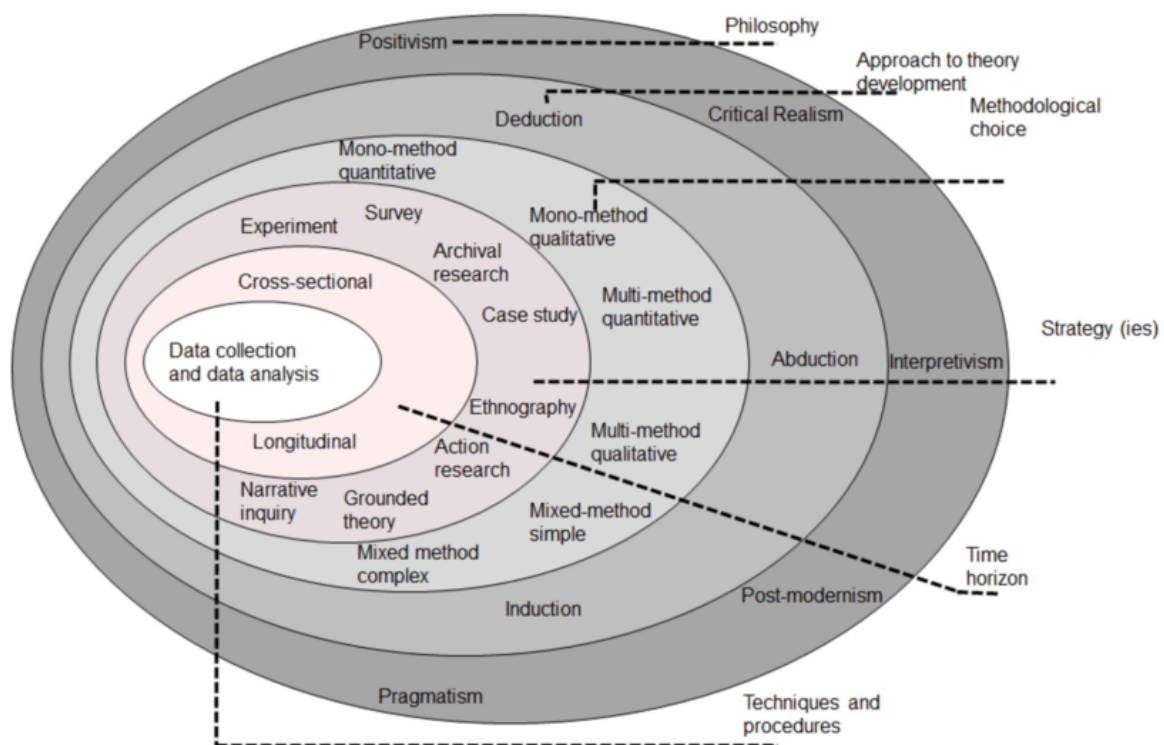


Figure 3.1: The research onion from Saunders et al. (2016).

The research onion's second layer deals with the approach to theory development, with three approaches given. The first approach, deduction, implies that research starts with a theory and research focus on to confirm or reject the hypothesis. The second approach is induction where research begins with observation and data collection, and

this leads to a description or analysis to form a theory. The third approach is abduction, where a phenomenon is observed and then followed up with a probable conclusion based on the evidence observed and the researcher moves between the theory and empirical data (Melnikovas, 2018). For this thesis abduction will be used, since the purpose of this study is to increase understanding of WMS implementations, a hypothesis should not be in place as it could bias the research towards fulfilling it.

The most obvious example of abduction used in the thesis is the addition of ABC-classification and path-optimization in the literature. These topics were brought up a lot during the case interviews and where thus added to the theory in order to equip the reader with the sufficient knowledge to understand the findings.

Another section where abduction was used was when deciding on how to present the findings. The first figure introduced in chapter one was subject to changes throughout the project (figure 3.2) as new insight from the empirical data and analysis affected gave a more nuanced perspective of what can be presented and not.

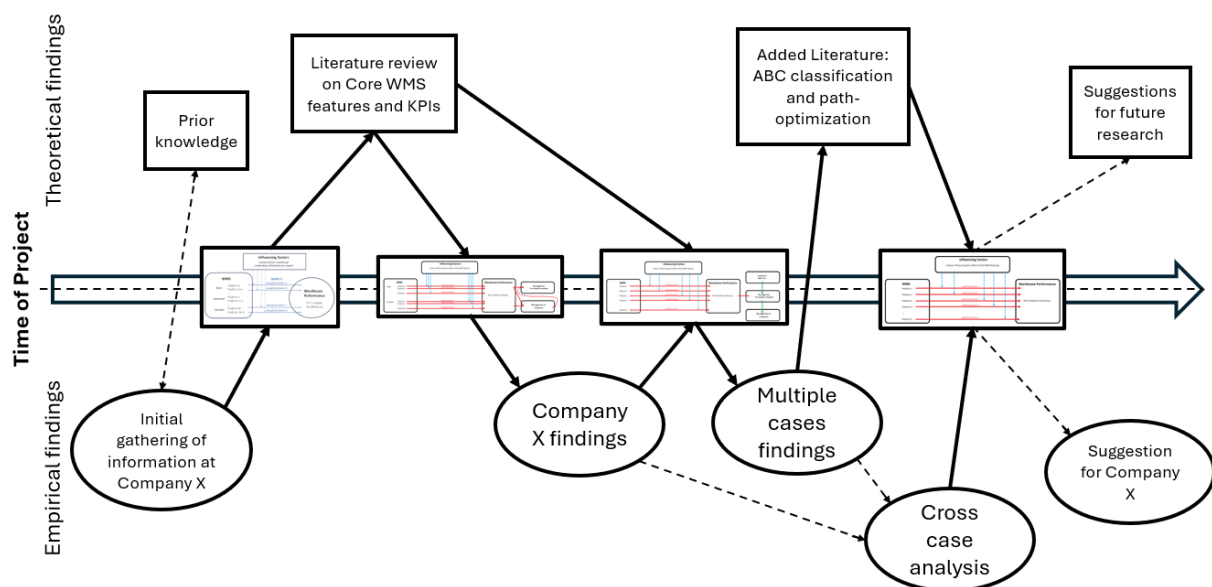


Figure 3.2 example of how abduction affected the concept.

Jumping forth, the fifth layer describes if the time horizon is cross-sectional or longitudinal. Cross sectional time horizon means that the study is short-term and involves collecting data at a specific point of time, while longitudinal is a long-term study where collection of data is repeated over a longer period to compare the data (Melnikovas, 2018). This thesis will be cross sectional since part of the purpose of the study is to help to decide for Company X if they are going to implement a WMS. To do that, data collected must be based on Company X right now. It's not possible to collect data beyond the decision since the decision is unknown and doing so defeats the purpose.

The third and fourth layer will be explained together in the method section, but to summarize them: this thesis will be multiple case study and this study's application will

be based on Yin's (2018) book called Case study research and applications: design and methods, 6th edition. Yin (2018) recommends that case studies are done in six interactive steps (figure 3.3). These steps will be explained in this next section of the thesis, which is the method.

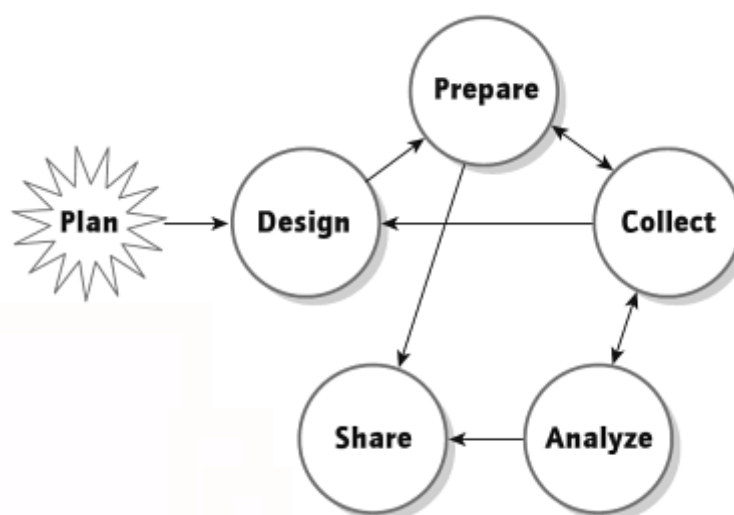


Figure 3.3: Case Study Method Sequence (Yin 2018) p.31

There are multiple research methods that can be used, Yin (2018) defines different purpose of a research as exploratory, descriptive, and explanatory; every research method can be used for all three purposes. Yin (2018) also defines different research methods are defined e.g. experiment, survey, archival analysis, history, and case study. There are also other research methods, but these are the most common.

Yin (2018) describes three conditions for when to use the different methods based on, form of research questions, required control over behavioural events, and focuses on contemporary events (figure 3.4).

Method	(a) Form of Research Question	(b) Requires Control Over Behavioral Events?	(c) Focuses on Contemporary Events?
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival Analysis	who, what, where, how many, how much?	no	yes/no
History	how, why?	no	no
Case Study	how, why?	no	yes

Figure 3.4: Conditions to choose methodology. (Yin 2018)

Form of research question:

The first condition has to do with how the research questions are phrased. The types of questions are defined as who, what, where, how, and why questions. Both questions in this thesis are of the 'how' type, this makes the experiment, history, and case study methods the most favourable for this thesis.

Requires control over behavioural events?:

The second condition has to do with how much control the researcher has over behavioural events. When the relevant behaviours cannot be manipulated, which is the case for this thesis, then the preferred methods are case studies and history.

Focuses on contemporary events?:

The last condition deals with whether the study focuses on contemporary events or only past events. This thesis deals with present events as well as past events and therefore the most fitting method for this thesis is a case study.

3.2 Plan

The goal of creating a plan is to help design a good case study, by planning how to collect, present, and analyse data fairly. Another goal with the plan is to share the finding and to bring closure to the case study. It is thus highly important to follow a clear methodological path and explain how it will be followed. A conventional starting place is to review literature and define the case study's research questions.

This study will be conducted as a multiple case study. The study will focus on Company X and a selection of other companies. Company X will serve as the problem setting of the study, while analysis of the multiple cases will provide insight to answer the problem.

3.3 Design

All types of empirical research studies have an implicit or explicit design according to Yin (2018). The design is the logical sequence that links the empirical data to the research questions, and then to the conclusions. When designing a case study there are five components of research design that stand out as more important, these are: a case study's questions, its propositions, its case, the logic linking the data to the propositions, and the criteria for interpreting the findings. The design section will be explained in three steps, first theory, then the types of design, and lastly an introduction of the actual design.

3.3.1 Theory

The design starts off with theory on WMS, presented in Chapter 2. Starting with fieldwork also has its perils, but theory development is much more important since it can help shape the upcoming case study (Yin, 2018).

For this thesis LubSearch Discovery and Google scholar were the main sources to find literature. When Google scholar was used the author made sure to double check if any of the papers were available using the LTH databases found at ludwig.lub.lu.se/menu.

A keyword search for “Warehouse management system” in the LubSearch Discovery database yielded a total of 29,165 results whereas 14,154 of those were academic journals. Out of these 29,164 results 47,8% were published within the last 10 years, 27,2% within the last five years and approximately 3% were written this year so far.

To get more specific and relevant literature further keywords were put into the search engine; combining “warehouse management system” with the keyword “case study” yields 1171 peer reviewed academic journals published within the last 10 years. These were combined with keywords responding to the different WMS features that are going to be researched.

Furthermore, to get better practical knowledge of WMS, some other sources of information used were websites of logistics companies, websites of WMS companies, Logistics and WMS blogs, and occasionally some social media. These sources were taken with precautions and were cross-examined with other sources and other literature before being used. Extra caution was used on company claims as their intent is to sell a product.

Lastly, the acronym WMS was used for subjects other than warehouse management systems. The final count of sources looked at was around 150+, of which 85 were used for the paper.

3.3.2 Types of case study design

When conducting a case study, it's important to early on determine what type of case study. Yin (2018) divides case studies into single case studies and multiple case studies (figure 3.5), both of these can then be holistic studies or embedded studies.

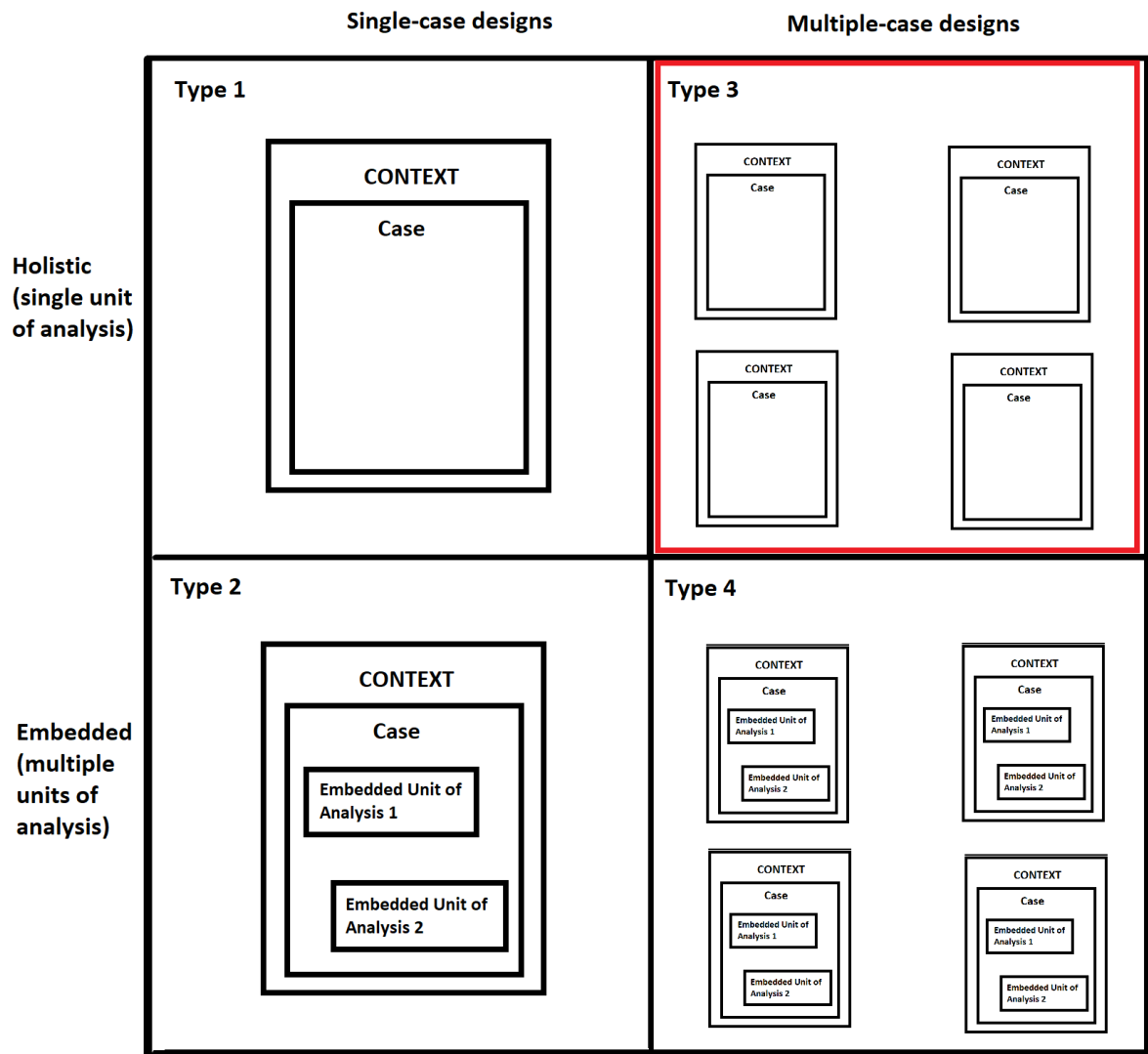


Figure 3.5: Types of design, redrawn from (Yin, 2018) p.84.

Yin (2018) argues that the rational to choose multiple case studies comes from that multiple case studies often have more compelling evidence and are more robust than single case studies. A multiple case study is also more reliably replicated. There are compelling reasons for doing both a single case study and a multiple case study, but this thesis will be a multiple case study. The type of study will be holistic. This choice was made to ensure that data collected is not biased and so that it's more trustworthy. The choice was also impacted by the fact that it is a general study on WMS's and since there are many types of WMS's it would be difficult to represent the entire industry if the study was restricted to one case with only one type of WMS.

3.3.3 The design

One important factor which steers the design is the unit of analysis that will be used. The unit of analysis is not the same as the unit of data collection, with the distinction that the unit of analysis being a broader more holistic frame (the "case") and unit of data

collection being smaller segments that point to the whole analysis (Yin, 2018). For this study the unit of analysis is “the change in warehouse efficiency as a result from implementing WMS features”.

The cases that are going to be studied are not going to be limited to any specific type of warehouses. The sources for the unit of data collection will be Company X, WMS vendors, and WMS customers. The unit of data collection is used to showcase the unit of analysis through interviews with the vendors and customers to get a holistic view (figure 3.6) and to make sure the answers are not biased, and the internet is used to gather literature.

The case selection will be based on certain criteria for the vendors. The first criterion is that the cases are WMS vendors. The second criterion is that the vendors are not too small. If the vendor is too small, then there is a risk that their product is not very developed, which could impact the result. Aside from the criteria there is also a bias that determines which vendors are contacted first. While no company that fits the criteria would be excluded, the vendors that are closer to the author, and the vendors that can communicate in the same languages as the author would be approached before a vendor that is for example in east Asia and can’t be contacted through English or Swedish.

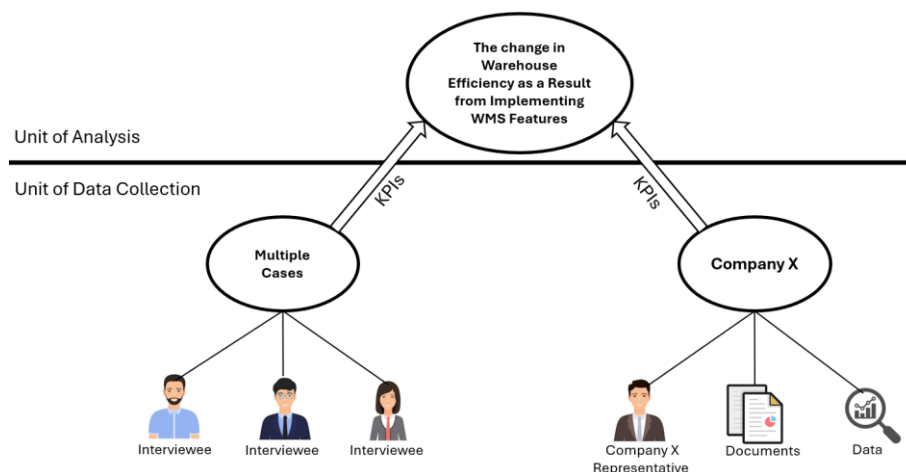


Figure 3.6: Difference between Unit of Analysis and Unit of Data Collection

The second types of cases are the customer cases, and the only criterion for these are that they are customers to the vendors that are going to be interviewed. The reason for why customers and vendors are matched is to both confirm if what is said is true and to ensure bias from the vendors don’t inflate the positivity of the answers. Among the list of vendors contacted are presented in table 3.1.

¹Table 3.1 List of vendors considered, which were contacted, and which agreed to interview

Company	Size	Proximity	Contacted	Answer
SAP	Big	Has office near	Yes	No
Vendor Company A	Medium	Has office near	Yes	No (originally yes)
Ongoing WMS	Medium	Same country	Yes	Yes
Vendor Company B	Big	Has office near	Yes	No
Noventus	Medium	Same country	Yes	Yes
Vendor Company C	Big	Has office near	Yes	No
Apport WMS	Medium	Same country	Yes	Yes
Vendor Company D	Big	Same country	Yes	No
Vendor Company E	Medium	Same country	Yes	No
Vendor Company F	Medium	Same country	Yes	No
Vendor Company G	Big	Same country	Yes	No
Vendor Company H	Medium	Same country	Yes	No
Vendor Company I	Medium	Same country	Yes	No
Vendor Company J	Big	Has office near	Yes	No
Vendor Company K	Small	Has office near	No	-.-
Vendor Company L	Big	Another country	No	-.-

For those that agreed to interviews, their customers were also contacted. There is not any need for further criteria for the customers since the study is not focused on a certain market or type of customer, but the goal is to get data that can be used for any type of warehouse. The final table of cases interviewed were:

Table 3.2 Final list of relevant vendors and their customers that were interviewed.

Company	Type of company	Product	Time and place	Duration
Ongoing Warehouse AB	WMS Vendor	Ongoing WMS	Microsoft Teams	1 hour 7 minutes
Apport Systems	WMS Vendor	Apport WMS	Microsoft Teams	57 minutes
Noventus Systems AB	WMS Vendor	Epix WMS	Zoom	1 hour 14 minutes
Company Y	3PL warehouse (Ongoing customer)	Warehousing	Microsoft Teams	1 hour 4 minutes
Company Z	Retailer (Apport customer)	(Censored due to privacy)	Zoom	52 minutes

As Yin (2018) recommends, a case study protocol (see chapter 3.4.4) along with a questionnaire (see appendix A) for interviews will help to make sure that the same standard of questions and work is held for each case. The cases will be conducted through information gathered from interviews, and the answers are going to be documented and then analysed. This is illustrated in figure 3.7.

¹ All companies that did not answer yes were anonymized, with an exception for SAP since they are important to the study.

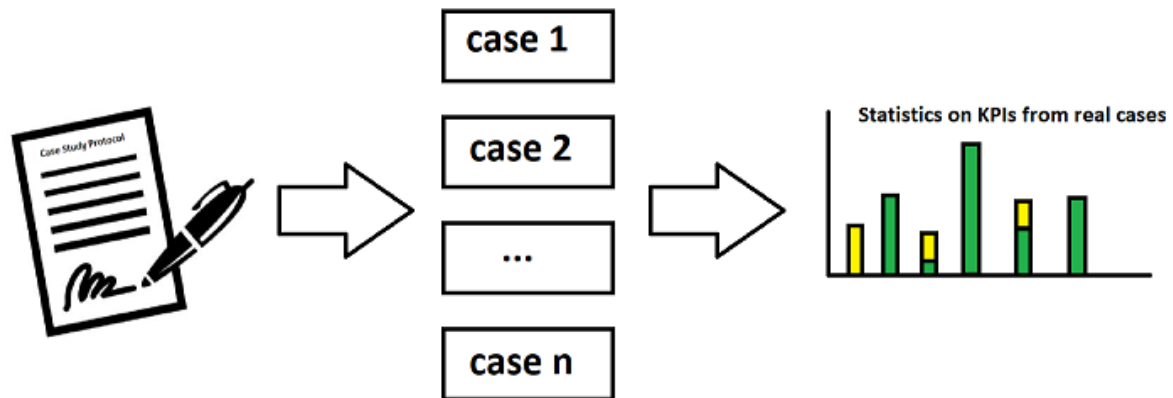


Figure 3.7: How the cases will be documented

3.4 Prepare

The preparation for data collection is essential for a good case study, as without a well done preparation the entire study risks being jeopardized. To avoid this Yin (2018) suggests five points of preparation. First is to make sure that the investigator has the desired skills and values, followed by training for a specific case study, developing a protocol for the study, screening candidate cases, and conducting a pilot case study.

The desired skills and values are about the demands that a case study puts on the intellect, ego and emotions of the researcher. The desired skills and values are composed into a list of five attributes.

The first attribute is to ask good questions, this is followed up by interpreting the answers fairly. Case study research requires an inquiring thought process when collecting data, the desired result for a case study is for the researcher to use the evidence collected and create a rich dialogue with it. When collecting case study evidence, it's important to quickly review the evidence and to think of why events or perceptions are like they are. The interview protocol served as a basis for the interviews, but every interview was different due to the nature of the answers. For example, in order to gather external influences on the WMS features follow up questions were sometimes asked.

The second attribute is to be a good listener. Listening means to receive information not only by hearing but by multiple modalities, like making observations or sensing what is going on. One important aspect of being a good listener is to be able to assimilate large amounts of information without being biased to any of them. It is highly important also to read between the lines and to understand what is meant when collecting information and not only what is said. The questionnaire focused more on the effect of the WMS rather than on external influences, but through careful listening and observation, follow up questions were often not needed as the interviewees often included things that would influence the WMS. This is why in the earlier example (on the first attribute) follow up questions were asked only sometimes.

The third attribute is staying adaptive. It's very important to be able to adapt to changes as a case study can change unexpectedly based on the gathered information. It's important to remember the original purpose of the case if procedural adaptations are necessary. If an adaptation happened the researchers need to maintain an unbiased perspective and to acknowledge the situations that can occur that may even cause the researcher to pursue a totally new study. In such cases the earlier stages of the case study need to be reworked as well. The study had to be adapted due to findings many times. As was shown in the literature, some parts had to be added in order to explain the results to the reader, but there are other adaptations that happen later on in the thesis as well.

The fourth attribute is having a firm grasp of the issues being studied. It's always best to stay on target and not sway too far off and the best way to do this is to recall the purpose of the case study; when preparing for the case study, the researcher should remember the rationale for the study. Important clues could be lost without a good understanding of the issues. Case study collection is not only the recording of data but also the ability to interpret the information as it is being collected and to know immediately if several sources of information contradict one another. This was ensured through the theory and through prior knowledge.

The fifth, and arguably the most important, attribute is conducting research ethically. If a researcher only seeks to use the case study to substantiate an already held position, then all the preceding conditions are invalid. The findings of the case study have to be evaluated fairly. A case study should fall under the set of values in so called research ethics. The highest ethical standards should always be strived for when doing research. These include not plagiarizing, not falsifying information, being honest, avoiding deception, and accepting responsibility of the work that is conducted. This is explained more in 3.4.3.

These five attributes were used throughout the entire preparation and implementation.

3.4.1 How to prepare

Before collecting data it's important to outline what data is going to be collected, and how and where it's going to be collected. The collection of data for this thesis will come from two sources; first is Company X and the second is the multiple cases. The data should help answer the research questions. Thus correct tools and knowledge is used.

3.4.2 What to do

The two data sources require different preparation. For the multiple cases, the most important tool is foreknowledge and the five attributes of desired skills and values that Yin (2018) outlines. It is extremely important to remember the research questions, the wanted information and the related theory when conducting an interview. To assure this, a case study protocol was used, that included what type of evidence to collect, what type of people to be interviewed, and events to be observed etc.

For the fieldwork at Company X, the evidence and data collected were essentially the data needed for the companies' values on the chosen KPIs as well as information to get a holistic view of their warehouse operations.

3.4.3 Protecting human subjects

The most important part of the prepare part is, according to Yin (2018), the protecting of human subjects. This will be different for Company X and for the cases. One group will not be protected less but the difference lies in that Company X has provided rules and limitations to what information can be used to provide the necessary protection for themselves. The role of the researcher is to honour these rules.

For the multiple cases the following steps were taken. First was to get a formal approval for the planned use of the interviewees by sending an email and asking them to participate in the study. The email also tied in with getting consent from them, and protection of their privacy, which was gained through asking whether their names and the companies names are allowed to be included in the study or whether they wanted to remain anonymous. The next step, also including Company X workers, was to make sure that they all were protected from any harm, be it physical through the fieldwork or integral harm that can lead to their positions being compromised. For Company X this would for example include not giving too much information so that any potential competitor reader can conclude what company the study is about. The last step will be to select the respondents fairly, for example not interviewing a manager at one company and a worker at another.

3.4.4 Case Study Protocol

Yin (2018) suggests that a case study protocol is used, see Appendix C. The case study protocol is directed at a single focus of data collection and should have four sections listed A to D.

3.4.4.1 Section A. Overview of the Case Study

Section A is an overview of the case studies, and should cover the background information about the case study, its substantive issues, and the relevant reading about the issues. A good overview will communicate to the informed reader the case study's purpose and setting (Yin, 2018).

3.4.4.2 Section B. Data Collection Procedures

Section B contains the data collection procedures, as it is essential to make properly designed field procedures. Data will be collected from people and institution in their everyday situations. The interviewee cannot deviate a lot from the agenda set by the question and is therefore constrained by ground rules set by the researcher. Section B emphasizes five major tasks: gaining access to key organizations or interviewees, having sufficient resources while doing fieldwork, developing a procedure for calling for assistance and guidance, making a clear schedule of the data collection activities that are going to be completed, and lastly providing for unanticipated events (Yin, 2018).

3.4.4.3 Section C. Protocol Questions

Section C pertains to the protocol questions, questions posed to the writer and not the interviewees. Section C focuses on questions related to the mental line of inquiry that the researcher has when creating the interview questions (Yin, 2018): Why should questions be asked? What information can be achieved through certain questions?

The protocol questions and interview guide questions are not the same, as the protocol questions should guide the researcher on what to think about when creating the questions for the interviews and when collecting data during fieldwork.

3.4.4.4 Section D. Tentative Outline for the Case Study Report

The last section D is the tentative outline for the case study report. It should have an initial outline of the case study report. This includes the facilitation of the data collection and the prevention of the possibility that secondary visits were necessary (Yin, 2018).

3.5 Collect

After preparation the collect phase can begin, where it's important to use the six sources of evidence laid out by Yin (2018) and many others. It's important to use supporting principles in addition to the sources. The principles are to use multiple sources of evidence, create a case study database, maintain a chain of evidence, and exercise care when electronic data is used. These principles should be used for each six sources of evidence: documentation, archival records, interviews, direct observations, participant observation, and physical artifacts.

All six sources, except the physical artifacts, were used when gathering data. A case study database was created in the form of a folder, including multiple sub-folders to help differentiate and sort different types of information. For example, in the literature review folder, all information was separated in sub-folders based on the topic of the literature as shown in figure 3.8. These sub-folders were further separated into more sub-folders based on the type of evidence source used. This made it possible to navigate quicker and easier when writing and rewriting the literature part. The same approach was used for all data collected, with minor differences in the division in the folders. The main folders were the fieldwork, divided in Company X and multiple cases, which included the empirical data and analysis, the methodology and method, the interviews, the literature, and a separate folder for all documents containing the written text.

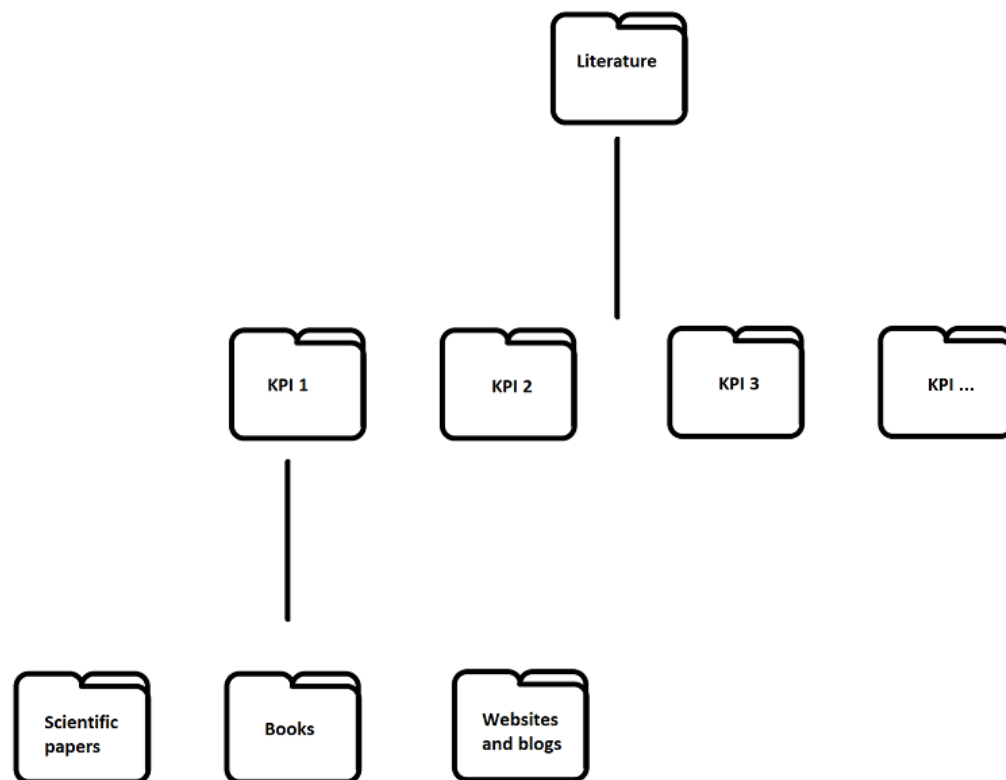


Figure 3.8: Example illustration of the structure of the data-base

Documentation pertains to a variety of different sources, including email, letters, personal documents, agendas, announcements, event reports, administrative documents, formal studies, evaluation, and news clippings (Yin, 2018). For the fieldwork with Company X the documentation will include data on demand for certain items, order lists, layout of the warehouse, list of their KPIs (that they use) and many more. Some documentation can't be gathered for the other parts of the thesis since access won't be available. For the multiple cases the documentation is limited to emails and interviews.

In general, archival records include things like “public use files”, service records, organizational reports, maps and charts, and survey data. For this study maps of the warehouse at Company X and organizational reports from Company X were used to get an understanding of the value for some KPI's. No other archival records were needed.

Interviews are often one of the most important sources of evidence for case study research. Interviews can help by suggesting explanations of key events. In an interview two jobs needs to be done (Yin, 2018). The first is to follow the research line of inquiry reflected by the case study protocol. The second is to verbalize the questions in an unbiased manner that serves the needs of the researcher's line of inquiry (Yin, 2018). This was applied when creating the interview guide. The interviews will be slightly different for the WMS providers and the customers. The goal of the interviews is to understand the impact on warehouse performance comparing before and after implementing a WMS, using the chosen KPIs. Thus, the questionnaire will have questions that address the improvement directly for each KPI.

When contacting the cases, it was made clear that neither the vendors nor the customers had extensive data on the KPIs collected which meant that while they would know how a certain area was impacted, they would most likely not know the exact percentage increased/decreased for the KPIs. This was due to multiple reasons, for the vendors they explained prior to the interviews that customers didn't report back their results, and from the customers it was narrowed down to them not having many KPI's that they checked and their KPIs were very specific to areas of their warehouses.

This influenced the interviews to be more like discussions where the findings for a question were extrapolated through other questions. This was done by asking how a certain feature of their WMS might affect a certain warehouse operation instead of asking for the change in numbers. For example, picking time after implementing their WMS was rephrased to "how did the WMS impact your picking time, and if you know, by how much?". This will not only give answers to the questions. but will also provide a wider understanding to why the WMS yields those answers.

Direct observations are important since the case study researcher most likely will be in a real-world setting where observation can serve as a great source of evidence. Observations can range from formal to causal data collection activities, including observing a meeting, sidewalk activity, work in the factory, classroom, etc. Direct observation was used at Company X to gather data on some of their KPI's. This was mostly done by watching warehouse employees work from a distance and measuring the needed data.

Participant observation is a special form of evidence source where the researcher is not a passive observer but active in the fieldwork. This provides unusual opportunities for the collection of case study data; the biggest opportunity is the ability to access events or groups that the researcher otherwise would not have access to.

Some observations did not reflect the full reality of the warehouse since they were in a low season at the time of writing this thesis. These observations were complemented by asking employees how certain things are at different times of the year, which was done in order to evaluate how it looks like during the high-season at Company X.

3.6 Analyze

There is no case study formula for analysing the case evidence, but there are tools that can make the analysis easier for the researcher, e.g. computer assisted tools. Computers allows for data to be categorized in large amounts; this data may have been collected through the multiple sources mentioned in the previous phase. When starting an analytic strategy one thing that the researcher can do is to "play" with the data (Yin, 2018). The objective is to search for patterns, insight, or concepts that seem promising. Other ways to play with the data are: putting information into different arrays, making a matrix of contrasting categories and filling the matrix with evidence, creating visual

displays, tabulating the frequency of different events, and putting information in chronological order or some other sequence. Any of these will move the case towards a general analytic strategy.

Yin (2018) proposes four general strategies: relying on theoretical propositions, working the data from the ground up, developing a case description, and examining plausible rival explanations. The strategy that is used for this thesis is his second strategy, and it involves working with the data from the “ground up”. This pertains pouring through the data, which can lead to suggestions of useful concepts. The data gathered covers the behaviour and events that the case study is trying to explain, and it is related to the embedded unit of analysis within the scope of the study.

The structure of the empirical data and analysis started with a description of the Company X warehouse in order to fit their position into the KPI chart and to understand how their warehouse operated. Then the case studies were described, followed by cross-case analysis in order to find patterns. The case studies were analysed to gain an understanding of where and why there are improvements, then they were compared to the theory on WMS's. Then a new analysis on Company X was made, which tried to adapt the case study findings to Company X's warehouse to conceptualize what the benefits and problems for implementing a WMS might be for them. This analysis considered Company X's ERP and their technological starting position, since a company without any software at all, like an ERP, will see greater benefits than one having software.

The interview observation findings were showcased in a before and after setting (table 3.3). Data that could be collected from the vendors and customers and presented as average percentual increase for certain KPIs then that were the preferable option. Otherwise, the data was given as a description of how certain areas are affected and in what direction they are affected i.e. positively or negatively.

Table 3.3 Before and after table to showcase findings

KPIs	Company X's KPI values	Average KPI improvement [%]	Average KPI values
Receiving			
Receiving time	x	y%	z
Dock door utilization	x	y%	z
Documentation processed accurately	x	y%	z
Put-Away			
Put-away time	x	y%	z
Put-away utilization of labour and equipment	x	y%	z
Correct put-aways (no errors)	x	y%	z
Storage			
Storage space utilization	x	y%	z
Storage accuracy	x	y%	z
Inventory days on hand	x	y%	z
Picking			
Picking Time	x	y%	z
Picking accuracy	x	y%	z
Picking utilization of labour and equipment	x	y%	z
Shipping			
Shipping time	x	y%	z
Order shipped on time	x	y%	z
Dock door utilization	x	y%	z

In table 3.3, Company X's values for the different KPI's are compared to the after-scenario of implementing a WMS, which is based on data gathered from WMS vendors and their customers. Table 3.3 is used in the analysis to present the effect of the benefits and problems (figure 3.9).

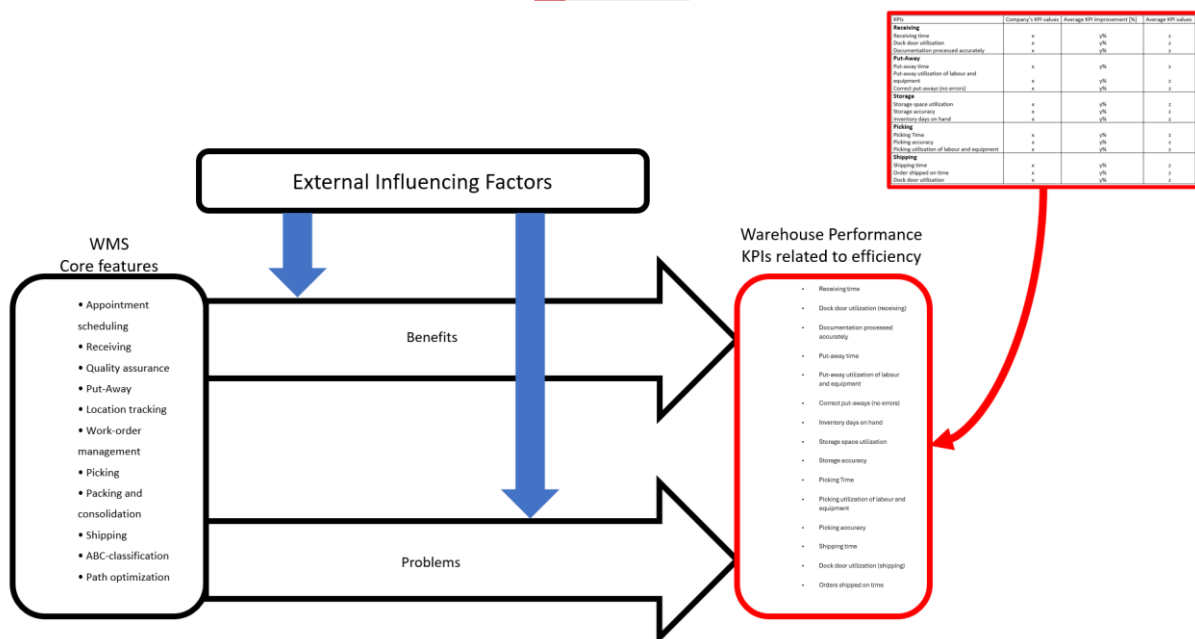


Figure 3.9: Visualization of where Table 3.3 is used.

Yin (2018) describes five techniques for case study analysis. Pattern matching is one of the most desirable techniques for case studies, according to Yin (2018). One compares empiric patterns with a predicted pattern developed before data was collected. If the

collected and predicted patterns appear to be similar, it shows the case study is valid and reliable.

The second technique is explanation building, which goal is to analyse the data through building and explanation of the case. If the explanations reflect some theoretical propositions that are significant to the case, then the study becomes of greater interest. Explanation building will be used in order to explain any patterns found.

The third technique is time-series analysis where one or more measures are tracked over time. This technique is not found relevant for this case; it could be used as a question during the interviews to gather data on long term changes of implementing a WMS and not only direct changes, but otherwise the technique is not judged relevant.

The fourth technique is logic models, which could stipulate and operationalize a complex chain of occurrences or events over a long period of time. The logic model will try to show how a given complex activity takes place. The logic model requires staged events in repeated case and effect patterns. This technique is not very relevant for this case study.

The last technique is the cross-case synthesis. This technique, according to Yin (2018), is very relevant for a case study with two cases but is also suitable for multiple case studies. This thesis compared the answers of multiple cases to each other, so cross-case synthesis was one of the analytical techniques heavily relied on.

3.7 Share

The last part of a case study is to share its findings. Yin (2018) finds it very important to have a flair when sharing the findings. Most notable researchers have been the types of people that liked to compose and liked to present the results. An important step in sharing a good case study is the intention of becoming good at composing, which concerns everything from tables, figures, charts, drawings to all kinds of other graphics. It is important to think through what is going to be done and develop some specific ideas, otherwise composing will be difficult.

One task is to identify the audience when designing the case study. There are many potential audiences, these range from academic colleagues, policy makers, practitioners, leaders of any kind, special groups, funder and sponsors, and many others. Each audience has different needs and no single composition can serve all audiences, this thesis will focus on the examiner, researchers that may want to use the finding of the study, and companies that want to implement WMS's. Yin (2018) argues that it is important to orient the case study research to the audience's needs and to make sure that there is no egocentric perspective in the study.

3.8 Trustworthiness

According to Nowell et al. (2017), a qualitative researcher has to be able to demonstrate that the data has been gathered, and the analysis conducted in a precise and consistent manner to be accepted as trustworthy (Nowell et al, 2017).

Trustworthiness can be broken down into four criteria: credibility, transferability, dependability, and confirmability (Enworo, 2022; Forero, 2018) following Guba & Lincoln (1989) (table 3.4).

Table 3.4 Four Criterion for assessing the trustworthiness of a qualitative research according to Guba & Lincoln (1989)

Quality criterion	Means of establishing trustworthiness	How this study will do this
Credibility	The credibility refers to the believability of the research findings. This involves making sure that a study will faithfully and accurately represent the phenomena that is investigated. Credibility can be gained through triangulation and member checking.	Triangulation is used by making sure a lot of important literature confirms each other. The same is done when collecting empirical data through similar questions asked to different vendor cases. If they give the same answers as each other, then that is a credible source for generalization of WMS's. Empirical data is also gathered through many different sources for Company X. The empirical data will also be checked by the respective cases to make sure that they're not taken out of context.
Transferability	Transferability deals with the extend that the findings of a study can be applied to, or as they put it transferred to, other circumstances or cases. Can the study be copied and applied to another similar situation.	The aim of the study is to make a generalized study that can be applicable to any warehouse. This will be done by taking the perspective of both WMS vendors and WMS customers. The data is also both from interviews and from theory and from data available on vendors websites (such as customer cases and lists of features confirming whether certain vendors have the same features as the interviewed ones) The most important step is to make sure the cases picked are relevant.
Dependability	The dependability is the establishing of how a study and its procedures are reliable and that the findings are not by a random chance. This criterion is strengthened by consistency in data collection and in analysis of the data.	The dependability is handled through the case study protocol and through the interviews, which make sure that the data collected is consistent and that the data analysed is consistent.
Confirmability	Confirmability is a criterion that relates to the objectivity and neutrality of the findings. Confirmability includes demonstrating that the study findings are not biased, maintaining a reflexive stance, and having a verifiable trail of documentation.	The choices of cases (that being both vendors and customers) when put together, make sure that the findings are not biased. If a vendor gives a biased answers that the others don't, or that the customers contradict, then that would be a sign of it being biased. The author also tries to be reflexive by examining the writing and being conscious about what is written to make sure the findings are not influenced by any external motive. The documentation is all saved in a very structured manner where everything can be reached easily in case something needs to be confirmed, this is for all literature and for the empirical data.

4. Findings

This chapter contains the empirical findings of Company X and empirical data of WMS systems based on data from WMS vendors and companies being their customers. The chapter first explains Company X's warehouse in more details, then explaining how data was collected, and then presenting that data for the 15 chosen KPIs. Finally findings from the multiple cases interviewed are given.

4.1 Company X

Currently Company X has an SAP ERP without a WMS. This SAP system does however include a lot of functions that are also part of most WMS's. These are functions such as a hand-held scanning device and barcodes used to register and track goods. The SAP system also provides a computer accessed program which makes it possible to find a lot of information on their goods, making it essentially a foundation for a WMS without the WMS functions added. This ERP-system works fine for one of Company X's warehouses, but simplicity makes a lot of operations non-optimal for the second warehouse. This second warehouse is the one analysed in the study.

4.1.1 Company X warehouse

The warehouse (figure 4.1) follows a FIFO policy and has over 17000 pallet locations. This warehouse handle goods that go either directly to customers or to retailers that purchase a lot of smaller orders such as one- or two-piece orders. There are on average 14 employees working with picking, and two employees working with put-away and bringing pallets from storage to picking. Receiving does not need any employees since the warehouse has a conveyor belt that brings in goods. Shipping does not have any employees either, instead external transport-providers' truck drivers are responsible for the shipping processes at this warehouse. There is also a packing machine where the pickers drop the goods which get packed automatically.



Figure 4.1: Vertical layout of the warehouse

The Company deals with a product-type that must be stacked with the heaviest products first when picked (they are all stored in EU-pallets on shelves). This leads to issues with the pick-routes which will be discussed in the picking section.

The 15 KPIs, that were introduced earlier, are divided into two dimensions: the warehouse operations and what type of KPIs. For Company X the empirical findings are presented with the warehouse operations in mind, and for every operation 3 KPIs (time, utilization, and quality) are discussed. Every section will start with an introduction of the operation to increase understanding of the processes. The structure for Company X will thus be the following: explaining the warehouse operation at Company X, time related KPI, utilization related KPI, and quality related KPI.

4.1.2 Receiving Operation and Receiving KPIs

Company X is a production company and at location X they have both their warehouse and production at the same site. Produced goods will be send approximately 100 meters with tractors to the warehouse. Their receiving method is primarily the conveyor belt

marked on figure 4.2, but for a small number of pallets weighing over 700 kg they have to receive them manually further down in the warehouse. The truck drivers put their pallets onto the conveyor outside the warehouse and the pallets automatically roll until they reach the end of the belt. Thus for most of the receiving no employees at the warehouse are needed. As a WMS cannot impact the physical work of the employees at receiving, the focus of this section will be on the conveyor belt receiving.

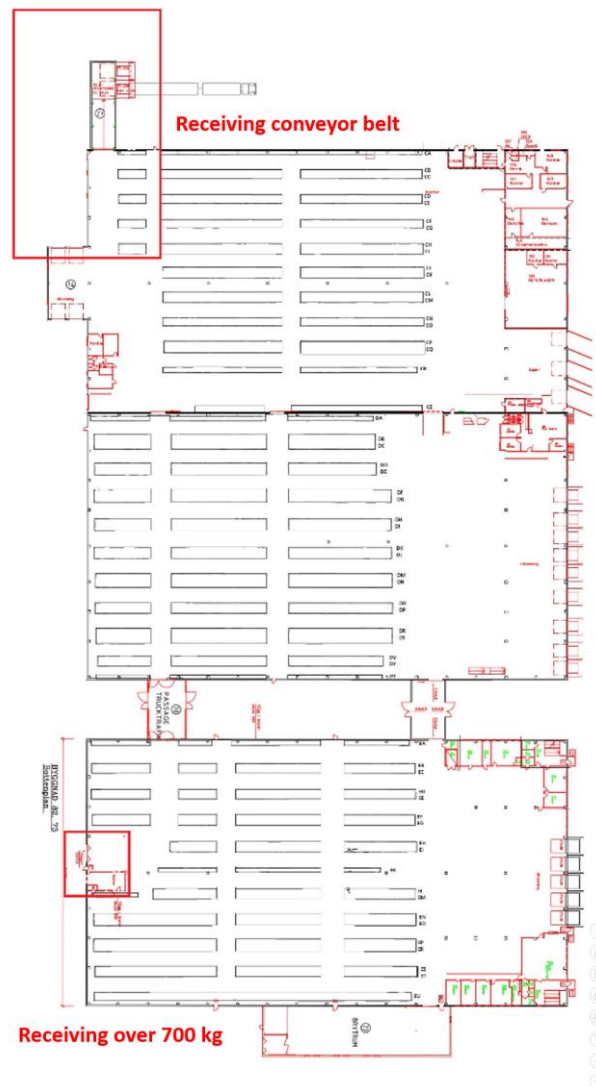


Figure 4.2: Two receiving areas marked on the warehouse layout

4.1.2.1 KPI 1 Receiving time.

The receiving time can be broken down into two parts for any warehouse. The first part is the actual physical work of unloading and moving goods to their put-away area, and the second part is the administrative time it takes to document the goods.

In Company X's current process, receiving is done automatically. The pallets roll on the conveyor belt, an employee picks up the pallet with a forklift and scans the pallet at the same time (figure 4.3).

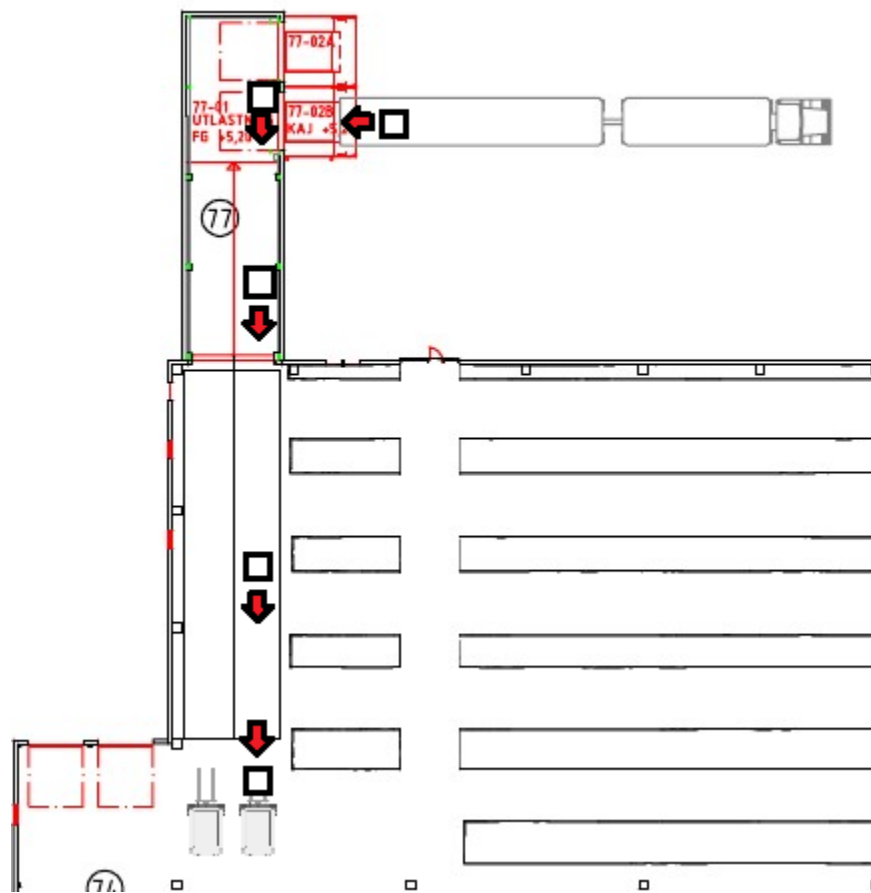


Figure 4.3: Visualization of pallets being received at the conveyor belt

This marks the end of the receiving and the start of the put-away operation. When the employee goes to pick up a pallet for put-away they scan the pallets and the goods are automatically documented into the SAP system. The employee can then proceed with the put-away right away. The receiving time can thus be broken down into 3 distinct parts for Company X.

1. the time it takes to unload pallets from the truck onto the conveyor belt
2. the time it takes for the pallets to reach the end of the belt
3. the time it takes to document the pallets.

All these three times were measured with the stop-watch function on a phone over the time-lapse of one hour and documented by pen and paper. The unloading of goods to the belt was measured to be on average 146,91 seconds, or 2,44 minutes. The time for one pallet to roll through an empty conveyor belt was 334,48 seconds, or 5,57 minutes. Most of the time there are items already on the conveyor belt since the put-away workers pick the pallets directly from the belt, and then they scan them from their forklifts for another 3 seconds. The amount of goods in the receiving does not matter as the put-away workers can start working as soon as the first item in line reaches the end of the belt, making the maximum receiving time to be estimated as:

$$146,91 + 334,48 + 3 = 484,39 \text{ seconds (8,07 minutes)}$$

Any time there are any items already on the conveyor belt the time becomes redundant since the belt is going to be filled up while the workers are removing items from it, in that case the perceived time for the worker becomes 0 seconds since there is no break of time without items on the conveyor belt. A WMS can thus not potentially improve the receiving time, besides maybe planning so that the conveyor belt never is empty if not needed be. In other words, as long as there are pallets on the conveyor belt the perceived receiving time for the employees is the total time it takes to document the goods, which was measured to around 3 seconds per pallet.

4.1.2.2 KPI 2 Dock door utilization.

The dock in this case is the conveyor belt. The belt is active from around 07:00 to 13:00 every day, a 6-hour time slot five days a week. The conveyor belt has a max capacity of 50 pallets. Measured over 47 weeks, the average amount of pallets entering the warehouse were 1215,87 pallets per week, not counting the first week of the year with 0 activity (week 31 had 7 pallets so it is included; figure 4.4).

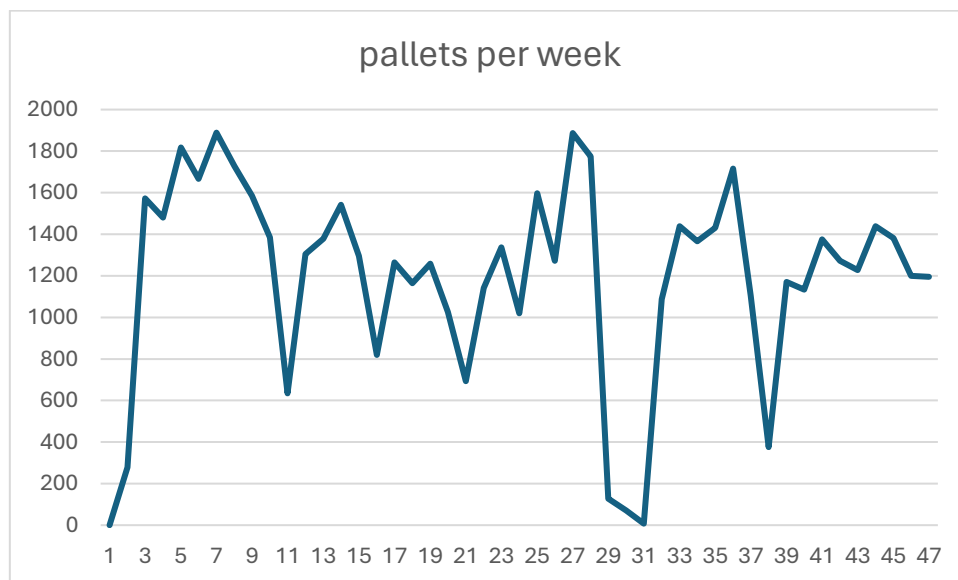


Figure 4.4: Graph showing pallets received from the conveyor belt for 47 weeks

These 1215,87 pallets, divided uniformly over the 30 hours per week that the belt receives pallets, gives an average of 40,53 pallets per hour, or an average utilization of 81,06%.

With the max capacity of 50 pallets at a time, and with the 30 hours that the belt is on, the total amount of pallets that can be received in one week in order for a full belt to be received every hour, is 1500 pallets. There are a total of 11 weeks where the pallets received were higher than 1500, with the highest being 1889 pallet. That would uniformly be equal to 125,9% of the conveyor belts capacity each hour. This does not account for the fact that the pallets are not brought in uniformly and the time it takes to remove pallets from the belt. The time it takes to remove pallets is the same as half the time of the put-away, since there are two employees in charge of put-away. This time is equals

to 1,41 minutes which means that if both workers are removing items from the belt, they would be able to put-away 42,47 pallets per hour. 42,47 pallets per hour amounts to 1274,33 per week, this means that on average the conveyor is bottlenecked for 23 out of 46 weeks, or 50% of the time. In other words, even though the average utilization is at 81,06%, for half the time it is at 100%. This leads to other employees having to help with the put-away, or the employees having to stay at put-away for longer than they should.

4.1.2.3 KPI 3 Documentation processed accurately.

The documentation process at Company X is very simple. The production site will put a label onto the goods. When the goods are received, an employee will scan the goods just before putting them away, and the goods will automatically enter the system when scanned. There are no errors at this stage, and if there were any errors, such as wrong products, this would have happened in production. It would thus not impact this metric at all since the goods received are documented as labelled. Because of Company X's current system and its efficient and simple process, the documentation processed accurately is at 100%.

4.1.3 Put-Away Operation and Put-away KPIs

The put-away is when the goods are physically sent to storage. For Company X this operation starts when an employee lifts a pallet from the conveyor belt with a forklift. At Company X, pallets are put into any storage space that is available, since they don't have a WMS they can't efficiently have ABC-classified storage locations. This leads to different product types being all over the shelves and in different shelves as shown in figure 4.5.

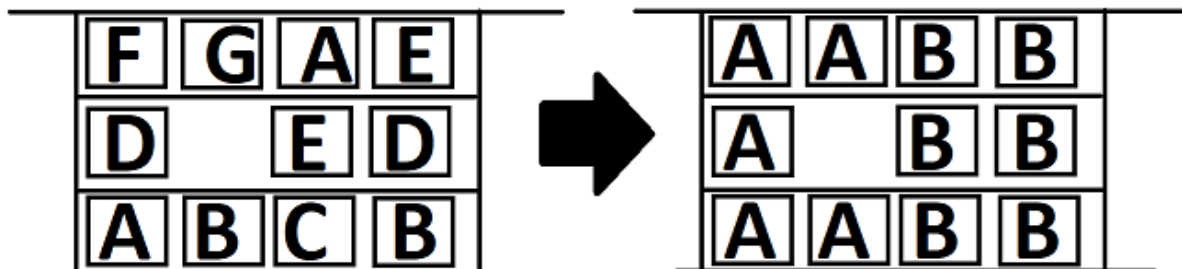


Figure 4.5: Left: how it can look at Company X right now, Right: how it could look with a WMS

A WMS would enable Company X to sort where to store the goods using ABC-classification. This would mean that items could be stored so the more frequently stored/picked goods would be stored/picked at locations closer to their operation. For put-away this could for example mean that the most used items would be stored closer to the conveyor belt and shorten the average distance needed to travel per put-away.

4.1.3.1 Put-away time.

The data collection at the put-away operation was done simultaneously as for the receiving, as the end of the receiving was the start of the put-away. Another timer was used to collect put-away data, and the time was measured as from the moment the forklift operator finished scanning, which marks the end of the receiving, until he was

back for the next pallet. The times were measured during a span of one hour of active work. The average put-away time for one employee, measured from multiple measured times, is 169,52 seconds, or 2,83 minutes per pallet.

The pallets per hour can also be calculated as one hour divided by half of the time it takes for one pallet, half because there are two employees. This results in 42,47 pallets per hour.

$$\frac{60 \text{ minutes}}{\left(\frac{\text{time per pallet}}{2 \text{ employees}}\right)} = \frac{60}{\frac{2,825}{2}} = 42,47 \text{ pallets per hour}$$

4.1.3.2 Put-away utilization of labour and equipment.

There are two employees in charge of put-away, that also are in charge of bringing down items from storage to picking. This means that they are not always available for put-away. Considering the data from the receiving dock door utilization, the average utilization would have to be:

$$\frac{\text{received goods per hour}}{\text{maximum goods put away per hour}} = \frac{40,52}{42,47} = 95,41\%$$

This is however under the assumption they can't let the conveyor belt have any items on it. In practice they leave the last set of pallets on the belt and put them away during the morning before 07:00. Counting the last set of items as being left on the belt then the received goods per week could be seen as 1/6th less (due to the last of the 6 hours of receiving not being removed). This would mean that the utilization would be:

$$\frac{40,52 * 5}{42,47 * 6} = 79,49\%$$

This is more realistic as it also accommodates time for the employees to deal with bringing down items from storage to picking.

4.1.3.3 Correct put-away.

Company X already have an SAP system includes scanners that tell them where they should store the goods. The only possible error that can be made is that employees go to put the goods in a certain place but accidentally put them in the place right next to it. According to three different employees at the warehouse, this does not happen very often since the storage utilization is at a very high level. Even if it does happen, the next time an item will be put into the storage location next to the first, the worker will see it is already occupied and scan it. In such a case the worker would correct the error and the error would be untraceable. For these reasons it's impossible to get any data on the mistakes and since the system also makes sure to correct such mistakes the value for correct put-aways becomes close to 100%. There is also the possibility that worker 1 puts a pallet in the wrong location and then worker 2 does not check the location and assumes that since it's the only spot available it's the right spot. But as there is no record of this happening yet, the correct put-aways is assumed to be close to 100%.

4.1.4 Storage Operations and Storage KPIs

The Storage is divided in 3 sections, as shown in figure 4.6. The different sections are not divided by product type since one product type stands for 75% of the stored goods. That product type is stored across the first two sections and the last section holds the rest of the stored goods.

4.1.4.1 Inventory days on hand

Company X does not measure the inventory days on hand, so this metric was measured by taking random samples from each of the buildings and then calculating an average. The average of 9 samples where 75,11 inventory days on hand. The samples were picked from each of the storage sections to get a fair representation of the storage.

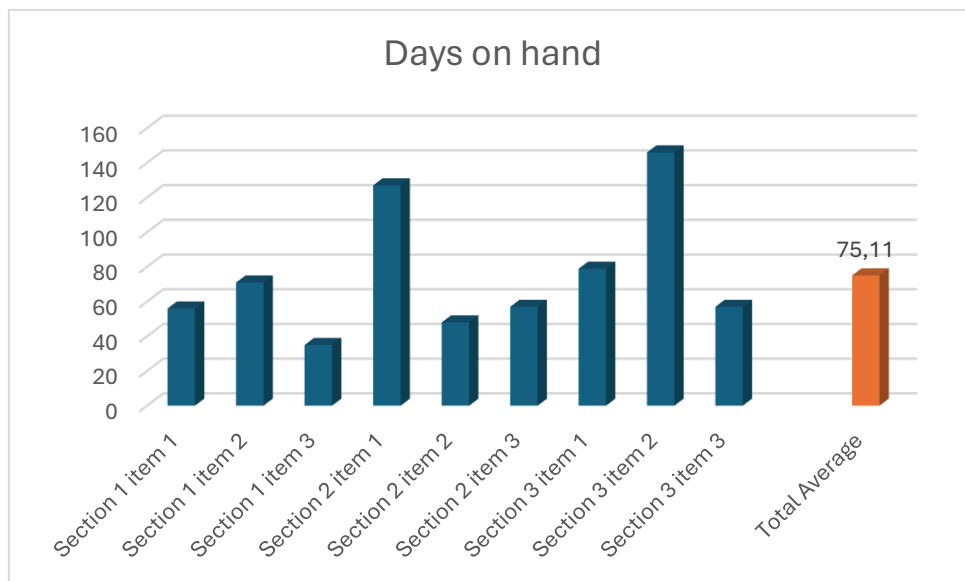


Figure 4.6: A graph showing the days on hand for 9 pallets, and an average of them

One type of data that Company X measures is the number of SKUs they have to throw away, most are obsolete products with expired shelf life but there are also products that have gotten damaged by different reasons e.g. bad handling, accidents or occasional bad packaging. The total amount of products that were thrown from the beginning of the year until mid-November was 29515 articles. From the data it is evident that whenever a batch containing large number of goods was thrown away, then it was due to them expiring, and when few goods were thrown away it was due to damages or other problems. The amount of goods thrown with more than 10 pieces in them amounted to 27990. Compared to the number of SKUs picked per day this would amount to 0,489% of the SKUs picked yearly (calculated using 21 workdays per month on average and adjusted until mid-November). While this does not seem much, the total worth of the goods thrown away is 363k SEK (Swedish Krona; 415,533 yearly). If a WMS can positively impact the inventory at hand, then there is an opportunity to reduce obsolescence and reduce cost.

4.1.4.2 Storage space utilization

The storage space utilization for Company X is high. The storage locations are divided into three categories: EU-Pallets B01, XYZ-type products, and P01, where the EU pallets stands for the vast majority of the storage locations. B01 and P01 are the same type of items, but the only difference is that B01 are full pallets in storage containing the most used type of products and P01 are pallets on the picking level. XYZ-type products are the other type of products that Company X stores in this warehouse, and they are not differentiated between floor level or shelf level.

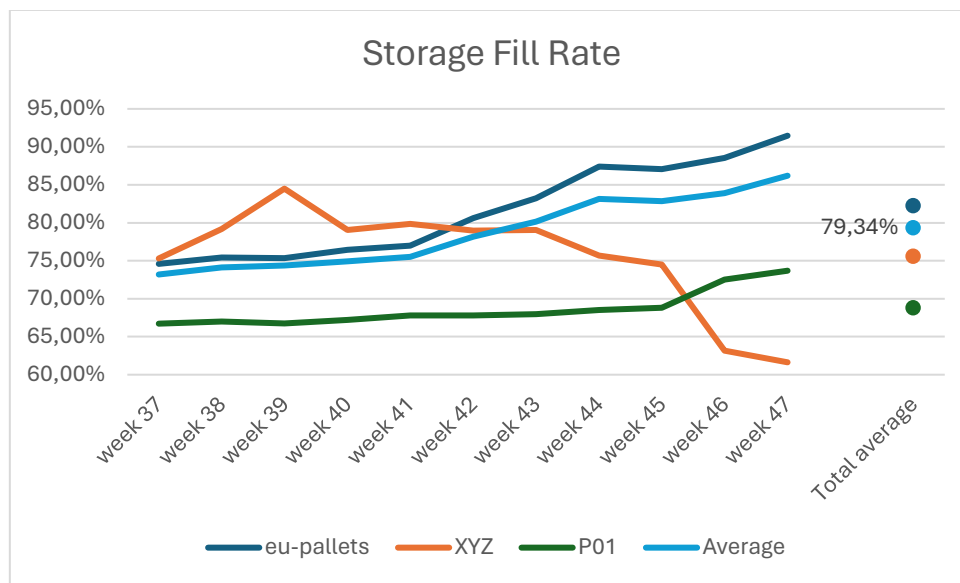


Figure 4.7: A graph showing the fill rate over 10 weeks

Calculated as an average for the entire warehouse, weighed with the amount of goods, then the warehouse has an average fill rate of 79,34% as shown in figure 4.7. There are however periods where the fill rate in the EU pallet range exceeds 90%, especially during the low season when they don't sell as much and Company X try to fill the warehouse in preparation for the oncoming high season. The shelf space on top of the layout is such that there is not much room to add further shelves, so the total storage space utilization is the same as the fill rate.

4.1.4.3 Storage accuracy

The storage accuracy is defined as having stored pallets in their correct locations, and having knowledge of where the items are. Since Company X has their SAP system this metric will show the same as for the correct put-aways, which is an unmeasurable process that is assumed to be close to 100%.

4.1.5 Picking Operations and Picking KPIs

Picking is the operation in a warehouse that stands for the most costs (Bartholdi & Hackman, 2019), and this is the case for Company X as well. Most warehouses thus seek to make their picking operation as effective as possible. At the time the fieldwork was conducted, Company X has an inefficient picking system, and they were aware of that.

4.1.5.1 Company X current problem with picking

As of right now, the warehouse at Company X have much more piece picking than full pallet picking. This is, as explained earlier, because they sell to retailers of all sizes. A lot of customers purchase only one or two products a week. This happens due to a policy where Company X offers free shipping once a week per customer. Most orders are not one or two products, but they are still mostly piece picking and not full pallets. Thus, the pickers have to navigate around the warehouse in order to fill up their orders. They also only pick one order at a time. This is where the problem starts. Due to the nature of their products the pickers have to pick the heaviest products first in order to be able to stack orders correctly. Since they don't have any software in place to effectively place out their goods in the storage, their picking paths become chaotic. There was also no picking path optimization implemented when the KPIs were measured. These factors combined would lead to the pickers passing through the same shelves multiple times to pick some orders, losing a lot of time and efficiency while picking. Four instances of how the picking routes look like are shown in figure 4.8.

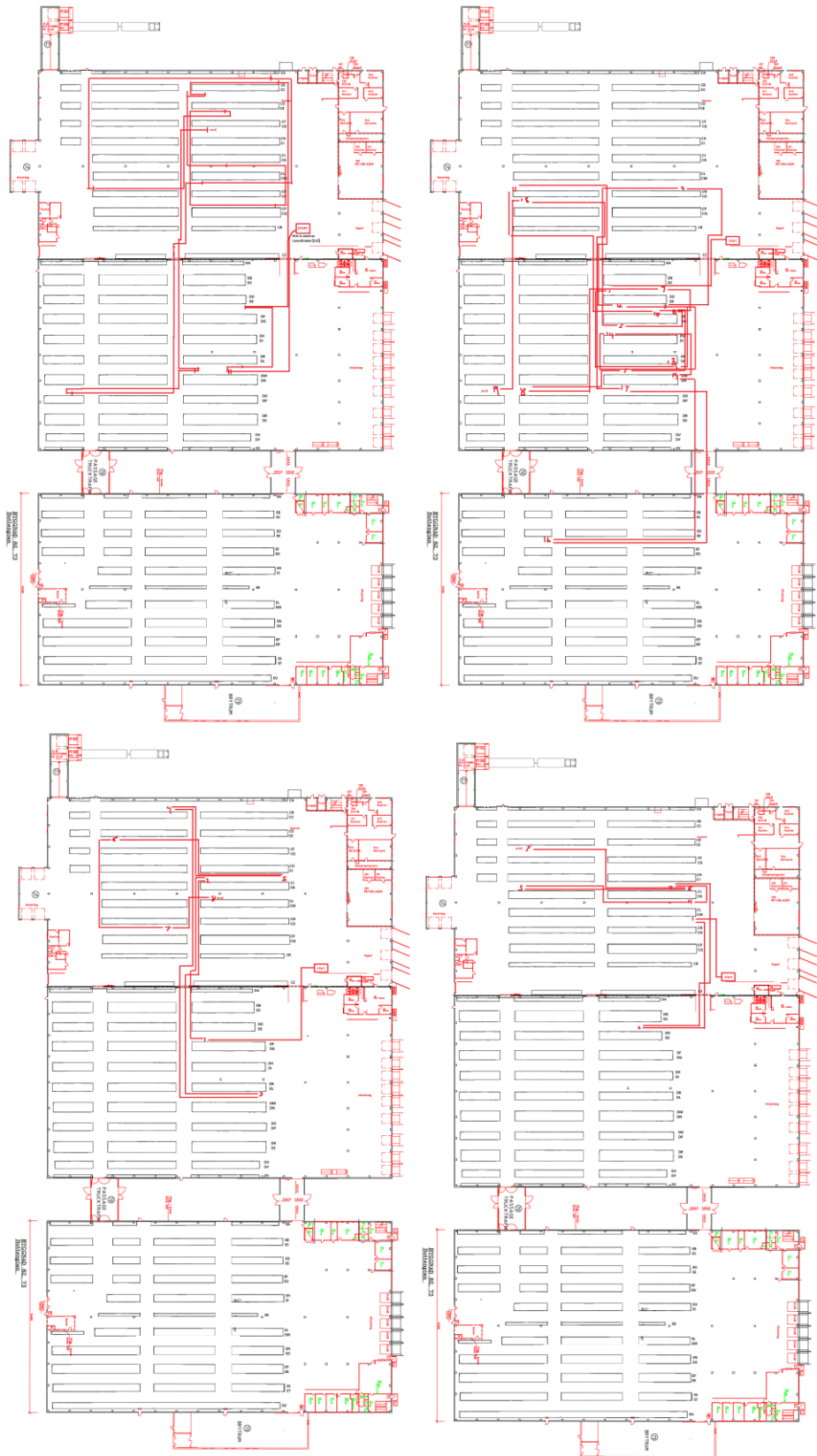


Figure 4.8: Four instances of how the picking routes can look if the pickers follow their orders.

4.1.5.2 Picking time

There were two ways to map the time it takes to pick one order. The first one was to use their scan data for their picks and then get the time between two locations. The second one was to gather data on how fast their trucks move and how long they spend at every picking location, and then to cross this data with data from order lists. The second alternative allows for a better understanding of how long the activities take. Looking only at the data from the picker's scanners will miss many variables such as waiting times, breaks, and activity changes. When they have picked all their items, they have to send the items to packaging as well. There is only one station for packaging and at this station the scanner does not show how long time they spend there or if there are waiting times to further delay their time spent. Thus, the time between two picks will be much longer than they seem. Another variable that the scanners do not consider, is explaining the waiting time that the pickers have when the goods are out and must be refilled from the shelves.

To calculate an accurate average picking time, the following data was collected: the distance traversed for 15 orders with a total of 115 picking stops, the time it takes at 50 picking stops taken at random, and the speed of the trucks. These three sets of data are used to get the average time to traverse the distance between the picking locations for the 15 orders and the average time it takes at a picking stop to then combine these to finally get the average time to pick one order.

From the 15 orders received the average distance to complete an order was 269,69 meters, with the longest distance being 789,20 meters and the shortest distance being 37,08 meters. The average time per stop was measured to be 41,93 seconds and the speed of the picking trucks were 8 km/h. Adding the average pick-stop time to all 15 orders yielded a total average 400,89 seconds per order, or 6,68 minutes. The longest time 1141,81 seconds and the shortest was 58,61 seconds.

To get an average picking time the total average time is multiplied with one over the picking utilization, which includes waiting for replenishment of goods during the picking.

$$400,89 * \frac{1}{0,93116} = 430,53 \text{ s}$$

The picking utilization value is explained in its own KPI section further down.

Due to the amount of backtracking used, the average distance between picking locations within an order was also collected. The data yielded a total average of 36,07 meters with the longest average distance being 49,67 and the shortest average 26,42 meters. This data is calculated as the average time between two picks for each order. There were cases where two picking locations were right next to each other in the order list, but there were also cases where a truck had to pass through the same shelves four or five times because of the bad planning, which is why the results are so high. This total

average is used together with the average time at stops to get the average time for each pick, which is 78,16 seconds. Adjusted with the picking utilization it is:

$$78,16 * \frac{1}{0,93116} = 83,94 \text{ s}$$

It's important to recognize that a WMS would affect the time spend traversing between the picking locations much more than the time it takes to do the actual physical picking of SKUs.

4.1.5.3 Picking utilization of labour and equipment

Company X have enough equipment for each picker, so there are not any waiting times for equipment. There is however a waiting time that occurs while picking. Due to the lack of planning in the warehouse, the pickers must wait a lot of times every day for goods to be carried down from the shelves to be picked. The problem exists due to the unplanned placement of goods in the storage and the chaotic purchasing from the customers. Sometimes the customer will order a full pallet of goods, sometimes they will only order x amounts of products. The system does not check if there are full pallets or not and the pickers are sent to a picking destination regardless. Sometimes there are only a few items left and then the picker must wait for another employee to get a pallet from anywhere in the storage. Due to the lack of planning, more often than not, the products are on a shelf at some other place than the picking destination, and this leads to waiting times for the pickers (illustrated in an example in figure 4.9).

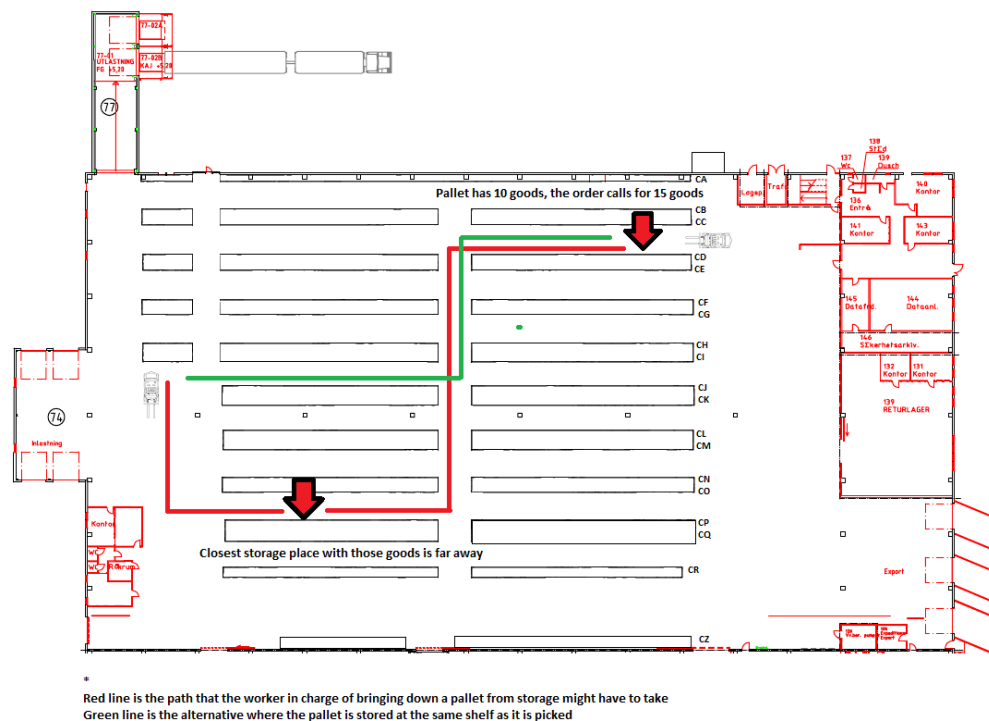


Figure 4.9: A visualization of how the route for bringing down items could be shortened

This is also because similar goods are not stored next to each other. If the same product types were to be placed next to each other, then this time would have been eliminated

for the popular items and new pallets would have been brought down after the picker leaves the area.

There are two employees in charge of carrying down items from the shelves and 14 employees in charge of picking. The two employees bring down, on average from data for 4 weeks, 5,74 pallets per man hour. The average waiting time for each individual bring-down occasion is, for the same period, 5,04 minutes. This means that both employees are busy bringing down pallets from the shelves for 28,91 minutes every hour. That is 48,19% of the time spent during the work activity. According to the employee collecting this data at Company X, the time spent waiting is only counted for when pickers are waiting, which means that this time does not include when they bring down pallets while not interrupting the pickers. Since these workers are unrelated to the pickers but their work is directly causing the pickers to wait, the picking utilization can be calculated as

$$1 - \left(48,19\% * \frac{2}{14} \right) = 93,12\%$$

Which means that almost 7% of the time for the pickers is spent waiting for goods to be brought down. Theoretically the utilization can reach 100% with better planning.

4.1.5.4 Picking accuracy

Company X already measures the picks per man/hour, and from data during a 4-week period the average was calculated into 115,56 individual picks per hour by every picker. Company X has on average 14 pickers per day and with two eight-hour shifts that equals to an average 25855,44 SKUs picked per day, or an average of 543594,24 picks per month. To get an accurate picture of picking accuracy, multiple factors must be considered and not just shipping errors. A list of errors from the consumers does not show the whole picture, as that list includes errors made at other sections and does not include invisible picking mistakes that are not recorded. Company X has provided a list of customer complaints for the duration of 10 months including all kinds of problems. Out of these, the complaints related to picking accuracy have to do with delivery shortage, delivery surplus, and wrong products. Most of these errors were about the quantity delivered and not wrong products delivered. The SAP system seems to already give a certain amount of control to Company X.

From another list of pick-orders with data from the last couple of years, the average amount of monthly orders containing picking mistakes was calculated to be 39,20 orders. Most of these orders have an error of one unit missing or surplus but other orders have up to 30 items missing and some are short by entire full pallets of goods. The average missing picks per order-complaint is 5,31. This means that the average wrong picks per month is equal to 208,12 SKUs. These would however only reflect the recorded errors. Some customers who purchase large quantities might not report if only one item is missing and other customers, regardless of the quantity ordered, might not report if they have gotten a surplus of items. Even then there are other factors to consider. When data was collected on picking at the warehouse, it was noted that the workers in one out of 50 locations noticed that they had picked wrong items and then they put the items

back in place. These errors do not cost any money directly, as the result of such an error is just the added time for the picker to go to the correct location.

The picking accuracy is thus:

$$1 - \left(\frac{(\text{wrong picks per month})}{\text{total picks per month}} \right) = 1 - \frac{208,1211}{543594,24} = 99,96\%$$

This number is also the result of the SAP features that they already have, which is part of a WMS foundation. Thus, the assumption is that implementing a WMS would not improve much.

4.1.6 Shipping Operations and Shipping KPIs

The shipping department for Company X is not ran by themselves at the location in city X. After packaging their goods, they put the goods at the dock area and then the truck drivers themselves must go in and load the items. Most of the times there is only one driver.

4.1.6.1 Shipping time

Since Company X does not handle their own shipment loading, the only time affected by the company is the time it takes to document items. This is however done automatically by their SAP system. The truckdrivers use the same systems so it takes them three seconds per pallet, and thus there is not much time that can be saved on this activity. Since the truck drivers work at different paces, combined with the fact that some shipments can consist of only one pallet while others can be a truckload of pallets, the shipping time will be defined as loading time per pallet instead of total time for one shipment to be sent away. Thus, the measures become more consistent. Had it been measuring the other way, then the result would not depict an accurate picture as some shipments take two to three hours and another can take as little as two minutes.

The average time to load one pallet, including the time to document that pallet, was calculated to be 67,93 seconds or 1,13 minutes. Currently, the time it takes employees at Company X is only the 3 seconds to scan the pallets before packing them. The documenting time is also the only time that a WMs can directly impact, just as for the receiving time.

One aspect that this does not account for, is that sometimes the truck drivers load pallets while Company X is still preparing more pallets. It can then happen that the truckdrivers have to wait in the middle of loading, but this is nothing that Company X controls since they don't load any shipments themselves.

4.1.6.2 Dock door utilization

The usual time dedicated to loading is a four-hour time slot per dock location. There are three locations depending on if the shipments are for the Swedish market, Danish market, or Norwegian market. The loading for the Swedish market starts earliest from around 13:00 to 17:00. There are a few shipments that happen outside of these times, but generally the different markets have their own shipping schedules of 4 hours. The

total number of shipments over the last 23 months (at the time of collecting the data) is shown in figure 4.10.

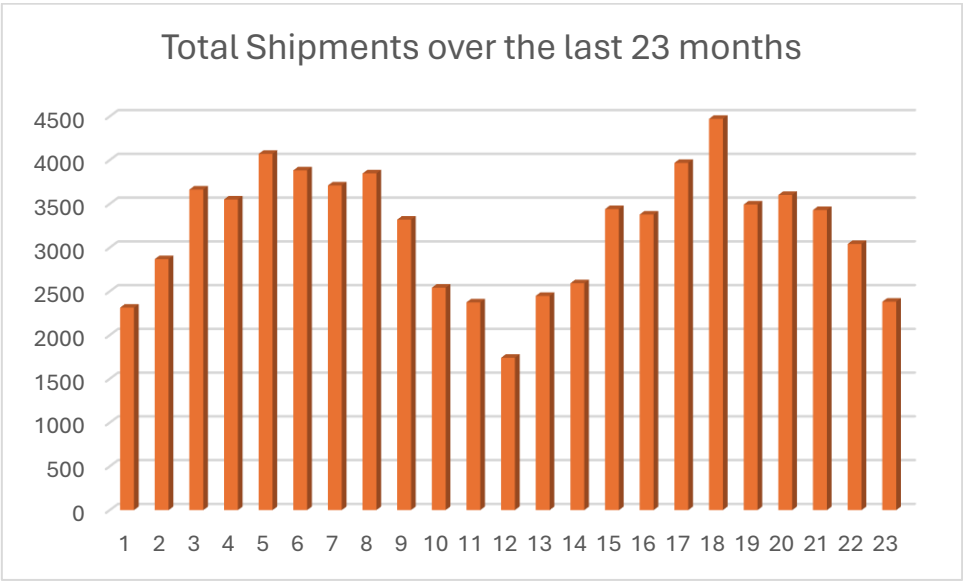


Figure 4.10: A graph of the total number of shipments over a period of 23 months

At the time of measuring, the market was at the lowest point of the year. The market for Company X follows a clear pattern resembling a sinus curve. At the lowest point of the season, the least number of monthly shipments were 1741 shipments, while the highest for the high seasons where 4471 shipments, which is 2,56 times higher. The average number of shipments per month for the two-year period is 3223 shipments. During the lowest point of the season the dock door utilization was measured to be 20% at the start of the shipping timeslot, 40% in the middle, and then back to 20% at the end of the shipping timeslot. This was then weighed with the highest month and the average of the entire year, resulting in the values is figure 4.11.

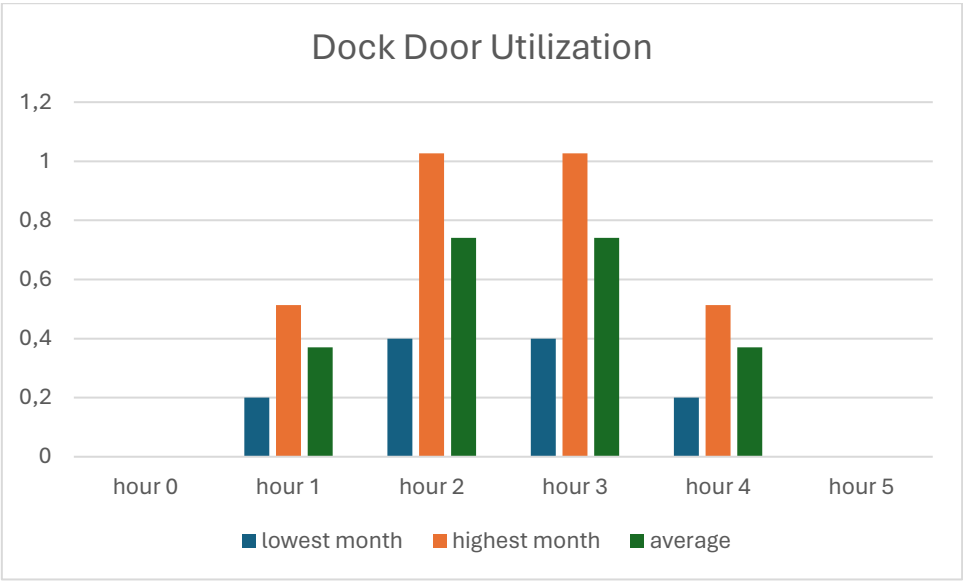


Figure 4.11: A graph of the dock door utilization

This shows that during the high season, the dock door utilization can reach 100% (103% rounded down since it cannot be more than 100%) during the middle of the time-period, and 51,5% during the start and end periods of shipping. These times are estimations based on the demand, but they concur with statements given by employees at the warehouse. One such comment is indirectly quoted as “during the high season the docks can be completely full for around one and a half hour to two hours a day”. This is the same as the data suggests.

The average dock door utilization for Company X is however at 37% and 74% for the calmer/busier hours of shipping. This yields a total average of 55,54% of dock door utilization.

4.1.6.3 Orders shipped on time

Company X does not have any sort of punishment if they don't manage to ship their orders on time. If a truck is scheduled to pick up items at a certain time, then that timeslot works as a preliminary time. All schedules are made to be a 30-minute time slot but most shipping take more than 30 minutes. The way that Company X does this, is by having the truck drivers call in when they want to pick up the goods. If the goods are prepared, or if they are close to done with the preparing, then they can come in to start loading the shipments. If the goods are prepared in advance Company X calls the truck drivers and tell them that they can pick up their goods earlier, and then they usually come early. If the pallets are not picked yet, then the truck drivers either go pick something in another location and check back with Company X later, or they wait in their trucks until the goods are prepared. Very seldom does it happen that a truck driver tells them that the order is too late and that they must pick it up the next day. Since the shipping times are so flexible the orders shipped on time is assumed to be close to 100%.

4.1.7 Conclusion of the Company X empirical data

The empirical data gathered at Company X, based on the KPIs (table 4.1), seems to suggest that their current system is not in need of any improvements when it comes to quality aspects. Due to the processes at Company X, receiving time and shipping time might not be affected either, the rest of the time and utilization aspects could be affected, depending on the findings.

Table 4.1 Company X's current values for the before and after scenario

KPIs	Company X values
Receiving	
receiving time	484,39 seconds per pallet
dock door utilization	81,06%
documentation processed accurately	≈100%
put away	
put-away time	169,52 seconds per pallet
put-away utilization of labour and equipment	79,49%
correct put-aways	≈100%
storage	
inventory days on hand	75,11 days
storage space utilization	79,02%
storage accuracy	≈100%
picking	
picking time	83,938 seconds per pick
picking utilization of labour and equipment	93,12%
picking accuracy	99,96%
shipping	
shipping time	67,93 seconds per pallet
dock door utilization	55,54%
orders shipped on time (according to schedule)	≈100%

4.2 Multiple cases

For the multiple cases the structure of the empirics will be presented differently, although the interviews were conducted with same structure as for Company X. The operations will not be described one by one but rather the other dimension of how KPIs were gathered: Time, Utilization, and Quality (table 4.2). This structure makes it easier to showcase the effect of a WMS, and interesting connections between the different sections will be clearer in the analysis.

This sub-chapter will start with an explanation of the cases and some general findings, followed up by different sections on the time related KPIs, the utilization related KPIs, and lastly the quality related KPIs.

Table 4.2 The KPIs chosen, with the types of KPIs highlighted

Operation	Time	Utilization	Quality
Receiving	Receiving time	Dock door utilization	Documentation processed accurately
Putaway	Putaway time	Putaway utilization of labour and equipment	Correct putaways (no errors)
Storage	Inventory days on hand	Storage space utilization	Storage accuracy
Picking	Picking Time	Picking utilization of labour and equipment	Picking accuracy
Shipping	Shipping time	Dock door utilization	Orders shipped on time

4.2.1 The Cases

These three vendors were interviewed were chosen since they are leading companies in their field and they were close to the author, making live interviews a possibility if they would agree. All interviews were finally held online. These companies also had broad customer lists on their websites, from which many of their customers also were geographically close to the author, making it easier to communicate and plan for a meeting.

4.2.1.1 Company background and context

Some general questions were asked before the KPI related questions to get a better understanding of the companies and influencing factors and how it could affect a WMS implementation.

4.2.1.1.1 Ongoing Warehouse AB

Ongoing is a WMS-provider that mostly serve 3PL (Third Party Logistics) customers or other types of logistics intensive businesses, but they also serve other types of companies with their own warehouse, such as eCommerce, retailers, wholesalers, and industrial companies. Ongoing bills their customers by the number of different customers/goods owners they have. If a 3PL warehouse handles goods from 20 different suppliers, then they should pay for each of the suppliers included into their system. It's also possible to choose to not use certain goods owners in the WMS. The cost is 270 euro per month for the first goods owner and then the cost is lowered the more goods owners Ongoing's customer has in the system.

The interviewee at Ongoing explained that two things that affect the results of a WMS implementation: how long the company had the WMS and how dedicated the company is to use the WMS functions. The Ongoing representative explained that when they implement their WMS to their customers, Ongoing try to make the first setup as easy as possible. He said that they might even start with only one goods owner in the warehouse system, or at the same efficiency as the previous implementation of the customers, and then they continuously improve the system one step at a time. The WMS and the customer analyses how to improve the process, realizes small improvements and then repeats. This means that the time spend since implementing their WMS is significant to the effect of the WMS.

The second influencing factor is the company dedication. If a company is more dedicated to improving their warehouse, the time it takes to improve the WMS implementation goes down. There are also many APIs (application programming interface) that Ongoing offers in order for the customer to build their own solutions on top of the WMS. The APIs are something that Ongoing recommends their customers to implement and the more personalized the customer makes their solution the bigger the effect of the implementation will be.

A third influencing factor, which is a result of the two previously mentioned, is the state of the warehouse at the time of implementing Ongoing's WMS. If the warehouse already has a WMS, then Ongoing's WMS will start at that configuration and then optimize. If the customer does not have any software at all then Ongoing starts by only implementing one goods owner into the system. The time it would take for the second type of customer to catch up to the first type of customer would be very long. But the perceived effect on the second more immature customer would be much larger since they will get more improvements.

Another important aspect to consider is the type of software that the customer uses. Ongoing has a very big list of software compatibility, when some of these are easier to implement their WMS with than others. The interviewee said that Ongoing WMS would be much easier to implement for an ecommerce customer than for example a company that uses full blown ERPs like SAP or Microsoft business centre. One solution for this is that Ongoing has integration business partners that build integrations between Ongoing's WMS and these ERPs. Ongoing would receive the monthly payments as usual but the customer integration partners would take a payment for the implementation from the customers. The type of software could thus influence both the cost of implementing a WMS and the speed of configuring a solution.

Ongoing also mentioned a problem that certain other WMS providers have. Ongoing is a cloud-based WMS and relies on internet access, but some other WMS's are server-based where they download applications on their computers and set up a server. With a server-based system the entire warehouse is threatened if the server has a problem. So, safety is traded for speed when choosing a WMS as internet issues could affect the speed.

4.2.1.1.2 Apport Systems²

The interviewee at Apport Systems explained that there are huge differences on the effect for the customers, based on how advanced software they already have. He said "where they come from defines how much they will gain" when talking about the customers. He expressed that the difference between companies that come from pen and paper and those with software is big. He explained that warehouses with limited

² The first 10-15 minutes of the interview voice recording, which included a little bit more than half the general questions, were corrupted due to bad internet connectivity but luckily some influencing factors managed to make it onto the voice recording.

warehouse support in their ERP will have a huge effect on the warehouse operations from the WMS implementation.

4.2.1.1.3 Noventus Systems AB

Noventus focuses a lot on 3PL customers, but they also have other types of customers with warehouses of any sizes, with some of their bigger customers having more than 300 000 shelf locations. The interviewee informs that they focus on automation solutions as well. and offer different advanced systems tailored to the customers with a starting cost of around 10-50 thousand SEK, but there is no roof on their price. Some customers have adjusted and improved their systems continuously for over 30 years. Noventus do not sell their WMS solution without tailoring it to their customer, and according to the interviewee there isn't any customer that hasn't had at least a little tailoring.

The interviewee at Noventus Systems AB ranks the greatest influencing factor as "keeping track of inbound". Most of the mistakes that happen if you have a WMS, he says, happen at the receiving operation. This is where human errors can still happen. He exemplifies that "the employee can say that a bike is a television" and then explains how the system would handle the bike as if it were a television, which would then go undetected until someone goes to pick the item.

The second influencing factor on the effect of a WMS is the type of problems the customers have. Since Noventus WMS is tailored to the customer, the customer issues will impact the solution of the WMS. If a customer has problems with receiving and put-away but handles picking, that means that the effect of the WMS would be much bigger on the receiving and put-away operation than on the picking operation.

4.2.1.1.4 Company Y

Company Y did not have any ideas on what influencing factors that affect their WMS performance on their warehouse are. But throughout the interview it became clear that they did not implement a lot of the functions that Ongoing offer. Not utilizing the WMS to the fullest could very much influence the results, but it was not something that they could comment on.

One thing that Company Y did mention was the KPIs they measure and find most important. These were picking time and storage utilization. While most of the KPIs suggested by the researcher were not measured empirically, Company Y could tell how the WMS affected the KPIs for most parts through other means of observation.

4.2.1.1.5 Company Z

Company Z's interviewee explained that Apport WMS has an easy interface with on/off functions for some of the more complex solutions. He explained that they have already seen great improvements in the warehouse. Company Z used to employ 13 warehouse workers, and since the implementation of the WMS, 3 of these have quit, that's 24% of the employees. The interviewee said he didn't need to employ new workers and they seemed already overstaffed with the 10 workers that remains. This although they have

not yet activated some of the most important functions such as ABC classifications and route optimization. It's expected that the warehouse will become even more efficient. "When you turn on these functions", he says, "Apport WMS will collect data for three months in order to create a database and in order to make calculations on products, important forecast, and many other things". At the time of the interview, he was a couple of weeks away from this data collection to finish. This makes both the choices of functions and the time of implementation influencing factors on the WMSs effect. These effects are internal to the WMS though.

One external effect that he mentioned was the amount of control at the reception and put-away operations. He explains that "a good job here makes the rest really easy", since this is the only operation where human errors could affect the WMS.

When it comes to the KPIs, Company Z finds the most important KPIs those related to reception and put-away, for the same reason as to why it is an influencing factor. Besides these KPIs they don't use any of the KPIs from the list provided by the author of the paper.

The KPIs and values provided were related to time aspects (table 4.3).

Table 4.3 KPIs measured at Company Z

Measured KPIs	Before WMS	After WMS
Backorders	5.5 hours	2 hours
DHL express (return time)	Not measured	30 minutes
Pre-programmed carkeys	Not measured	1 hour
Purchasing orders – stock orders	48 hours	8 hours
Returns form dealerships	48 hours	8 hours
Local manufacturers	Not measured	5 hours

It seems obvious that their KPIs are specific to their warehouse and could not be generalized, except for backorders.

4.2.1.1.6 Customer reviews online

One additional source of information used were customer reviews. When the vendors were asked about numerical data on how their customers were impacted by their WMS, Ongoing and Apport linked to their customer case stories on their websites. Noventus has a long list of customers, but without any reviews. Even though they were not interviewed, customer case reviews published by SAP and Vendor X were also collected.

All reviews did not include empirical data, but the available ones were collected before the interviews to be compared with the analysis (Appendix B).

4.2.2 KPIs related to Time

The time aspect of the warehouse operations is one of the most important aspects, as the time affects a lot of the efficiency. There seems to be a lot of money to be gained in having faster warehouse flow, but no vendor could give values for how much time is changed since every single application of a WMS leads to different results. All vendors could however give insight on how the WMS could lead to changes in the time KPIs.

4.2.2.1 Receiving Time

Ongoing claims that the receiving time should reasonably be faster. He explained that with a WMS received goods get scanned, and then sent to the next operation. The scanning takes only a couple of seconds, so if the company that implements the WMS is, in his words, primitive and uses something like excel, then the time spent for receiving will be drastically faster. Ongoing explains that the physical time to receive is not impacted, but the administrative time gets shortened.

Apport WMS impacts the receiving time in the same way. Inbound goods get scanned within seconds, and if there is no barcode on the goods, a barcode can be generated and attached to the goods with just a few clicks on the scanner. The physical time does not get affected, but the administrative time spent documenting is reduced to a couple of seconds.

Noventus think differently. According to Noventus their responsibility starts once the scanning of goods has happened, and they don't recognize the receiving time but their responsibility starts once put-away starts. The administrative work does not take that long and since they do offer scanners, they do impact the receiving time, and their WMS also uses only a couple of seconds for scanning goods.

The customers give different perspectives. Company Y explains that the receiving time differs tremendously depending on who their goods owner is. With Ongoing WMS, they can sometimes scan 20 EU pallets in one transaction, saving enormous time compared to doing it manually, but with smaller deliveries it can take a lot longer since then they must scan a lot of things. They explained that the physical time is also affected by this since a shipment of 3 large items could take 1 hour to receive while a shipment of many bandy sticks could take an entire day. If goods owners don't put barcode labels on their goods, they must look at the delivery note and enter the scanners and create a label. This external factor could lead to longer administration times. Even when there are labels, all companies don't put the delivered amount in the label. Then there is a chance that a few seconds of time is added when scanning, as they must key in the number on the scanner. If there are no external issues and goods arrive with the ideal labels, then it takes a couple of seconds to scan.

Company Z adds another perspective and argues that since there are more steps with the WMS the receiving line might take few seconds longer. But since the control is increased, they win a lot of time when looking at the warehouse holistically since they don't spend time searching for items. Their perspective comes from changing from one

WMS to another and not from nothing to a WMS. He further explains that since he hasn't enabled all the functions of Apport WMS yet, he can still lower the receiving time, and is expecting to lower the receiving time from an average of 5.5 hours to 2 hours.

4.2.2.2 Put-away Time

Ongoing explained that the put-away time can be greatly impacted by the knowledge that comes with the WMS. Knowing where to go and being certain that there is a location available to put-away the goods can save a lot of time for a company. He further explained that the ABC classification would allow for goods on average to be placed strategically closer to the most important operation areas, means that the most used goods are which are picked much more often, are placed closer to the receiving area in order to shorten the average distance travelled. Another layer of time improvement comes with the path optimizations, as making as few turns and as little backtracking as possible also saves a lot of time.

Apport Systems said that time is saved, by a lot, for most of their customers. He explained that warehouse employees no longer must look for locations, as they know exactly where they are going to put their items and the WMS shows them the shortest and most optimal pathway there is, which save a lot of time. This differs for customers based on how much information control they already have. Customers with ERPs that already support some warehousing activities might gain less than customers that have to guess whether a shelf space is available or not.

Noventus explained that their WMS affects the warehouse location selection. This is done with location optimization and functions that over time determine the warehouse layout, the storage locations, and what locations that are prioritized. This would over time turn the warehouse into an optimized warehouse, in terms of goods storage locations. This is essentially ABC classification with the extra step of layout optimization.

Company Y describes that their put-away time has got considerably better. They can control much more and control it more freely using Ongoing WMS. One aspect they believe gives them an edge on the put-away time, when compared to their previous system is that they can now receive entire lines of purchases and chose how many of each to move to the storage. This saves a lot of time as they can divide certain orders and send for example half to storage and the other half directly to shipping in case it was a backorder. It also saves time if they want to replenish locations at the picking level.

Company Z emphasises on the precision of the put-away, saying that the time is "more or less the same". Having to scan the products when they put them in storage leads to less errors made, before they used to forget to document and lose articles this way. This saves time that would have been spent searching for items instead, so there is an indirect time gained from their new WMS.

4.2.2.3 Inventory Days on Hand

The inventory days on hand is not something that is directly improved according to Ongoing WMS. But they argue that the full visibility and measurability of the warehouse does increase the overall flow, which lead to less need for storing goods, which leads to items entering and leaving quicker, thus lowering the inventory days on hand. He specifically said that the measurability makes FIFO easier to use, which lower the time inventory spends at the storage since goods are no longer lost and forgotten.

Apport WMS explains that the inventory days on hand drops as the storage accuracy gets higher. While this has to do with FIFO as well, the interviewee explained that it mainly affected by how much of a buffer the purchasing department need to secure to be able to deliver what is ordered. The more control and information you have, the less of a safety buffer is needed. Another thing to consider is the supplier, as some suppliers deliver on time and others have unstable deliveries, the stability of the suppliers affect the inventory days on hand as well.

Noventus says that the improvement of flow will lead to less time in storage as well.

Company Y does not measure this at all, but Company Z explains that the Apport WMS allows them to register and differentiate articles, in the system, based on if they have best-before dates or not. The interviewee at Company Z further explains that it's possible to handle these items differently, such as pushing them out on sales if they get close to their dates.

4.2.2.4 Picking Time

Ongoing WMS's holds that the picking time is faster for their customers. Their customers usually don't report back any data post implementation, but the picking time is something that get improved for most of them. The picking time is decreased as much as possible for the customers that chose to implement the ABC classification and the pathway optimization. Ongoing has a default pathway optimization function, but it is also customizable to be able to adapt to all kinds of warehouses. ABC and path optimization is time saving for companies that already have good information systems, but for other customers the most time saving aspect is that they don't have to search for items. When warehouse employees are picking, they know exactly where to go.

For Apport WMS, the picking time is impacted in the same way as for put-away. Apport explained that the employees don't have to search for picking locations and they don't have to worry about there not being enough items at said location. If a picker needs 10 products, then the WMS will send the picker to the fastest path to gain 10, whether that be to a location that has more than 10 items in it, or whether it is two locations where the closest location is less than 10. The shortest, fastest, and most optimal pathway is chosen.

Noventus gives a similar explanation as the other two WSM vendors. One time saving feature is that it eliminates all the times the pickers go to the wrong spots. Noventus adds the time saving aspect of the time it takes new warehouse employees to adapt to

the warehouse. Newer employees would have to memorize the warehouse prior to a WMS, which would cause them to be slower than other workers. Now they just follow the instructions from the WMS, and they do not have to learn the warehouse by heart.

Company Y experiences a faster picking time and a better scanning module with Ongoing WMS. Company Y says “I can’t put my finger on what it is, but overall, it’s faster”. He explained that they can custom fit picking orders more for their customers, they have more control on everything. Company Y does not use ABC classification, but they do use the route optimization. Their path is determined by the heaviest goods first and then the WMS determines the fastest location and pathway to pick the order list. They gain a lot of picking time with the multi-picking that Ongoing WMS allows them to do. Instead of picking smaller orders one by one, they can now stack multiple orders on the same pallets, eliminating a lot of backtracking to and from the packing area and storage area.

Company Z thinks that the indirect effect makes it difficult to know if it is better. They save the time it takes to start picking once the orders are lined up. Their old system was affected by slow programs and slow printers, and it would take them 10 minutes to determine the order and to load lists into their system, and then 5 minutes to print the order lists. Their new system will make the order list within seconds and send the orders directly to the employee’s scanners, and they save 15 minutes three times a day with their new system. They have not implemented the ABC classification and route optimization yet.

4.2.2.5 Shipping Time

The shipping time is the last time measured before items are send out of the warehouse. Ongoing WMS explains that, just as for the receiving, the physical work cannot be impacted, but the administrative work is affected. It takes only a couple of seconds to scan shipments. Unlike at receiving, where goods can come without labels, at the shipping operation everything will be labelled so the documenting will always only take seconds. One feature that decreases this time even further is that Ongoing WMS can scan multiple pallets with one scan. If 20 pallets are going to the same shipment, then the only pallet that needs to be scanned is the very last pallet in the line. The system recognises that the previous pallets are going to the same place and automatically registers them as scanned. This lowers what was already ridiculously low into even lower. This is however a special feature that they offer, and not a default feature. The interviewee explained that customers with a lot of frequent shipping activities can benefit more from this feature than smaller and slower warehouses.

Apport WMS has the same benefits in the shipping department as for the receiving department. That is, the documenting time takes a matter of seconds to do and the physical times is unaffected.

The same goes for Noventus, labels are printed if they are not already there at the receiving, so the administrative shipping time takes only a couple of seconds.

Company Y does not measure this at all, but they did confirm that the scanning takes a few seconds. Company Z on the other hand saw a great indirect improvement in the shipping time. Since the whole flow of the warehouse is faster with Apport WMS, they noticed that on average their last shipment was sent out 30 minutes earlier each day.

4.2.2.6 Summary on Time related KPIs

Table 4.4 Collection of answers on the Time related KPIs

Time	Ongoing	Apport	Noventus	Company Y	Company Z
Receiving time	Faster Only a couple of seconds of administrative work through scanning Physical time not affected	Faster A couple of seconds to scan, maybe a few clicks on scanner if no label Physical time not affected	Thinks their responsibility starts after already having scanned. With that said scanning takes only seconds.	Depends on the type of products, can take an hour or a day depending on how many different items and the quantity of the items. Also affected by if there is a label or not.	WMS adds more steps -> more time. Overall time is saved through added control by removing the time spend searching for lost items.
Put-away time	Knowing where to go and being certain that it's an available location saves a lot of time spend otherwise searching for free spots. ABC classification and path optimization makes it even faster.	Time saved by a lot; warehouse workers no longer have to look for locations. Time saved depends on the level of warehouse support the customers software already has.	WMS affects warehouse location selection through location optimization and essentially ABC classification.	Considerably better Much more control, can now receive entire lines of purchases and chose how many go to storage and how many goes elsewhere.	Greater precision saves time spent correcting errors instead.
Inventory days on hand	Indirect improvement through full visibility and better flow	Higher accuracy lowers inventory days on hand, less need for safety stock (buffer)	Better flow leads to less time spent in storage	Does not measure	Can store products with expiration dates differently.
Picking time	Faster Through less searching time and ABC classification and pathway optimization	Faster Does not have to search for goods and path optimization	Faster Eliminates times spent going to the wrong spots. New employees don't need to learn the layout	Faster Uses the route optimization. Uses multi picking	Faster Saves 15 minutes 3 times a day, as orders are instantly sent to scanners instead of stuck printing
Shipping time	Administrative (documenting) takes seconds, physical work not affected. Can register multiple pallets	Documenting takes a couple of seconds, physical not affected	Labels always on at this stage, takes seconds to scan.	Does not measure	Great indirect improvement. Last shipment of the day is 30 minutes earlier on average.

	with only one scan.				
--	---------------------	--	--	--	--

4.2.3 KPIs related to Utilization

Among the cases, the KPIs related to the utilization were the least used KPIs out of the three types studied.

4.2.3.1 Receiving Dock Door Utilization

The interviewee at Ongoing did not know how their system could affect the dock door utilization, but said it is possible to implement features that check whether a dock door is occupied. However, they do not experience that customers are having a problem with this.

Apport Systems also claims that this is not directly affected by a WMS , but that the WMS does affect it indirectly. By reducing receiving time, the whole inbound gets more effective. This means faster unloading, which leads to trucks moving away faster, which in turn leads to lower dock door utilization.

Noventus WMS has slot planning as optional for the customer. The slot planning can be used in order to make sure that all receiving goods don't come at the same time and create bottlenecks for the receiving operation.

Both Company Y and Company Z explain that their warehouses are too small for the dock doors to be bottlenecked. They have not thought of measuring the dock door utilization since it does not cause any bottlenecking problems.

4.2.3.2 Put-away Utilization of Labour and Equipment

Ongoing argues that the Put-away utilization of labour and equipment will increase as it becomes clearer for the warehouse workers where they must go and what they have to do. The utilization is also dependant on time, so when the put-away time decreases the need for both workers and forklifts decreases.

Apports agrees, that through more effective put-away processes and overall processes the utilization will become better over time.

Noventus does measure this KPI, but a bit differently. They measure it as the put-away utilization per operator and per equipment and can see what is left to do for the operator/equipment. Their perspective is "what do we have left to do now". They measure this individually for their customers, not saving it into one database so they could thus not give any numbers on this KPI.

Company Y does not measure this at all. They currently don't see any difference and explain this due to not yet having implemented ABC classification.

Company Z does not measure it either, but they find it “Way more effective than before”. Company Z explains that the utilization is higher since the workers know where the equipment is.

4.2.3.3 Storage Space Utilization

The storage space utilization gets more affected, according to Ongoing. The increased control over which warehouse locations are occupied, and what goods exists in the warehouse, will improve the storage utilization. Knowing for certain what is in storage will lead to less stocking. The increased flow of the entire warehouse will also lower the need for storage space.

Apport confirmed that better overall processes and faster flow will lead to less need for storage space. The increased control and visibility also impact the ability to forecast the stock buffer and more control leads to less storage need.

Noventus measure how much of the surface is used and the fill rate. He said that faster warehouse flows lead to more optimal storage fill rate. Noventus also collect data on whether goods are stored at the correct place, defined as if the place is the most optimal location for storage. Overtime their system might move an item from a good location to a low priority location, and vice versa, depending on if it is delaying the flow. This will lead to better storage space utilization.

Company Y reports having the same storage space utilization as before but explain that they already had a WMS before. Company Z reports an improvement since changing to Apport WMS, which lets them assign location spots to the products. Products are no longer going to whatever random location that is available but have designated spots which give more control.

4.2.3.4 Picking Utilization of Labour and Equipment

Ongoing holds that the picking utilization of labour and equipment improves. The increased visibility and control will result in less errors and faster picking, which leads to more efficiency for both pickers and picking equipment. Some features improving the picking utilization much is the support for multi-picking that Ongoing offers. Single picks, or one-piece picks, become much more effective. Instead, multiple pickers picking one product each, the feature allows one picker to collect multiple single pick orders on one trip. Ongoing WMS also support packing to make sure that the multiple picks do not mixed when packaged.

Apport Systems explains an indirect increase through more effective put-away and picking processes. The interviewee worked with a warehouse that implemented Apports WMS, and after 1 year 37 trucks were decreased to 25 trucks as the utilization of equipment improved much.

Noventus had the same answer for the picking utilization as for the put-away utilization.

Company Y does not measure this KPI. Since they changed one WMS to another, they didn't see any great difference. But they admitted a big difference in utilization compared to the situation without WMS and worked only with pen and paper.

Company Z added that their processes are more flexible now, which improves the utilization. The visibility makes them know what “needs to be done and stuff”, which is interpreted as they have more information, and that having more information leads to better utilization.

4.2.3.5 Shipping Dock Door Utilization

For all interviewees the answers on dock door utilization were the same for shipping as for receiving.

Ongoing did not know how it is affected, while Apport said that reduced process times leads to faster loading which leads to better dock door utilization. Noventus said that time slot planning exists for both inbound and outbound, and neither Company Y nor Company Z measured this and they did not see any differences.

4.2.3.6 Summary on Utilization related KPIs

Table 4.5 Collection of answers on the Utilization related KPIs

Utilization	Ongoing	Apport	Noventus	Company Y	Company Z
Dock door utilization (receiving)	Don't know how it could be affected by a WMS	Not directly affected, indirect improvement from faster inbound	Slot planning can prevent bottlenecking	Does not measure	Does not measure
Put-away utilization of labour and equipment	Becomes better as a result from the time improvements and the visibility and control improvements	Indirect improvement from overall better processes	Does not measure. (gave no answer)	Does not measure	Does not measure
Storage space utilization	Becomes better as control and visibility increases	Becomes better as control and visibility increases (communication with purchasing becomes better)	Becomes better due to faster flow. With time less popular goods get sent to less priority locations and vice versa.	Same as before (went from one WMS to another)	Much better Can designate locations for products by type.
Picking utilization of labour and equipment	Becomes better due to increased visibility and control. Less errors and faster times also impact the utilization. Greatly impacted by multi-picking	Indirect increase through more effective put-away and picking processes. Gives example of going from 37 trucks to 25 trucks after 1 year of implementation.	Does not measure. (gave no answer)	Not much difference from one WMS to another. BIG difference from pen and paper to WMS.	Is better due to more flexibility

Dock door utilization (shipping)	Don't know how it could be affected by a WMS	Not directly affected, indirect improvement from faster over all warehouse processes	Slot planning can prevent bottlenecking	Does not measure	Does not measure
---	--	--	---	------------------	------------------

4.2.4 KPIs related to Quality

The quality based KPIs were the ones most affected by a WMS and the only KPIs that both vendors the customers felt comfortable to provide numerical values for. Reasons were that for the vendors these values were the similar for each of their customers. The customers found these values easier to keep track of and the quality aspects were also their reasons for implementing a WMS. As all the quality KPIs are directly linked to control, visibility, and knowledge in the warehouse.

4.2.4.1 Documentation Processed Accurately (at Receiving)

Ongoing measures that the documentation processed accurately is pretty almost 100% for their customers. "The system will not make a mistake", the interviewee argues, "so if there is a mistake made then it's a human error. You scan a label, and the WMS will handle the rest".

Apport WMS also reported that almost no administrative errors exist since as one only scans the label on the inbound goods and enters whatever needs to be entered on the hand held device.

Noventus also confirmed close to 100% and emphasised that if any error is made then it is at this moment. A worker could for example scan the wrong product, or enter the wrong product after scanning, or enter the wrong quantity.

Company Y and Company Z also report around 100%. Company Z explains that "when a truck arrives and finish unloading, then they scan the number and add the number of pallets, it's 100% accuracy basically, it takes seconds".

4.2.4.2 Correct Put-aways

Ongoing also puts the correct put-aways at almost 100%. Since there is full visibility of everything in the warehouse, such as what location is available and occupied, what is in that location, where equipment's are, what needs to be done, there is not much room for errors. The WMS tells the worker exactly where to go and when the worker goes there the location is available.

Apport Systems also gave a value of almost 100%, saying "you don't have to consider anything, the system tells you where to go, and it will be correct". He adds "and it will also be the shortest possible distance". Apport mentioned that many companies differentiate between their goods and have, for example, pallets stored in one location and boxes for pieces at another. Depending on received amount one will be instructed by the WMS to put it "there, there, or there", stating that the system can be very flexible.

He lastly adds that many rules can be set up for put-away processes in order to guide the user to the most effective put-away as possible.

Noventus mention that automatic warehouse location selection is based on algorithms. The operator gets an assignment to drive to a certain place, scan the location and then the goods, and the accuracy is close to 100%.

Company Y confirms correct put-aways to be almost 100% with Ongoing WMS.

Company Z emphasises this is where the WMS shines the most and explains that the 100% visibility leads to close to 100% correct put-aways. Prior to implementing Apport WMS, Company Z had a massive problem with losing goods during put-away.

4.2.4.3 Storage Accuracy

Storage accuracy was defined differently by the interviewees. The author's intended definition, from the literature review implied how often products are documented in the wrong location. This KPI is very dependant on the correct put-away KPI with the only difference being that an item could be put-away into the wrong location and then be corrected.

Ongoing interviewee assures that the visibility from their WMS will put this at almost 100%, which Apport confirmed.

Noventus measure storage accuracy as "is this the perfect location for storage" rather than "is this stored where it says it is", but also claims that their accuracy is at 100%. For the author's intended definition, they also said 100% accuracy.

Company Y also reported "pretty much 100%" Company Z explained that since implementing the WMS, they've had one inventory audit and out of 80 locations only 1 single item was placed at the wrong location. This item was a special part which they had 2524 different types of, and the interviewee meant that errors are almost non-existent.

4.2.4.4 Picking Accuracy

Ongoing argues that their WMS makes it impossible to pick the wrong item, and explained that the handheld device will give an error message if the picker scans the wrong product. Thus, the accuracy for picking should be 100%. A mistake that can be made is related to the quantity, as the picker could pick the wrong quantity of items, but not the wrong type.

Apport Systems also measured accuracy as 100% for picking. He explained that for one customer the WMS implementation increased the picking accuracy by 15% landing them at 100% afterwards.

Noventus shortly answered that the picking accuracy is close to 100%, but not 100 since there are still human errors where the wrong number of products are picked.

Company Y explains that with Ongoing WMS, picking errors do not happen very often (almost 100% accuracy). Almost no picking errors exist where the type of product is wrong, but when picking errors happen it is the quantity that is wrong. During multi-picking it can happen that the picker put the product in the wrong carriage.

Company Z have 99.9% of picking accuracy, as before. They had measured it before and had 40 picking mistakes out of 22 thousand lines picked. He says that it could possibly be lower now, but they don't measure it because it was already so good before.

4.2.4.5 Orders Shipped on Time/on Schedule

The orders shipped on time could very well be affected. Ongoing exemplify that if the customer knows that, for example, PostNord will arrive at 14:00 then the WMS will prioritize the postNord orders so that they are ready before. There was not any given value for this KPI, as he argued that if the customers book more than they can handle then the system cannot help them.

Apport explains that if a warehouse does everything manually, then you would have a list in a huge pile in the warehouse, and you would have no idea what is going to be completed when. In the WMS, he says, you have a warehouse management follow up screen which shows all the orders, and you can sort the orders based on departure time and execution time giving you full control. Which means that the warehouse manager can see how close to the deadlines the orders are and can shift personal if being a little back on the picking. The system also gives out notifications and reminders. In Apports simplest WMS version one can just sort on the deadlines and see how much time remains until the deadline, but in their most complex version the user will have a report with calculated finish time based on the deadline for the order, departure time for the trucks, the number of pickers logged in, and historical performance of these pickers. He describes that the system goes as far as being able to predict for example 10:00 in the morning when the orders are allocated to make an order finished at 17:40 in the evening. Knowing already in the morning whether or not the orders will be done before the departure time gives the opportunity to do something differently.

Also Noventus does not give a number on this. Noventus provide with planning, which consider departure times in the order planning. If you sell more than you can handle, then there's nothing to be done, says the interviewee. As a rule of thumb their system will base the orders on what priority the orders have.

Company Y explains that with the Ongoing WMS shipping delays do not happen that often. And most of their shipments are handled on time, to 98-99%.

Company Z has seen an improvement with Apport WMS, and orders shipped on time are around 100%. One improvement observed is the last shipment departures 30 minutes earlier on average when compared to before.

4.2.4.6 Summary on Quality related KPIs

Table 4.6 Collection of answers on the Quality related KPIs 6

Quality	Ongoing	Apport	Noventus	Company Y	Company Z
Documentation processed accurately (receiving)	≈100%	≈100%	≈100%	≈100%	≈100%
Correct put-aways	≈100%	≈100%	≈100%	≈100%	≈100%
Storage accuracy	≈100%	≈100%	≈100%	≈100%	≈100%
Picking accuracy	≈100%	≈100%	≈100%	≈100%	≈100%
Orders shipped on times	Could be affected. WMS has function to prioritize orders to meet departure times	Could be affected. Simplest WMS version let's user see departure times. Most complex WMS version lets customer know when the orders get filled, the minute they will be done based on deadline, departure time, number of pickers, personal historical performance of pickers.	Could be affected. System bases orders on priority. Can take into account departure times.	≈98-99%	≈100% Additionally, the last shipment is sent out on average 30 minutes earlier than before implementing Apport WMS

5. Cross Case Analysis

The cross-case analysis will follow the structure of the multiple case findings (time, utilization, quality), and then end with a summary of the cross-case analysis.

First the findings from the multiple cases will be compared to each other and with the theory in order to illustrate potential patterns and similarities, as well as differences between theory and practice. These findings will then be compared to Company X's situation.

In the summary, benefits and problems will be summarized and illustrated, followed by influencing factors, and lastly a section on KPIs.

5.1 Time

Time related KPIs are what ultimately could save the warehouse the most money, especially through time saved on picking and put-away. This as half of the pickers time is spent on traveling (Moeller, 2011) and picking stands for 55% of the whole warehouse operating costs (Bartholdi & Hackman, 2019; Zhang & Jiang, 2022; Moeller, 2011). Even though the vendors did not collect data from their customers, and the customers did not measure most KPIs, the multiple case findings showed that time related operations are affected by a WMS.

5.1.1 Receiving time

5.1.1.1 Cross-case analysis

All three vendors agreed that the receiving time can get faster through the implementation of scanners. The scanners would be used to instantaneously document the reception of a product with the click on a button, or sometimes with a few clicks depending on whether the label had the quantity counted or not. This would save a lot of time for companies that document everything manually.

According to Kulinska & Giera (2019) a lot of risks due to human errors exist in the receiving operation. Company Z perceived that the WMS added some extra steps which made the receiving process a few seconds longer, but it saved a lot of time later as the added control mitigated almost all of these errors, and not time had to be spent correcting them. Company Z hope to lower their receiving time by 63% with their new WMS, but without detailing how.

The 3PL Company Y confirmed vendors views but added that their customer was an external factor affecting the performance of the WMS. If their customers already used labels containing all sorts of information, then it would just take a couple of seconds to scan the products. But if their customer would not include needed information or would not label goods at all then the time spent documenting would increase. Although not comparable to working with pen and paper, the extra time needed to search up the item,

click the amount on the scanner, print, and stick a label on the goods, would increase the time from a couple of seconds to a couple of minutes.

One thing the vendors did not mention, but observe for with Company X, is the possible improvement from automating the receiving. However, all the vendors have support for this.

5.1.1.2 Company X analysis

Company X's SAP ERP system already provides a lot of warehouse management support. Company X already have scanners, and also an automated conveyor belt. Since Company X produces their products in the building next to the warehouse, they make sure to always label them. Hence, no external factors at the receiving could affect them. With that said, their current ERP offers similar support as a WMS in regard to the receiving time. Company X would not improve anything on this KPI with a WMS implementation. Their receiving time would still be two or three seconds of scanning and whatever the time it takes for the EU pallets to roll through the conveyor belt.

One thing mentioned in the literature that the interviewees did not mention as times saving is the appointment scheduling aspect, many WMSs have support for dock appointment scheduling, which can make processes easier and faster (SAP, n.d; IMB Sterling Warehouse Management System, 2021; Descartes, n.d). This is something that Noventus affirms when asked on the dock door utilization as they explain that they can prevent bottlenecking through slot planning. Bottlenecking could be a cause for certain warehouses that slows down not only the receiving operation, but the whole warehouse.

5.1.2 Put-away time

5.1.2.1 Cross-case analysis

Ongoing and Apport argued that the put-away time can be greatly impacted. They both agreed that the knowledge gained from the WMS would contribute to save a lot of time otherwise searching for locations. Putting items at the wrong locations and the inaccurate tracking and quantity of goods, is according to Prasad Ramesh (2021) a usual mistake that is made at the put-away. The vendors statements of this saving "a lot of time" for customers is also confirmed by Company Z who used to have this problem.

Ongoing, Apport, and Noventus's also agree that ABC classification and pathway optimization would affect the speed of the put-away workers. This could directly lower the average time it takes to put-away one unit of goods by having the most popular goods to be stored closer to the receiving area. Since put-away stands for 15% of the expenses according to Bartholdi & Hackman (2010), an ABC classification could be used to optimize the picking.

Noventus offers layout optimizations in addition. Logically, this optimization could consider the best layout for receiving and shipping docks in order to make picking and put-away benefit the same from ABC classifications.

Company Y also brings up that the added control has led to considerably better put-away times. They now can choose whether or not to fully store goods, or whether to send, or to break up and send parts, either directly to shipping or to picking locations in order to replenish them. Which means that sometimes put-away can be skipped.

5.1.2.2 Company X analysis

Company X already has much information and knowledge through their ERP. They can see whether a storage location is empty, and the device tells them where to go. But Company X does not have any ABC classification or path-optimization, two aspects that Company X can gain from. Currently the put-away workers pick up pallets from the conveyor belt and place them at whatever free location that the device ERP assigns them. The layout optimization (mentioned by Noventus) could be less applicable as the warehouse already is crammed with shelves and the different departments would be very costly to move around.

5.1.3 Inventory days on hand

5.1.3.1 Cross-case analysis

Inventory days on hand was not mentioned in the literature review on WMSs, but in the review on warehouse operation KPIs. Ongoing finds an indirect improvement through the improvement of the flow, which is affirmed by Noventus and Apport. Ongoing and Apport holds that a WMS will help making FIFO easier to use. Apport further explains that the increased control and visibility opens up information sharing with the purchasing department and the sales department. Bad information sharing is an external influence that affects how the warehouse, especially the storage operation, fares off. Lao et al. (2012) argues that poor quality control decisions in the warehouse can lead to a large level of defective products. All three vendors agreed that the stock on hand would decrease as the material-flow became faster, which leads to shorter inventory days on hand.

Company Z explained that with their new WMS they could register and differentiate goods based on best-before dates, which would allow the sales department to see these items in the system and push them out on sales a good time before they expired.

5.1.3.2 Company X analysis

Company X seems to have a problem with defective products but are not aware of it. While they can see locations, and when searching certain locations, they can see what goods are there, the ERP is currently not giving enough information for them to make decisions based on faulty and expired products. Compared to the entire picked goods only 0,489% get thrown away. The cost of expired products still reached 363k SEK at the measured period (adjusted to 415k annually). This problem could be lessened with the WMS function mentioned by Company Z potentially saving hundreds of thousands SEK yearly for Company X.

Another aspect of the information that comes with a WMS, is that observing presumably obsolete articles, would lower the risk of purchasing department of stocking up on the items. Having unnecessary stock would also increase the inventory days on hand so a WMS could lower stock with this feature as well.

5.1.4 Picking time

5.1.4.1 Cross-case analysis

According to Bartholdi & Hackman (2019), Zhao et al. (2018), and Fjodorov et al (2023), a WMS equips operators with mobile or desktop apps which makes tracking equipment and goods easy. All three vendors also brought this up. Pickers no longer have to search for items, and as Noventus puts it, the WMS “eliminates all of the times the pickers go to the wrong spots”.

According to Anđelković & Radosavljević (2018) optimisation of the picking process includes travel time, search time, retrieval time, and return time. While the information removes the search time, the travel time and return time are affected through ABC classification and path optimization according to all three vendors. All vendors agree that a WMS will improve the picking time through the ABC and path optimization, as both features optimize the traveling in order for “the shortest, fastest, and most optimal pathway” to be chosen. The retrieval time is not affected by the WMS since the operators picking do not move their limbs faster from the software.

According to Ahmed (2023) and Raama et al. (2012) training the employees is important in order to implement a WMS successfully. Noventus brings up a point which makes Ahmeds and Raama et al.’s claims redundant. The interview at Noventus said that one time that is saved is the time it takes to train new warehouse employees, since the scanner tells the operator exactly where to go and what to do. Thus, removes the need to train new employees as much, especially since they don’t have to memorize the warehouse layout and products information.

The two statements are different in nature, Ahmed (2023) and Raama et al. (2021) seems to be talking about already existing employees needing to adapt to the new system, and Noventus talks about new employees with no present habits. Noventus’ statement from Noventus proposes that training for a WMS change is very easy. The new, and possibly different, aspects of a WMS include looking at a scanner to know the next location, and scanning before you pick. Unless someone deliberately does not want to follow instructions, training should not be an issue according to the author of this paper. Raama et al. (2012) also mentions that a WMS implementation without process changes will not lead to cost savings, which has also been shown to be false from the empirical findings, which makes the author conclude that Noventus statement of training as being easy, is more trustworthy.

Noventus statement implies not only time saved during training, but also during picking (and all other operations). This, as a new employee would normally perform activities

much slower than a veteran employee, while the WMS would reduce the time needed for the new employee to get at the same efficiency as a long-time employee.

The literature mentions consolidation, as when one order is completed with multiple items (Karasek, 2013). The findings bring this one step further; a WMS can support multiple orders to be picked at one trip. Company Y explains how Ongoing WMS allows them to multi-pick single pick orders, or as Ongoing themselves call it, one-piece picks. This could eliminate a lot of time spent backtracking and moving to and from the packaging and storage.

One other aspect which only Company Z brought up, was that picking time can also be affected by the orders being printed given out to the pickers faster.

5.1.4.2 Company X analysis

Company X do not have the problem of not finding goods as their ERP sends the pickers to correct locations. One problem a WMS could solve Company X is that their current ERP sends pickers to locations that might have too few items, with pickers waiting on average 7% of their active working time for other employees to bring down pallets for them. Using a WMS would not send workers to a location with too few items, and that location could also be replenished before it is emptied.

An ABC classification and pathway optimization would help Company X. Empirics show that they struggle with a lot of backtracking and sub-optimal traveling. For some of their worst orders paths were crossed five or more times when traversing between the locations. This happens since they have to pick products based on weight, and products are placed at the any location with no consideration other than if the location is free. Company X's ERP (SAP) also offers ABC analysis, that allow for both manually entered ABC classification, and using machine learning that will determine the popularity of the goods based on recorded data (according to SAP's help portal on how to set up a "Strategy for ABC Analysis" (SAP, n.d)).

Single-order picking is a big problem for Company X. Many of their orders are one-piece orders, which makes the picking time much higher than it could be. Out of 15 orders analysed, 5 of those had fewer than or equal to 5 locations, one order was a 2-location order, and two of the five orders were single pick orders where only one product was put on an entire EU pallet (figure 5.1). Thus, multi picking (mentioned by Company Y) could thus affect Company X's picking time by a lot.

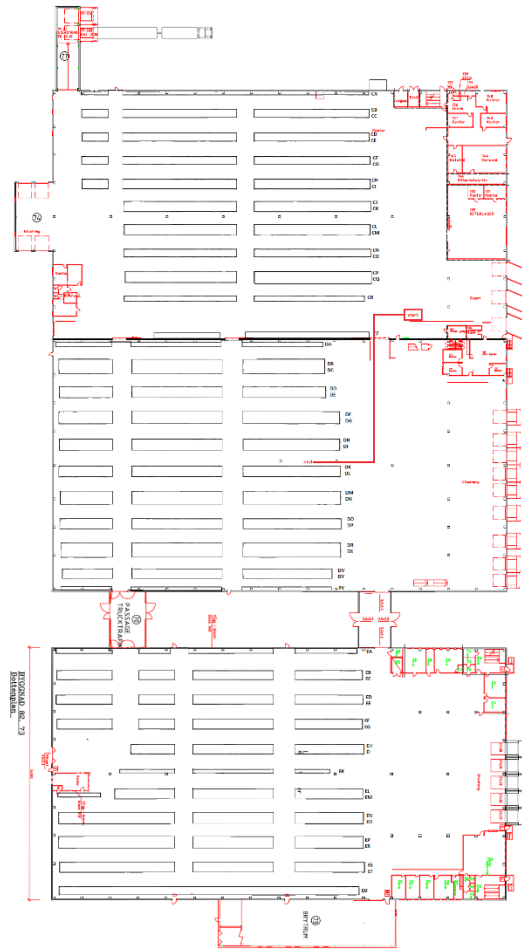


Figure 5.1: Layout of the Company X warehouse with the route of a single-pick order drawn in red

5.1.5 Shipping time

5.1.5.1 Cross-case analysis

All three WMS-vendors found no influence on the physical time it takes to load pallets into a truck, but the only time that could be saved with a WMS is the administrative time through the barcode scanning. Company Y and Company Z confirmed this. Ongoing described one optimal feature making it possible to scan multiple pallets that are going to the same shipments, with only one scan.

Company Z also added that through faster overall processes in the entire warehouse, their last shipment was sent out 30 minutes earlier.

5.1.5.2 Company X analysis

Company X would not see any benefits or problems regarding their shipping time from a WMS implementation since they don't handle their shipping themselves.

5.1.6 Conclusion on time

The cases are overwhelmingly in agreement that the time aspect will become affected positively by a WMS. That the vendors even brought up the same features as examples. While all three vendors mentioned their WMS's huge number of features, all exemplified with ABC classifications and path optimizations which are broader functions. Customer companies Y and Z instead gave more specific features being important for their warehouses. The multiple cases further differentiate between direct and indirect improvements.

The direct time improvements come through features such as ABC classification and path optimization, which were brought up by all vendors and at least mentioned by the customer cases. Other direct time improvements were the time saved in documenting for both inbound and outbound flow.

All cases also agreed about the indirect improvements as a result from increased control and visibility. Both vendors and customers agree that a WMS gives 100% visibility of everything in the warehouse, and they attributed time savings to mistakes that were caused by a lack of information. This included time spent searching for items and time spent correcting mistakes.

Time to search for equipment appeared in the literature review but was not brought up during the interviews. This could be a size related problem for only very big warehouses, as it would be difficult to lose a forklift in a smaller warehouse.

5.2 Utilization

The utilization-related KPIs were the least important ones, in the sense that a WMS showed least effect on these KPIs. Effects might be less visible as well, but the findings showed that 11 out of 25 KPIs gave the answers “does no measure” or “don’t know”.

5.2.1 Dock door utilization (receiving)

5.2.1.1 Cross-case analysis

The vendors had different views. Ongoing did not know how their system could affect the dock door utilization. Apport on the other hand found an indirect effect that comes with faster processes. As the unloading is faster the trucks move away quicker as well, this leads to better dock door utilization and reduces the chance of bottlenecks.

According to Ackerman (1997) it should be possible to reduce waiting time at receiving and also shipping departments through scheduling truck appointments. Noventus also bring this up and mention that they offer slot planning for truck arrivals which can help prevent bottlenecks.

Company Y and Z did not measure this at all.

5.2.1.2 Company X analysis

Dock door utilization is not a big problem for Company X, as the current average utilization is 81%. However, in 11 out of 47 weeks the pallets per week would overflow the conveyor belt capacity, without considering the time needed to remove pallets from the belt. Based on the numbers, the dock door is occupied 23% of the time, and scheduling could affect the inbound receiving by spreading out the deliveries.

5.2.2 Put-away utilization of labour and equipment

5.2.2.1 Cross-case analysis

According to Istiqomah et al. (2020) one advantage with a WMS is that goods can be stored more optimally since workers know where to find the items. Both Ongoing and Apport said this would indirectly improve the utilization. Both also said that as the put-away time gets more efficient, so does utilization.

Noventus did not measure this KPI, and neither did Company Y and Company Z.

Company Y doesn't see any differences at the moment and attributes this to not having implemented the ABC classification. But Company Z found a huge improvement in their utilization. This was attributed to the knowledge of where the equipment (that is going to be put-away) is.

5.2.2.2 Company X analysis

Company X does not have big problems with their put-away. But since the put-away generally stands for, according to Bartholdi & Hackman (2010), 15% of the warehouse operating expenses, Company X could gain from this operation as well. But Company X must consider that having two employees at put-away, the utilization must be halved in order for them to save much.

5.2.3 Storage space utilization

5.2.3.1 Cross-case analysis

All three vendors seemed to agree that faster flow leads to a more efficient storage space utilization. Ongoing and Apport add that the information and control that is gained also lead to less storage space utilization.

While Company Y has the same storage as before, Company Z reports having it much better now.

5.2.3.2 Company X analysis

Company X's storage is sometimes close to full, which is not ideal. One reason is that spring is their high demand season, and to keep up with the demand they build up extra stock during the autumn and winter. Having much faster put-away and picking, would increase their ability to handle less safety stock in the warehouse, which brings the problem to production. If production is unable to keep up with high demand, and that is

the reason for safety stock, then there is not much that can be done. Otherwise, Company X could gain from a WMS to decrease their storage space utilization.

5.2.4 Picking utilization of labour and equipment

5.2.4.1 Cross-case analysis

Ongoing and Apport agree that the more effective flow leads to better picking utilization. Apport's interviewee mentioned one warehouse he worked in where the utilization of trucks decreased by one third.

Ongoing added that the multi-picking feature they offer would improve a lot on the picking utilization.

Noventus, Company Y, and Company Z do not measure this KPI, but Company Z had observed this being improved.

5.2.4.2 Company X analysis

Picking utilization is an area where Company X could gain a lot. A faster picking process would lead to better utilization of both operators and forklifts. This would allow for Company X to either reduce staff and sell equipment or chose to not hire new workers in case of a higher demand. The ability to pick multiple order in one trip would improve the utilization much for Company X. A WMS would improve, for sure, the waiting time for replenishment. Currently pickers have to wait 6.68% of the time spent working, something that would be removed. Without impacting how they pick, the utilization would improve by at least 7,39%.

$$\frac{1}{0,931} = 7,39\%$$

5.2.5 Dock door utilization (shipping)

5.2.5.1 Cross-case analysis

All multiple cases answered similarly for dock door utilization for shipping as they did for the receiving. That is, Ongoing, Company Y, and Company Z did not have anything to add. Apport thinks faster processes improve it, and Noventus did provide a feature slot planning which he said could improve it.

5.2.5.2 Company X analysis

Company X does not have much to gain from a WMS in this aspect. Sometimes during high demand season they get 100% dock door utilization, but they almost never can't keep up with customers. Since the truck drivers have to load everything themselves it's also more difficult to impact this operation. The only thing a WMS would provide is that the full visibility could allow them to schedule times more accurately. With an implementation of Apports extreme example, where one knows in the morning the minute the shipments will be ready (according to the WMS's prediction), the dock door

utilization could be improved by trucks arriving exactly when needed. Slot planning could also help, but Company X are not in much need of improving this KPI.

5.2.6 Conclusion on utilization

The KPIs related to utilization where almost always reliant on the time and quality (control and information) aspects. The utilization KPIs did not display the effects of the WMS, and for 44% of them interviewees gave no input at all.

5.3 Quality

The quality related KPIs gave the most conclusive answers to the effect of a WMS. The quality KPIs are those related to information visibility and control, which is the core of a WMS.

5.3.1 Documentation processed accurately

5.3.1.1 Cross-case analysis

A faulty receiving process can create a lot of problems further down the flow of operations according to Ackerman (1997). A WMS removes most of these problems by adding full control and visibility of the entire flow. Ongoing, Noventus, and Company Z mentioned that any mistake made would be due to human errors at the receiving. Once a product is correctly entered into the system, the WMS does not allow for mistakes according to Ongoing and Apport. All five cases reported that with a WMS, documentation processed accurately is very close to 100%.

5.3.1.2 Company X analysis

Since Company X has an ERP with a lot of warehouse support, including scanners, barcodes, and tracking of items, they are also close to 100%. Company X would not gain much improvement in this KPI from implementing a WMS. But they could benefit from that a WMS would give more information and provide better accessibility to that information.

5.3.2 Correct put-aways

5.3.2.1 Cross-case analysis

All five cases reported that with a WMS there are almost no errors during the put-away. All five claimed approximately 100% accuracy on this KPI. Ongoing explains that this comes from with the full visibility, and knowing for sure whether a location is occupied or not. Apport confirmed by saying “you don’t have to consider anything, the system tells you where to go, and it will be correct”. Noventus explains that algorithms automatically select where you go.

Company Y and Company Z affirms this as the outcome of a WMS. Company Z explains how it eliminated all occasions of their goods being lost due to operators forgetting where they put them, or forgetting to document their locations.

For a normal warehouse the process would go like in figure 5.2: the put-away worker scans the product they pick up, go to the location that the WMS tells them to, drop of the product, and then scan to notify that they're done.



Figure 5.2: Illustration of put-away simplicity with a WMS

5.3.2.2 Company X analysis

Company X are already following the “normal put-away” process with their ERP, which explain why they already have almost 100% accuracy, and there is not much improvement potential for Company X.

5.3.3 Storage accuracy

5.3.3.1 Cross-case analysis

According to Lubandy (2016) it is unlikely plausible to have good quality assurance without any software, such as a WMS, if the storage facility is complex. The storage accuracy is a measure of the quality assurance; storage accuracy corresponds to how many SKUs are placed at the locations that they are documented in. All three vendors said that the accuracy in the storage is close to 100%.

The customer cases affirm this, with Company Z giving the example of an inventory audit where one single item, part of a collections of 2524 different items making it prone to mix-ups, was placed in a wrong location out of 80 locations tested. Thus, errors were described as “almost non-existent” by Company Z.

5.3.3.2 Company X analysis

Company X also reported storage accuracy as 100%. But there are differences in the accuracy between the ERP used and the level of visibility that a WMS gives. Company X can look up certain items and get a list of locations or look up a certain location and get what products are placed there. But the interface is very inconvenient, and the pickers do not get information on the quantity. While the ERP can count the quantity, it does not do it automatically which make pickers arrive to locations without enough goods. Their ERP is like a fully functioning robot, with all of its limbs and functions but without processor (brain). For Company X a WMS would improve the level of information available to the next step.

5.3.4 Picking accuracy

5.3.4.1 Cross-case analysis

Due to the increased visibility, all five cases agreed that picking accuracy for a company using a WMS would be almost 100%. Ongoing, Noventus, and Company Y mentioned that while it is impossible to pick the wrong type of item, the accuracy can't be put as 100% since quantity mistakes can still occur due to human errors.

This is due to the process that a WMS makes the operator to follow (figure 5.3). The operator checks his next location, drives there, picks and scans the items, and drives to packaging. The scanning is what eliminates errors. Ongoing explained that if a wrong type of product is scanned then the scanner will give an error message, and the operator knows that they went to the wrong place by mistake.

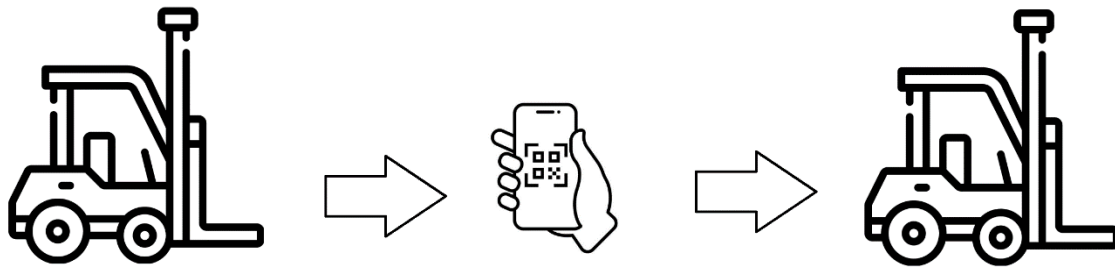


Figure 5.3: Illustration of picking simplicity with a WMS

5.3.4.2 Company X analysis

Company X follow a similar process with their current ERP. They have a 99,96% picking accuracy and most of the mistakes are due to quantity errors. The implementation of a WMS would thus not impact this aspect of the warehouse.

5.3.5 Orders shipped on time

5.3.5.1 Cross-case analysis

While the customer cases answered orders shipped in time to be 98-99% and close to 100%, the vendors did not want to give a number. Vendors argued it to be completely possible for sales departments to sell more that the warehouse can handle, and in these cases, there is nothing any type of software can do. However, all agreed that a WMS can support getting orders shipped on time. Ongoing and Noventus bring up that their WMS's can control the order planning to make sure that work orders get finished on time. This ties to the entire section of Work-order management from the literature (Chapter 2.2.6).

Apport gives an example of their complex WMS's being able to predict the minute an order will be ready, based on deadline for the order, departure times for the trucks, number of pickers, and historical data of these pickers. Knowing early in the morning whether an order will make it in time allows for managing the orders differently as well.

5.3.5.2 Company X analysis

Company X have no issues with orders shipped on time. There is thus no incentive for them to focus on this, as delays do not cost them anything extra. Their system is very flexible, and their orders shipped on time is already approximately 100%.

5.3.6 Conclusion

A WMS give absolute visibility and control of the warehouse, and almost all answers to the quality KPI questions showed that a WMS would give approximately 100% accuracy. From the cases, it seems like any problem that might occur does so at the receiving stage.

Kulinska & Giera (2019) mention that some of the risks in the receiving has to do with incorrect identification of goods, incorrect sorting of goods, and incorrect labelling of goods. All of these were addressed by the case interviews at one point or another. The WMS would almost completely eliminate these risks. But another type of risk, that Kulinska & Giera (2019) mention, are handling of defect goods and damaged goods. This was not mentioned, during interviews, to be affected by the WMS.

5.4 Summary of cross-case analysis

Besides the quality related KPIs, most of the answers did not include numerical values. And even if they did, it would not be fair to use an average as benchmark since every warehouse is different and get benefits in different areas. Thus, a numerical suggestion could result in false expectations.

5.4.1 Benefits and Problems

5.4.1.1 Benefits

The greatest benefit, which is included to some degree in all WMS's, is the complete visibility and control gained. Added with forecasting predictions, the vision and control can become so powerful that a warehouse can, exemplified by Appoint WMS, predict the minute of a shipment departure from the time the customer order enters the system. The visibility almost entirely eliminates errors from all the warehouse operations. Besides the benefits that are always gained, a WMS allows for their customers to activate new features such as ABC classification. ABC classification will optimize the locations of goods in order to reduce time as much as possible for the pickers and put-away workers. Added to the optimized locations, a feature like the pathway optimization will make sure that the operators always take the absolute shortest routes, reducing times even further. Another feature that could reduce time of trips is the multi-picking features described by Ongoing WMS and Company Y. Being able to pick many orders with one trip eliminates the backtracking from the packaging and storage location between each order. As a result from the faster flow, all vendors agree that the warehouse storage utilization would shrink.

A WMS also gives opportunities for future benefits. One such opportunity, mentioned by Company Z, is that the warehouse department barely have to communicate with their purchasing department, as the purchasing employees can see everything that they need through the WMS, which could result in less costs and less stock. Another opportunity for benefits, and probably the most important, is that the improved processes make the warehouse more equipped to handle higher demands. Another opportunity is that the WMS vendors upgrade and add new functions to their WMS's all the time. Besides new functions being available, the WMS will likely be able to adapt or include to warehouse changes. These changes could lead to profit opportunities, be it from less staff or more demand.

5.4.1.2 Problems

From both the literature review and the case studies, it became apparent that a WMS does not have many problems, especially when contrasted with the benefits (figure 5.4). There can be problems when one system is compared to another, but when WMSs are looked at holistically the problems are limited to the costs and sometimes, if the WMS is server-based and not cloud-based, the potential single point of failure, as mentioned by Ongoing. Another problem is the employee training, if the staff is not trained on how to use a WMS the effect of it may suffer (Ahmed, 2023; Raama et al., 2012).

There are also external problems. One of these, mentioned during the interviews, is the supplier dependency. If the suppliers to the warehouse do not have compatible software or hardware, this will slow down the warehouse. If the suppliers, for example, do not put labels on the goods, then the warehouse have to make their own labels. Another external problem is company growth that can lead to increased WMS costs. Some WMS vendors have a pay plan that increases as the number of goods owners in the system increases, Company Y went from a couple of suppliers to more than 25, as a result they could not afford to keep their old WMS and changed to one that had another type of payment plan. The last external problem is that there can be integration challenges depending on what type of software the warehouse already uses. This is also brought up in the literatures review by Andiyappillai (2020). Integrating a WMS could as a result be very costly.

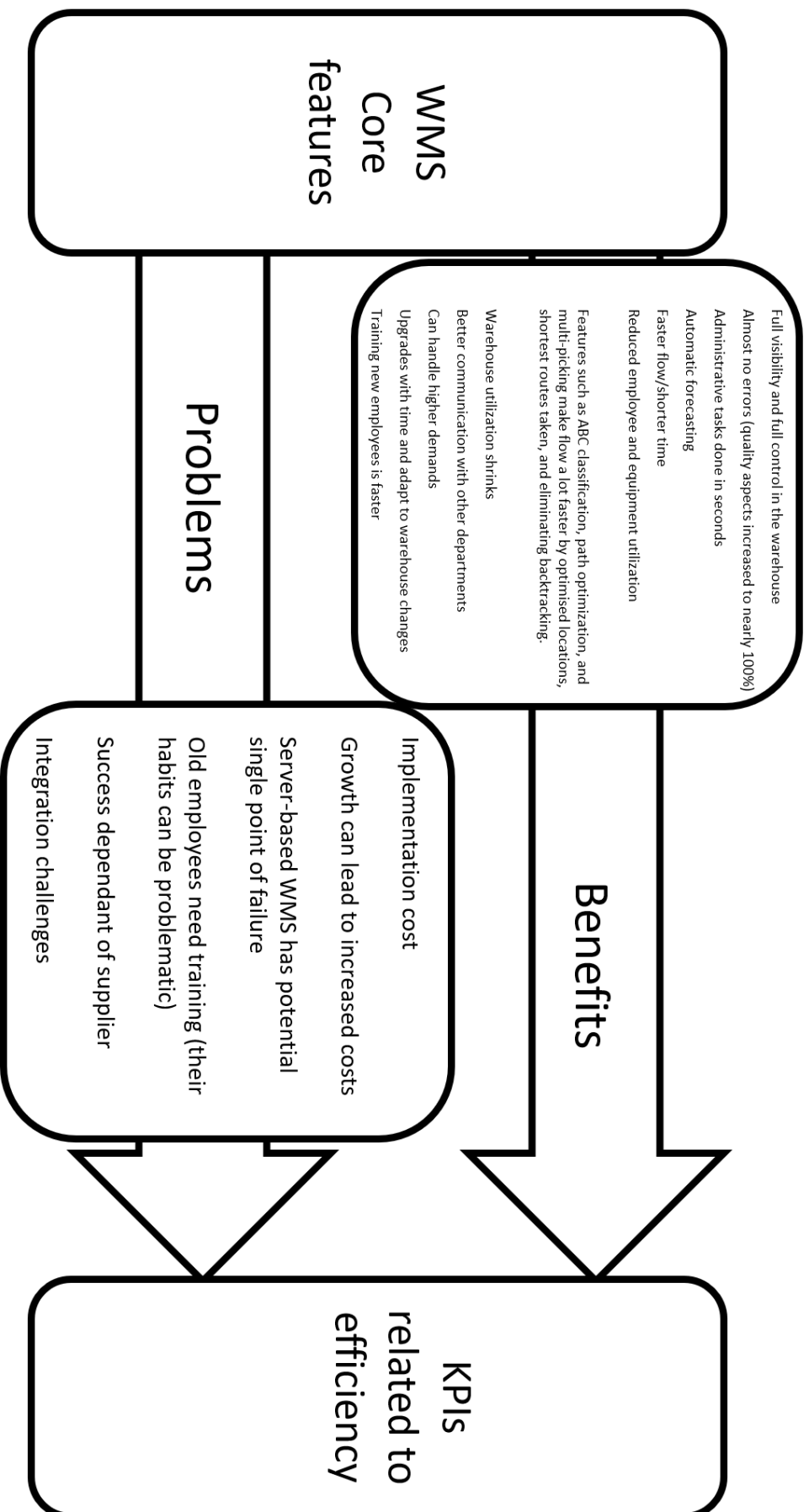


Figure 5.4: The benefits and problems from the empirical data

5.4.3 Influencing factors

The external influencing factor mentioned the most during the interviews and the literature review were the human errors. Human errors are one of the biggest influencing factors for both the warehouse operations and the WMS as most mistakes with a WMS happen due to human errors at the inbound.

Another influencing factor, mentioned by Ongoing and Apport, was the type of software used by the company implementing a WMS. The cost and time to implement a WMS depends on how easy it is to integrate the customers software's with the WMS.

Ongoing also mentioned the technical level of the customers before implementing a WMS. How advanced customer warehouses are influences the effect of the WMS as a customer that works with pen and paper would gain more than a customer that upgrades from one WMS to another. This is also suggested by the customer cases data which show that some customers double their picking speed, and others increased their picking speed by 10 times. Or one company increasing productivity by 15% and another by 200%.

One influencing factor mentioned by Ongoing and Company Z is how long time the customer has had the WMS. Ongoing mentioned that the WMS is as progressive system where the user can optimise solutions continually. Company Z mentioned that e.g. ABC classification features requires time to collect data in order to forecast which locations are the most optimal to place goods.

Ongoing also mentioned the dedication of the customer to implement features and optimize their warehouse. Noventus mentioned that the context of the customer mattered as well. The problem that the customer wants to solve will influence how much warehouse operations are affected.

Company Y explained that goods owner reliability influences the efficiency of the WMS.

Another influencing factor mentioned by Company Z and Apport, was the communication with other departments. This was also mentioned in the literature (table 2.5).

Company Z mentioned the quality of equipment as an influencing factor. They used the reduction of time to print orders from 15 minutes to a few seconds as an example.

Lastly, Company Y mentioned the product types as an influencing factor. An inbound pallet of smaller items would take longer time to process than a one large item. This was also mentioned in the literature (table 2.5).

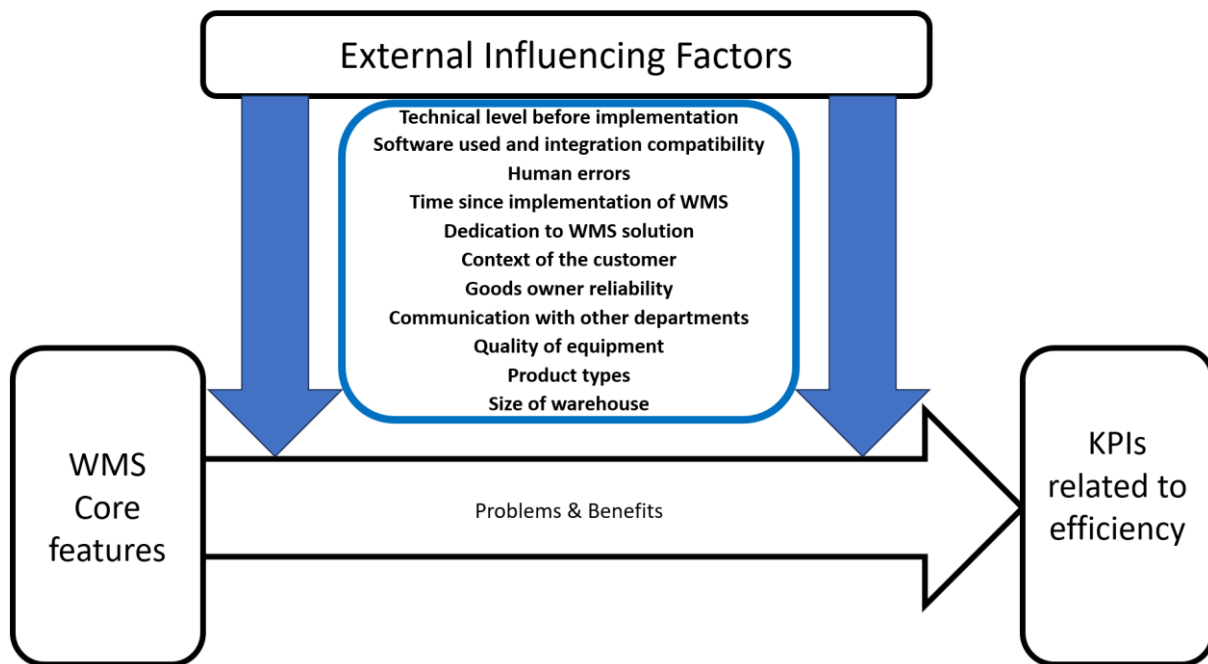


Figure 5.5: External influencing factors from the empirical data

One influencing factor mentioned in the literature³ that was not brought up in the interviews, and left out (figure 5.5), was the size of the warehouse.

5.4.4 KPI results

Since no average KPI improvements were achieved from the empirical study, the table introduced in chapter 3 (table 3.3) was changed (figure 5.6).

KPIs	Company's KPI values	Average KPI improvement [%]	Average KPI values
Receiving			
Receiving time	x	y%	z
Dock door utilization	x	y%	z
Documentation processed accurately	x	y%	z
Put-Away			
Put-away time	x	y%	z
Put-away utilization of labour and equipment	x	y%	z
Correct put-aways (no errors)	x	y%	z
Storage			
Storage-space utilization	x	y%	z
Storage accuracy	x	y%	z
Inventory days on hand	x	y%	z
Picking			
Picking Time	x	y%	z
Picking accuracy	x	y%	z
Picking utilization of labour and equipment	x	y%	z
Shipping			
Shipping time	x	y%	z
Order shipped on time	x	y%	z
Dock door utilization	x	y%	z

KPIs	Company before WMS	Company after WMS
Receiving		
receiving time	x	y
dock door utilization	x	y
documentation processed accurately	x	y
Put-away		
put-away time	x	y
put-away utilization of labour and equipment	x	y
correct put-aways	x	y
Storage		
inventory days on hand	x	y
storage space utilization	x	y
storage accuracy	x	y
Picking		
picking time	x	y
picking utilization of labour and equipment	x	y
picking accuracy	x	y
Shipping		
shipping time	x	y
dock door utilization	x	y
orders shipped on time (according to schedule)	x	y

Figure 5.6: The change of the scenario table from the left to the right due to the empirical findings

Based on the findings from the interviews (tables 4.6, 4.7, and 4.8) the effect of a WMS implementation on the KPIs is as follows (table 5.1).

³ (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005; Lorenc & Burinskience, 2021; Zhang & Jiang, 2022)

Table 5.1 Table showcasing expected result of implementing a WMS based on the study findings.

KPIs	Effect after WMS implementation
Receiving receiving time dock door utilization documentation processed accurately	Faster (scanning takes a couple of seconds) Can be influenced by slot planning ≈100%
Put-away put-away time put-away utilization of labour and equipment correct put-aways	Faster (knows where to go, no mistakes) Indirect improvement (from overall better flow) ≈100%
Storage inventory days on hand storage space utilization storage accuracy	Indirect improvement through overall better flow Improves due to increased control and visibility ≈100%
Picking picking time picking utilization of labour and equipment picking accuracy	Faster (much faster with ABC classification and path optimization) Indirect improvement through overall better flow ≈100%
Shipping shipping time dock door utilization orders shipped on time (according to schedule)	Faster (scanning takes a couple of seconds) Can be influenced by slot planning ≈100%

Table 5.1 does not have a before section as it is a generalized finding which can be utilized by any warehouse situation.

It's important to note that the effect size is dependent on the influencing factors. A company, like Company X, with software that include support for warehouse management will not improve much on quality aspects benefits, such as picking accuracy, since their current system gives sufficient visibility. For this reason, the after will be similar to the before, which is approximately 100%.

Company X has an automated receiving and they don't have responsibility for the shipping, so the shipping time and the receiving time would also not be affected by a WMS implementation. The picking and put-away times are also not affected by time aspects relating to quality, such as going to the wrong location, but the times could be improved by ABC-classification, path-optimization, and multi-picking. There is however an improvement from an increased quality aspect were knowing how many goods are at the locations could save time otherwise spent waiting for replenishments. The storage inventory days on hand could benefit both from the improved flow and from increased visibility as Company X has a minor obsolescence problem.

Table 5.2 Expected results for Company X

KPIs	Company X before WMS	Company after WMS
Receiving		
receiving time	484,39 seconds per pallet	484,39 seconds per pallet
dock door utilization	81,06%	possible improvement with scheduling
documentation processed accurately	≈100%	≈100%
Put-away		
put-away time	169,52 seconds per pallet	could be improved with ABC and path-optimization
put-away utilization of labour and equipment	79,49%	could be improved with ABC and path-optimization
correct put-aways	≈100%	≈100%
Storage		
inventory days on hand	75,11 days	could be improved from better flow
storage space utilization	79,02%	could be improved from better flow
storage accuracy	≈100%	≈100%
Picking		
picking time	83,938 seconds per pick	could be improved with multipicking, ABC, and path-optimization
picking utilization of labour and equipment	93,12%	could be improved with multipicking, ABC, and path-optimization
picking accuracy	≈100%	≈100%
Shipping		
shipping time	67,93 seconds per pallet	67,93 seconds per pallet
dock door utilization	55,54%	possible improvement with scheduling
orders shipped on time (according to schedule)	≈100%	≈100%

The utilization KPIs are mostly dependent on the time and quality KPIs, so for storage space, picking, and put-away utilization the expected effects would be similar to the time aspects (table 5.2). The dock door utilizations are however not influenced by any change in the flow. For any effect to take place it is dependent on features like appointment scheduling, which is made possible through the increased control and visibility.

6. Reflections & Recommendation

In this chapter the findings will be reflected on, starting with unexpected outcomes and then the results from the cross-case analysis. This is followed by a recommendation for Company X on whether or not they should implement a WMS, and a smaller recommendation for any company thinking of implementing a WMS. The discussion and recommendation are subjective from the authors perspective.

6.1 Reflections on the findings

6.1.1 Unexpected outcomes

While it was expected that the full list of KPI's compiled for the study would not be used by the companies interviewed, discovering that most of them were not actively measured was unexpected. Most unexpected was that the KPI picking time, one off the most vital KPIs that affects the cost of the picking operation, was not measured. All respondents were very much aware of how the picking time was affected by a WMS, but it was not something they measured directly. Another, slightly less unexpected outcome was the discovery that none of the vendors had performance data collected from customers on before and after implementation. This is probably why the vendors were careful to not claim any numerical improvements, but instead gave explanatory answers on how each of the KPIs were affected, and by what features they were affected.

Another unexpected result was the overlap on the features given in literature and in interviews. Interestingly, the interviews not only included aspects of every feature from the literature review, but also discussed certain other features not included in the literature review. All vendors said that there were too many features to include them all, and yet they managed to bring up the same features as found in the literature, suggesting that the core features given by Bartholdi & Hackman (2019) are very central to WMSs. In addition, all cases provided insight on ABC classification and path optimization. Another feature brought up by some of the cases was multi picking. Since these features were mentioned by the cases, both vendors and customers, I believe they should have appeared more often when researching WMS systems and they should be seen as core features.

Another unexpected result was the difficulty to find any problems with a WMS. Be it from literature online, customer reviews, or from the interviews, there were not much data on how a WMS could negatively impact a warehouse besides perhaps costing too much. Starting this WMS-study I thought I would be able to find at least some problems. It's understandable that the vendors might not mention any problems since they could be positively biased. But even when interviewing the customers, they almost only provided positive comments of the WMS.

The most unexpected result, or rather lack of result, was for me one of the influencing factors on WMS's. While the interviewees did mention the state of their previous

software's as an influencing factor, there were no mentions of the size of the warehouse. This is something I expected to be one of the biggest influencing factors as it was mentioned a lot in the theory (Bartholdi & Hackman, 2019; Hompel & Schmidt, 2005; Lorenc & Burinskience, 2021; Zhang & Jiang, 2022). I believe this outcome is because companies with small warehouses do not have the same problem that bigger companies have, and they do thus not seek to get complex warehouse management systems as it would both be too expensive and not as effective.

6.1.2 Results from the cross-case analysis

From the cross-case analysis, it became clear that the greatest effect of a WMS is the added quality aspects of visibility and control. A WMS would give full visibility of everything in the warehouse and can be customized to track things outside of the regular such as goods tracking. The cross-case analysis exemplified tracking goods stored in shelves and other locations by registering the location as occupied in the system. The literature review also included tracking bigger objects using tracking devices in case there are no organized locations that can fit them. It is however possible to achieve the same level of visibility and control as a very basic WMS through other software's, such as certain ERPs with warehouse management support.

Time related improvements seems to come both as an effect from the core WMS-features, as well as an effect from some more advanced WMS-features that one can choose to implement. As the visibility and control eliminates errors throughout the warehouse, time is saved both searching for locations and items, and from no longer moving to wrong locations. Besides this, the available WMS-features ABC classifications and pathway optimizations brings the time saved to another level. The ABC and pathway optimizations lead to items being stored in optimal locations in order for the average distance travelled to become the shortest, and the routes the operators take will be the shortest distances as well. It's important to note that these features cannot function without the visibility and control that the WMS primarily gives.

The utilization based KPIs were least used. It's not necessarily that these aspects are the least important aspects to be affected by a WMS, but rather they are the least visible. Utilization aspects are the least visible since they are dependent on the time aspects, which in turn are dependent on the quality aspects. It may thus be difficult for a company to measure for example the utilization of labour and equipment. If the operators do more work in shorter time, then the utilization becomes higher. One way to measure this indirectly is by how many workers the company can lay off, but that is a one-time measurement and not something to monitor over time.

6.2 Recommendation to Company X

My recommendation to Company X is to further pursue the idea of implementing a WMS. Company X does not have much to gain when it comes to the quality aspects mentioned throughout the study, but they have a lot to benefit from improving the picking, put-away, and storage departments through time saving WMS-features.

Although the ERP that Company X are using already give a lot of warehouse management support, it is like a body with no brain compared to a WMS. If every feature is a limb, the ERP gives support, making everything visible but you have to manually move its limbs. A WMS will activate its brain and so it can do everything by itself. All information that is available for Company X in their ERP can, with a WMS, be utilized in order to optimize and automate a lot of processes. Most importantly, it gives access to ABC classification and pathway optimization, which the WMS can do automatically. One area that would certainly be improved is the picking time and utilization, that is currently slowed down from waiting for locations to be replenished. This waiting time alone would improve the picking operation by around 7% and considering that there are 14 pickers, a 7% improvement would mean that one picker could be allocated somewhere else or laid off.

Another helpful WMS-feature, existing both for SAP and the other systems, is support for multi picking. Company X currently have an issue where single items are placed on entire EU-pallets, and they are currently researching (outside of this study) smaller packaging containers for these orders. SAPs WMS offers a cart-picking solution for this problem, where a cart with multiple boxes is used in order to place single pick items in the boxes. This would not only make the multiple trips to pick single items into one trip, thus eliminating a lot of time spent backtracking to and from the packaging location, but it would also complement their ongoing project since the containers could be used as boxes for multi picking.

Since Company X has an internal policy to use SAP software and not include any third-party software, I recommend them to use SAP when choosing their WMS. However, I recommend consulting third-party WMS-vendors with available integration solutions for SAPs ERP and get estimates of their implementation costs. This is important since SAP set their prices through negotiation and, even though SAP is a market giant, knowing competitors' prices will help in negotiating. Mentioning other options, even if Company X does not consider them, could give a better hand in negotiating. In the worst-case scenario that SAP is much more expensive than the competitors, then Company X has enough information on how a WMS would benefit them, and information on implementation, to open up dialogue internally on their policy.

7. Conclusion

This concluding chapter will wrap up the study by addressing the purpose of the study, answering the research questions, then describing the contribution to academia, and lastly by giving suggestions for future research.

7.1 Purpose and Research Questions

The purpose of the study is to increase understanding of how to analyse whether a company should implement a WMS or not. This purpose is investigated through the four research questions proposed in chapter 1.4.

RQ1: What are the benefits and problems of different WMS features?

RQ2: What external factors influence the warehouse performance and the WMS features effects?

RQ3: How would implementing a WMS impact warehouse performance and how is this translated into financial gain?

RQ4: How would implementing a WMS impact Company X specifically?

The first three research questions are addressed by the complete figure (figure 7.1) devised in chapter 1.3 in order to address the problem. Research question 4 is derived from applying the context of Company X to the study findings.

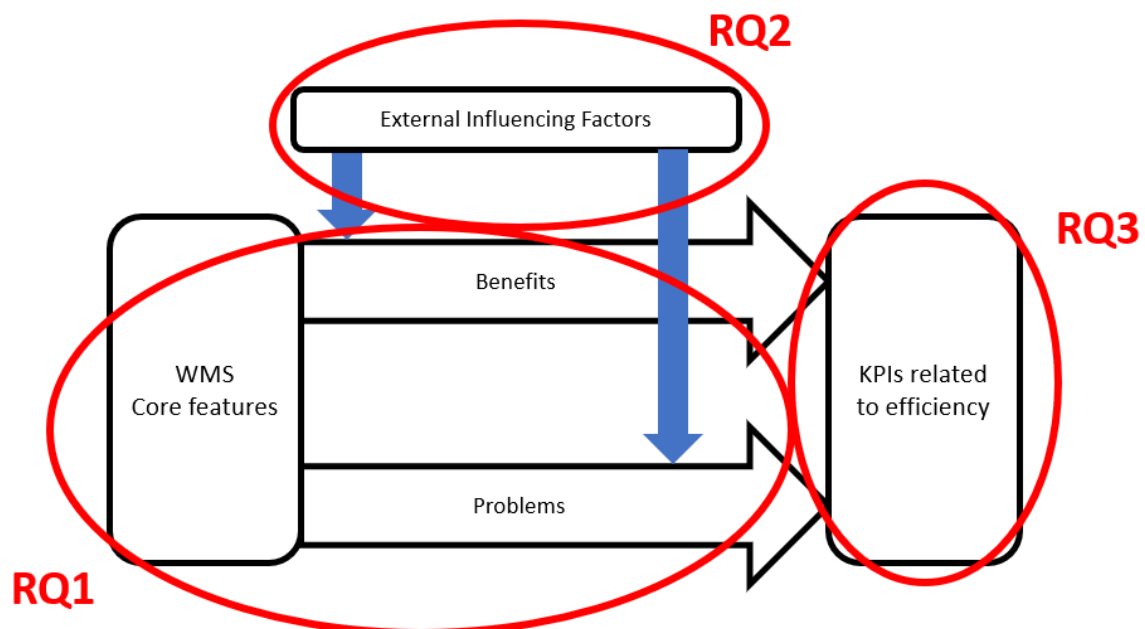


Figure 7.1: Research questions visualised in the purpose-plan figure

7.1.1 RQ1: What are the benefits and problems of different WMS features?

The first research question is “What are the benefits and problems of different WMS features?”. The core features from the theory support four of the five warehouse operations, that is the receiving, put-away, picking, and shipping. Even though storage was not included initially, the case findings revealed that WMS’s have support for storages as well. The other core features that were listed were appointment, scheduling, quality reassurance, location tracking, work-order management, and packing & consolidation. These other features are all complementary to the warehouse operations.

One of the most affected areas is the receiving operation. WMS’s have a lot of features supporting receiving. The most important WMS features are the administrative/documentation features. One such feature is the support for hand-held devices and barcode scanning, which is the backbone of the rest of the WMS. The hand-held devices let the workers scan incoming goods, which are then registered into the system instead of writing with a pen and paper and then entering them into an excel file or logbook. This step is crucial and makes sure that the system knows to 100% what is entering it. Another benefit from this is the faster documenting speed. If goods in inbound have labels on them, documenting takes just a couple of seconds, which can be an incredible improvement for some. Another benefit is that handheld devices remove almost all errors that can be made when documenting without them. One resulting small problem is the added steps that must be followed with a WMS, the inbound time per good could take a couple of seconds longer.

The certainty gained by scanning inbound goods is the basis that allows for features such as tracking. When goods are moved, the scanners are used to update their locations. This gives the WMS 100% visibility of where all goods are and how many goods are there. The system automatically also track which locations are empty. The benefits of knowing with certainty everything’s locations, are that warehouse employees don’t have to search for anything. If it is a put-away worker, then the location he is directed to will always be available. If it is a picker then the appointed location will always have the correct goods. This eliminates a lot of time spent searching for items or going to the wrong spots. Another benefit is that items are no longer lost in a warehouse with a WMS.

Another type of features that support the receiving are appointment scheduling features. The studies findings revealed that WMS’s can support appointment scheduling by allocating time-slots for incoming and outgoing goods. This avoids long waiting times that could create bottlenecks in the warehouse flow. This also affects the shipping in the same way.

Even though storage was initially not mentioned as a core feature, there is multiple support for storage which benefit other operations as well. One feature includes the rearrangement of goods and even rearrangement of storage locations, for an optimized

set up. This is for example done through ABC classification, where the goods are ranked after customer demand frequency in order to place the most demanded items in the storage location closest to the other operations. This would lower the average travelling time as the workers more frequently visit these places. The WMS's allow for any type of ABC specification. ABC classification is an ongoing process and if one item becomes less important the WMS will start placing it further away from the best locations. The benefits are on average shorter picking and put-away time and lower storage stock as a result of the faster flow.

The put-away operation is affected by the scanners and the information increase as well. Put-away workers pick up goods from receiving, look at their device to know where to go, and go there. They will no longer go to a location that already have goods. The receiving was done correctly and the tracking is in place, the WMS will not make mistakes. Another feature that further decreases the put-away time, is path optimization (or route optimization). A WMS can give the exact route for a put-away operator to make the shortest route.

The route optimization is even more effective for picking. The route optimization for picking can include all locations in an order and optimize the route to pick all locations in the shortest path possible. This can lead to extreme benefits in time as it can eliminate a lot of backtracking. The route optimization can be combined with the ABC classification and items often ordered together can be placed in locations next to each other. The WMS can also determine which items in an order to pick first, which even further increases the picking speed.

Picking also receives benefits from features such as multi picking. WMS's can have support for multi picking, where many smaller orders are picked on one trip instead of on multiple trips. The benefits of this are once again time saved in picking.

Another type of features that a WMS can use is work-order management features. A WMS can determine which orders should be picked in order to prepare them for departure. The full visibility and information that a WMS gives allow for forecasting whether or not they will be able to ship orders in time. Knowing this information means that changes can be made to prepare orders differently.

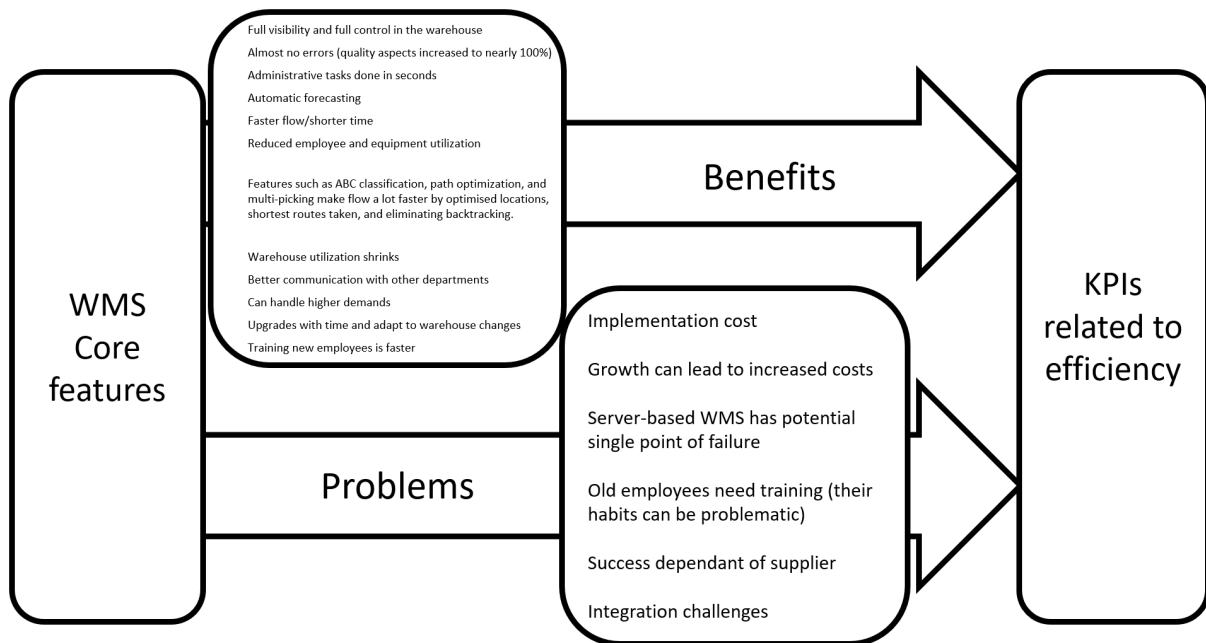


Figure 7.2: The benefits and problems

There are many features that were not mentioned during the interviews but could provide more benefits. The biggest benefit is gained when all features work together; the absolute biggest benefit of a WMS is the full visibility and control of the entire warehouse. The control and visibility benefits gained from a WMS can become so complex that, as mentioned by one of the cases, it becomes possible to know already when getting the order list in the morning, the approximate minute that the orders will be ready for shipping. Everything in the warehouse can be tracked and utilized, even down to the minute details of how effective employees are in specific tasks of different operations. The second greatest benefit is the time saved throughout the different operations. This benefit is ranked second because it depends on the traceability and control, but the faster flows can save a company a lot of expenses.

There are not many problems found with a WMS. The problems mentioned (figure 7.2) by the cases were the high cost of implementing a WMS, method of payment leading to increased costs if the warehouse grows, the risk of a single point of failure if the WMS is server-based, training employees to adapt to the changes, goods owner dependability, and integration challenges. One other perspective given by two interviewees was the possibility of employees refusing to change as they fear losing their jobs, but this was not researched further and is just a speculating thought.

Two more problems, mentioned in the literature review, were that the tracking is confined to the spaces added in the system, and that WMS's might not work for real time order-arrival and short shipping schedule times. But these problems were not found in the empirical data.

7.1.2 RQ2: What external factors influence the warehouse performance and the WMS features effects?

Throughout the interviews the representatives gave comments and scenarios on influencing factors that can affect the effect of a WMS (figure 7.3). On top of these, there was one factors given by the literature review that was not mentioned during the interviews: the size of the warehouse.

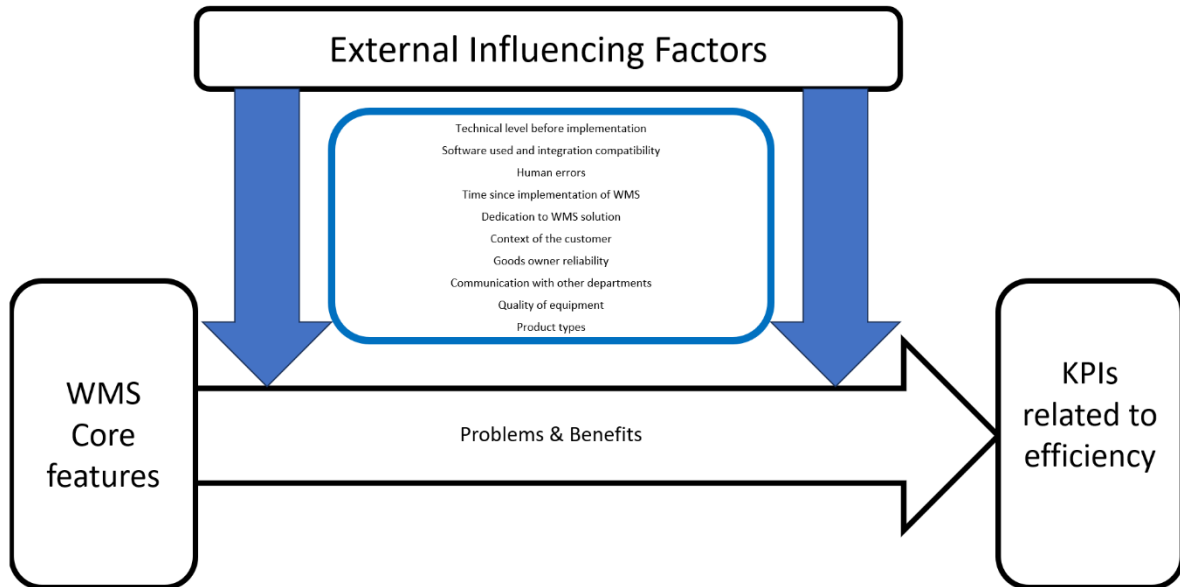


Figure 7.3: External influencing factors from the empirical data

The biggest influencing factor on the effect of a WMS is the technical level of the company before getting a WMS. If the company has no software at all then the effect of the WMS will be big. However, if the customer already has some sort of software with a lot of warehouse management support, such as an advanced ERP, then the effect of implementing a WMS will be much smaller. Since the greatest benefit of a WMS lies in the information and control it gives, changing from software that already give information and control would not result in many improvements, and then the benefit of the WMS lies more in other advanced features that build on the information and control.

The type of initial software also affects the WMS benefits through its compatibility to the WMS. If the initial software is difficult to integrate with the WMS, then it can affect the features, but it will also affect the time and cost for implementing the WMS.

One of the biggest external factors to the warehouse performance is human errors, as human errors over time can lead to lost goods filling up the storage, wrong picks costing a lot, and many other problems. While a WMS almost entirely deals with the problem of human errors, inbound receiving is still susceptible to this. If something is wrongfully scanned at the receiving dock, sometimes the system will not find the mistake until it's already shipped out. Mistakes could include putting the wrong label on something, scanning the wrong item, not checking for damaged goods, not checking quantity of

items etc. The level of care at the receiving operation determines how well the WMS works.

Another influencing factor of WMS effects, described by most cases, was the time spend with the WMS. A WMS uses data over time in order to forecast certain things for its algorithms to work. This means that the longer the system is in place, the more accurate the WMS becomes. Some features require certain amount of data to work at all, and this means that the full potential of a WMS cannot be achieved immediately.

Company's dedication to optimize their WMS also influences how great the WMS effects are. Some WMSs provide a package and then it is up to the company to implement the features they need and want. If companies don't learn and understand what the WMS can do, it can greatly deter its effectiveness.

Another influencing factor is the problem that the company is facing. Since WMS's are customized for warehouses, the WMS solutions often focus on the problems of the specific warehouse. A WMS can have a greater effect on picking speed for a company with picking problems than for a company with receiving problems.

One factor that influences both the warehouse operations, and the effect of the WMS, is the goods owners and transport provider carriers working with the company. All suppliers do not comply with the changes. The suppliers might not put labels on at all, which will slow down the receiving as labels have to be printed and put on. Truckers might not use scanners, which increases the shipping process.

Warehouse performance is also heavily reliant on communication with other departments. If sales, storage, and purchasing don't have good communication then there is a possibility of, for example, a bullwhip effect to build up. This is where the uncertainty of demand causes actors along the chain to order more than they need, causing purchasing to fill up stock for much more than sales is selling. While this problem can be solved with a WMS, the refusal to partake in information sharing and building of silos can still affect the warehouse and WMS.

Another influencing factor mentioned was the quality of the equipment. Having very slow machines and slow printers can slow down the rest of the warehouse performance. If printing labels takes multiple minutes, then the effect of the WMS will be diminished. For WMS's based on internet connection, bad internet could also be an issue. Faster equipment leads to a better WMS.

The last influencing factor is the type of products. Pallets full of smaller things take longer to scan than big and few goods. The task of scanning each product could in some scenarios make counting smaller products even slower than without a WMS as every item has to be scanned and labelled.

7.1.3 RQ3: How would implementing a WMS impact warehouse performance and how is this translated into financial gain?

The implementation of a WMS would impact warehouses differently based on their unique situations. One thing that is guaranteed for every warehouse is that the visibility and control gained with a WMS will be almost 100%. This means that everything pertaining quality aspects, such as documenting accuracy, picking accuracy, storage accuracy etc would be almost 100%. The workers would always know where to go, and the locations would always be the correct locations.

An important implication of this finding is that any company could measure and gather data on their operation's own quality based KPIs. They would then know better what is to be expected from implementing a WMS. Everything from documenting errors, put-away and picking accuracy, and storage accuracy etc could be measured and the potential improvements estimated as benefits. This also extends to the time for documenting and registering goods when moved throughout the warehouse, received, and shipped. By measuring the time it takes to receive goods and predict an expected change (e.g. substituting the time it takes to document all items with a couple of seconds of scanning time), an estimate of benefits can be made.

Table 7.1 Table showcasing expected result of implementing a WMS based on the study findings

KPIs	Effect after WMS implementation
Receiving receiving time dock door utilization documentation processed accurately	Faster (scanning takes a couple of seconds) Can be influenced by slot planning ≈100%
Put-away put-away time put-away utilization of labour and equipment correct put-aways	Faster (knows where to go, no mistakes) Indirect improvement (from overall better flow) ≈100%
Storage inventory days on hand storage space utilization storage accuracy	Indirect improvement through overall better flow Improves due to increased control and visibility ≈100%
Picking picking time picking utilization of labour and equipment picking accuracy	Faster (much faster with ABC classification and path optimization) Indirect improvement through overall better flow ≈100%
Shipping shipping time dock door utilization orders shipped on time (according to schedule)	Faster (scanning takes a couple of seconds) Can be influenced by slot planning ≈100%

There are many ways that this could translate into financial gain, but the study could not predict how much that will be. Every implementation is different, and some companies gain only 15% overall improvement while others gain over 200% improvement (Appendix B). Some ways a company could financially gain from a WMS are:

- No error -> no refunds

- Less picking errors -> less goods lost
- Better control of orders shipped on time -> no extra payments
- Faster flow -> less storage utilization
- Faster flow -> shorter inventory days on hand -> less goods thrown away
- Faster flow -> less need of employees and equipment
- Faster flow -> capacity for more demand -> more sales

The faster flow is contingent on the information visibility and control and is improved by multiple features in multiple areas.

7.1.4 RQ4: How would this impact Company X specifically?

The impact that a WMS would have on Company X would depend entirely on the WMS features that Company X select to implement. Company X already have SAPs ERP which has moderate support for warehouse management, including a scanner system and location tracking. Company X would thus not benefit as much from the visibility and control aspects as another warehouse with less software support would (table 7.2). Today operators at Company X already don't have to search for locations and the locations that SAP provide have the correct types of items (however not always enough quantity, so waiting for replenishment is common). There are still areas where the visibility would be improved but not enough to make a big difference.

Table 7.2 Expected results for Company X

KPIs	Company X before WMS	Company X after WMS
Receiving		
receiving time	484,39 seconds per pallet	484,39 seconds per pallet
dock door utilization	81,06%	possible improvement with scheduling
documentation processed accurately	≈100%	≈100%
Put-away		
put-away time	169,52 seconds per pallet	could be improved with ABC and path-optimization
put-away utilization of labour and equipment	79,49%	could be improved with ABC and path-optimization
correct put-aways	≈100%	≈100%
Storage		
inventory days on hand	75,11 days	could be improved from better flow and information
storage space utilization	79,02%	could be improved from better flow
storage accuracy	≈100%	≈100%
Picking		
picking time	83,94 seconds per pick	could be improved with multipicking, ABC, and path-optimization
picking utilization of labour and equipment	93,12%	could be improved with multipicking, ABC, and path-optimization
picking accuracy	≈100%	≈100%
Shipping		
shipping time	67,93 seconds per pallet	67,93 seconds per pallet
dock door utilization	55,54%	possible improvement with scheduling
orders shipped on time (according to schedule)	≈100%	≈100%

With a WMS, Company X could improve the put-away and picking speed. If Company X choose to implement more advanced features such as ABC classifications and route optimization then these operations, which amount to around 70% of the warehouse costs (Bartholdi & Hackman, 2019), could be improved significantly. Further implementation of features such as multi-picking would improve the picking speed to be even faster. However, if Company X only get a WMS and don't implement more than core features, then they won't improve much from their current situation.

Right now Company X stores their goods at the closest location available, if Company X would use ABC classification and store their A-class goods closer to the packing area, then Company X could improve their picking speed (figure 7.4)

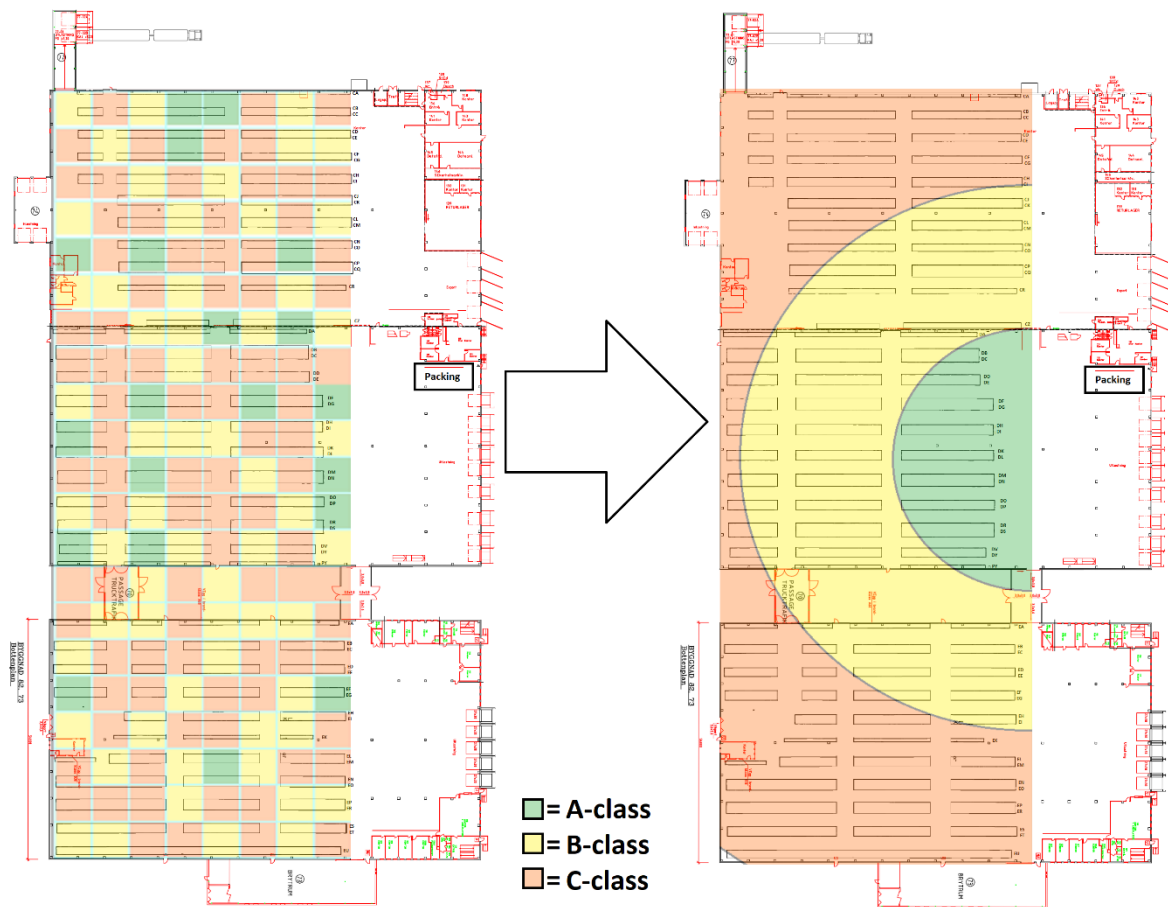


Figure 7.4: Example of how Company X's warehouse (left) could use ABC classification (on the right)

In the example, A-class goods are put close to the packing area since after an order is completed the picker will start his next order from the packing area. Having the most frequent goods placed closer to packing would limit the movement further away, thus saving a lot of time compared to all goods being scattered everywhere. A WMS can also take into account goods that are often sold together, the weight of goods, and any requirement that the warehouse has, when selecting items locations.

Besides the ABC classification, the route optimization is another feature that can improve the speed of the different processes. The route optimization is a feature using algorithms that calculate the absolute shortest path for every destination the WMS sends workers to. Be it a one-way destination in put-away, or through managing an entire customer order and calculating which goods should be picked first, and the shortest path for each of them. This synergises with the ABC classification which would improve the picking speed and the put-away speed.

Another feature that would improve Company X's picking speed much is the multi-picking features. Currently Company X has many one-piece picks, or two-piece picks,

where they use a whole EU-pallet for picking just one or two items. The pickers have to go from the forklift area to the location, then to packing, and then start the next order. With multi-picking all the one-piece picks, or small orders, could be condensed into one trip completely eliminating the multiple trips to and from the packing area. When combined with route optimizations, the multi-picking would improve the time even more, and when combined with the ABC classifications the picking locations would on average be more optimal as well making the distance travelled even shorter.

Figure 7.5 is an example of how 8 one-piece orders could look like with Company X's current system and if improved with multi-picking and route optimization (but not using ABC-classification).



Figure 7.5: An example of how the route would change for eight one-piece orders with multi-picking

In the example locations were chosen randomly, and the original path travelled is five times longer than with multi picking. Another benefit gained from the multi-picking is that EU-pallets could be exchanged for boxes that can be stacked and placed on movable carts, or on one EU-pallet, saving space in the warehouse as well.

A WMS could lead to less safety stock needed as well. The increase in visibility and control of the stored goods could also lead to cost savings on obsolete goods and what

is thrown away. Right now, Company X has a very good control over their goods and only 0,49% of their yearly goods get thrown away. While this is good, it still becomes expensive because of the scale of the warehouse. From January to October these goods added up to 363k SEK. A WMS could make the detection of items getting obsolete better, which would then enable Company X to stop ordering more of that item and/or push it out on sale, potentially lowering the cost of throwing obsolete goods away.

7.1.5 Fulfilment of the Purpose

The purpose, to increase understanding of how to analyse whether a company should implement a WMS or not, is addressed by combining the answers to the first three research questions resulting in the completed figure (figure 7.6).

The complete figure is a condensation of the entire study findings and starts by listing the core WMS features. Then the benefits and problems divided into those attained from theory and those from the study findings. Then influencing factors, and lastly it shows the expected results on the 15 KPIs chosen for the study to showcase the effect of the WMS on the warehouse performance.

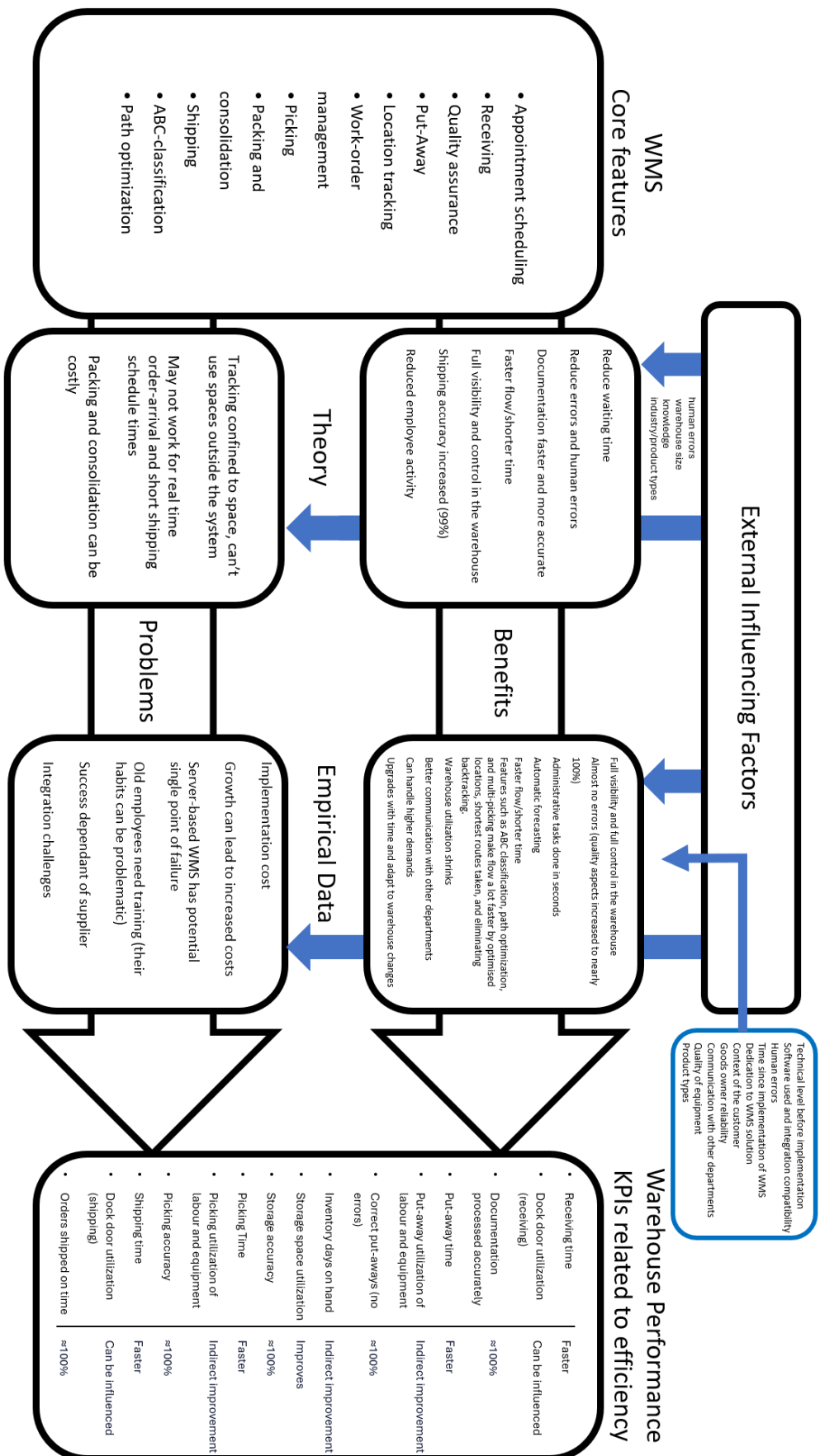


Figure 7.6: Complete figure explaining benefits, problems, influencing factors, and effect on warehouse performance through 15 KPIs.

7.2 Contribution

The theoretical contribution of this study has focused on the benefits and problems of features that a WMS has on warehouse operations, and how external factors influence these benefits and problems. The cases confirm the list of core features given by Bartholdi & Hackman (2019) and extends this list by pointing out the importance of features such as route optimization and support for ABC classification.

There is currently a lack of academic literature on WMS's that generalize their effect, as previous literature mostly are single case studies of implementations. This study contributes with a more general view of a WMS's effect through the combined view of vendors, customers, and literature. It specifically contributes through the study's findings of how much visibility and control can be gained with a WMS, and the effects that the visibility gives.

Currently, there is also a lack of academic research on factors influencing a WMS's performance. This study contributes to explaining and generalizing important factors that influence benefits of a WMS implementation.

The method of collecting data was based on warehouse performance KPI's from Staudt et al. (2015), Kusriani et al. (2017), and Faveto et al. (2021), where KPIs were selected based on how often they occurred in studies and their relevance. The study contributes by confirming that time and quality related KPIs from previous studies are relevant, but also by exposing a lack of visibility in utilization based KPIs. The study also ties together the KPIs from warehouse performance and WMS's.

The study contributes to practice by outlining what a company can expect to gain from implementing a WMS. This can be applied to any company that wants to implement a WMS. A company can study their own warehouse, and how advanced their current type of software is, and then determine whether a WMS is expected to give many benefits, and what types of benefits. This is especially true for Company X which was examined both on their different warehouse operations and on specific KPI's in those operations.

7.3 Limitations and future research

Due to the limited period of this study, It should however be noted that the transferability of the study is compensated through other means of collecting data, such as case customer reviews and case studies from literatures.

Another limitation is that the study was conducted by only one author. This increases the risk of biased perspectives and opinions when collecting, analysing, and presenting the data. However, the study has been discussed with the supervisor and with other opposing students during meetings with the supervisor, which lead to for example the decision to include more data from customers. Being a sole author also affected the

scope and speed of the study. Having a partner could have resulted in more data and in different data being collected.

There are many areas that could benefit for future research. The biggest area has to do with the current lack of generalized academic literature on WMS's. A broader multiple case study which could include many more vendors and many more companies would be interesting. This type of study could be applied to any section of a WMS, as the current types of academic literature are mostly limited to single warehouse cases or implementations. Some areas, building on this study, that could be further researched are the perceived effects of WMSs by vendors and customer, the external influencing aspects on a WMS, and the reason as to why some warehouses increase their productivity significantly and why some increase their productivity only by a few percent. These areas are already explored in the study, but further research could concentrate specifically on each of these topics.

There is also a lack of academic research into KPI's directly related to WMSs. This is also touched by this study, which reveals that there is an opportunity to research which KPI's are the most relevant for a warehouse through the lenses of a WMS.

Another aspect, mentioned by various parties, was the possibility of employees rejecting change in fear of a WMS resulting in them being laid off. Research could be done in order to find how warehouse employees are affected by a WMS implementation. Is the WMS ethical from their perspective, do they benefit from it by doing less work, or are they negatively affected from it by doing more work or being laid off.

The size of the warehouse as an influencing factor on the effect of a WSM is another area for future research. It goes without saying that a small "warehouse" sized as a room inside of an apartment, does not need a WMS. But where is the line drawn between size and useful impact? The customer cases did both mention that some features might benefit larger warehouses, but that they were too small (e.g. appointment scheduling). A study on how much a WMS benefits warehouses based on the size of the warehouse would be interesting.

Lastly there is also a lack of generalised academic work available on what features WMS's have. There are many WMSs with hundreds of features, most of which are only available through the WMS-vendors websites, which makes the information susceptible to biased opinions and skewed perspectives. Data could be collected from multiple vendors and software's and analysed, providing a comprehensive and unbiased assessment of features offered. This approach could contribute to a more informed understanding of the capabilities and limitations of different WMSs and of WMSs as a whole.

References

- Ackerman, K, B. (1997) “Practical Handbook of Warehousing, Fourth Edition”
- AI & linked in community. (2023). “How can WMS improve your shipping accuracy and speed?”. LinkedIn. Received: 2023-10-01. Electronically available: www.linkedin.com/advice/0/how-can-wms-improve-your-shipping-accuracy
- Andiyappillai, N. (2020). “Factors Influencing the Successful Implementation of the Warehouse Management System (WMS)”, International Journal of Applied Information Systems (IJIAS), vol 12
- Andelković, A. Radosavljević, M. (2018). “Improving Order-picking Process Through Implementation of Warehouse Management System”, University of Nis
- Ahmed, M. (2023). “ Top 5 Challenges in WMS Implementation”, SCMdojo [blog], 06 February, Electronically available: <https://scmdojo.com/top-5-challenges-in-wms-implementation/> [2023-08-25]
- Afolabi, R. (n.d). “WMS for the SMB: Factors to Consider When Implementing a Warehouse Management System”, NetAtWork [blog], Electronically available: www.netatwork.com/wms-smb-factors-consider-implementing-warehouse-management-system/ [2023-08-25]
- Assis, R. Sagawa, J, K: (2018). “Assessment of the implementation of a Warehouse Management System in a multinational company of industrial gears and drives” Gest. Prod., Sao Carlos vol 25.
- Badwi, M. (No date). “What is the impact of a WMS in your supply chain”. SCJUNCTION, Received: 2023-10-01. Electronically available: www.scjunction.com/blog/impact-wms-supply-chain
- Baek, D, S. (2023). “Revisiting conventional business frameworks with Oxford’s fresh perspective”. Retrieved 2024-02-01. Electronically available: www.sbs.ox.ac.uk/oxford-experience/blogs/sehyeon-baek/revisiting-conventional-business-frameworks-oxfords-fresh-perspective
- Baker, P. Canessa, M. (2009). “Warehouse design: A structured Approach”, European Journal of Operational Research

Bartholdi III, J.J. and Hackman, S.T. (2019, version 0.98.1) Warehouse & Distribution Science

Behzadan, A, H. Aziz, Z. Anumba, C, J. Kamat, V, R. (2008). "Ubiquitous location tracking for context-specific information delivery one construction sites". Elsevier.

Boysen, N. Stephen, K. Weidinger, F. (2022). "Efficient order consolidation in warehouses: The product-to-order-assignment problem in warehouses with sortation systems". Tandfonline

Chen, J, C. Chen, H, C. Huang, P, B. Wang, K, J. Huang, c, j. Ting, T, C. (2013). "Warehouse management with lean and RFID applications: a case study", Springer.

Chytilova, E. Demirova, S. Jurova, M. (2019) "Key Performance Indicators the providers of logistic services: experience of selected companies"

Cin7 Core. (2022). " Warehouse put-away process: How does it enhance inventory management?", Cin7 Core, Retrieved 2023-09-30, electronically available: dearsystems.com/blog/warehouse-put-away-process-how-does-it-enhance-inventory-management/

Cuofano, G. (2024). "30 Frameworks For Decision-Making". FourWeekMBA, Retrieved 2024-02-01. Electronically available: <https://fourweekmba.com/frameworks-for-decision-making/>

Descartes. (No Date). "Descarted Dock Appointment Scheduling | 7 Core Capabilities To Maximize Efficiency" Retrieved: 2023-09-20. Electronically available: www.descartes.com/resources/knowledge-center/descartes-dock-appointment-scheduling

Duong, V, D. Kim, H, J. Gui, L. Kim, K. H. (2016) "A Simulation-based Testbed for Evaluating an Appointment System in Port Terminals"

Enworo, O, C. (2022). "Application of Guba and Lincoln's parallel criteria to assess trustworthiness of qualitative research on indigenous social protection systems".

Emeralc insight.

Extensiv. (2022). "Warehouse Put-away Process: tips & Optimization Methods", Extensiv, Retrieved 2023-09-30, electronically available: www.extensiv.com/blog/warehouse-put-away-process

Extensiv. (2022). "Warehouse Quality Control Explained & How to Implement it", Extensiv, Retrieved 2023-09-30, electronically available: www.extensiv.com/blog/what-is-warehouse-quality-control-how-to-implement-it

Faveto, A. Traini, E. Bruno, G. Lombardi, F. (2021) "Development of a key performance indicator framework for automated warehouse systems" Management and Production Department, Politenico di Torino.

Fjodorov, A. Ulp, S. Alam, M, M. Kuusik, A. (2023). "Inertial and positioning sensors fusion for indirect location tracking in warehouse inventory management". international Conference on Control

Forero, R. Nahidi, S. Costa, J, D. Mohsin, M. Fitzgerald, G. Gibson, N. McCarthy, S. Aboagye-Sarfo, P. (2018). "Application of four-dimension criteria to assess rigour of qualitative research in emergency medicine". BMC Health Services Research.

Forger, G. (2018). "The Path Forward for ERP WMS", Modern Materials Handling.

Frost, C. Gustafsson, M, S. (2018). "Operational management through key performance indicators: A case study performed at the warehouses at Fresenius Kabi". Uppsala Universitet.

FTMaintenance. (2019). "What is Work Order Management?". Retrieved 2023-09-30. Electronically available: ftmaintenance.com/maintenance-management/what-is-work-order-management/

F.Curtis Barry & Company. (n.d) "6 Factors That Influence WMS Project Cost and Schedule Over-Runs", Electronically available: www.fcbco.com/blog/6-factors-that-influence-wms-project-cost-and-schedule-over-runs [2023-08-25]

Harb, A. Kassem, A. Chartouni, M, A. Chaaya, L, B. (2016). "Effects of Warehouse Management and Engineering System on Cost Reduction and Operations Improvement". IEEE Xplore

Halawa, F. Dauod, H. Lee, I, G. Li, Y. Yoon, S, W. Chung, S, H. (2020). "Introduction of a real time location system to enhance the warehouse safety and operational efficiency"

Hompel, M. Schmidt, T. (2007). "Warehouse Management Automation and Organisation of Warehouse and Order Picking Systems" Springer

Hopstack, (2023). "Warehouse Receiving: Process, How To Optimize & Best Practices". retrieved 2023-09-30 Electronically available: www.hopstack.io/blog/improve-the-warehouse-receiving-process

IMB Sterling Warehouse Management System. (2021). "Scheduling Dock Appointments". Retrieved: 2023-09-20. Electronically available: www.ibm.com/docs/en/warehouse-management/9.5.0?topic=tasks-scheduling-dock-appointments

Inbound Logistics (2017). "Top 6 Factors for Selecting and Implementing a WMS", Electronically available: <https://www.inboundlogistics.com/articles/top-6-factors-for-selecting-and-implementing-a-wms> [2023-08-25]

- Istiqomah, N, A. Sansabilla, F, P. Himawan, D. Rifni, M. (2020). "The Implementation of Barcode on Warehouse Management System for Warehouse Efficiency". Journal of Physics: Conference Series 1573.
- Jarasuniene, A. Ciziuniene, K. Cereska, A. (2023). "Research on Impact of IoT on Warehouse Management". Sensors.
- Jin, X. Yu, L. (2022) "Research and implementation of high priority scheduling algorithm based on intelligent storage of power materials. Elsevier
- Karasek, J. (2013). "An Overview of Warehouse Optimization". Brno university of Technology
- Kučera, T. (2017). "Logistics Cost Calculation of Implementation Warehouse Management System: A Case Study", University of Pardubice
- Kulinska, E. Giera, J. (2019). "IDENTIFICATION AND ANALYSIS OF RISK FACTORS IN THE PROCESS OF RECEIVING GOODS INTO THE WAREHOUSE", Sciendo, Foundations of Management vol 11.
- Kusrini, E. Novendri, F. Helia, V. (2017). "Determining key performance indicators for warehouse performance measurement – a case study in construction materials warehouse", Universitas Islam Indonesia
- Lam, C.H.Y, Choy, K.L. Chung, S.H. (2010). "Framework to measure the performance of warehouse operations efficiency", The Hong Kong Polytechnic University.
- Lao, S, I. Choy, K, L. Ho, G, T, S. Yam, R, C, M. Tsim, Y, C. Poon, T, C. (2012). "Achieving quality assurance functionality in the food industry using a hybrid case-based reasoning and fuzzy logic approach", Elsevier.
- Lim, M.K. Bahr, W. Leung, S. C.H. (2013). "RFID in the warehouse: A literature analysis (1995-2012) of its applications, benefits, challenges and future trends", International Journal of Production Economics
- Lorenc, A. Burinskience, A. (2021). "Improve the Order Picking in e-Commerce by Using WMS Data and BigData Analysis".
- Lubandy, R. (2016). "THE IMPACT OF WMS SETTINGS TO ENSURE QUALITY REQUIREMENTS OF PHARMACEUTICAL PRODUCTS" Silesan University of Technology and Kominski University
- Nowel, L, S. Norris, J, m. White, D, E. Moules, N, J. (2017). "Thematic Analysis: Striving to Meet the Trustworthiness Criteria". International Journal of Qualitative Methods Col 16:1-13-

Mao, J. Xing, H. Zhang, X. (2018) "Design of Intelligent Warehouse Management System"

Marziali, M. Rossit, D. A. Toncovich, A. (2021) "Warehouse Management Problem and a KPI Approach: a Case Study". Departamento de Ingeniería, Universidad Nacional del Sur.

Mecalux. (2022). "Picking process in the warehouse: maximum throughput with a WMS". Retrieved: 2023-10-01. Electronically available: www.mecalux.com/blog/picking-process-in-warehouse

Mecalux. (2022). "Warehouse consolidation: what's its role in logistics?". Mecalux. Received: 2023-10-01, electronically available: www.mecalux.com/blog/warehouse-consolidation

Melnikovas, A. (2018). "Towards an Explicit Research Methodology: Adapting Research Onion Model for Future Studies". Journal of Futures Studies.

Mikkelsen, C. (2017). "Vad kostar ERP-integration i ett WMS-projekt?". Apportsystems. Received: 2024-02-03, electronically available: <https://apportsystems.com/sv/viden-om/blog/vad-kostar-erp-integration-i-ett-wms-projekt/>

Modula. (2022). "Warehouse Consolidation [Benefits + Automated Solution to Streamline Warehouse Operations]". Modula. Received: 2023-10-01, electronically available: modula.us/blog/warehouse-consolidation/

Moeller, K. (2011). "Increasing warehouse order picking performance by sequence optimization". Elsevier.

Nee, A, Y, H. (2009). "Warehouse Management System and Business Performance: Case Study of a Regional Distribution Centre". ICOCI.

Oracle. (no date). "System-directed Quality Control (QC)", Oracle Warehouse Management Cloud Online Help, Retrieved 2023-12-10, electronically available: https://docs.oracle.com/en/cloud/saas/warehouse-management/21c/owmol/onlinehelp/topics/system_directed_quality_control_qc.html

Pajic, V. Radivojevic, G. Kilibarda, M. (2021) "INFLUENCE OF KPI OF LOGISTICS PROCESSES ON LOGISTICS COSTS". University of Belgrade.

Parametric. (no date). "11 Frameworks to Organize Your Business Strategy: An essential set". Retrieved 2024-02-01. Electronically available: <https://parametricpro.com/blog/11-frameworks-to-organize-your-business-strategy>

Porter, M, E. (2008). "The Five Competitive Forces That Shape Strategy". Harvard Business Review. Retrieved 2024-02-01. Electronically available: <https://hbr.org/2008/01/the-five-competitive-forces-that-shape-strategy>

Prasad Ramesh. (2021). "What is put-away strategy and how is it done in warehouses?", ERPNext. Retrieved 2023-09-30, electronically available: erpnext.com/blog/warehouse-management/put-away

- Raama, A. Subramanya, K.N. Rangaswamy, T.M. (2012). "Impact of warehouse Management System in a Supply Chain", International Journal of Computer Applications, Vol. 54
- Red Stag Fulfillment. (2023). "Package Consolidation: What It Is And How It Saves You Money". Received: 2023-10-01, electronically available:
redstagfulfillment.com/package-consolidation-what-it-is-and-how-it-saves-you-money/
- SAP. (No date). "Advanced Shipping and Receiving", SAP. Received: 2023-10-01. Electronically available: help.sap.com/docs/SAP_S4HANA_ON-PREMISE/e3dc5400c1cc41d1bc0ae0e7fd9aa5a2/65c4edc97c5c45048192fb079cfd87f0.html
- SAP. (No Date). "SAP Extended Warehouse Management (SAP WEM): SAP Dock Appointment Scheduling". Retrieved: 2023-09-20. Electronically available: help.sap.com/docs/SAP_EXTENDED_WAREHOUSE_MANAGEMENT/3d97bec9bf1649099384bb8167df3cf2/b01229f30240482f9a1acd4ac553bb8a.html
- SAP. (No Date), "SAP Work Manager" Retrieved 2023-09-30. Electronically available: www.sap.com/products/scm/work-manager.html
- SAP. (No Date), "Strategy for ABC Analysis" Retrieved 2024-01-29. Electronically available:
<https://help.sap.com/docs/SCMCSMRP/188784aaa798469bb2fcc7cd442b01e8/1e34afb6f711014892a2b114f204223.html>
- Sarsby, A. (2016). "SWOT analysis: a guide to SWOT for business studies students"
- ScanTexas (n.d) "Key Factors fo an Improved Warehouse Management System"
- Electronically Available: www.scantexas.com/warehouse-management-system-key-factors/ [2023-08-25]
- ShipBob, (retrieved 2023-09-30). "Warehouse Receiving Guide". Electronically available:
www.shipbob.com/warehouse-management/warehouse-receiving/
- Staudt, F, H. Alpan, G. Mascolo, M. Rodrigues, C, M, T. (2015) "Warehouse performance measurement: a literature review". International Journal of Production Research.
- Stobierski, T. (2019). "HOW TO DO A COST-BENEFIT ANALYSIS & WHY IT'S IMPORTANT", Harvard Business School Online. Retrieved 2024-02-01. Electronically available:
<https://online.hbs.edu/blog/post/cost-benefit-analysis>

Supply Chain Digest. (2006). The 11 Greatest Supply Chain Disasters. Retrieved March 2, 2017 from Supply Chain Digest: www.scdigest.com/assets/reps/scdigest_top-11-supplychaindisasters.pdf

Tee, K, X. Chew, M, T. Demidenko, S. (2011). “An Intelligent Warehouse Stock Management and Tracking System based on Silicon Identification Technology and 1-wire Network Communication”. IEEE.

Tejesh, B, S, S. Neeraja, S. (2017). “Warehouse inventory management system using IoT and open source framework” Elsevier.

Torabizadeh, M. Yusof, N, M. Ma’aram, A. Shaharoun, A, M. “identifying sustainable warehouse management system indicators and proposing new weighting method”. (2020). Journal of Cleaner Production, vol 248.

Trinidad, A. (2021). “Crucial Factors for Implementing Warehouse Management System”, SIPMM, Electronically available: <https://publication.sipmm.edu.sg/crucial-factors-implementing-warehouse-management-system/> [2023-08-25]

Vailshery, L, S. (2023). “Share of warehouse management software market worldwide in 2023, by vendor”, Statista. Electronically available: <https://www-statista-com.ludwig.lub.lu.se/statistics/503241/worldwide-data-warehouse-management-software-market-share/>

Whiting, G. (2023). “WMS implementation guide including checklist & project plan”, Electronically available: www.explorewms.com/wms-implementation-checklist.html [2023-08-25]

Yang, J, X. Li, L, D. Rasul, M, G. (2020). ”Algorithms Evaluation for Improving Classification and Counting Model in Warehouse Receiving Management”, IEEE.

Yin, R.K. (2018). Case study research and applications: design and methods, 6th edition. Thousand Oaks, CA, SAGE Publications Inc.

Zhang, Y. Lin, W,H. Huang, M. Hu, X. (2021). ”Multi-warehouse package consolidation for split orders in online retailing”. European Journal of Operational Research 289.

Zhang, R. Jiang, D. (2022). “Order-Picking Efficiency in E-Commerce Warehouses: A Literature Review”. Journal of Theoretical and Applied Electronic Commerce Research.

Zhao, Z. Zhang, M. Yang, C. Fang, J. Huang, G, Q. (2018). ”Distributed and collaborative proactive tandem location tracking of vehicle products for warehouse operations”. Elsevier

Zimmerman, D. (2020). "A History of Warehouse & Inventory Management Systems",
Electronically available: www.extensiv.com/blog/a-history-of-warehouse-inventory-management-systems [2023-08-15]

Appendices

Appendix A – Interview Questions

Interview Questions

Note that the interviews were held in a semi-discussion and if the answer could not be given directly further questions were asked in order to extrapolate the answer. The questions serve more as a guide to what I want answered. The same questions were asked to both vendors and customers, with slight differences based on which of the two was interviewed.

General Questions:

1. Can you tell me a little about your WMS in general? What are its strongest and most important features?
2. What are the most important aspects for a WMS to work?
3. What were/are the most important reasons for you/your customers to implement a WMS?
4. What does, according to your/your customers experiences, lead to the biggest profit from implementing a WMS? Is there any function that contribute more than others?
5. Do you have different levels of WMS based on how advanced WMS the customer wants?/ how advanced is the WMs you have implemented.
6. What does your WMS systems cost?
7. Do you have any success stories in form of customers where it has gone very good after implementing your WMS? (not asked to customers)
8. Do you have any failure stories in form of customers where it has gone very bad after implementing your WMS? (not asked to customers)
9. What warehouse performance indicators do you think are the most important, and which do you measure?

KPI related Questions:

Receiving

1. Receiving time
 - a. How is receiving time affected by a WMS? (ask for numbers)
 - b. How does your WMS affect the receiving operation in your warehouse?
 - i. Like the time it takes to document goods or the physical time of receiving?
2. Dock door utilization
 - a. How is the receiving dock door utilization affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the dock door utilization?
 - i. Does it have planning functions?
3. Documentation processed accurately
 - a. How is the documentation processed accurately affected by a WMS? (ask for numbers)
 - b. Does your WMS affect the way documents get processed? And if so how?

Put-away

1. Put-away time
 - a. How is the put-away time affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the put-away times at your warehouse?
 - c. Are there any WMS functions that can for example shorten the time it takes to determine where the goods are going to be sent, or the physical time to send them?
2. Put-away utilization of labour and equipment
 - a. How is the utilization of labour and equipment affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the utilization of labour and equipment for at warehouse?
 - c. Is there some function/feature that can help planning when put-away needs to be done? (avoid bottlenecking for example)
3. Correct put-away
 - a. How is the correct put-away affected by a WMS? (ask for numbers)
 - b. Are there some kind of function/features that help lower human errors at the put-away?
 - c. Like for example, tracking products and affecting how the scanner puts products into the system?

Storage

1. Storage space utilization
 - a. How is the storage space utilization affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the storage space utilization?
 - c. Are there for example any support for ABC based storing optimization?
2. Storage accuracy
 - a. How is the storage accuracy affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the storage accuracy?
 - c. Are there any ways the WMS could affect how often the pickers will pick wrong goods?
3. Inventory days at hand
 - a. How is the inventory days on hand affected by a WMS? (ask for numbers)
 - b. Are there any functions/features in a WMS that can affect the inventory days on hand? If so explain how.

Picking

1. Picking time
 - a. How is the picking time affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the picking time?
 - c. Are there for example features such as path optimization, documents scanning, planning of routes etc that can affect the time?
2. Picking accuracy
 - a. How is the picking accuracy affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the picking accuracy?
3. Picking utilization of labour and equipment
 - a. How is the utilization of labour and equipment affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the picking utilization of labour and equipment?

Shipping

1. Shipping time
 - a. How is the shipping time affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the (shipping) time it takes from when a truck enters the warehouse until it leaves?
 - c. Are there features that affect the time (such as documentation scanning and planning for example)?

2. Orders shipped on time/ on schedule.
 - a. How are the orders shipped on time affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the number of orders sent out in time/according to schedule?
3. Dock door utilization
 - a. How is the shipping dock door utilization affected by a WMS? (ask for numbers)
 - b. How can a WMS affect the dock door utilization?
 - c. Are there any functions/features that affect the planning of truck arrivals to avoid for example bottle necking?

Appendix B

Table B Data from customer cases of Ongoing WMS, Apport WMS, SAP WMS, and Vendor X. All taken from their websites.

Vendor	Ongoing	Apport	SAP	Vendor X
Customer 1	3-4 h/day reduction in order & inventory management	Saved 500-600 thousand NOK in picking errors alone	100% traceability Error-free delivery 50% less time from order to invoice. 0 delivery failures to date	2 times picking productivity 2.5 million NOK to be saved
Customer 2	15% productivity increase	Went from 36 to 20 workers	100% transparency in real-time	Picking speed increased from 25 picks per hour to 170 (6.8 times faster)
Customer 3	Halved picking staff	10 times fewer picking mistakes	4 times faster close-to-close process 3 times faster order-to-delivery lead time for spare parts 14% increase in employee productivity	Picking accuracy increased by 50% Picking efficiency increased by 25% Overall efficiency increased by 30-35%
Customer 4	Orders fulfilled increased by 20-30%	Saves 200,000 NOK in picking mistakes. Went from 26 to 23 workers. Revenue increased from 500 million to 700 million	95% reduction of unnecessary data in one of their processes 0 need for online archiving	99,96% delivery accuracy (aka picking errors)
Customer 5	Time from receiving order to sending it reduced to a few minutes	Doubled picking speed	48% reduction in data redundancy 98% increase in scheduling efficiency (went from 240 minutes to 258 seconds to schedule products) 30-50% reduction in inventory levels	60% less time for goods receipt
Customer 6	Increased sales by 100%		Reporting procedures leading to 95% productivity gain 11 hours saved in time used to generate reports	100% picking accuracy 100% product traceability
Customer 7			15-20% increase in sales	2 times picking speed 100% picking accuracy
Customer 8			100% automation of incoming materials 20% less time to calculate production costs	10 times increase in order picking rate 3 times total efficiency 100% picking accuracy
Customer 9			3 days time saved from tracking products	

Customer 10			7% reduction in warehouse space needed 16% in staff needed	
Customer 11			1.1 million euro saved through inventory reduction	
Customer 12			5 times faster inbound, went from several hours to 30-minute waiting time. 3 times increased warehouse volume with same resources used.	
Customer 13			20% revenue growth	
Customer 14			40% improvement in operational efficiency 15% reduction in days sales outstanding (?) 98% deliveries made on time 33% reduction in dead and slow-moving stock 20% improvement inventory turnover	
Customer 15			15% increase in forecast accuracy 25% increase efficiency of it support? 10% reduction in days in inventory 10% reduction days sales outstanding expected	

Appendix C

Section A. Overview of the Case Study

A.1 Mission and goals reflecting the interest of the Company X

The goal of this case study is to help Company X with their decision of whether to implement a WMS in their warehouse in City X.

A.2 Case Study Questions

RQ1: What are the benefits and problems of different WMS features?

RQ2: What external factors influence the warehouse performance and the WMS features effects?

RQ3: How would implementing a WMS impact warehouse performance and how is this translated into financial gain?

RQ4: How would implementing a WMS impact Company X specifically?

A.3 Key readings

All readings used served their purpose, some of the key readings would be these three books and these three papers:

Table C.1 Important readings

Title	Author and year of publishing
Warehouse & Distribution Science	Bartholdi, J, J. Hackman, S, T. 2010
Warehouse Management: Automation and Organisation of Warehouse and Order Picking Systems	Hompel, M, T. Schmidt, T. 2005
Practical Handbook of Warehousing	Ackerman, K, B. 1997
Warehouse performance measurement: a literature review	Staudt, F, H. Alpan, G. Mascolo, M. Rodriguez, C, T. 2015
Impact of Warehouse Management System in a Supply Chain	Ramaa, A. Subramanya, K, N. Rangaswamy, T, M. 2012
Factors Influencing the Successful Implementation of the Warehouse Management System (WMS)	Andiyappillai, N. 2020

A.4 Protocol role in guiding case study researcher

The role of the protocol is to make sure that the researcher does not get caught up in useless and time-consuming activities such as needlessly chasing an activity which does not have much to give or by asking irrelevant questions. This is done by reminding the researcher of the purpose of the study and by guiding the researcher into asking the correct questions/seeking helpful evidence.

Section B. Data Collection Procedures

B.1 Fieldwork contact persons

Fieldwork contact persons consists of Person X working at Company X, representatives from Ongoing WMS, Noventus, and Apport WMS, and representatives from one of Ongoing's customers, and one of Apport WMS's customers, labelled person Y and person Z.

B.2 Data collection plan

The data expected to be collected is the required data to fill Company X's values for the different KPIs and to get average and values and improvement percentages from the different cases. This includes the following type of data:

Table C.2 Type of data that needs to be collected.

KPI	From Company X	From Case Companies
Receiving time	Full time it takes at the receiving operations, including time for documenting received items and physically receiving them. If data is not already available, it is gathered with a timer and then approximated.	Data on WMS providers customers receiving times before and after implementing a WMS. If they have average improvements for their customers, then that is preferable. Time after implementation is also acceptable.
Dock door utilization	Data on how long docks are occupied, how long they are empty, and if there are queues of trucks at any times.	Data on WMS providers customers dock door utilization before and after (or only after) WMS implementation, an average for all their customers is preferable.
Documentation processed accurately	Data on warehouse documentation errors at the receiving stage: how often it happens and in what quantity.	Before and after statistics of receiving documentation processed accurately from their customers. (data of only after is also acceptable)
Put-away time	Data on Company X's put-away time. If data not available, then it will be measured with a timer.	Data on WMS providers customers put-away time before and after (or only after) WMS implementation, an average for all their customers is preferable.
Put-away utilization of labour and equipment	If not available then what will be measured is if there are any queues at put-away, how long it takes for a put-away process to start, and the availability of equipment for put-away	Data on WMS providers customers put-away utilization before and after (or only after) WMS implementation, an average for all their customers is preferable.
Correct put-aways	Data on put-away errors.	Data on WMS providers customers correct put-aways before and after (or only after) WMS implementation, an average for all their customers is preferable.
Storage space utilization	How much of their storage space is being utilized. Data on how much physical space is covered with shelves and operating areas and how much of the shelves and other areas that are being utilized.	Data on WMS providers customers storage space utilization before and after (or only after) WMS implementation, an average for all their customers is preferable.
Storage accuracy	Data on how often items are stored at wrong places. If data is not available, then a search for wrongly put goods will be conducted and used as a measurement.	Data on WMS providers customers storage accuracy before and after (or only after) WMS implementation, an average for all their customers is preferable.
Inventory days on hand	Data on inventory days on hand.	Data on WMS providers customers inventory days on hand before and after (or only after) WMS implementation, an average for all their customers is preferable.
Picking time	Data on picking time. If not available, then picking time will be measured with a timer from the moment a pick order is issued until it arrives to packing/shipping. An average is made from many of these observations to account for different pick paths and different orders.	Data on WMS providers customers Picking time before and after (or only after) WMS implementation, an average for all their customers is preferable.
Picking accuracy	Data on picking accuracy. If not available, then picks will be checked against their orders at the end of the picking.	Data on WMS providers customers Picking accuracy before and after (or only after) WMS implementation, an average for all their customers is preferable.
Picking utilization of labour and equipment	Data on how often orders are waiting to be picked and the availability of workers and equipment for picking. If not available, then data will be collected by author of the study.	Data on WMS providers customers Picking utilization before and after (or only after) WMS implementation, an average for all their customers is preferable.
Shipping time	Data on the time from goods enter the shipping operation until they are shipped, includes waiting time, documenting time, loading time, and any other time that may be there. If no available, then times will be collected separately from the author of the thesis.	Data on WMS providers customers Shipping time before and after (or only after) WMS implementation, an average for all their customers is preferable.

Order shipped on time	Data on late shipments. If not available, then personal will be asked to track this KPI for a certain amount of time.	Data on WMS providers customers Order shipped on time before and after (or only after) WMS implementation, an average for all their customers is preferable.
Dock door utilization	Same as for receiving, but for shipping.	Data on WMS providers customers Dock door utilization before and after (or only after) WMS implementation, an average for all their customers is preferable.

B.3 Preparation prior to fieldwork

As preparation, prior to the fieldwork the researcher had to get familiarized with the warehouse at Company X. This includes to understand where operations were located and operated. Another preparation was to find and contact relevant people working for different WMS providers for interviews, as well to develop an interview guide.

Section C. Protocol Questions

C.1 Company X questions

- How is the warehouse set up? Describe different operations in detail, including their locations, the deployment of personnel. and the equipment available.
- why is the warehouse set up like that, what are the advantages?
- Why have they not got a WMS?
- Are there any factors that make the warehouse compatible with a WMS implementation (meaning that they could benefit from it)?
- What is Company X's values in relation to the KPIs chosen?
- What problems could Company X get from a WMS?

C.2 Multiple Cases questions

- What are the biggest hinders when implementing a WMS? And how is it overcome if possible? (what negatives/problems are there with a WMS?)
- What are the positives of a WMS both in the broader sense and in relation to the chose KPIs for this study?
- What relevant data do I need to get trustworthy values for the KPIs?
- What are the prices for WMSs (needed for an analysis for whether it is worth it or not)?

Section D. Tentative Outline for the Case Study Report

D.1 Audience for the report

There are two types of intended audience for the study. First, people that will read and oppose the study, including students, the case manager, and the examiner of the thesis. The second group, the beneficiaries of the study, includes Company X and any other company not having a WMS, as well as any academic writer who will benefit from using the study for further research.

D.2 Extent of documentation and how to ensure secondary visits don't occur.

For the data collected at Company X, the data was recorded into a computer. Various programs depending on the data were used, primarily MS Words and MS Excel. Notes

were also taken with pen and paper for the fieldwork, which later were entered into a computer program.

For the multiple cases, the data collection was different. The interviews were done with a recording device and with full attention from the researcher. The researcher had pen and note block in case some very important topics were brought up to write down the timestamp to easier find it, or in case extra questions pop up mid-interview and the researcher does not want to lose the thought.

The interviews were later re-listened with intense note taking (using computer programs), and great focus on anything related to the KPI values. All the cases were categorized into their own folders and then cross examined. Once the raw data was turned into evidence a separate folder included the evidence from all cases as a means to make it easier to find patterns and commonalities.

When the data was not enough, the researcher first sent an email with the information sought after. This could happen due to bad questions. If the first interview did not yield any good evidence, it may be an indicator that the interview guide has to be redone and the questions rethought. The researcher avoided this by being direct with the intent of the questions while ensuring the integral safety of the interviewee.

D.3 Length of report (estimate)

The study may end up at around a hundred pages. The author aimed to limit the pages from exceeding 120 pages, excluding the reference list and appendix.