The effective integration and optimization of Warehouse Management Systems

A Systematic Literature Review

Bachelor thesis for International Logistics Program

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DEPARTMENT OF MECHANICS AND MARITIME SCIENCES

CHALMERS UNIVERSITY OF TECHNOLOGY
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PREFACE

This thesis is the culmination of my bachelor's degree at Chalmers University of Technology's program, International Logistics. The program's comprehensiveness enriched my understanding of functionings and mechanisms within the vast frame of logistics and supply chains. I want to express my gratitude towards Chalmers as an institution and all professors, guest lecturers, and staff who allowed a successful educational start to my academic journey. I also want to express my sincerest appreciation towards Kühne Logistics University who provided an insightful and educative exchange semester.

The subject of this thesis emerged from the combination of my keen interest in the creation of enhanced operational efficiency, acquired learnings from my studies, and my growing curiosity about software functions. Writing about software such as a Warehouse Management System with limited prior knowledge about system development and functioning was challenging and demanded my full attention. Conclusively, this taken-upon challenge has resulted in a personally increased knowledge base, and I am looking forward to following the future development of warehouse management.

Finally, I want to thank Fredrik Olindersson for supervising this project and further express gratitude towards Gerhard Guron, founder and business developer at Ongoing WMS, for insightful dialogues, discussions, and feedback enhancing the quality of this thesis.

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SAMMANDRAG

Vikten av att adressera lagers roll i leveranskedjor baseras på ökande förväntningar från kunder och en växande komplexitet av lageraktiviteter. Lagerhanteringssystem har introducerats som ett verktyg för effektiv hantering av lager. Arbetet undersöker hur ett lagerhanteringssystem kan förbättra lagerlogistik genom utförandet av en systematisk litteratur undersökning. Undersökningen initierats med en utredning av barriärer som utmanar en lyckad integrering och implementering av lagerhanteringssystem. Därefter utforskas praktiska implikationer av lagerhanteringssystem och hur dessa kan bidra till ökad operationell effektivitet i lager. Resultaten visar på att den huvudsakliga utmaningen som hindrar en lyckad implementering hänvisas till lednings- och organisatorisk motståndskraft baserat på motvillighet att investera, engagera och anpassa sig till ny teknik. Gällande lagerhanteringssystems praktiska bidragande till förbättring av lagerlogistik visar resultaten på ett expansivt appliceringsområde som tillåter ökad operationell effektivitet. Huvudsakliga fynd i denna fråga hänvisas till systemets förmåga att förenkla operativa processer, optimera strategier och samarbeta med framväxande teknologier genom nyttjandet av realtidsinformation. Betydelsen av det sammanställda resultaten hänvisar till argumentationen för vikten av att anskaffa ett lagerhanteringssystem för företag som bedriver lagerverksamhet och identifieringen av viktiga överväganden som behöver undersökas vid anskaffning av ett lagerhanteringssystem. Presenterat resultat är begränsat inom ramen för den utförda systematiska litteratur undersökningen och överväganden om lagerhanteringssystems potentiella effekt på verksamheters konkurrensfördelar, ekonomiska vinster och miljö har inte gjorts.

Nyckelord: lager, lager optimering, lagerhantering, lagerhanteringssystem, lagerhanteringssystem barriärer, lagerhanteringssystem optimering, systematisk literaturundersökning

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ABSTRACT

The significance of addressing warehouses role in supply chains is based on increased expectations from customers and the growing complexity of warehouse operations. Warehouse Management Systems (WMS) have been introduced as a tool for the effective management of warehouses. The thesis delves into how WMS can improve warehouse logistics by conducting a Systematic Literature Review (SLR). To address how WMS can improve warehouse logistics, the study initializes by investigating considerations challenging a successful system implementation and integration. Thereafter, the study explores the practical implications of WMS and how it can contribute to enhancing warehouses operational efficiency. Findings suggest that the principal challenge and barrier hindering a successful implementation refers to managerial and organizational resilience, based on a reluctance to invest, commit, and adapt to new technologies. Regarding WMS practical contribution to warehouse logistics, findings demonstrate that WMS has an expansive field of applications allowing increased operational efficiency. Key findings refer to the system's ability to simplify operational processes, optimize strategies, and cooperate with emerging technologies by utilizing real-time information. The significance of the concluded results is the argumentation for the importance of acquiring a WMS for businesses operating warehouses and the identification of key considerations, affecting the successful implementation, that needed to be examined when acquiring a WMS. The presented findings of the study are limited within the scope of the adopted SLR and considerations about WMS potential effect on businesses competitive advantage, businesses financial winnings, and the environment have not been made.

Keywords: Warehousing, warehouse optimization, warehouse management, Warehouse Management System, Warehouse Management System barriers, Warehouse Management System optimization, systematic literature review

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ACRONYMS AND TERMINOLOGY

AR	Augmented Reality
DST	Decision Support Tool
EDI	Electronic Data Interchange
ERP-system	Enterprise Resource Planning system
HCI	Human-Computer Interaction
Heuristic	A solution based on trial and error or vaguely defined rules
IoT	Internet of Things
KPI	Key Performance Indicator
RFID	Radio Frequency Identification
RTLS	Real-Time Location System
SCN	Supply Chain Network
SCM	Supply Chain Management
SKU	Stock Keeping Unit
Stochastic	The involvement of random variables
SLAP	Storage Location Assignment Problem
TAM	Technology Acceptance Model
WMS	Warehouse Management System

1. INTRODUCTION

This chapter introduce the subject and scope of the thesis. The chapter includes an introducing background, aim of the study, research questions, and delimitations.

1.1 Background

Warehouses have evolved from their fundamental functioning as simple storage centers to being an essential link in supply chains by providing critical distribution and fulfillment services (De Koster et al., 2017). Technological advancements and increased expectations from customers necessitate warehouses to transition towards serving a more pivotal role in supply chains. This makes warehousing a more complex concept and practical business, subsequently creating more possibilities for improving warehouse operations to further enhance warehouses overall productivity.

According to De Koster et al. (2017), the management of a warehouse plays a critical role in the effective utilization of warehouses and operations performed within, resulting in increased effectiveness. Managing warehouse flows and operations effectively has introduced an information-based software known as a Warehouse Management System (WMS). De Assis & Sagawa (2018) stipulate that a WMS aims to optimize the flow of material and information, maximize the utilization of space, and enhance operations in a warehouse by systematically controlling, monitoring, and recording warehouse flows and operations.

Considering the increased complexity where warehouses play a larger and more critical role in the entire supply chain, the need to find and invest in a fitting WMS and implement business-specific features grows (Baruffaldi et al., 2019). Acknowledging and discussing the challenges and issues of implementing a WMS is according to Baruffaldi et al. (2019) a key for organizations to assess and determine the benefits of implementing a WMS. Furthermore, Baruffaldi et al. (2019) imply that understanding and evaluating how warehouse-specific processes and operations can interact with an associated management module in a WMS is essential to determining a WMS contribution to potentially more effective warehouse operations.

1.2 Aim of the study

The objective of this thesis is to address how WMS can improve warehouse logistics by presenting a compilation of the integration and optimization of WMS. This is to further understand the importance of an efficient WMS in a warehouse setting. To gain such comprehension, the report will first aim to examine the implementation and integration process of a WMS, which aims to provide insights into what challenges and barriers arise in the process. Secondly, the report intends to delve deeper into warehouse-specific operations and how these are/or can be optimized by WMS modules, to understand how a successful WMS affects warehouse logistics.

1.3 Research questions

The following research questions (RQs) are subsequently formed to meet the purpose of the thesis.

1. What are the key challenges and barriers for the successful implementation and integration of a Warehouse Management System?

2. How can a Warehouse Management System enhance warehouse operations and the overall operational efficiency in a warehouse?

1.4 Delimitations

The thesis is limited to exclusively considering information and findings that emerge within the framework of the literature review as results. To remain within the aim and narrow the scope of the thesis, further limitations had to be made. It is important to note that the thesis investigates WMS as an optimizing software and managerial tool. Thus, considerations of how the RQs relate to potential environmental effects have not been made. Furthermore, the thesis does not examine general organizational effects in terms of potential financial winnings and competitive advantages of improved warehouse efficiency.

2. THEORY

This chapter presents the theoretical framework for the thesis. The chapter accounts for warehouse management systems, warehousing and operational strategies, management methodologies, and technological integration and adaptation. The presented theory embeds the foundational concepts necessary to understand presented findings from the literature review and interpretations made based on the results.

2.1 Warehouse management systems

A WMS is an information system used in warehouses to manage and control warehouse operations. WMS can be a software on its own or integrated into enterprise resource planning (ERP) systems. It can work as a software as a service, provided by a third party who maintains the system, or as cloud computing, where a vendor hosts both the software and hardware and the user accesses the WMS via a web browser (Richards, 2022).

Richards, (2022) explains that the software can track data and information within a warehouse by using automatic identification and data capture (AIDC) technology, for example barcodes and/or radio frequency identification (RFID). When new data enters, and is communicated to a WMS via AIDC technology, the information is validated and added to the system. A WMS keeps a precise record (instantly updated with new data entries) of inventory in terms of stock keeping units (SKU), quantity, and location. Thus, Richards, (2022) describes a WMS as an observational tool that provides real-time tracking and visibility of inventory, movements, order status, and performance metrics.

Furthermore, it is important to note that different WMS consist of various functionalities regarding warehouse operations (Richards, 2022). A WMS can for example facilitate operational tasks by providing optimal storage location assignment, routing strategies, and picking strategies. The system can also be utilized to generate work orders, shipping labels, packing slips, and other relevant documentation.

2.2 Warehousing and operational strategies

Warehouses accumulate a major part of the operations and costs in supply chains and are therefore an essential link in today's supply chains (Richards, 2022). In accordance with Richards (2022), warehouses exist in different shapes, forms, and sizes all depending on their respective purpose. There are similarly multiple types of warehouses for example raw material storage, finished goods storage, consolidation centers, and sortation centers which are all designed to accommodate their respective purpose and what operations are performed within.

All general warehouses consist of a set of fundamental flows, each demanding certain corresponding operations. The main flows in warehouses are receiving, cross-docking, order picking, value-adding services, shipping, and return processing (Richards, 2022). Table 1 presents the main flows and corresponding operations performed within warehouses.

Table 1
Warehouse flows and corresponding operations

Warehouse flow	Corresponding operations
Receiving	Unloading of incoming goods, inspection of quality and quantity, and updating inventory

Cross-docking	Transfer of goods directly to the shipping area.
Storage	Allocation of storage location and storage of goods.
Order picking	Collection of goods based on received orders.
Value-adding services	E.g. tagging, labeling, and assembly of goods.
Shipping	Inspection of quality and quantity of goods, coordination with carrier pickup, loading of goods, and updating inventory.
Return processing	Receival, inspection, and restocking of returned goods.

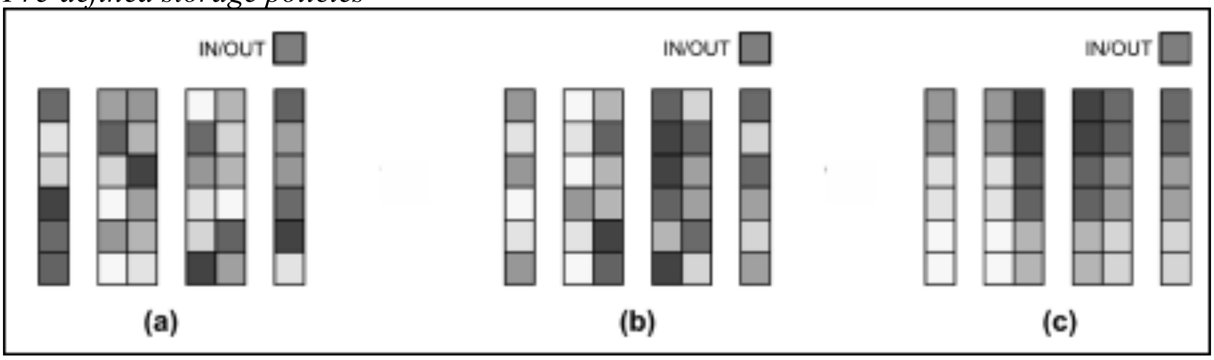
According to Leon et al. (2023), the general main areas of improvement in warehouse operations are storage location assignment, picking route determination, and order picking strategy. Leon et al. (2023) continues and states that the objective function of effective storage location allocation refers to its influence on minimizing travel distances for picking operations. Consequently, storage location has a significant impact on routing strategies which in turn relates to order picking.

2.2.1 Storage policies

Reyes et al. (2019) describes the storage location allocation problem (SLAP) as the concern to optimize storage space utilization and material handling by effectively allocating SKUs to their respective most advantageously storage locations. SKUs differences in customer demands and physical characteristics along with warehouses storage space availability and storage capacity creates the foundational concern of the SLAP. A plethora of different strategies and methods to approach the SLAP exist. The use of the pre-defined storage policies (random, class-based, and dedicated) is one of the most common practical approaches to address the SLAP (Leon et al. 2023). The random storage policy assign SKUs randomly. A class-based policy divides warehouses into product-categorized zones, and SKUs are placed randomly within its class zone. The dedicated storage policy assign SKUs to a dedicated storage location, determined based on the SKUs characteristics. Figure 1 illustrate how SKUs are stored based on the different presented storage policies.

Figure 1

Pre-defined storage policies



Note. *Storage policies: (a) Random, (b) Class-based, and (c) Dedicated. Retrieved from Leon et al. (2023), used under CC-BY.*

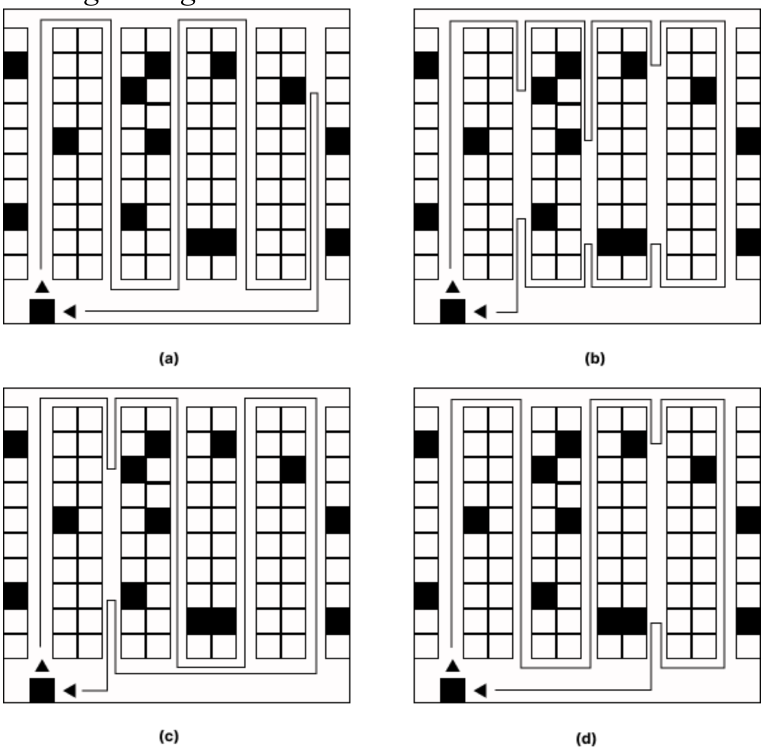
2.2.2 Routing strategies

Routing strategies in warehouses refers to the methodically determination of the path to be taken when picking SKUs in a warehouse. Effective routing strategies can find optimal paths to take when picking orders to minimize travel distance and time (Erasmus Research Institute of Management, n.d.). There exist multiple different routing strategies suitable to be applied for different scenarios.

According to Erasmus Research Institute of Management (n.d.), the most common routing strategies are the S-shape, largest gap, combined, and optimal strategy. In the S-shape strategy, pickers enter aisles from one end and leaves on the other until all SKUs have been picked. Aisles that do not contain SKUs to be picked are skipped. Largest gap routing directs pickers to enter each aisle from both ends, up to the point of the largest gap between SKUs to be picked. Once pickers reach the point of the largest gap, they return and continue to pick in the next aisle. The combined strategy facilitates a mixture of the s-shape and largest gap strategy. For each aisle, a choice of whether to return or go through the entire aisle is made. The choice depends on where the SKUs to be picked is in the next aisle. Lastly, the optimal strategy refers to routings which are based on algorithms that calculates the shortest routes. Figure 2 illustrates a picking scenario and routes based on each of the accounted for routing strategies.

Figure 2

Routing strategies



Note. *(a) S-shape, (b) largest gap, (c) combined, (d) optimal.*

2.2.3 Picking strategies

Picking strategies refers to the method used to pick SKUs in a warehouse. Multiple different picking methods are applied in warehouses to optimize the accuracy and efficiency of the picking process (Richards, 2022). All strategies have their respective different advantages and disadvantages, and each have a different level of suitability for different scenarios and conditions. The most adopted picker-to-goods picking strategies according to Richards (2022) is pick by order, cluster-/batch-, zone-, and wave picking. Pick by order is the generally most used method in practice where orders are picked individually. There are slightly different versions of the cluster/batch picking strategy. However, they are all sharing the same foundational idea that multiple orders are picked simultaneously in groups. In zone picking, warehouses are divided into zones and each picker is assigned to pick within a specific zone. Once all SKUs in an order within a zone is picked, the picked SKUs is passed to the picker working in the next zone, who continues fulfilling the order. Lastly, with wave picking, orders are grouped and picked in waves based on the consideration of order priority, order deadline, and shipping deadline.

2.3 Management methodologies

Richards (2022) states that quality management of a warehouse is a necessary element to maximize the effectiveness and productivity of the flows and operations performed within a warehouse. This to be time-effective and of high service to customers. The management of a warehouse refers to the continuous monitoring and assessment of warehouse operations. According to Richards (2022), measuring key performance indicators (KPIs) that report the status of operations is important to analyze a warehouse performance. This to further identify operations and flows in need of optimization.

2.3.1 Lean management

Engelseth & Gundersen (2018) presents the term lean, which originates from Toyota's production system, and its applicability in a warehouse setting. Lean refers to the management strategy used to develop procedures to increase flow efficiency by eliminating waste (i.e. in-practice inefficiencies). Griffiths (2023) exemplifies wastes as time-inefficiencies, excess inventory, and employee idleness. The reduction of such waste can consequently enhance operational efficiency.

Lean management is based on five core pillars: value, value stream, flow, pull, and perfection (Griffiths, 2023). Firstly, value refers to the identification of what factors of a product or service brings value to a customer. Value stream is the visualization of the end-to-end steps a product or service go through whereas flow is the continuous movement over the value stream. Establishing pull refers to being responsive and operate in coherence with actual customer demand. Lastly, perfection is the ongoing pursuit of continuous learning and improvement.

According to Engelseth & Gundersen (2018), lean management is principally a manual technique to identify and eventually reduce waste by modelling and reviewing current operations. There exist multiple different tools and methodologies used for the implementation of lean management. Griffiths (2023) presents 5S, value stream mapping, Kanban systems, Just-In-Time, and Poka-Yoke, as techniques for efficient lean management. 5S stands for sort, set in order, shine, standardize, and sustain and is the systematic approach of realizing that an organized workplace is a productive workplace. Value stream mapping embeds the core pillars value stream and flows by visualizing them for the identification of bottlenecks. Kanban systems are used to establish pull by signaling demand when work is needed. Just-In-Time is another method to establish pull with the aim to only operate in accordance with what is needed and when it is needed to synchronize operations and demand. Lastly, Poka-Yoke refers to the error-proof design of operations to prevent occurrences of mistakes and errors in operations.

2.3.2 Change management

Organizational change describes the shift from a current state to a desired future state (Hussain et al., 2018). Outcomes of organizational changes is uncertain and can challenge peoples value, competence, and handling ability. Consequently, people within organizations oppose changes, unless they are assured that the changes will result in an improvement compared to the current state.

Multiple models exist to address and optimize the organizational change process. This study will further consider Kurt Lewin's three step (unfreeze, change, refreeze) change model presented by Hussain et al. (2018). The initial step, unfreezing, refers to the preparation of change. This involves the creation of organizational awareness about the need for change by destabilizing the status quo. The method is performed to streamline the implementation of new practices. The second step, change, describes the actual implementation process where the change is introduced. Lastly, refreezing, refers to reinforcing and institutionalizing changes by integrating the change into e.g. organizational policies and practices to prevent relapses to a previous state.

Hussain et al. (2018) consider the change process from three distinct aspects: employee involvement, knowledge sharing, and leadership. Effective employee involvement in the change process is described as dependable on leadership. Involvement can be increased by employee empowerment, created when leaders value employee involved activities like feedback and input sessions. Knowledge about the change need to be shared effectively among all stakeholders to create a common knowledge base and competence necessary for changes. Active leadership refers to the need of direction, vision, and guidance through changes which shall be provided by leader figures.

Hussain et al. (2018) continues and discuss change managements managerial implications and stipulate that leadership is the most fundamental element affecting the overall success of the change process. Employee involvement is described as the component with the main impact on the shift between the states of changes and knowledge sharing is declared as a key catalyst for the unfreezing step. Consequently, all three aspects are interrelated and crucial to consider for an effective and successful organizational change.

2.4 Technological integration and adaptation

Modernizing current practices to improve operational efficiency necessitates the application and integration of new information and communication technologies (Haj & Dhiaf, 2019). This section further explores the theory and principles related to the successful implementation of technology and the optimization of operations through technological integration.

2.4.1 Technology Acceptance Model

The technology acceptance model (TAM) is a theoretical framework that investigates users' acceptance and adoption to new technology (Marikyan & Papagiannidis, 2023). The TAM is based on users' perception of technologies usefulness and ease of use which influence users' attitude towards using new technology. Usefulness refers to the degree a user finds technology to improve a task and ease of use refers to the degree a user finds a technology to be operated without difficulty. Marikyan & Papagiannidis (2023) describes the TAMs applicability as a 3-step process. Firstly, a systems design and features are experienced by a user. Thereafter, the experience triggers a cognitive response where users perceive the systems usability and ease of use. Lastly, the response forms an attitude towards using the experienced system.

According to Marikyan & Papagiannidis (2023), TAM is an important tool to apply for predicting user behavior and facilitate the acceptance of new technology. Therefore, the model can be used by organizations to enable informed decision making when implementing new technology in a business to investigate the forthcoming perception of usefulness and ease of use.

2.4.2 Human-Computer Interaction

Human-Computer Interaction (HCI) is defined by Kanade (2022) as a field that studies the optimization of user and computer (in this context, all digital tools are referred to as computers) interaction. With the emergence of new and complex technologies, HCI covers how interactive interfaces and designs can streamline human-computer communication and collaboration. Thus, the objective of HCI is to improve usability and user experience to create an efficiently designed computer.

According to Kanade (2022), HCI is based on 4 key structures: the user, goal-oriented task, interface, and context. The user refers to the group or individual that interacts with the computer, where HCI consider users' needs and cognitive capabilities to create a seamless interaction. Goal-oriented tasks is the operation a user intends to perform by utilizing a computer where the complexity of the task, user-required knowledge needed to interact with the computer, and time to perform the task shall be considered. The interface component refers to the examination of interface related aspects that affects the users experience and ability to interact with the computer. Lastly, context address the need to factoring in external environmental circumstances that affects the context of operating the computer.

Kanade (2022) means that HCI is indispensable to consider for computer developers to create an efficiently usable product for the user. HCI is fundamental to recognize for businesses that regularly use computers to complete tasks. This because it affects the user ability to perform tasks, which in turn affects a business efficiency.

2.4.3 Internet of things

Internet of things (IoT) can according to J. Chen & Zhao (2019) be described as a concept covering both a technical and a practical perspective. The technical perspective of IoT refers to physical objects with the ability to collect and transmit data through a network, which allows automatic information processing and exchange. RFID readers and unmanned aerial vehicles (UAVs) are examples of such physical objects. The practical perspective of IoT refers to the network creation between all interconnected devices within an IoT environment. J. Chen & Zhao (2019) further describes the IoT architecture as a model containing a perceptual-, network-, and application layer. The perceptual layer is used for collecting information (for example through an RFID reader). The network layer process the information transmitted from the perceptual layer and the application layer visualize the information.

2.4.4 Radio frequency identification technology

RFID technology operates through the employment of magnetic and electromagnetic fields, enabling the communication between electronic tags and RFID readers (Du, 2021). Said technology allows the identification and exchange of data at high speeds. Additionally, RFID readers can read moving tags and multiple tags simultaneously.

The essential function of the technology is further described by Du (2021) as a five-step process. Firstly, an RFID reader emits electromagnetic waves. When the electromagnetic waves meet an electronic tag, a response is generated, and an interaction between the tag and reader is created. Thereafter, the tag reflects a signal containing encoded information, stored within the tag, to the reader. The reader detects the reflected signal and decodes the stored information. Lastly, the RFID reader control and process received information for further distribution.

3. METHOD

This chapter presents the thesis adopted methodology used to answer the research questions. This includes the research strategy, bias, research design, literature collection, and data structure and qualitative data analysis.

3.1 Research strategy

The thesis has employed a Systematic Literature Review (SLR) as a methodology to retrieve and analyze literature. SLR allowed an evaluation of all retrieved literature related to the topic of the thesis and a thorough investigation of the RQs by providing an objective and reliable overview of the topic. The usage of SLR is according to Denscombe (2014) an appropriate method to conclude previous research on a topic, allowing a rigid overview of all the preceding research. Denscombe (2014) states that the employment of a SLR is beneficial for the reduction of bias since the method is transparent about the search, inclusion process, and quality judgement of the literature. This is therefore a useful strategy to gather previous literature to conclude and structure results to the thesis research questions.

It is important to point out that the thesis adopted a specific version of SLR. Durach et al. (2017) provides an approach which is presented as adopted and more suitable for research within the field of supply chain management (SCM), allowing a more effective methodology for the thesis. The use and function of the revised version of SLR will be further explained in chapter 3.3 Research design.

3.2 Bias

Durach et al. (2017) discusses potential biases regarding the performance of the supply chain adopted SLR that can occur and affect the outcome of the different steps of the SLR. According to Durach et al. (2017), bias can be divided into the following four types: sampling bias (including retrieval- and publication bias), selection bias (including inclusion criteria- and selection bias), within-study bias, and expectancy bias.

Durach et al. (2017) describes the types of biases as following: Sampling bias refers to the failure of retrieving all relevant studies, which can be a result of an inadequate and/or incomplete search of literature in addition with errors related to availability to published studies. This may lead to an incomplete and non-representative sample. Selection bias is an effect of inaccurate selection criteria alongside a subjective inclusion of literature, based on the researcher’s own perceptions of search results. Subsequently, selection bias can result in the exclusion of relevant literature, which in turn results in inaccurate findings. Furthermore, within-study bias can occur in the failure of a well-defined data extraction process, resulting in a false outcome of the review. Lastly, expectancy bias arises by the researcher’s predisposed expectations and wrongful interpretations of the results in the process of synthesizing primary studies. This may lead to a subjective and incorrect outcome of the review.

To minimize the occurrence of sampling and selection bias during the literature collection process, an extensive search was created, and inclusion/exclusion criteria was carefully determined. Expectancy bias, applicable during the abstract and full text analysis for exclusion, was averted by the determination and use of a standardized procedure. The performance of the search procedure, text analysis, and the determination of inclusion criteria are further explained in chapter 3.4 Literature collection. Lastly, the occurrence of within-study bias was avoided by extracting literature in a methodically and organized way (se chapter 3.5 Data structure and qualitative data analysis for an in dept description of this process).

3.3 Research design

The SCM adopted SLR was developed as a reaction to the traditional SLRs disregard of ontological and epistemological idiosyncrasies in SCM (Durach et al., 2017). Durach et al. (2017) argues that the following characteristics of SCM challenges the use of a traditional SLR: theoretical boundaries of SCM, units of analysis, sources of data, study context, definitions, and the operationalization of constructs in SCM, and research methods.

Traditional SLRs are performed with the following steps: (1) Define research questions, (2) Determine required characteristics of primary studies, (3) Retrieve sample of potentially relevant literature, (4) Select pertinent literature, (5) Synthesize literature, (6) Report the results. Durach et al. (2017) SCM adopted SLR follows the same steps as the traditional SLR but includes more precise guidelines for the execution of each step which has been followed in the thesis research. Table 2 presents each of the steps and the corresponding executed activity in accordance with Durach et al. (2017) SCM revised SLR.

Table 2
Research design and performed activities.

Steps	Performed activity
1) Define research question	RQ1: What are the key challenges and barriers for the successful implementation and integration of a Warehouse Management System? RQ2: How can implementation of WMS enhance operational efficiency in a warehouse?
2) Determine required characteristics of primary studies	Determined inclusion criteria's: Right publication type (peer-reviewed articles, journals, papers, and books). Relevant subject to thesis. Right language (English). Fully available. Reasonable number of citations compared to publishing year.
3) Baseline sample	Searched in the academic database Scopus with a carefully selected search string to identify all relevant literature of the theoretical framework.
4) Select pertinent results	Included literature in accordance with the determined inclusion criteria's (see step 2).
5) Synthesize literature	Organized literature into distinct categories in relation to the RQs and formed thematic areas used for extraction.

6) Report the results	Reported the results and provided an overview of relevant findings in the reviewed literature

3.4 Literature collection

The search for literature and data collection was conducted in March 2024 in the abstract and citation database Scopus. A combined search string was used to obtain literature relevant to the RQs in Scopus. The search was firstly divided in two parts (one for each RQ). "Warehouse management system" was used as a key phrase alongside additional keywords for the respective RQs. The determination on what keywords to be included in the search was thereafter made on a trail-error basis where potential keywords of little to no significance to the resulting number of literatures were removed. This resulted in a combined search string illustrated in table 3.

Table 3

Combined search string used for retrieving literature in Scopus.

Key phrase		Keywords RQ1		Keywords RQ2
Warehouse management systems	AND	Implementation	AND	Operations
		OR		OR
		Integration		Optimization
		OR		OR
		Barriers		Efficiency
		OR		OR
		Challenges		Performance

Retrieved literature was then filtered in Scopus according to determined inclusion criteria and results not meeting the inclusion criteria were excluded from the result. The criteria were developed based on the assessment of necessary characteristics needed for a publication to provide percipient information about the RQs. The assessment resulted in the following criteria's: right publication type, relevant subject to thesis, right language (English), fully available, and reasonable number of citations regarding publishing year.

Thereafter a review of all abstracts from the remaining literature was performed to exclude literature of irrelevance and then, a full text analysis of all remaining literature was conducted for a further filtration of the results. The literature exclusion in these two steps was based on any findings of complete irrelevance to the RQs, and such literature was excluded.

To identify any potentially relevant studies that were excluded from the initial baseline sample, forward snowballing was applied. Forward snowballing refers to the technique of tracking references by an examination of studies cited in the primary literature (Wohlin, 2014). Resulting studies was thereafter refined on the same basis as the initial bassline sample. Literature that met the inclusion criteria and was determined to be of contribution to the research was included.

Table 4 illustrates an overview of the literature collection process, including results from each of the steps of data refinement.

Table 4
Summation of the literature collection process.

Parameter	Result
Number of retrieved literatures	445
Number of literatures excluded from inclusion criteria.	231 (Wrong publication type) 44 (Wrong subject area) 4 (Wrong language) 23 (Not fully available) 67 (No/low number of citations)
Number of literatures excluded from abstract analysis	14
Number of literatures excluded from full text analysis.	6
Articles added from forward snowballing.	8
Total literatures	64

3.5 Data structure and data quality analysis

To conduct the fifth step of the SLR, the resulting literatures was exported to the qualitative data analysis software NVivo. NVivo allowed an extensive synthetization process where significant findings from each literature was sorted into thematic categories depending on the topic of retrieved information. The initial categorization was as specific as possible regarding respective finding to structure all areas of interest for the respective RQs. Thereafter, findings in categories that were considered to cover similar topics was merged. The literature was reviewed in two rounds to avoid potential indulgences of relevant information. After the review, sorting, and categorization of relevant findings from each literature, the categories were rearranged and divided into sets of overarching themes.

4. RESULTS

This chapter complies gathered results and lays the foundation for answering the research questions. This chapter is divided in two parts (4.1 Barriers for implementing a warehouse management system and 4.2 Optimization of warehouse operations, each covering the respective associated research questions.

4.1 Barriers for implementing a Warehouse Management System

This section presents the resulting findings regarding the main barriers and challenges for the successful implementation of a WMS. The barriers are divided into three main themes (selection of WMS process, system integration, and managerial and organizational resilience), each containing sets of sub-barriers. Table 5 illustrates the barriers and their respective sub-barriers along with used sources.

Table 5

Summary of barriers for implementing a WMS.

Barrier theme and sub-barriers	Reference
Selection of WMS process	
Selection methodology	[2, 4, 7, 43]
Evaluation of selection criteria	[4, 43, 57]
Customizability of WMS	[13, 18, 43, 57, 60]
System integration	
Integration and cooperation with organizations IT-infrastructure	[13, 18, 33, 40, 48, 54, 57, 62, 66, 74]
Integration and cooperation with organizations supply chain network	[7, 25, 38, 57, 60, 61, 66]
User-centric integration	[5, 18, 52, 57]
Managerial and organizational resilience	
Organizational commitment	[5, 7, 8, 18, 28, 32, 52, 57]
Readiness to adopt and change to new technologies	[1, 3, 6, 8, 18, 25, 28, 32, 34, 40, 54, 57, 69]
Reluctance to invest in new technologies	[7, 8, 52, 54, 57, 69, 72]
Implementation time	[18, 44, 57]
User compliance to new technology	[3, 12, 18, 29, 33, 52, 57]

4.1.1 Selection of Warehouse Management System process

4.1.1.1 Selection Methodology

Apak et al. (2016) and Kara et al. (2024) criticize the commonly use of heuristic approaches based on empirical observations and untested theories when selecting a WMS. This since such an approach may not consider all functions and criteria of significance. Therefore, Apak et al. (2016) and Kara et al. (2024) presents a multi-criteria decision-making method to approach the WMS selection problem where all areas of relevance can be identified and weighed to determine the most fitting WMS.

Accorsi et al. (2014) and Baruffaldi et al. (2019) each presents similar decision support tools (DSTs) aiming to find warehouse flows that can be optimized to aid managers regarding what WMS features may be needed. The DSTs performs sequential analyzes, generates alternative warehouse settings and configurations (based on the studied warehouse), and simulations of what if scenarios. Graphical user interfaces illustrate results and KPIs for the different simulated scenarios. Hence, the DSTs allow analyses and comparisons for decision making when implementing a WMS or a WMS feature.

4.1.1.2 Evaluation of selection criteria

Apak et al. (2016) means that managers spend a large amount of valuable time to evaluate their WMS, and further states that determining WMS selection criteria and desired outcomes/benefits (prior to its implementation) can reduce the need of complex and time-consuming evaluation processes. Kara et al. (2024) compiles a total of eight selection criteria's that should be considered when selecting a suitable and efficient WMS. The criteria are as following: price/cost, ease of use, support, performance, integration/compatibility, security, maintenance/repair, and reliability. Each criterion and their level of importance was determined through a literature review and expert consultation. Ease of use and integration/compatibility was considered as the selection criteria with the highest importance level. Consequently, Kara et al. (2024) means that a successful WMS needs to be easy to use and easily integrated into all processes. Min (2006) also concludes that ease of use and system integration are the most important criteria for the selection of WMS after surveying users about the implementation of a WMS.

4.1.1.3 Customizability of Warehouse Management Systems

Poon et al. (2009) and Caridade et al. (2017) argues that all warehouses differ in terms of their physical aspects, which in turn necessitates different considerations and adjustments. The need to perform multiple adjustments during the implementation of a WMS creates a distrust to the system and its potential (De Assis & Sagawa, 2018). Kara et al. (2024) further states that no well performing WMS is standardized and applicable for multiple different warehouses and Min (2006) means that warehouses with more than 10 000 SKUs or 10 000 order lines per day require tailor-made WMS. Min (2006) further states that companies that implements non-tailor-made/standardized WMS (no matter their number of SKUs and order lines) can require more than 10 adjustments/modifications of significance.

4.1.2 System Integration

4.1.2.1 Integration and cooperation with organizations IT-infrastructure

Caridade et al. (2017), Reyes et al., (2019), and Johnston et al. (1999) concludes that the main challenge for a seamless implementation of a WMS is related to issues arising during the integration of the WMS with already existing information systems in an organization.

Legowo & Wijaya (2022) studied a case company which used three systems (WMS, ERP, and sales/distribution), but none of the systems was integrated with each other. This resulted in an inefficient data input processes where 3 employees were assigned to input the same data to the respective system. Min (2006) further stipulates that WMS operating stand-alone (46.7% of surveyed users) fail to advantage the potential success of a WMS. This because the non-existing integration of WMS and other supply chain execution systems delays warehouse operations. For example, an outbound transportation carrier cannot be scheduled until the order is picked, released by the warehouse, and the information is sent to the organizations transportation management system.

Furthermore, Halawa et al. (2020) discovered the occurrence of errors in time synchronization when integrating a WMS in an organization with already existing real time location systems

(RTLS). Due to time zone differences and differences in clock time, a significant amount of time variations resulted in inaccurate metrics and analysis.

Integration testing is commonly used in practice to realize technical indicators in respect to each part of a software when integrating a WMS in an organization. Zhang & Pan (2022) argues that prior to performing an integration test, a unit test should be conducted. A unit test is a simple test method which realize potential error codes of a software's ability to perform tasks. Trying to integrate a software without determining the system's ability to perform tasks will affect the integration test since the occurrence of error codes in the integration phase is more complex to amend (Zhang & Pan, 2022).

De Assis & Sagawa (2018), Mao et al. (2018), and Tong et al. (2023) further complies the benefits of integrating WMS with ERP. Most companies already have complex ERP systems that optimizes the management of business owned recourses. A WMS integrated with an ERP system allows automatic data communication that continuously updates information to each module within the ERP system. For example, a purchaser (working in a purchase module) will always have real-time data of inventory levels which can be used to calculate and plan how much of an item is needed.

4.1.2.2 Integration and cooperation with organizations Supply Chain Network

The global extension of today's Supply Chain Networks (SCN) where organizations collaborate with a vast number of different actors, all operating in different time zones with their respective organizational boundaries, challenges the effective sharing of information (Poon et al., 2009). Hrušecká et al. (2018), Ramani et al. (1995), and Engelseth & Gundersen (2018) all point out that organization's failure of sharing information effectively with their SCN cause supply chain inefficiencies such as the bull-whip effect. They further stipulate that having an information system like a WMS that is cooperating and sharing information with collaborators in supply chain networks creates a key advantage point for a business and a more effective SCN. Baruffaldi et al. (2019) builds further upon the issue of information sharing and availability in SCNs and states that common business practice where limited information is available from collaborators constrain the benefits of the WMS implementation and usage. Data access is necessary for a WMS to function optimally. For example, a WMS needs information about weight and volume to determine optimal storage location of incoming items.

Similarly to the issue of WMS integration with organizations own IT-infrastructure, Min (2006) presents an example where there is no interface with the warehousing and transportation process. Therefore, the warehouse must manually communicate information to the transportation companies during the shipping process, and thus not utilizing all functionalities within an effective WMS. Tong et al. (2023) Further states that a WMS which is integrated to a company's ERP can allow data exchange with business collaborators to coordinate and enhance business activities and management performed outside the organization.

4.1.2.3 User-centric integration

Autry et al. (2005) states that it is the technology and not the human users that is the driver contributing to the increased efficiency in warehouse operations and tasks. Autry et al. (2005) continues and means that WMS is easy enough for users to understand and that little to no investment in training in the use of the software should be necessary.

However, De Assis & Sagawa (2018) argues that despite having implemented all technological functions in a WMS successfully, the system is still operated by employees that need to be qualified to operate the WMS correctly for the system to function as intended. Furthermore, Llopis-Albert et al. (2019) concludes that warehouse workers are more concerned of potential difficulties in handling of new technology rather than financial factors which managers tend to be more concerned about. The results from surveyed employees and managers working in a company that just implemented a WMS concluded that ease of use should be considered the top priority for a successful integration (Min, 2006). This with the rationale that users need to understand the software well, and that difficulties in understanding certain functions and inner workings created a frustration rather than relief among the users.

4.1.3 Managerial and organizational resilience

4.1.3.1 Organizational commitment

A survey (put to WMS users) aiming to compile the main issues of the WMS implementation process concluded that lack of managerial commitment is one of the main barriers (Min, 2006). Haj & Dhiaf (2019) and Baruffaldi et al. (2019) means that organizations are reluctant to commit to a WMS implementation process due to the unknown outcomes and uncertainty of the benefits. Battista et al. (2014) and Fumi et al. (2013) consequently noticed a tendency for organizations to rather implement subsystems for specific warehouse flows instead of fully equipped WMS.

When looking into a company directly after a successful WMS implementation (De Assis & Sagawa, 2018) noted that an effective implementation process could first be realized after the organization was fully committed. When all involved actors committed to the new system and new work procedures could the benefits quickly be noted. Similarly, Llopis-Albert et al. (2019) and Autry et al. (2005) means that involving all relevant actors by bringing in different points of view leads to better use of management and decision making, which facilitates a more successful implementation process.

4.1.3.2 Readiness to adopt and change to new technologies

Hamdy et al. (2022) and Ali & Kaur (2022) Argues that organizational readiness is essential for a beneficial WMS implementation. Surveyed warehouse managers agree that online data is a key for effective supply chain communication. However, a majority still use fax, phone, and email for information sharing. Johnston et al. (1999) further argues that tight regulations and firm constraints can hinder a WMS adaption whereas De Assis & Sagawa (2018), Min (2006), Haj & Dhiaf (2019) and Mao et al. (2018) mean that organizations do not believe that improvement in warehousing can bring financial winnings. Thus, they are not willing to conduct thorough investigations in how their warehouse functions can be improved.

Fumi et al. (2013) and Battista et al. (2014) finds that organizations are not willing to adopt and implement a WMS since they do not realize the need, possible functionalities, and potential benefits of a WMS. Engelseth & Gundersen (2018) also concludes that management are reluctant to change practices due to the uncertainty of effects and that lean management practices should be applied. Similarly, Bag et al. (2018) and (Abdul Rahman et al. (2023) means that organizations fail to conduct continuous reviews to find bottlenecks and areas of improvement in their supply chain. Wang et al. (2010) suggest that top management should try WMS prototype testing to realize the benefits of adopting a WMS which consequently can create the absent readiness to adopt to new technology.

4.1.3.3 Reluctance to invest in new technologies

Mao et al. (2018) and Llopis-Albert et al. (2019) means that managers primarily pay attention to financial factors rather than technological. They further stipulate that managers are not willing to pay for a sufficient WMS due to them not realizing how increased warehouse efficiency can be an economic resource.

Min (2006) and Baruffaldi et al. (2019) concludes that managers identify the cost of WMS implementation as a major challenge for the process and emphasizes that managers believe that the costs are difficult to control due to the unknown amount of work needed for modifications and system training. The authors means that organizations fail to take all overhead charges and long-term benefits into account and perform clear cost/benefits analysis.

Wang et al. (2010) further brings up that the more advanced the WMS are, the more costly they are. Therefore, many warehouses cannot afford the newer, more advanced WMS which results in the implementation of more plane and generic WMS. Battista et al. (2014) studied a case where managers realized the need of efficient warehouse management but did not want to invest in a full-scale WMS. Hence, the organization searched for a cheaper alternative, resulting in their implementation of a storage assignment policy. This was beneficial for the storing process, yet little to no benefits in other warehouse flows could be found. Similarly, Zaman et al. (2023) studied an organization seeking to optimize their supply chain performance through warehousing processes. The managers implemented a cheaper WMS with limited functions and advanced technology and no positive effect on the organizations supply chain performance could be found.

4.1.3.4 Implementation time

According to (Min, 2006), 30% of surveyed WMS users needed a significant modification phase to realize a successful WMS implementation, which could take from 15-30 months. (Khan et al., 2022) further states that the process of WMS implementation is always staggered. De Assis & Sagawa (2018) states that protracted IT-transitions, like the implementation of a WMS, due to the need of extensive modifications creates a disbelief in system efficiency.

4.1.3.5 User compliance to new technology

De Assis & Sagawa (2018) states that one of the largest challenges for implementing a WMS was the cultural shock for workers. The cultural shock is further explained as the major changes in practices and the deprivation of decision autonomy. Ali & Kaur (2022) and Binos et al. (2021) further studies how changes in the human-machine interaction influence the warehouse environment. They state that implementing a new WMS can alter the human-machine balance in a warehouse which in turn can result in stress due to fear of job security. A similar statement is presented by Llopis-Albert et al. (2019), who concludes that management and shareholders care more about obtaining profits while workers stress more about potential difficulties in handling new systems and care about maintaining their jobs. When the software is perceived as a black box (when internal workings is not understood) by users, a frustration due to lack of knowledge about system functions arise (Min, 2006).

Gademann & Velde (2005) studied the effects on user compliance to a WMS when the WMS was perceived as a black box. Routes suggested by the WMS was perceived as inefficient by users, resulting in the users deviating from the WMS routing solutions. Similarly, Halawa et al. (2020) studied drivers' compliance to routes generated from a WMS. Tracking the trips from one vehicle for one day resulted in the finding that 52% of the trips were non-compliant to the WMS. The commonality of non-compliance could not be rejected after studying all vehicles and drivers over a one-month period. Patterns in deviations could be found which suggested that certain trips to aisles and areas where the drivers had longer travel distances resulted in deviations. However, the deviations caused longer travelling time overall and multiple occurrences of congestion which affected the warehouse overall efficiency.

4.2 Optimization of warehouse operations

This section presents the resulting findings regarding WMS ability to overcome operational bottlenecks and increase the efficiency of warehouse operations. The WMS functions are divided into five main themes (management enhancement, data processing and analytics, Internet of Things, enhanced interaction and visualization, and application on specific operations), each containing a set of sub-functions/tools. Table 6 illustrates the main themes and their respective sub-functions/tools.

Table 6
Summary of WMS contribution to the optimization of warehouse efficiency.

Themes and sub-functions/tools	References
Management enhancement	
Lean management	[1, 6, 14, 18, 22, 25, 38, 41, 49, 69]
Real-time performance monitoring	[1, 5, 9, 18, 22, 23, 69, 73]
User-centric workforce empowerment	[12, 18, 33, 35, 59, 64]
Data processing and analytics	
Harnessing stochastic models	[27, 36, 49]
Data and association rule mining	[16, 17, 50, 62]
Electronic data interchange	[32, 61]
Internet of Things	
Internet of Things adaptation	[3, 15, 23, 34, 44, 47, 66, 74]
Real time location systems	[10, 23]
Sensors	[12, 72]
Radio Frequency Identification	[14, 18, 23, 35, 44, 51, 57, 58, 60, 69, 72]
Unmanned aerial vehicles	[11, 71]
Enhanced interaction and visualization	
Augmented reality	[41, 72]
Voice-directed systems	[45, 57]
Application on specific operations	
Receiving process	[14, 18, 30, 44, 45, 47, 57]
Storage location allocation and utilization	[1, 8, 17, 18, 35, 37, 40, 44, 46, 49, 50, 53, 67, 68, 69]
Picking and routing optimization	[16, 19, 29, 40, 41, 47, 56, 57, 64, 65]
Shipping process	[14, 18, 23, 30, 35, 44]

4.2.1 Management enhancement

4.2.1.1 Lean management
Jumahat et al. (2023) and Wang et al. (2010) states that managerial support and acceptance of new technologies greatly affects the success of WMS in terms of its efficiency. Abdul Rahman et al. (2023) means that WMS modernizes warehouse processes meanwhile, De Assis & Sagawa (2018) exemplifies a case where the utilization of a WMS allowed the extinction of identified ineffective practices. Bag et al. (2018) further states that WMS can be used to conduct effective periodic management reviews to identify and solve bottlenecks in management and operations.

According to Hrušecká et al. (2018), WMS technology itself is not sufficient to ensure system efficiency and means that applying lean management control mechanisms, adapted to current warehouse conditions and a set of goals can contribute to reduced response times**.** Engelseth & Gundersen (2018) discuss and propose to merge lean management with WMS for process improvement where lean practices can complement a WMS as an organizational backup that considers human perceptions and ideas. Both Dotoli et al. (2015) and Leon et al. (2023) notes that the use of WMS allows lean management practices based on data-driven solutions and propositions to identify critical issues and optimal configurations of current practices. Consequently, applying such lean management can be of use to find appropriate responsive actions and save time in operations. J. C. Chen et al. (2013) studied a warehouse that applied lean management principles (in addition to their WMS) to minimize waiting times and unnecessary motions and concluded that the total average operation time required for a SKU could be reduced by 79%. The application also allowed the management to implement a well-functioning cross-docking feature for time sensitive inventory.

4.2.1.2 Real-time performance monitoring
Benatiya Andaloussi (2024) explains that WMS continuously calculates KPIs that can advance the optimization of warehouse performance by providing real-time information about actual circumstances, conditions, and constraints. Du (2021) means that KPIs and real-time information allows managers to track and monitor operations which is useful for preparing warehouse activates and Dotoli et al. (2015) states that such monitoring can be used to track warehouse performance to further identify bottlenecks in certain operations and flows. Similarly, Wang et al. (2010), De Assis & Sagawa (2018)**,** Abdul Rahman et al. (2023), and Y. Zhang & Pan (2022) means that using real-time metrics and KPIs from a WMS allows the effective monitoring of changes in inventory levels which is used for decision making. This rather than the comparable alternative of having managers base decision on mere memory that is sub-optimal and subject for errors/mistakes. Autry et al. (2005) further investigates how using information from WMS creates more informationally agile organizations and finds the occurrence of hierarchical benefits, meaning that the beneficial use of WMS provided information further creates higher external capabilities (benefits experienced by external parties in the SCN).

4.2.1.3 User-centric workforce empowerment
Reverting to the previously accounted for barrier regarding human compliance to the WMS. Although the system is advantageous for managerial decision-making and operation optimization, De Assis & Sagawa (2018) argues for the importance of recognizing that the system is primarily used by the warehouse workers. Humans have limited cognitive resources which results in their restricted decision-making capability in terms of bias, errors, and time. Hence, WMS shall act as a DST, augmenting human decisions (Binos et al., 2021). As

already presented, Halawa et al. (2020) exemplifies the resulting consequence of congestion in warehouse traffic when the workers do the decision-making without regarding the WMS proposition. Saderova et al. (2020) further concludes that the warehouse workers abilities are significant and affects the time to store and pick goods. Similarly, Hehua (2021) concludes that the utilization of workers can be reduced significantly after implementing a WMS, meaning that the efficiency of each worker greatly improves.

Furthermore, Passalacqua et al. (2020) studies the impact of implementing gamified interfaces in WMS to increase employee engagement and performance. A gamified interface can include elements like goal-settings, feedback, performance metrics, competitions, and narratives. Such elements shall be implemented with caution due to the potential negative impact on well-being of users. Results from the study indicate that gamification can lead to long-term motivation and performance enhancement if implemented with caution.

4.2.2 Data processing and analytics

4.2.2.1 Harnessing stochastic models

Warehouses are to some degree stochastic environments, thus shall current modules and functions within the frame of WMS better account for the occurrence of randomness (Ho et al. 2024). Fattah et al. (2016) means that incorporated stochastic models that consider the occurrence of random effects and outcomes can be used to determine probabilities of stock-outs and calculate averages of performance indicators. Leon et al. (2023) continues and discuss that algorithms which account for randomness and historical data can be used to enhance already existing and optimized deterministic models.

4.2.2.2 Data and association rule mining

Reyes et al. (2019) emphasize that the use of data mining techniques in warehouse settings can be of great benefit when aiming to increase operational performance and efficiency. Association rule mining is a concept within data mining that refers to identifying relationships of significance to create in-practice guidance for decision making (M.-C. Chen et al., 2005). J. Li et al. (2016) means that association rule mining can be applied in modern WMS to identify how SKUs interacts and relates to each other. This can for example discover different SKUs sets that has repeatably been acquired by a customer. Chiang et al. (2011) presents association rule mining based on product turnover rate and distance between storage location and depot to optimize the storage location assignment module in a WMS. Consequently, SKUs could be stored based on historical order patterns which resulted in a more strategic storage location assignment module.

4.2.2.3 Electronic data interchange

Ramani et al. (1995) means that implementation of electronic data interchange (EDI) network allows automatic information and data distribution. EDI can for example automatically provide information about warehouse activities, inventory levels, and order statuses to collaborating parties. Haj & Dhiaf (2019) further explains the data exchange process as an automatically triggered process realized after the occurrence of a triggering event. For example, when a customer place an order and the WMS receive and confirm/accept the order, a confirmatory purchase order (document containing purchased items) can directly be returned to the customer. Both Ramani et al. (1995) and Haj & Dhiaf (2019) concludes that integrating EDI functions in warehouses can increase operational efficiency by reducing required manual activities.

4.2.3 Internet of Things

4.2.3.1 Internet of Things adaptation

The use of IoT technology can convert warehouse operations from manual practices to automated processes which can reduce resource, time, and energy consumption and simultaneously enable improved control of inventory and data storage (Ali & Kaur, 2022). Lee et al. (2018) claim that manual warehouse operations is not suitable in industry 4.0 and that developing IoT technology for WMS should be the main direction to enhance warehouse efficiency. Lee et al. (2018) further states that adopting IoT to a WMS establish a tool for human-machine cooperation which can be incorporated to enhance warehouse operations and consequently the overall warehouse performance. Tong et al. (2023) means that WMS need to integrate IoT to technology to develop automatic processes and Khan et al. (2022) further states that "The integration of IoT in recent years has become a game changer in terms of efficient warehouse management". By allowing automatic data and information transmission within its network, the IoT-adopted WMS creates an unchallenged communication channel. The integration of a prototype IoT-adopted WMS in a warehouse resulted in the improvement of 88% in terms of time to complete warehouse tasks compared to the previous used WMS (Khan et al., 2022).

To constitute a foundation for automatic data communication, Du (2021) propose a system that incorporates RFID technology, bar code technology, infrared sensing, and GPS sensors in a WMS to establish all three layers of an IoT architecture. Simulations of applying the system finds that efficiency of all warehouse processes improves, and most significantly with the increase of orders and SKUs. Z. Zhang, (2022) propose another IoT-based interface to be implemented in a WMS. Simulating the IoT-based interface resulted in enhanced levels of warehouse performance metrics such as order accuracy, buffer inventory level, and task utilization. Similarly, J. Chen & Zhao (2019) test an IoT-adopted WMS based on RFID in a warehouse and concludes that the system could operate steadily without collapse, increase efficiency in management of operations, and that only a small amount of scanning errors occurred. Hamdy et al. (2022) further investigates the effects of adopting IoT-based technologies in WMS and concludes that it can enable information based real-time decision making, reduce inventory costs from 40-70%, and achieve overall efficiency through the reduction of communication time.

4.2.3.2 Real-time location systems

Combining RTLS with WMS can according to Du (2021) and Bencak et al. (2022) realize several unique analyses. For example, Du (2021) discuss the use of heat maps which can be used to visualize warehouse performance, allowing identification of areas prone to congestion and disobediences to picking and routing policies. Bencak et al. (2022) further states that incorporating RTLS with WMS can improve quality of obtained data which can be further used to improve overall operational efficiency.

4.2.3.3 Sensors

Zaman et al. (2023) describes sensors as hardware-tools that can "Detect physical phenomenon (i.e., pressure, force, acceleration, temperature, etc.) can convert data into an output typically in the form of an electronic signal". Zaman et al. (2023) continues and states that the integration of sensor-detected data in WMS can be used to monitor warehouse conditions (e.g. to control temperature sensitive goods) and automate operation procedures such as inventory counting. Binos et al. (2021) further means that the use of sensors can create agile WMS modules with the function to base decisions on real time data and information.

4.2.3.4 Radio frequency identification technology

RFID technology is a type of sensor and the most brought up example in current literature regarding the use of specific IoT technologies. Khan et al. (2022) Discusses the common use of barcode stickers and states that it is more effective than a system using manual data input. However, barcode stickers have a limited durability, can only read one code at a time, and are more prevalent to errors such as duplicated readings. Du (2021) further criticize the use of manual data input in WMS because of its unnecessary complexity and high probability of errors due to large data handling and means that implementing RFID technology is necessary to optimize warehouse operations.

Pane et al. (2018) realize the limitation of barcodes and delves further in to the shift from barcode to RFID technology and states that “RFID technology is seen as the answer to the barcode technology’s weaknesses…”. Pane et al. (2018) surveyed warehouse workers after implementing RFID technology in their WMS and concluded from the results that the active WMS users perceived it to simplify work processes, save time in operations, and reduce scanning errors (in comparison to previously used barcode system). However, Z. Li et al. (2015) and Pane et al. (2018) address the potential occurrence of a problem with RFID technology. Multiple RFID devices, other equipment, and in some instances SKUs that emits radio frequencies in a warehouse can interfere and interrupt a desired readers attempt to receive a signal from a specific tag, thus resulting in incorrect readings.

De Assis & Sagawa (2018) states that integrating RFID technology to WMS is a solution to overcome errors and limited functions of barcode stickers and Hehua (2021) means that such integration can solve problems with manual information input/output, inventory tracking, and monitoring of warehouse operations. Zaman et al. (2023) and Min (2006) means that RFID technology can reduce the time of locating a storage location and improve stock monitoring by providing visibility of inventory. After integrating RFID technology in a WMS, Poon et al. (2009) finds that the overall visibility of the entire warehouse is improved, and that the productivity is increased in terms of reducing time to complete tasks. For example, the time for the WMS to assign a task and material handling was reduced from 2 minutes to 15 seconds. J. C. Chen et al. (2013) finds that application of RFID could reduce the total operation time by 36% and similarly, Du (2021) finds that the receiving and shipping process time can be reduced by 40% and 33% respectively. Wang et al. (2010) presents another example on the effects of integrating RFID technology in a WMS and concludes that improvements can be found in following areas: inventory visualization and management, task assignments for storage and retrieval, and loading time.

4.2.3.5 Unmanned aerial vehicles

Unmanned aerial vehicles is another example of an IoT technology and Yang et al. (2023) focus their research on the development of a UAV system in warehouses to primarily scan packages by QR codes. Yang et al. (2023) argues that the system can provide real-time inventory counts and monitor the safety of the warehouse interior. However, conducting direct scanning of QR codes necessitates a 90° angle. Otherwise, complex image processing is required for the UAVs to read the codes. Similarly, Beul et al. (2018) studies the use of UAVs in warehouses and concludes that it can be of benefit when performing more extensive stocktaking processes due to its automation of tasks and ability to reach areas that are difficult to access.

4.2.4 Enhanced interaction and visualization

4.2.4.1 Augmented reality
Augmented reality (AR) can be applied in WMS to streamline processes by enabling interactive 3-dimensional visualizations. Zaman et al. (2023) discuss applications allowed by using AR headsets and exemplifies the ability to virtually move across the warehouse, display optimal routing paths sourced from the WMS, and highlight items that are to be picked based on assigned picking lists. Jumahat et al. (2023) further discuss the concept of pick-by-vision, which is enabled by incorporating AR technology with WMS. By compiling earlier studies on the topic Jumahat et al. (2023) concludes that the use of AR in warehouse settings can contribute to operational efficiency by simplifying picking processes and reduce travel distances.

4.2.4.2 Voice-direction systems
The WMS can further benefit by incorporating voice-directed systems. Min (2006) Presents a case were such a system reduced picking errors by 60-70% and late picks by 50%. Klabusayová (2013) further explains the use of voice-directed system, where warehouse workers are equipped with voice terminals that can guides and assign orders to the workers by vocal commands. After studying the effects of incorporating a voice-directed system, Klabusayová (2013) concludes that the average error rate in picking was reduced from 15 to 2 errors per shift per worker and the labor productivity in terms of pallet handling increased from 10 to 20 pallets handled per shift per worker.

4.2.5 Application on specific operations

4.2.5.1 Receiving process
When goods have been unloaded and arrives in a warehouse, the receiving process is the initializing warehouse operation. J. C. Chen et al. (2013) and Khan et al. (2022) describes that smart WMS with fixed RFID readers (located in a strategic position where all entering goods pass) can automatically scan incoming SKUs. This allows an automatic information update and transmission about incoming goods and their characteristics (stored in their tags) which consequently eliminates the need of timely and manual counting and data input. Goudarzi et al. (2016) further describes that based on the information on the scanned tags, the WMS checks if goods have pre-defined identification keys or not. If the SKUs has already been defined, the WMS shall have necessary characteristics and handling information about the SKUs. If the incoming goods are of a new type to the WMS, the system will create a new product type with a unique ID along with information about the unit. De Assis & Sagawa (2018) could reduce the total time of the receiving process (loading and confirming goods characteristics) by 60% and required operators in the incoming dock after implementing a WMS. Similarly, Lee et al. (2018) reduced the average time of the receiving process from 2.54 to 0.96 minutes with automatic scanning and data transmission.

Min (2006) further exemplifies increased warehouse functions after implementing WMS. This is done by presenting a case where the WMS could identify goods that needed to be moved directly, which allowed the direct determination if goods shall be placed at the warehouse cross-docking station, resulting in reduced process time for time sensitive goods.

Min (2006) continues by suggesting that implementing EDI functions within WMS enables automatic communication within SCN which can optimize efficiency of planning for receiving goods. Klabusayová (2013) exemplifies the use of EDI in receiving activities and means that EDI communication to the warehouse allows the WMS to plan for coming events and activities.

4.2.5.2 Storage location allocation and space utilization

Johnston et al. (1999) means that assigning the most optimal storage locations is the most complex warehouse management feature and Lorenc et al. (2021) highlights the importance of effective storage location allocation by concluding that optimal picking is strongly correlated to picking route distance which is significantly related to storage locations. Abdul Rahman et al. (2023) concludes that maximizing and utilizing storage space (i.e. storing as many SKUs as possible in optimal locations) is the second most critical indicator used to increase warehouse productivity.

Both Hehua (2021) and Khan et al. (2022) concludes from their respective studied warehouses, that implementing RFID technology reduced the time of the storage procedure (i.e. storing, verifying, and system updating) by 65% and 79% respectively.

Lang et al. (2020) means that it is difficult to effectively assign association rules on individual SKUs in warehouses with many different SKUs. Therefore, Lang et al. (2020) presents a text-based clustering method to optimize storage allocation. The method is based on an algorithm that clusters SKUs with similar attributes into categories until all SKUs belong to a cluster. Thereafter, the clusters are rated based on the order frequency of their constituting SKUs and the highest rated (most frequently ordered) cluster are assigned to the location with the least distance to the depot. Battista et al. (2014) presents a multiproduct slot allocation heuristic to maximize the utilization of storage space. The allocation method is based on each SKUs velocity (computed as the number of handling movements within the warehouse during a defined period) and SKUs storage compatibility (allowing different compatible SKUs to be stored in the same slots). The SKUs are systematically sorted by velocity (decreasing) and the SKU with highest velocity is assigned to the storage location with least distance to the depot. Thereafter, following SKUs are assigned to the next available and compatible slot.

Leon et al. (2023) means that attempts to solve the SLAP with dedicated storage location policies (for example, the previously presented multiproduct slot allocation model) are strictly deterministic while the problem is of a stochastic nature, at least to some degree. Thus, Leon et al. (2023) presents the practical application of incorporating an algorithm that considers a certain degree of randomness to determine storage allocations. The algorithm initially works on similar principles as the previously accounted for deterministic models but for each instance, a stochastic proposition that factors in a degree of randomness (between 0.3 and 0.5) is simulated. For each instance where the stochastic simulation can result in a lower “cost” (in terms of travel distance) compared to the deterministic solution, the stochastic proposition is chosen. The algorithm further allows the comparison of a strictly dedicated policy (by setting 0 as the degree of randomness) and a randomized policy (by setting 1 as the degree of randomness).

De Assis & Sagawa (2018) further discourage the use of dedicated storage policies and presents the use of combining a fixed and random storage policy to optimally assign storage location. A presented method is based on assigning each SKU a fixed storage position in the most accessible aisles. The fixed storage locations shall vary in size to accommodate their respective SKUs characteristics and demand. Thereafter, the exceeding SKUs can be placed randomly in the less accessible aisles. SKUs shall be picked from the fixed positions after orders are placed, and when the stock in a fixed location reach a set threshold or reorder level, the WMS automatically generates a relocation order to move SKUs from the random to the fixed position. Hou et al. (2010) means that storage location re-allocation is not specifically recognized as an independent warehouse activity. However, the active and effective use of said method can further utilize storage space and locations to accommodate more and new SKUs. Hou et al. (2012) propose a 3-step re-allocation model where (1) current storage space data is acquired from the WMS, (2) inventory information to corresponding storage location is derived, and (3) optimal action for storage re-allocation is presented.

Tsamis et al. (2015) emphasize the need to create adaptive storage assignment policies that are resilient towards the increase of highly fluctuating customer demands. Tsamis et al. (2015) proposed a storage strategy that use historical order frequency and turnover rates for SKUs to determine the optimal storage location. Consequently, SKUs with a high order frequency and turnover rate will be placed closer to the depot. Similarly, Chiang et al. (2011) discuss the use of data and association rule mining for assigning the optimal storage location. A proposed method is presented solve the SLAP by allocating SKUs with a historically high frequency of appearing in the same orders in the same aisles. Therafter, it can assess SKUs turnover rate to determine the optimal distance from the storage to shipping location. Moreover, the method allows dynamical adjustments of SKUs to consider order patterns and seasonality of SKUs. Tufano et al. (2022) continues to describe the benefits of applying machine learning and data mining for effective storage allocation of new SKUs. Tufano et al. (2022) means that machine learning based on historical data about SKUs attributes (e.g. volume and weight) and order patterns (e.g. demand and seasonality) can be used to predict the outcome of strategic decisions which in turn can be used for effective storage allocation. However, both Chiang et al. (2011) and Tufano et al. (2022) states that the effective application of such a method is limited to cases where crucial data is available.

Wang et al. (2010) shifts the focus from the use of optimal storage locations to reduce travel distance and increase of space utilization to invariable warehouse environments by stating that when warehouse environments change, complex algorithms and methods will not adapt. Wang et al. (2010) means that the use of WMS, allows considerations of changes in warehouses physical environment to make a more agile warehouse that is flexible to larger changes.

4.2.5.3 Picking and routing optimization

Saderova et al. (2020) concludes that a WMS which controls the picking and routing process is optimal to collect items time-effectively. A basic function of how a WMS process an outgoing order is described by Johnston et al. (1999). Once an order is received, the WMS verifies if current inventory can fulfill the received order. If an order is verified, a picking list containing SKU ID, quantity of each SKU, and the location of each SKU is generated.

Interactive and visualizing technologies can be incorporated in a WMS to improve the physical picking and travel activity performed by a picker. Jumahat et al. (2023) presents AR implementation as a tool to reduce the rate of wrongly picked SKUs and travel time and Min (2006) advocates that the use of voice-directed systems has similar beneficial effects.

Adopting order batching as a picking policy can according to Gademann & Velde (2005) and Johnston et al. (1999) further enhance the picking process since the policy allows the collection of multiple orders simultaneously which in turn can reduce the total travel distance. Lee et al. (2018) presents the direct effect of implementing a WMS which facilitates order batching and concludes that the total average picking time of an order was reduced by half. Gademann & Velde (2005) continues and suggest that incorporating complex algorithms that can divide orders into batches in WMS can create an automated and effective batch creation process. One example of how a WMS can consolidate orders into batches is to adopt association rule mining where current orders with high associations (i.e. the different orders consist to a certain extent of the same SKUs and/or SKUs stored near each other) are batched (M.-C. Chen et al., 2005). Menéndez et al. (2017) considers another order batching method that considers the due date of each order and batches the orders with the closest due date into a batch until the batch is full (when the batch reach the limit of the picking capacity). After a batch is full, a new one is created. Batches are therefore created and a sequencing rule which prioritize orders with the closest due date is incorporated.

Shiau & Lee (2010) further suggest merging the picking and packing module within WMS to optimize the processes and allow the packing of orders directly after being picked. A test of the combined function was conducted and resulted in reduced operational time and the elimination of transferring picked batches to a packing area.

4.2.5.4 Shipping process

Du, (2021) means that placing right SKUs and quantity of SKUs in the shipping area (for further distribution) and transferring the information of said activity to update inventory levels is the most important part of the shipping operation in a warehouse. Implementation of WMS (without IoT-adopted technologies) improved reliability in the shipping process in terms of correct items and quantity of items being shipped. However, no efficiency in the operation could be noted (De Assis & Sagawa, 2018). Moreover, Khan et al. (2022) States that the use of RFID technology integrated in WMS can optimize the shipping flow by removing the need for manual checkout procedures in inventory modules and consequently save time by automating said function. J. C. Chen et al. (2013) describes how a general shipping process can operate with RFID technology as following: Firstly, when goods are placed in the shipping area, a fixed RFID reader scans tags on the goods, compare it to received orders, and record the activity. Thereafter, the information from the reader is directly and automatically transmitted to the WMS. Lastly, the WMS returns a confirmatory value if the tag is read correctly or not. If the scanned quantity or item is incorrect, the WMS can automatically issue new workorders to correct the error. After testing the integration of RFID technology to the WMS, the time of reading, inspecting, and checking that goods are compliant to customer orders before shipping was reduced from 16 to 1.5 minutes (Hehua, 2021). Furthermore, by subtracting the outgoing SKUs from a current inventory level, a WMS can communicate when SKUs reaches low levels based on pre-defined re-order levels which aids the avoidance of stockouts (Goudarzi et al., 2016).

5. DISCUSSION

This chapter presents a discussion of the adopted method. The chapter further discuss identified findings and key theory related to the RQs ans is divided based on the main themes for the respective RQs.

5.1 Discussion of method

In a context of a SLR, validity refers to the extent of how the research accurately represent current literature. Reliability further concerns the establishment of consistency and repeatability in the review process which further aims to represent the literature accurately and credibly. Through a rigorous methodology with a comprehensive search and data extraction strategy that gathers current and representative literature, validity and reliability can be enhanced.

The strengths of adopting a SLR as a method for this thesis can be categorized into four themes: comprehensiveness, transparency, minimized bias, and synthesis of evidence. Comprehensiveness refers to the methods allowance to conduct a thorough examination of existing research, assuring a wide understanding of the subject. The method is transparent and replicable which enhances the trustworthiness of the research. Bias is minimized by using a systematic and standardized method for the search, selection, and review of literature which further ensures the credibility of the findings. Lastly, SLR allowed the synthesis of findings from multiple studies which facilitates a literature-complementing function and the identification of patterns and gaps in the literature.

Limited scope, resource intensity, and quality variability were identified as factors of disadvantage with a potential limiting effect on the results and reliability. The scope of retrieved literature may overlook relevant studies due to the limitation of using one academic database (Scopus) for the search and the set of strict inclusion criteria. Conducting the SLR is further both time and resource-intensive which requires a corresponding effort to effectively utilize the method. Lastly, the quality of the literature and each study's contribution varied which impacts the reliability of the synthesized findings. However, studies included in the initial baseline sample that were of low quality and/or contribution could be removed by thoroughly assessing the content of each study during the abstract and full-text analysis which increased the validity.

Similar to a SLR, a narrative literature review provides a qualitative summary of research on a specified topic. The method allows the synthesization of existing knowledge and offers detailed contextualized and theoretical insights, useful for exploratory research. However, this alternative method is in comparison to a SLR characterized by its flexible approach and lack of structured search strategy. This method allows the broad exploration of a diverse set of sources and can be conducted with fewer resources and less time than a SLR. However, it is subject to an increasing risk of selection bias due to the increased allowance of subjective interpretations and inclusions of literature. This makes the method less reproducible and may affect the reliability and validity of literature. Consequently, this method may be more appropriately adopted for research with limited prior literature where theoretical development is needed.

A case study is another alternative method applicable to investigate the thesis-adopted research questions. A case study involves an in-depth analysis of a particular case or a small number of cases and provides contextualized insights into the research topic. This approach allows for a thorough investigation conditioned by practical and real-world insights into qualitative and quantitative data. Data can be collected using various methods, such as interviews, experiments, and observations to identify results, patterns, and key themes. Although this method can provide detailed information, it is resource-intensive and has limited generalizability due to its focus on specific cases. Furthermore, findings based on interviews, experiments, and observations are subject to interpretation and researcher bias. This approach may be appropriate to answer the formulated research questions. However, one must expect the results to be less general and unable to account for a broader scope in the large field of warehousing.

5.2 Selecting the right Warehouse Management System

The findings related to the WMS selection process point out the need of adopting an effective methodology for organizations to primarily realizing their specific needs. This will in turn amplify the successful implementation of WMS. Usage of simple heuristics is realized as the main barrier for this process. Such heuristics is criticized by both Apak et al. (2016) and Kara et al. (2024) when procuring a WMS because it is not a fully rationalized method. Decisions based on empirical and subjective observations can be biased and fail to consider all areas of relevance and their respective level of importance. For example, Zaman et al. (2023) presents a case where managers focused too much on the cost which compromised the quality of the acquired system and failed to be of use to improve operations. Methodically approaches and the application of data-driven DSTs can detect what operations need optimization rather than the comparative heuristic approaches. DSTs can simulate alternate scenarios and generate key metrics for the scenarios, allowing extensive analyses and comparisons for implementation considerations.

An effective consideration process leading to the determination of what criteria are of highest importance for the system implementation is key for organizations to realize what WMS and what features are of most importance. Kara et al. (2024) and Min (2006) emphasize the need of considering the TAM and HCI principles by stating that ease of use is the most important criteria to consider for a WMS to be successful. By applying the TAM, organizations can investigate how future users will perceive the implementation of WMS and considering HCI principles can be of value to examine different WMS interaction performance.

WMS shall further not be realized as prefabricated products since all warehouses differ. Consequently, WMS need to be customized and adjusted to meet different needs, conditions, and circumstances for its successful implementation. This aspect further correlates with the cost and time barriers since adjustments and customizations prolong the implementation time and increase the cost of the system.

The significance of WMS vendors ability to provide support and maintenance to the software is absent in the reviewed literature. However, the level of said ability can be deemed beneficial to consider since such service is crucial for addressing software issues and ensuring that the WMS remains functional.

5.3 System integration

For a WMS to operate efficiently and as intended, it needs to be integrated with organizations existing IT-infrastructure and their SCN. The integration process is complex but necessary for effective system communication and information sharing. Synchronising data and integrating different software systems forms the basis of said complexity. Thus, the integration barrier primarily refers to arising compatibility issues and inefficiencies caused by non-integrated systems. Occurrences of such instances is exemplified by Halawa et al. (2020) who discovered the issue of errors in time synchronization due to the unsuccessful integration with an already existing system, and Min (2006) who found that stand-alone WMS does not allow the system to function at its potential. A WMS integrated into organizations more extensive systems, such as ERP systems, can harness the benefits of information availability and intercommunication which can further be distributed to entire SCNs to coordinate the warehouse activities with the entire supply chain.

Despite Autry's et al. (2005) argument that it is the technology and not the users that facilitates improvements in warehouse efficiencies, a WMS must be operated as intended to function as indented. Consequently, a seamless integration must consider the integration and its impact from a user-centric perspective. In accordance with the TAM, users must perceive the system as useful and easy to use to accept the technology. This further strengthen the need of incorporating HCI principles in WMS design to enhance user experience and efficiency. This positively affects users' perception on usefulness and ease of use which facilitates the acceptance of new technology. From an organizational perspective, can the benefit of system training programs be considered to enhance user expertise and bridge the constraints between complex systems and user efficiency.

5.4 Managerial and organizational resiliance

Organizations limited commitment and inability to adopt to new technologies are two strongly accounted for and correlated barriers for implementing a WMS in the reviewed literature. The barriers and resistance are based on the uncertainty of outcomes and convenience of using what already works, even if it is not optimal. As noted by Battista et al. (2014) and Fumi et al. (2013), hesitant organizations tend to rather implement subsystems and singular functions to specific processes rather than full-scale WMS. Such approach can improve certain function but is concluded to have a minimal impact in the overall warehouse efficiency. By considering change management principles, such organizations can unfreeze their status quo to realize the need of change, leading to their acknowledgement that implementing WMS are necessary to improve warehouse efficiency.

Furthermore, the disregard of warehouses being an economic resource facilitates a reluctance to invest in WMS which further constitutes the challenge for implementing WMS. Concurrent with the concluded need of tailor-made solutions and modifications that increase costs and are time-consuming, the hesitancy to implement a WMS is escalated. This is because the implementation process can be perceived as uncontrollable in terms of time and cost. If organizations do not realize the importance of investing in WMS, no WMS will be implemented to begin with. Baruffaldi et al. (2019) presents that the performance of thorough cost/benefits analysis can overcome said hinder. By realizing the already accounted for determination of system requirements, a cost/benefit analysis can consider the complexity and extent of needed system to better comprehend required resources for the implementation.

Changes in the human-machine balance in warehouses affect the environment and can cause stress and frustration among warehouse workers which constitutes the last reviewed finding within the barrier theme. A major problem in human compliance to WMS was found in warehouses by both Gademann & Velde (2005) and Halawa et al. (2020), suggesting that measurements must be taken to make sure that warehouse workers operate in symbiosis with WMS rather than against it for it to function as indented. The problem further highlights and relates to the importance of system acceptance and interaction which can be met by considering the TAM and HCI principles to conclude the successful WMS implementation.

5.5 Management enhancement

Findings related to how WMS enhance management points to the importance of considering the relationship between management and technology. Both Jumahat et al. (2023) and Wang et al. (2010) means that managerial support and acceptance of new technology affects a WMS efficiency which correlates with the importance of realizing the effective application of a change management model and the benefit of the TAM.

The use of KPIs and real-time information, calculated and presented by WMS, can effectively realize enhanced efficiency in a warehouse. This because real-time metrics provides fundamental objectives used for decision making (Y. Zhang & Pan, 2022).

Leveraging WMS functions and information can help managers to identify operational bottlenecks, conduct reviews and monitor operations. Consequently, WMS can be perceived as a tool that enables the implementation of lean management in terms of its ability to visualize the performance of flows and operations in a warehouse. The benefit of the allowance of lean management practices in warehouses is strengthen by Dotoli et al. (2015), Leon et al. (2023), and J. C. Chen et al. (2013) who concludes that lean management improves operational efficiency in warehouses. Thus, WMS can further reduce waste and increase flow efficiency.

WMS is a beneficial tool to augment human decision making to increase the performance of system users (Binos et al., 2021). A WMS with a well-considered HCI interface allows users to effectively perform tasks, leading to increased efficiency. Adopting gamified elements can increase user engagement and performance (Passalacqua et al., 2020). Consequently, creating a more interactive user-machine environment is beneficial for the system to function as intended and increase user involvement and abilities which leads to the overall warehouse performance enhancement.

5.6 Data processing and analytics

Harnessing stochastic models and methods within the scope of a WMS functions lays the foundation for data processing and analytics in the reviewed literature. The reviewed literature emphasizes the need to regard the occurrence of randomness in warehousing. Fattah et al. (2016) and Leon et al. (2023) means that incorporating measures that to some degree consider the possibility of an event being random can enhance the most adopted deterministic strategies. Thus, stochastic models and algorithms better account for a realistic warehouse environment.

Data mining and association rule mining does not necessarily account for randomness, but it is the most brought up example of how a WMS can better and more realistically process and analyze data to improve warehouse operations. The incorporation can identify patterns regarding SKUs historical demand and create relationships between SKUs which can be used for e.g. better storage allocations and predictions (Chiang et al., 2011). However, it is important to note that data mining requires historical data to mine. Therefore, it is not applicable for new SKUs or SKUs with limited historical information.

EDI is rather a tool used for communicating processed data and works along a WMS to streamline processes by reducing the number of manual activities required (Haj & Dhiaf, 2019). Consequently, EDI reduce waste in terms of time-inefficiencies. EDI that derives data and information from WMS can further streamline communication channels with entire SCNs by effectively and automatically distributing information.

5.7 Internet of things

Among the reviewed literature, the integration of IoT and its including technologies in WMS is the most described general method to optimize warehouse processes and increase efficiency. IoT in a warehouse context is described to be used to convert manual practices to automated processes and provide real time information of events (Khan et al., 2022). Referring to the automatic intercommunication of occurrences and smart network creation IoT allows, warehouses shifts to become living entities. Thus, IoT technologies can recognize warehouses stochastic nature and create real-time responsiveness.

The combination of RTLS and WMS is briefly described by Du (2021) and Benack et al. (2022), who means that it can facilitate analysis of warehouse performance. Utilization of RTLS can allow responsive decision making. For example, congestions and non-compliance can be identified by monitoring heat maps which allows managers to actively intervene when necessary.

RFID is the most considered type of sensor to be used in warehouses to optimize procedures. Pane et al. (2018) concluded that RFID outperforms its comparable alternative (barcodes), and means that RFID simplify work procedures, reduce operational time, and diminish scanning errors. Consequently, the application of RFID technology reduce waste and is in line with the creation of flow efficiency and lean principles.

An UAV is a type of technology related to IoT that has been studied in a warehouse context by Yang et al. (2023) and Beul et al. (2018). UAVs area of use is presented as wide and potentially beneficial to conduct tag readings and inventory counts while functioning as monitoring devices. However, how UAVs can optimize the procedures is speculative and certain areas of concern remains unanswered. Simultaneously, their reading capabilities are presented as limited. Thus, current UAVs shall not be considered as tools that can optimize warehouse operations.

5.8 Enhanced interaction and visualizations

Findings related to how incorporating interacting and visualizing technologies in WMS can improve warehouse operations is limited but relevant to include and discuss in terms of how it can simplify operations. It involves HCI, regarding how complementary technologies can be implemented to enhance human-computer collaboration.

Making use of new and emerging technologies like AR to streamline procedures is considered highly relevant by more recent studies. Primarily, AR can simplify operations from a user-centric perspective by visualizing picking routes and SKUs to be picked (Zaman et al., 2023). This in turn leads to increased efficiency of the picking operation. Similarly, adopting voice directed systems can both simplify operations and increase flow efficiency (Klabusayová, 2013).

Simplifying optimal but hard to interpret routing and picking strategies can improve users' compliance to WMS and therefore further constitute a partial solution for the presented challenge regarding the disobedience of travelling on suggested routes. Furthermore, previously discussed gamification elements can be incorporated with AR and voice directed systems to increase employee engagement which correlates with their performance. For example, goal-settings and feedback can be visualized within the AR or orally presented by voice terminals to create interactive and involving elements.

5.9 Operations enhancement

WMS functions during the receiving- and shipping process in warehouses are rather similar and less flexible compared to its application to the storage, routing, and picking functions. However, that should not be mistaken for WMS ability to optimize the operations performed during said flows. Fixed RFID readers located where all units pass when receiving and shipping can completely automate the inspection of quantity and update of inventory levels (Khan et al., 2022). EDI can further utilize SCN communication by automatically trigger a response once an event is recorded (Min, 2006). This can for example be the automatic confirmation, including a generated packing list, that an order has been shipped which is sent once a fixed RFID reader in the shipping area record the shipments departure.

Rahman et al. (2023) stated that optimal picking is strongly correlated to routing distance and travel time which in turn is depending on storage allocation. On similar terms we can see that the largest focus in current literature is based on solving the SLAP and optimizing storage location. This since it greatly affects the routing and picking. Various approaches to optimize storage locating assignments is presented and more recent studies focus on adapting newer emerging solutions that is based on association rule mining and considers warehouses as stochastic environments. This constitutes a clear shift from the most adopted storage policies (random, class-based, and dedicated) that are fixated on isolated decisions and rigid definitions. This is exemplified by Leon et al. (2023) who presents a stochastic algorithm that factors in a degree of randomness and Tufano et al. (2022) who presents an algorithm that creates associations based on historical data.

There are no studies that propose similar suggestions to routing and picking strategies. WMS are in these cases rather presented as systems which facilitates the use of specific and traditional policies. Different variations of clustering and order batching are the most proposed picking policies to be used to increase productivity of picking and reduce routing time. In these cases, a WMS can calculate the optimal batches based on a defined set of considerations. For example, Menéndez et al. (2017) proposed to batch orders based on closest due date. Regarding routing strategies, WMS is mostly presented as a tool that can adopt a specific dedicated routing strategy that effectively determine the routes pickers should take. However, none of the reviewed literature emphasize how an optimal route is calculated.

5.10 Technology in society

By addressing the environmental and ethical aspects of a WMS, organizations can demonstrate their consideration and acceptance of their social and sustainable responsibility. This approach fosters a holistic organizational perspective, aiming to achieve a balanced and responsible use of technology like a WMS.

Despite the research delimitation of investigating the potential environmental impact within the scope of a WMS, it is important to consider and discuss a WMS as a tool and technology playing a role in society. A WMS could be seen as an indirect tool to establish more sustainable practices. A WMS ability to effectively utilize resources and increase warehouses overall efficiency can allow the reduction of energy consumption which in turn reduces carbon emissions. For example, by being able to reduce errors in receiving, picking, and shipping operations (J.C. Chen et al., 2013; Jumahat et al., 2023; Pane et al., 2018) a WMS can contribute to the reduction of resource-consuming returns and rehandling of goods.

As a controlling and monitoring tool, a WMS can limit the number of lost or damaged SKUs which in turn reduce the need for reproduction and transportation of replacements. Consequently, waste is reduced, contributing to more sustainable practices. Moreover, a WMS can influence segments outside warehouses, within entire supply chains, through effective information sharing (Engelseth & Gundersen, 2018; Tong et al., 2023). Thus, a WMS can indirectly affect activities and operations with a broader environmental impact.

However, it is important to note that a WMS consumes energy and relies on IT infrastructure (servers, data centers, and networks) which requires energy and resources. Therefore, conducting a thorough cost/benefit analysis is essential to determine if the energy used to operate a WMS is less than the energy savings from a WMS.

Furthermore, a WMS can reduce manual labor and activities in warehouses, for example by adopting algorithmic solutions for storage location assignments (Leon et al., 2023) and RFID readers to automate scanning procedures (Khan et al., 2022). The reduction of such tasks can make work less grueling. AR can simplify procedures (Jumahat et al., 2023) and UAVs have the potential to completely substitute high-risk manual tasks (Beul et al., 2018), which further may reduce the risk of labor-related accidents, leading to a more secure work environment.

However, automation of tasks can swiftly change working conditions, reduce decision autonomy, and decrease job opportunities for human workers. This stipulates the formulation of workers stress of maintaining their jobs due to their fear of being replaced by machines as concluded by Ali & Kaur (2022) and Llopis-Albert et al. (2019). Therefore, organizations must consider their social responsibility and manage these changes responsibly to protect the well-being of their employees.

Moreover, a WMS handles large amounts of data related to inventory and shipments, which can be very sensitive and need protection from unauthorized access and breaches. Consequently, this necessitates robust security measures for organizations to build trust with stakeholders and comply with regulatory requirements.

A WMS poses both environmental and ethical challenges as well as opportunities. By proactively addressing these aspects, organizations may not only enhance their operational efficiency but also contribute to society. Thus, organizations shall acknowledge their responsibility, ensuring that their implementation and use of WMS align with broader social goals.

6. CONCLUSION

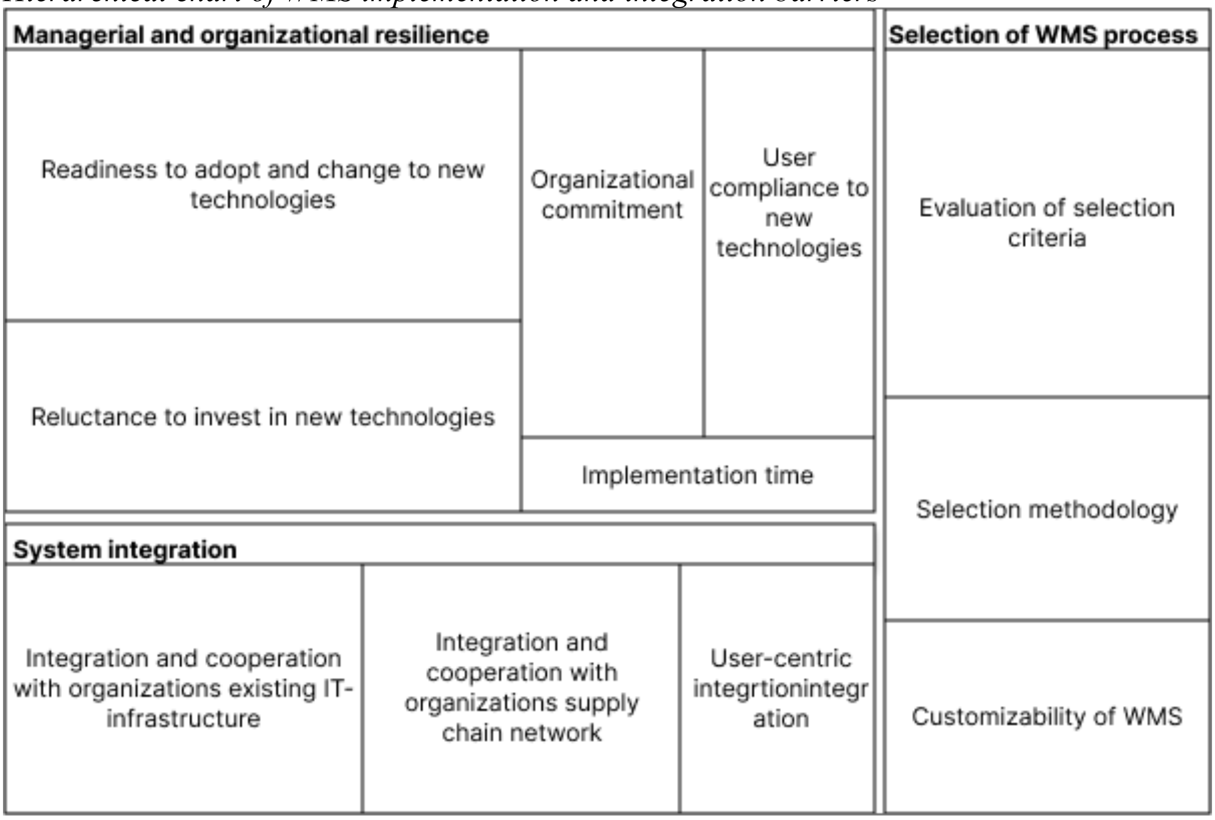
This chapter summarize the found results of the literature review in relation to the respective RQs. The chapter is divided based on the two RQs and structurally presents key findings of significance regarding the aim of the study.

6.1 Research question 1

To fulfil the aim of study in this thesis, challenges and barriers hindering the successful implementation and integration of a WMS was initially investigated. The gathering and review of literature identified three main barrier themes including a set of sub-barriers. The respective weight in terms of number of literature accounting for each barrier is illustrated by figure 3.

Figure 3

Hierarchical chart of WMS implementation and integration barriers



The selection of WMS process as a barrier to the successful implementation of a WMS refers to the difficulty for organizations to effectively apply a selection method, realizing what criteria's a WMS shall comply with are of most importance, and understand that WMS need to be customized.

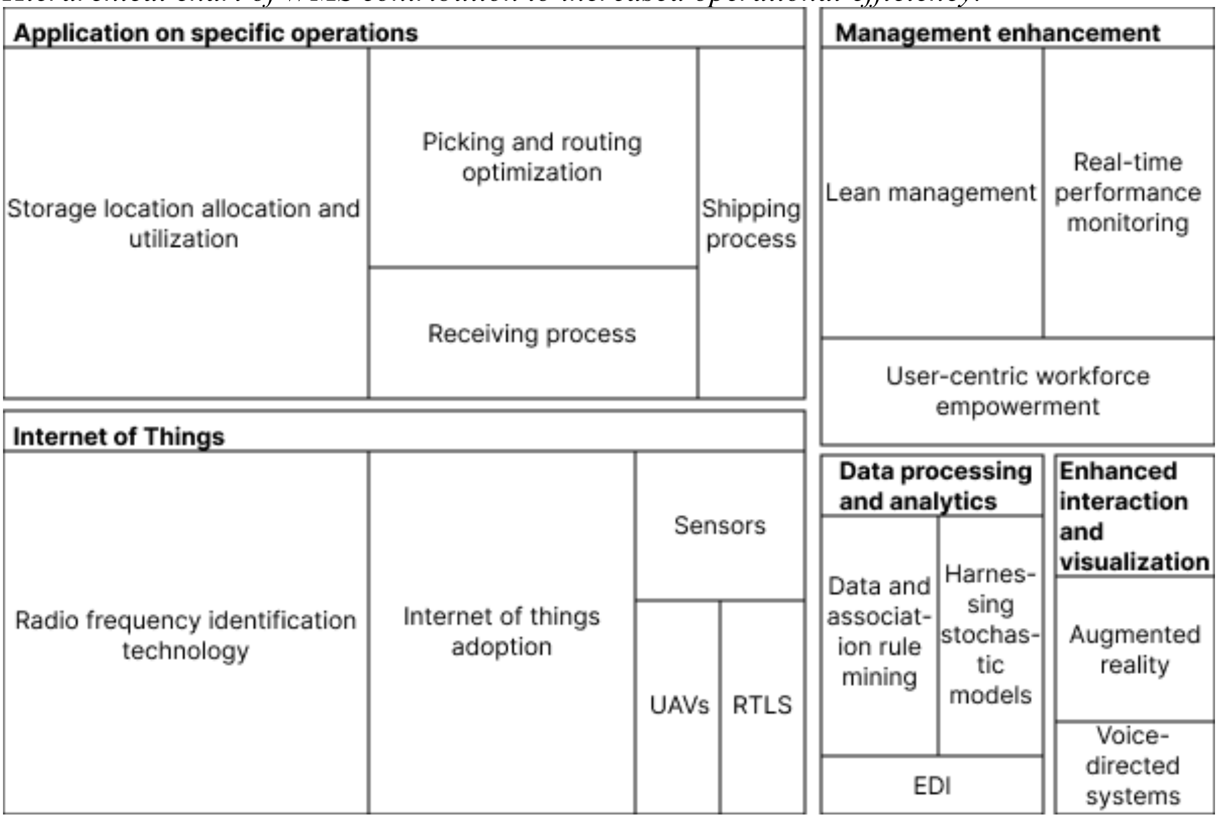
The system integration barrier primarily refers to constrains arising with WMS compatibility to operate effectively and as intended and function with other technical resources, both internally within organizations IT-infrastructure and externally with organizations collaborators. Reviewed literature further considers this barrier from a user-centric perspective, meaning that if a WMS shall function as intended, it needs to be used as intended.

The managerial and organizational resilience barrier is the most frequently accounted for barrier. Organizational readiness to accept and commit to new technology are the barriers most represented by the literature. Furthermore, the time-consuming process and cost of the technology establish a reluctance to implement a WMS. Lastly and similar to the integration barrier from a user-centric perspective, reviewed literature means that the change to new technology, altering the human-machine balance in warehouses, can create a cultural shock leading to frustration and obstinately among users.

6.2 Research question 2

To further fulfil the aim of study in this thesis, WMS contribution to the enhancement of operational efficiency in warehouses was investigated. The gathering and review of literature identified five main themes related to how a WMS can enhance warehouses operational efficiency. The respective weight in terms of number of literature accounting for each theme is illustrated by figure 4.

Figure 4
Hierarchical chart of WMS contribution to increased operational efficiency.



WMS enables improvement of the management of warehouses by providing real-time performance monitoring that managers can utilize for effective and responsive decision making. A WMS can further complement the application of lean management practices used to reduce waste and increase flow efficiency. From the user-centric perspective, a WMS can augment decision making to reduce the effect of humans limited cognitive resources.

WMS ability to effectively process and analyze data can further facilitate improved use of real-time recorded data. Consequently, WMS can consider warehouses as stochastic environments and account for random events and effects. Structurally collected data about warehouses historical activities and SKUs can further be utilized for data and association rule mining that WMS can advantage to determine optimal operational strategies. Lastly, the interconnection between WMS and EDI can automate and optimize both internal and external communication channels.

Warehouses adoption of IoT, functioning in connection to WMS, can enhance warehouse operations by effectively automating previously manual processes and data communication. Furthermore, RTLS can be combined with WMS to extend the range of possible analyses. Sensors that can detect physical events, convert it to data, and distribute the data to WMS is a type of IoT technology. RFID technology is a type of sensor and the most recurring pillar among literature referring to improving warehouse operations with IoT technology adoption. The benefits of applying RFID technology primarily refers the atomization of data recording and distribution to WMS, leading to reduced errors and operational time. UAVs is further exemplified as an IoT technology, but more research and development are needed to determine its functional benefit for improving warehouse operations.

Adopting interactive and visualizing technologies in coherence to WMS can facilitate the simplification of operation execution, resulting in the reduction of errors and time to perform tasks such as retrieving SKUs.

WMS ability to improve warehouse specific flows and corresponding operations is mostly visible in the receiving and shipping process together with storage, picking, and routing strategies. The improvement of the receiving and shipping process is similar because of the similarity of operations performed within the processes, and mainly refers to the automation of scanning and updating inventory. WMS can further be utilized to perform advanced calculations determining optimal storage locations, routings, and picking strategies to reduce the response and handling time of orders.

7. RECOMMENDATIONS FOR FURTHER RESEARCH

The literature review summarizes existing literature within the scope of the investigated RQs and provides a fundamental overview of the conceptual use of WMS and challenges arising when implementing said system. This to synchronize elemental and process specific literature. Consequently, future research may use this work to create an overview of the importance and function of WMS to further delve deeper into how WMS along with emerging technologies can optimize specific warehouse processes.

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