Aalto University
School of Business

Optimizing warehouse operations using automation and artificial intelligence

A comparison through a benchmark company

Bachelor's Thesis
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Information and Service Management

Fall 2021

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Title of thesis Optimizing supply chains through automation and artificial intelligence

Degree Bachelor's degree

Degree programme Information and Service Management

Thesis advisor(s) Markku Tinnilä

Year of approval 2021 **Number of pages** 24 **Language** English

Abstract

Modern customer requirements in different fields require companies to adapt to the ever-changing situations. The field of logistics is by no means exempt from this. Companies with warehouses around the world need to be able to react quickly to orders that could be sent halfway across the world. This thesis examines the possibilities that companies have, to optimize their operations to match the requirements of the modern world. The focus point is the optimization of operations with the usage of automation and artificial intelligence. This paper will also present examples of issues with a benchmark company that could possibly be solved by implementing automatized processes into their operations along with artificial intelligence.

The findings presented in this thesis include the adoption of automated warehouse management systems to improve the collecting efficiency. It will also demonstrate the benefits of implementing automated storage and retrieval systems that evidently reduce the amount of spoilage and improve the storage, shipping and picking accuracy. The benefits of artificial intelligence are introduced. They include optimized route planning for the collecting phase as well as increased accuracy in inventory planning.

Overall, this thesis demonstrates on a theoretical level, why adopting automation and artificial intelligence should be considered by all warehouse managers. The vast benefits and solutions that are presented in the findings from previous literature are finally compared to the operations of the benchmark company and they provide insight as to why at least the benchmark company should further investigate the possibilities of adopting automated systems along with artificial intelligence into their operations.

Keywords Automation, Artificial intelligence, Warehouse management, Optimization

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1 Introduction

Supply chains have existed for thousands of years. There has always been a need for transporting products to one place and storing them in another. In the modern world transporting goods is so natural to us that most people do not even tend to think about it, it is just something happening around us constantly. UPS or Amazon trucks and more recently Wolt entrepreneurs are a common sight amongst us and great examples of one part of the supply chains of different products.

These aforementioned examples are however just one part of the supply chains, and they happen to be highly visible. However, the products that they are delivering to the customer have to be stored somewhere. This is one of the not so visible parts of supply chains and will be the main focus of this thesis.

Artificial intelligence has been a growing field of study for years now. Implementation of AI into the operations of companies has been constantly growing and by 2020 25% of large US companies had implemented artificial intelligence into their operations (Koriacanac, 2020). Artificial intelligence as a term, or AI in this thesis, can be simplified to computer systems that perform like a human being would (Mahroof, 2019).

This thesis will discuss the benefits associated with adopting automation and artificial intelligence into the operations of warehouse companies. The issues and possible solutions are presented through a comparative study of previous literature and the current operations at a benchmark warehouse company located in the capital region of Finland.

1.1 Research objectives and research questions

Automation and AI are already used in the everyday operations of many companies, and they keep on increasing their popularity. Especially in car manufacturing, the use of robotics is a crucial part of the process. However, automation and AI have not been implemented in all fields yet. This paper intends to dive deeper into the depths of what is possible with the use of AI an automation in the field of grocery storing.

The research objective of this study is to demonstrate how automation and AI could be implemented in grocery warehouses and what the benefits of investing in them are. This

paper aims to demonstrate how automated warehouse processes could optimize the operations at the final warehouse of products before they are transported to various retail stores or directly to the end customer.

To help formulate an answer to my research objective, this paper aims to answer the following research questions:

1. What is the impact of automated warehouse processes?

2. How can AI and automation help reduce spoilage?

3. How can AI and automation be implemented into the benchmark company?

All in all, these research questions are meant to be answered in this paper and they will work as guidelines throughout the research.

1.2 Scope of research

The topics related to this research paper, automation, AI and supply chain management are all widely studied. Therefor this paper needs to be strictly focused on a certain aspect of these in order to be relevant compared to other studies of the fields. This paper will focus on the final stages of supply chain management, or simply the operations management of the final warehouse for groceries.

The research on AI and automation will be limited to what is applicable to a warehouse and what is actually needed in one in terms of collecting, storing and shipping the products. This paper will not cover the possibilities and requirements of automating the whole warehouse operation but rather the aforementioned processes in it. This way the research will not be too broad and lose its focus from the research objective.

1.3 Structure of the research

This thesis is structured into 5 chapters. The first chapter was the introduction section that worked as a build up for the following chapters. Chapter 2 consists of a literature

review that covers the theoretical background of the research. This chapter aims to provide insight as to what has already been studied on the subject and provide existing knowledge that can be used to support the research objective. Chapter 2 will also introduce the company I have worked at that will be used as a benchmark for this research

Chapter 3 will describe how I have conducted my research. It will introduce what supporting data is used to support the research objective and how it is collected. The final aspect of this chapter is how the collected data is analysed in order to find supporting claims for this research.

Chapter 4 will be focused on the results of my research. The main focus of this chapter is to answer the research questions and demonstrate what the data collected provided in terms of answering the research questions. Since this paper is based on a literature review, this chapter will go over the key findings from previous research and discuss how these findings can be applied to the research objective of this paper.

Chapter 5 will be a conclusion to my research with a summary of the key findings. Chapter 5 will include a section discussing the implications to previous research. It will also consider how my research could be useful in actual companies, or in this case the company that will be the benchmark for my research. To conclude chapter 5, there will be a section focussed on how the subject could be studied even further in order to make use of the findings in a larger aspect. This section will also go over the limitations to research.

2 Theoretical background

In order to make sense of the research for this paper, it is important to understand the theory behind it. Automation and AI are such wide subjects that the main ideas from them need to be clarified. This paper also focuses on operations management so that will be covered as well. This chapter will also introduce the operations of the benchmark company so that they can be considered in later chapters in light of the theory presented here.

2.1 Automation

Modern day requirements in the field of logistics requires companies to adapt automated processes into their systems. Currently there are five main ways that the order picking is performed in warehouses (Jaghbeer, Hanson and Johansson. 2020). These five ways are:

1. Collector manually collects items
2. Automated system works with collector by bringing them the item
3. A robot collects the items
4. A robot collects and pack the items
5. Completely automated system without robots or human picking, e.g., dispensers

The process in the benchmark warehouse belongs to the first category where a collector manually collects the orders, packs, and moves them to the shipping area. These are all part of the warehouse management system. The system works by controlling the processes in a warehouse, like collecting, storing, and receiving. Another key function is recording how much and of what product is coming in, shipped out or otherwise moved inside the warehouse (Ramaa, Subramanya and Rangaswamy. 2012). All this is done to improve the efficiency of the warehouse and keep track of inventory levels.

2.1.1 Automated warehouse management system

Just like in the benchmark company, human errors can have large effects on the efficiency and overall processes of a warehouse. Atieh et al (2016) state that human errors are one of the main reasons that automation is required in warehouse management. Atieh et al (2016) continue on by suggesting that a Business Process Modelling and Notation (BPMN) would be the start of the process towards an automated warehouse management system. This would allow the users to comprehend the current processes so that there is a base to start from.

The automated warehouse management system, combined with artificial intelligence that can learn from previous data and results, supervised learning, could very well lead to optimized collecting and storing. In order to optimize the whole collecting phase, the following stages of collecting need to be optimized (Broulias et al. 2005):

1. Travel time to the collecting space
2. Search time for the correct product
3. The actual collecting time of the products
4. The time it takes to transport the order to the shipping area

The optimization of these stages will be further discussed in chapter 4.

The automation of the picking process has been under intensive research due to the growing demand of fast paced orders from customers. A modern warehouse system needs be able to quickly react to changes and therefor the automation of some, if not all processes has become increasingly popular. Companies have begun using automated storage and retrieval systems in their operations to match the increasing demands and needs of customers.

An automated storage and retrieval system is capable of working the receiving, storage and collecting phases of a warehouse operation. Benefits of such a system also include the accuracy and efficiency at which the machine can operate (Manzini, Gamberi and Regattieri. 2005).

One order picking system is a dispenser-based automated system that consists of dispenser channels that pick out the correct amount of the right product based on the order (Caputo and Pelagagge. 2006). This process is not completely automated, however. Once a product runs out from the storage space so that the dispenser can not process it, the storage space needs to be manually filled. Caputo and Pelagagge (2006) go on and state that incomplete orders or otherwise faulty orders are to be manually completed, meaning that there is still a need for manual labour even with systems that are automated.

The benefits of using an automated storage and retrieval system and a warehouse management system have been studied to some extent by Nantee and Sureeytanapas (2021). Their research documented the findings reported by warehouse managers from two different companies about how the integration of automated storage and retrieval system along with a warehouse management system affected different criteria that were deemed suitable for the case study.

Table 1. Improvement ratings of economic performances of the two companies (Nantee and Sureeyatanapas. 2021)

Categories	Criteria	Improvement rating
		−2 −1 0 1 2
Productivity and resource utilisation	Equipment downtime	
	Work simplicity	
	Labour productivity	
	Equipment utilisation	
	Space utilisation	
Accuracy	Storage accuracy	
	Shipping accuracy	
	Picking accuracy	
	Damage and loss	
Responsiveness and flexibility	Warehouse order cycle time	
	Delivery flexibility	
	Order size flexibility	
Financial outcomes and market presence	Customer satisfaction	
	Operating costs	
	Profit	

As seen from the table, the warehouse managers from both companies reported an improvement in most of the criteria. The implications of the reported data to this thesis will be further discussed in chapter 4.

2.2 AI in logistics

Artificial intelligence is becoming increasingly popular in the business world with more and more companies using AI in their operations. Logistics is one field where all kinds of data are used to manage the supply chains and the single processes within it. The need for artificial intelligence keeps growing due to the globalization of supply chains.

According to research, three trends have been identified that are driving factors in supply chain management and logistics in general (Klumpp. 2018).

These trends are:

1. Optimizing global supply chains.
2. A need for supply chains to be agile
3. Increasing need and pressure for sustainable supply chains

In order for companies to stay on top of these trends, smart logistics is a driving force in modern day supply chain management. Artificial intelligence is able to learn from previous data and this can be used to find patterns and relationships within the processes (Nemati et al. 2002). The next segments will introduce what smart logistics is all about and how the industry 4.0 concept has been a driving force in digitalizing and automating warehouse management and logistics due to modern day requirements.

2.2.1 Smart logistics

Smart logistics can be characterised as technology driven logistics based on smart products and smart services (Uckelmann. n.d). Uckelmanns research demonstrates a few important functions of smart products that can be utilized in logistics.

- System recognizes items that belong to a cold chain
- The system can identify different items and their environment
- The system recognizes its location and issues a warning signal if the product doesn't fit in the location
- The system can identify if there is something missing

Within supply chains, following the products in various ways is crucial. Their location needs to be clear so that an estimated time of arrival can be planned but also their specific information needs to be followed. By this I mean that the name and specifics need to be registered as well as the condition of the products, has the cold chain been broken, are there dents in car parts when they arrive to the assembly line or was it the right product that was shipped. All these need to be taken into consideration for a successful supply chain in various industries. Technical components that form the successful monitoring bases of a product include identification, locating and sensing (Kirch, Poenicke and Richter. 2017).

As stated previously, tracking products throughout their lifecycle is crucial. Anandhi, Anitha and Sureshkumar (2018) present RFID tagging as the leading tracking method

due to the amount of data it can hold and provide. The RFID tag can participate on the Internet of Things and therefor a machine-to-machine connection can be made that then allows for the different parts of the supply to communicate together. This will in turn allow tracking of the state of products, meaning for example that has the cold chain been broken. Another benefit of RFID tagging is the accurate knowledge of products in inventory (Anandhi, Anitha and Sureshkumar. 2018).

According to Boute and Udenio (2021) supervised learning is, especially in smart logistics, the most common form of machine learning. In all its simplicity, supervised learning can be explained as having input and output variables and predicting the output of unknown variables based on the results from previous, so-called training inputs and outputs (Cunningham, Cord and Delany. 2008). Boute and Udenio (2021) present examples that supervised learning can be used in, in the field of logistics. These examples include demand forecasting, predicting the estimated time of arrival and predicting throughput times.

2.2.2 Industry 4.0

According to Klumpps (2018) trends in supply chain management, the modern supply chain and field of logistics need to be agile and flexible and able to cater to the ever-changing requirements of customers and the globalization of supply chains. A concept, formed in 2011 called Industry 4.0 caters to these needs. This concept meant increased digitization and automation of supply chains and processes in general (Lee et al. 2017).

According to the research by Lee et al (2017), customer requirements and the need for flexible processes has made the manual operations at a warehouse suboptimal. Furthermore, their research states that the order picking process, or collecting phase in the benchmark company, can accumulate 50-55% of all expenses from operating the warehouse. As a solution to this, Lee et al (2017) present their view of integrating fuzzy clustering technique to warehouse management systems. From this the system would come up with the optimal order picking or collecting method and this would lead to increased efficiency through the collecting phase.

The change from traditional warehouse management system to a more complex and capable management system has become evidently more and more necessary for companies that wish to thrive in the field of logistics. An intelligent warehouse management system has been generated to replace the traditional systems mainly due to their limitations (Pulungan et al. 2013). According to their research, Pulungan et al

(2013) demonstrate that the new intelligent warehouse management system has five sub-systems, each with different functions working to manage the operations at a warehouse.

These sub-systems are:

1. Intelligent logistics system
2. Adaptive warehouse system
3. Intelligent forecasting system
4. Realtime transportation monitoring system
5. Intelligent executive summary system

Table 2. Average picking route length reduction (Zunic et al. 2018)

Number of ordered items	Average length reduction after one month (%)	Average length reduction after nine months (%)
30-40	17.34	17.3
20-29	12.5	11.4
10-19	10	10.2
5-9	7.1	12.6
0-4	4.4	14.5

Table 1 demonstrates the reduction in picking route length in the research conducted by Zunic et al (2018). The results are part of a study from warehouses where they had integrated artificial intelligence algorithms throughout the warehouse management system. These specific results were gathered after implementing an algorithm that was designed to optimize the collecting route. These results will be further discussed in chapter 4.

2.3 The benchmark company

The benchmark company that is under review in this paper is a Finnish frozen grocery warehouse located in the capital region of Finland. It serves as a storage for companies such as Subway, Kotipizza, Valio, amongst others. I have gained extensive knowledge of the processes at the warehouse by working there as a collector and an instructor. Through

this knowledge I am able to analyse how the processes could be altered in light of the data that is gathered from previous research.

2.3.1 The three stages of operations

Currently the warehouse´s operations consist of three stages. First is the receiving stage where the products that are to be stored at the warehouse, are processed and unloaded from trucks. This is a manual job requiring a forklift to lift the pallets from trucks. The pallets are then scanned into the system so that they are ready to move on to the next stage.

The second stage is filling the storage spaces at the warehouse. For the sake of simplicity this stage will be called fillers in this paper. The fillers job is to collect the products from the receiving centre and place them in their assigned slots inside the actual storage facility. This was done by forklifts as well and there were generally 2-3 fillers per shift at the warehouse.

Another task of the fillers was to fill empty collection spaces. These were the so-called active storage spaces where collectors could come collect their orders. Due to the storage facility being so large and there being so few fillers, the active storage spaces were often empty, and this stalled the whole process. The fillers had their own task of moving products from the receiving centre to the empty storage spaces so at times there wasn't anyone available to fill empty active storage spaces.

The final stage of the operation was the collecting stage. Again, for the sake of simplicity, this stage will be called the collectors. The collecting stage worked as follows, the collectors picked up a list from the supervisor's office that contained the product and the amount of product that the customer had requested. The products were listed in alphabetical order to simplify the collecting route. The task in all its simplicity was to get an empty pallet or two on the back of the low forklift and start driving around the warehouse, collecting the products and piling them on the pallets. Once this was done the pallets were taken to the shipping area where they were wrapped in cling foil, marked, and left ready to be loaded on to a truck that would deliver them to the customer.

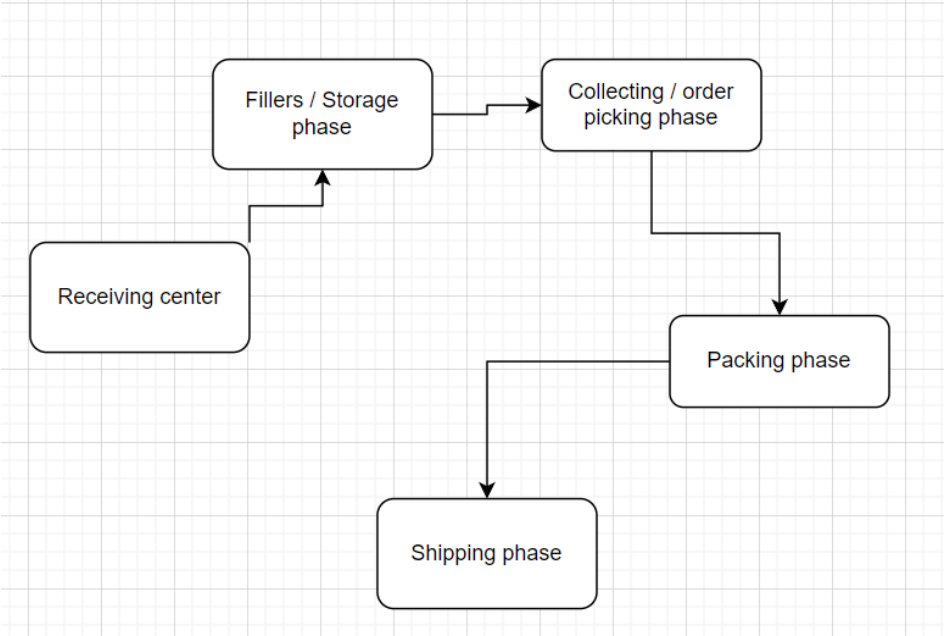

Figure 1. Flow chart of the processes at the benchmark warehouse

2.3.2 Issues with the collecting phase

The collecting phase had a few small details that needed to be taken into consideration for every order. Every time there was frozen meat on the order list, the collectors were required to weigh the box by scanning it with a scanner. Approximately half of the meat products however, required the weight to be manually filled into the scanner because the scanner did not register their barcode. This usually stalled to process of collecting, especially if there were loads of meat products to be collected.

If the collector did not realise the small mark on the order sheet that showed which products needed to be scanned and weighed, they would eventually have to take down the whole order form the pallet and find the barcodes of the products and scan them. This was because the system where the collectors listed their finished orders did not accept the order as finished if the products had not been weighed.

This leads to another issue that often stalled the process of collecting. Each order needed to be registered on a computer as finished so that they could be marked as ready to be shipped. This stage often stalled because they needed to be manually registered into the system by scanning a barcode and then filling out information. Many collectors and only two computers for this led to a que building up, especially on busy days.

Another key aspect that the collectors needed to take into consideration was that sometimes the active collection spaces were empty because like said earlier, the fillers

had their own task and could not always fill the active spaces on time. This meant that the collector had to first find a filler, inform them of what space was empty and then either wait for the filler to fill it as soon as they could or skip that space, collect the rest of the order, and come back to that space lastly so that they wouldn't waste time.

This process had two downsides to it. Either the collector waits for an unforeseeable time for the filler to fill the space or they risk forgetting to collect the missing products. Waiting for the filler meant that you lose time and might not achieve the required 100% collection efficiency during the day. Not collecting the correct amount on the other hand meant that the collector would be fined for the mistake and the fine amount would be deducted from their bonuses that started racking up every time they achieve a collection efficiency of more than 100%.

Another key issue was the amount of spoilage that formed every day. Granted that sometimes the fillers also dropped pallets, but the majority of spoilage was due to errors made by collectors. Everyone wanting to reach the strict requirement of 100% collection efficiency and possibly the bonuses after that caused pressure and collectors would try to be as fast as possible. This inevitably led to careless mistakes that caused the boxes to break meaning that they couldn't be shipped off anymore and were regarded as spoilage.

3 Methodology

The research for this paper is based on a literature review. The topics selected for review include warehouse management, automation, and artificial intelligence. Reviewing these subjects is crucial in order to understand the big picture behind this research. This paper compares the findings from previous literature to my personal findings at the benchmark company and hence the topics reviewed need to be narrowed down to only the relevant subjects. The main sources for previous research have been Google Scholar and Aalto Primo to some extent.

A literature review generally consists of four phases (Snyder. 2019):

1. Designing the review
2. Conducting the review
3. Analysis of the reviewed literature
4. Writing the actual review

The first phase consists of coming up with the research objective and in general, presenting why the research should be conducted. This stage was completed and recorded in the research plan for this thesis. The next stage of conducting the review is selecting the appropriate source materials and examining those to form a suitable network of references. Thirdly, the reviewed literature needs to be analysed in order to pick out the relevant information for this thesis (Snyder. 2019). The scope of this research was presented in chapter 1 and the literature studied for this thesis has remained within those set guidelines. The fourth and final stage is writing the review based on the source material, as done extensively in chapter 2.

For this paper, a literature review is the best source of material since the resources for me to test out for example optimizing the time it takes to fully collect an order or how much the overall productivity of a warehouse increases by automating certain products are non-existent. Therefor, reviewing literature based on research done by people with adequate resources or the possibility to do a case study with a warehouse company will provide me with loads of applicable information. This information can then be compared to the benchmark company and studied in light of the research objective and research questions.

The information that I have gathered for this thesis is fairly new. This is because even though the field of logistics and warehouse management has been studied for decades,

the breakthroughs in automation and artificial intelligence have been studied more thoroughly since the early 2000´s. Be limiting my research to more recent years, the literature review stays on top of only the necessary information required for this thesis.

Reviewing literature of course has its own downfalls, as does any other research method. For me it has been to find credible sources that can be used for this research. Reading and reviewing different literature based on the selected topics has allowed me to narrow my research to the ones that best demonstrate the understanding of the topic.

Since this thesis is based on a literature review, I cannot compare empirical data to my personal findings. The way the findings for this thesis are analysed is based on a thorough examination of the processes at the benchmark warehouse and then comparing this knowledge to the findings from previous literature. This will allow me to compare concepts that are in use at the benchmark company and concepts that could be used based as shown in previous research. By demonstrating an accurate knowledge of the current processes, I can provide insight as to how the concepts from other research could be integrated into the company's operations.

4 Results

The reviewed literature gave a broad spectrum of concepts that provide insight as to how the operations at the benchmark warehouse could be improved. The research findings are not, however, limited only to the benchmark company but all companies working in the field of logistics and warehouse management. Throughout the literature studied for this thesis, there was one common factor amongst the previous studies conducted. This was that in order to succeed in the modern competitive world of logistics, supply chains and warehouse management needs to take a dive and modernize operations to stay up to date with the ever-growing demand of globalization and customer satisfaction.

This chapter will discuss the findings from the literature reviewed and how they relate to the research objective, research questions and what they demonstrate when compared to the operations of the benchmark company. The first segment will demonstrate the key findings in terms of the research objective and research question. This chapter will conclude with the analysis of how these findings could be applied at the benchmark company when considering the different issues that there were with the operations.

4.1 Findings from previous literature

The review of previous studies on modern warehouse management and all other related literature presented in chapter 2 provided a deep understanding of the subject at hand. The research presented findings from different sources that all revolved around the same point of view. In modern warehousing and supply chain management the need for automation and the use of artificial intelligence is increasing constantly. The number of customers keeps on growing due to supply chains spreading widely across the globe. This forces companies to adapt to situations quickly and manual labour may not be sufficient to react accordingly.

Especially the order picking, or collecting phase, is something where human resources might not be sufficient in some companies simply due to the fact that order amounts and sizes are increasing. As mentioned in chapter 2, Lee et al (2017) state that the collecting phase can accumulate up to 50-55% of the expenses from running the warehouse operations. This alone could be a justification for automation of some if not all of the collecting phase.

All in all, the research of how artificial intelligence and automation could improve the operations at a warehouse are quite vast but actual documentation of it still remains fairly limited when compared to how largely studied the field of logistics is. The theoretical benefits are mentioned in numerous studies, but they have to be taken into consideration with caution. This is because different types of technology are used in different fields, and this is why some system in one field might not be applicable in another. For example, the product sizes in a car part warehouse are much larger and often irregularly shaped when compared to for example the pharmaceutical industry.

The main focus of most of the research was on the collecting phase of the warehouse operations. This specific phase was widely studied throughout the reviewed literature. Throughout the studies, numerous benefits were presented of implementing artificial intelligence and automation to the collecting phase. These benefits included more efficiency and accuracy in the collection process which in turn lead to a higher level of customer satisfaction. Like stated throughout this thesis, modern supply chain management and warehouse management require optimal performance in order to match the increased levels of demand from more and more international customers.

The overall clear benefits of implementing automation into warehouse operations include increased productivity. Automation also has a reducing effect on the number of defective products, less spoilage and general waste. In the modern world a company can also leverage their position against competition by integrating automation and artificial intelligence to their operations (Jagtap et al. 2020). This is because adapting automation and artificial intelligence helps build an image of being innovative and modern.

In the research done by Jagtap et al (2020), they also identify the different ways that automation and robotics can be used in warehouse operations. Their findings include some of the same that are presented in this thesis, but they also introduce new technology that can be used. They present an AGV as one of the solutions to improve warehouse operations. These are automated guided vehicles that can be controlled to move products around a warehouse. Another example of robotics that Jagtap et al (2020) mention in their research is the use of swarm robots that can move products in the warehouse. These robots move around on mounted railings.

Jagtap et al (2020) conclude their section on robotics by stating that automation and artificial intelligence are factors that are becoming increasingly popular in companies due to the development of the Industry 4.0 concept. This, however, does not mean that all companies are immediately willing to adapt to the new ways of managing a

warehouse. Their research states that some companies are unwilling to adapt due their perceptions of the costs included with adapting such technology. The initial investment cost and the true cost of maintenance is a concern among many within the logistics industry.

Table 3. Benefits associated with adapting automation and artificial intelligence into warehouse operations

Benefits of automation and artificial intelligence
- Increased collection accuracy - Decreased amount of spoilage and waste - Increased efficiency - Increased accuracy in inventory management - Higher customer satisfaction - Competetive advantage

Overall, the literature studied for this thesis provide an extensive review of the subject and present different solutions that can be adapted into different warehouse operations. The research that is specifically focused on food logistics is quite limited but the general ideas that are presented in research based on other subjects can be vied from a food logistics point of view.

4.2 Assessing the findings by comparing them to the benchmark company

The current operations at the benchmark company are generally old fashioned when compared to the findings presented in the reviewed literature. The operations that were the main focus of this thesis, collecting, storing and shipping, were manually handled at the benchmark company. Based on the reviewed literature, in order to maintain competitiveness amongst others in the field of food logistics, the benchmark company would need to adopt at least some of the aspects of automation and artificial intelligence presented in this thesis. This would allow them to optimize the operations presented in chapter 2, that did have faults and issues.

The operations at the benchmark company had three stages. The first being the receiving centre where the products that were coming from manufacturers were initially processed into the warehouse system. From there the second stage of operations came in and moved the products from the receiving centre to their issued storage spaces and active collection spaces. The third and final stage of operations was the collecting phase. During this phase, collectors manually collected products from their active assigned collection spaces onto pallets and once an order was complete, they transported the full orders on pallets to their assigned shipping area.

As stated by Broulias et al (2005), in order to optimize the whole collecting phase at the benchmark company, the travel time to the collecting space, the search time for the correct product, the time it takes to collect the item and finally transport it to the shipping area need to be optimized. At the benchmark warehouse the collection phase was the biggest cause of problems, as presented in chapter 2. An alternative solution to this issue could be to implement and automated storage and retrieval system as demonstrated by Manzini, Gamberi and Regattieri (2005). This would allow for a more accurate and efficient way of collecting and storing the correct products.

Another possible implementation into the benchmark company´s operations would be the adoption of a dispenser-based collecting system as presented by Caputo and Pelagagge (2006). The warehouse storage spaces are already built as rows and would provide the infrastructure for a dispenser on the lower levels where the active collection spaces are. This would reduce the risk of collectors collecting the wrong amount because the dispenser would give out the correct amount of product for every order.

The data presented by Nantee and Sureeyatanapas (2021) presents concrete evidence of the benefits associated with automated storage and retrieval systems along with a warehouse management system. The data presented in table 1 demonstrate unanimous improvements in storage, picking and shipping accuracy along with a clear decrease in the amount of damage and loss. The data collected also shows an improvement in customer satisfaction and space utilization in the warehouse.

Artificial intelligence along with automation can help further optimize the operations at the benchmark company. Tagging products with RFID tags can help locate the correct products faster than by searching manually for the product. This step is mostly aimed at the storage phase of the operations. The products were stored in empty storage spaces and those spaces sometimes were marked wrong in the storage system leading to missing pallets of products and therefor stalling the whole process because fillers could not fill

empty active collection spaces. An RFID tag would allow for accurate searching of the correct pallet of products. As stated by Anandhi, Anitha and Sureshkumar (2018), RFID tagging is the leading tracking method.

Reducing the time, it takes for the collector to travel around the warehouse collecting all the correct products is one of the factors that need to be optimized in order to improve the overall operations. Implementing artificial intelligence algorithms into the warehouse management system can be used to optimize this collecting route. Data presented in table 2 show clear reductions in the length of the picking route after one and nine months.

This can be seen as a benefit of artificial intelligence and could work to encourage the warehouse managers to adopt artificial intelligence systems in other aspects of warehouse management as well. Supervised learning as presented by Boute and Udenio (2021) could allow for improvements in for example demand forecasting. This would in turn allow for improvements in managing the number of employees working. At the benchmark company, there were often especially during the summer, loads of employees not working efficiently because there were too many at work due to inaccurate demand forecasts.

At the benchmark company, there is not a necessary need to automatize and implement artificial intelligence in all phases of operations. The clear need is strictly in the collecting phase. Adopting these solutions presented, could lead to a better flow of products and more towards optimized operations. One company working at the forefront of intelligent warehousing is AutoStore. Their system consists of robots working in a cubicle warehouse and utilizing an automated storage and retrieval system (AutoStore. 2021).

AutoStore as a company offers intelligent, automated warehousing solutions in the field of groceries, retail, third party logistics, industrial and healthcare. Their system provides accuracy and efficiency in collecting the right products on time. The company also promises the ability the increase the warehouse capacity quickly in order to match the modern-day requirements from customers during for example black Friday campaigns (AutoStore. 2021).

The system presented by AutoStore could be a valuable investment from the benchmark company at least in some capacity. The benchmark company requires adaptability especially during different holiday seasons when large quantities of certain products are ordered. All in all, the benchmark company requires increased efficiency in the collecting

phase and these solutions presented in this thesis could be of valuable assistance in redesigning their operations.

5 Discussion and conclusions

This section consists of an overview of how the findings and analysis presented in previous chapters, could work in favour of companies reading this thesis. It states how the findings could be used in a practical setting. The limitations related to this thesis are also covered. Finally, a few research ideas are presented in order to further investigate the overall issues presented in this thesis.

5.1 Implications to practice

The implications to practical usage of this thesis are vast. Loads of companies besides the benchmark company for this thesis struggle with modernizing their operations and are falling behind competition. Conducting better research into what is possible with the use of artificial intelligence and automation at a warehouse could help struggling warehousing companies adapt to the modern requirements of the field.

The findings presented in this thesis clearly demonstrate why automation and artificial intelligence are viable options for all companies working in the field of logistics. This thesis provides those companies an overview and platform to further investigate the modern requirements and how they could be matched. The field of automation and artificial intelligence are vastly studied through numerous different industries. This thesis however demonstrates the issues and possible theoretical solutions of one warehousing company still not performing at its full potential.

5.2 Limitations and future research

This thesis has of course its own limitations. The biggest one being the fact that the operations of only one warehouse company were studied and discussed in this thesis. This does not allow for comparison between different companies with similar operations to accurately distinguish the specific needs of improvement in the field of warehousing. This thesis justifies the benefits associated with automation and artificial intelligence but does not discuss weather the way the operations are handled could be one of the reasons for the issues explained in chapter 2.

Limitations in this thesis also include the inability to gather proper, current data from the benchmark company. This could have provided more justification as to why improvements in their operations are necessary. Proper data could also have provided

insight as to what the issues with the operations are in terms of statistics. Collectors were given a stat sheet at the end of each month with the exact number of orders they had finished, number of mistakes reported from the customers and other advanced data. These numbers along with a careful analysis of the operations could provide more information as to how to start improving the processes at the warehouse.

Future research on the subject could be conducted with interviews from employees from similar warehousing companies to offer a wider view into the core issues of the industry. Are the issues with waste only limited to the company discussed in this thesis or do similar problems appear in other companies within the field of food logistics? Because of worldwide issues with food being wasted and there being people with limited access to proper food, a solution to the spoilage issue should be studied more thoroughly from the warehouse management point of view.

As stated by Jagtap et al (2020) the costs associated with adopting new warehouse management systems and technology along with the perceived maintenance costs still remains an issue for some companies. Future research could be done to further understand the benefits of modernizing operations from a cost standpoint. How much is actually required to invest and run a company with modern automated systems? Presenting concrete numbers and statistics could help encourage companies to take a leap into the modern era of warehouse management.

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