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Making material handling more efficient - Reduction of non-value-adding activities at a wood products company

Effektivisering av materialflödet – reducering av icke värdeadderande aktiviteter på ett trävaruföretag

Karin Gyllengahm

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Summary

The forest industry is one of the most important businesses in Sweden, accounting for 9-12 percent of the Swedish industry's total occupation, export, turnover, and added value. Although the investments made by the Swedish forest sector reached a new record during 2017, the industry stills struggle with low profitability. Development of the value chain can be decisive for sawmills to raise their solvency, such as improving productivity and achieve cost-saving through adopting operations management initiatives. By identifying non-value adding activities, organisations can achieve flow efficiency and thereby improve the flow of material.

Material handling is considered as one of the most potentially profitable areas for cutting down costs, which involves several processes. Order picking is seen as the most important and most challenging process to optimise among the many operations that occur within warehouses. Professionals acknowledge order picking as the highest priority for productivity improvements since its operations have a significant impact on the overall performance as part of the logistics chain. The emphasis on quality improvement and customer service has increased, forcing managers to focus more on minimising product damage, lead time, and picking accuracy.

With this background, it became important to analyse the process of order picking within the forest industry and see if there are certain aspects to be considered to increase productivity and efficiency. The study aimed to identify non-value adding activities within the existing inventory management and material handling at a wood company, focusing on the order picking process. The intent was to explore opportunities for improvement with the support of operations management theory.

The approach was a single case study to gain a deeper understanding of the topic being studied. Both quantitative and qualitative methods were adopted, through focus group interviews, time studies, observations, and inventory statistics. The collection of data was analysed to conduct a value stream map and calculate the lead time for ten orders, corresponding to 81 order lines. The performance was measured for each order line, including productivity, cycle time, and financial measures. Further, an ABC analysis was carried out to divide the product range according to their importance and reasoning about inventory layout and material management. By identifying the non-value-added activities and causes of these wastes, improvements were further discussed.

The results showed that unnecessary inventory and transportation occurred most often followed by defects, waiting, inappropriate processing, and unused employee creativity. The number of unnecessary movements of packages occurred to a great extent. The main factors causing it were incorrect positions, unstructured storage areas, and non-standard packages. The recommendation is to allocate products according to demand and order frequency periodically, pick orders in direct connection to production, and to perform stocktaking regularly to make sure that the package's accessibility is consistent with reality. Further, the existing compartments should be utilised better to avoid temporary storage and mixed compartments which will decrease transportation and unnecessary movements of packages.

Keywords: *ABC analysis, agility, business modelling, inventory, inventory layout, lean, material handling, operations management, order picking, value stream map, VSM*

Sammanfattning

Skogsindustrin är en av de viktigaste sektorerna i Sverige och står för 9–12 procent av den svenska industrins totala ockupation, export, omsättning och mervärde. Även om investeringarna från den svenska skogsindustrin nådde ett nytt rekord under 2017, kämpar branschen fortfarande med låg lönsamhet. Utveckling av värdekedjorna kan vara avgörande för sågverk för att höja deras soliditet, som att förbättra produktiviteten och uppnå kostnadsbesparingar genom att anta verksamhetsstyrningsinitiativ. Genom att identifiera aktiviteter som inte tillför värde, kan organisationer uppnå flödeseffektivitet och där genom förbättra flödet av material.

Materialhantering betraktas som ett av de mest potentiellt lönsamma områdena för att sänka kostnaderna, vilket involverar flera processer. Orderplockning ses som den viktigaste och mest utmanande processen för att optimera bland de många operationer som sker inom lager. Experter hävdar att orderplockning bör vara högsta prioritet för produktivitetsförbättringar eftersom dess verksamhet har en betydande inverkan på den totala prestanda som en del av logistikkedjan. Tyngdpunkten på kvalitetsförbättring och kundservice har ökat, vilket tvingar ledningen att fokusera mer på att minimera produktskador, ledtid och förbättra plockningsnoggrannheten.

Med problembakgrunden i åtanke, uppstod ett intresse i att analysera processen för orderplockning inom skogsindustrin och undersöka om det finns vissa aspekter som bör beaktas för att öka produktiviteten och effektiviteten. Syftet med studien var att identifiera icke-värdeadderande aktiviteter inom befintlig lagerhantering och materialhantering hos ett träföretag med fokus på orderplockningsprocessen. Avsikten var att utforska möjligheter till förbättring med stöd av operativ ledningsteori.

Studiens angreppssätt var en enskild fallstudie för att få en djupare förståelse för ämnet som studerats. Kvalitativa och kvantitativa metoder tillämpades genom en fokusgruppintervju, tidsstudier, observationer och lagerstatistik. Insamlingen av data analyserades för att skapa en värdeflödesanalys och beräkna ledtiden för tio ordrar, motsvarande 81 orderrader. Prestationen mättes för varje orderrad inkluderat produktivitet, ledtid och finansiella värden. Fortsättningsvis, utfördes en ABC analys för att dela in produktsortimentet sett till betydelse och föra ett resonemang om lagerstruktur och hantering av material. Genom att identifiera de icke värdeskapande aktiviteterna och dess orsaker, kunde förbättringar senare diskuteras.

Resultaten visade att onödigt lager och transport skedde i hög utsträckning, följt av defekter, väntan, olämplig bearbetning och att personalens kreativitet inte togs tillvara på bästa möjliga sätt. Antalet onödiga förflyttningar av paket inträffade till stor del. De viktigaste faktorerna som orsakade det var felaktiga positioner, ostrukturerade lagringsområden och icke-standardpaket. Rekommendationen är att klassificera produkter sett till betydelse enligt efterfrågan och beställningsfrekvens med jämna mellanrum, plocka ordrar i direkt anslutning till produktionen och utföra inventeringar regelbundet för att se till att paketets tillgänglighet är förenlig med verkligheten. Vidare bör de befintliga facken utnyttjas bättre för att undvika tillfällig lagring och blandade produkter och längder i samma fack vilket minskar transport och onödiga paketförflyttningar.

Nyckelord: *ABC analys, affärsmodellering, flexibilitet, lager, lagerstruktur, lean, materialhantering, operativ ledningsteori, orderplockning, värdeflödesanalys, VSM*

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Thank you!

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Karin Gyllengahm

Abbreviations

Abbreviation	Explanation	First introduced
ABC analysis	A selected assortment is divided into groups or classes (A, B and C) depending on a certain value	Page 5
Half-package	A standard sized package once it has been processed from sawn timber	Page 27
KPI	Key performance indicators	Page 15
LAVC	Lean agile value chain	Page 7
VSM	Value-stream mapping	Page 1
WMS	Warehouse managementsystem	Page 6

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1 Introduction

This chapter provides a background to the study and the problem area around it which the study is built upon. Furthermore, the aim of the study and its research questions are presented. The scope of the study is also described and delimitations. The chapter concludes with the outline of the report.

1.1 Problem background

The forest industry is one of the most important businesses in Sweden, accounting for 9-12 percent of the Swedish industry's total occupation, export, turnover, and added value (Skogsindustrierna 2020). The forest industry does not only contribute to the Swedish economy to a great extent, but it also has a key role in the development towards a more sustainable and biobased society. From 1991 until 2018, the development of prices for wooden products has increased (Lindström 2020) and during 2017, the investments made by the Swedish forest industry reached a new record (Skogsindustrierna 2018), accounting for 23 percent of the total investments in the Swedish industry that year. However, the sawmill sector in Sweden still struggles with low profitability (Lindström 2020). Lindström (2020) believes that one of the reasons can be insufficient integration within the value chain ahead. Continuously, profitable sawmills are seen to have the ability to maximise utilisation of the logs for optimisation. This indicates that the development of new products and value chains can be decisive for sawmills to raise their solvency, such as improving productivity and achieve cost savings by adopting operations management initiatives.

With global competitive pressures, the forest industry and businesses in general, have responded by implementing a variety of strategies to enhance customer value and reach a successful supply chain management (Soon & Udin 2011). Supply chain management is referred to as integrating key business processes from end-customer trough suppliers that provide products, services, and information that are value-adding for customers and other stakeholders (Lambert 2008). An effective supply chain management requires concurrent improvement in both internal operating efficiencies and customer service levels. Offering customer service means consistently high on-time delivery rates, high order-fill rates, and a low rate of products returned. Internal efficiency within the organisation applies to find ways to lower operating and sales expenses (Hugos 2018). Logistics is a part of supply chain management, including planning, implementation, and controlling the storage of goods, services, and related information. Logistic management is about controlling the flow and make it more efficient.

To achieve flow efficiency, the need for a well-functioning operational logistics strategy is substantial (Sandberg & Abrahamsson 2019). In today's demand and supply volatility, value chains must react quickly when changes occur and even discover changes before happening (Sabri & Shaikh 2010). In other terms, being lean is not enough, companies must also be agile. Agility is necessary for contexts where the customer requirements for variety is high (Christopher 2000; Christopher & Towill 2001). An agile strategy is further argued to be applied in situations where the customer values a high level of service in the form of high accessibility and short lead times rather than low costs (Sandberg & Abrahamsson 2019). Both the lean and agile strategy requires minimisation of total lead-times from the point a customer places a request for a product until the products are delivered (Christopher & Towill 2001). By combining lean and agile models, an optimum strategy can be established and advantages can be reached to a greater extent (Reiner 2009; Sindi & Roe 2017).

To improve the flow of material and reduce non-value-added activities, organisations must understand where the waste exists throughout the supply chain (King & King 2017). Hence, value-stream mapping (**VSM)** has become an important tool for organisations to improve their material flow and productivity (Stephens & Meyers 2013). Furthermore, reducing costs and eliminating nonvalue added operations. VSM can be defined as the process to evaluate which components or step in the production that contributes to efficiency or product quality. By using the concept of VSM, organisations can develop the flow of material and information to improve the process further and reduce the excessive handling of material.

As of today, material handling is considered as one of the most potentially profitable areas for cutting down costs (Dongre & Mohite 2015). It is said that a company's production costs will automatically be reduced if the flow of material improves (Stephens & Meyers, 2013). It is argued that material handling accounts for 30–75% of the total cost of a product (Sule 1994; Sujono & Lashkari 2007; Dongre & Mohite 2015). Furthermore, greater efficient handling of materials can reduce the cost by 15-30% regarding the manufacturing system operations. The shorter the material flow is through the facility, the costs of reductions will be larger (Stephens & Meyers 2013). Material handling as such is not a production process, neither an activity that adds value to the product (Dongre & Mohite 2015). However, material handling is necessary to operate processes and get the products delivered to customers. But, depending on the material and its packaging, a higher degree of handling can increase the risk of damaging the goods (Lumsden 2006) which further impacts the value of the product. Within material handling, the focus should be to reduce the waste within its processes (Huber 2014). Order picking is one of these processes, an important one that stands for a great share of the total material handling costs. It is also one of the most labour-intensive functions (Frazelle 2016). Hence, hypothetically the margins should increase if the flow of material becomes more efficient and reactive to changes.

1.2 Problem description

Order picking "involves the process of obtaining the right amount of the right products for a set of customer orders" (Le-Duc 2005 p. 3). The activity is seen as the most important and most challenging process to optimise among the many operations that occur within warehouses (Habazin *et al.* 2017). Out of the four main activities that occur in warehousing; picking, shipping, receiving, and storing, the picking operations stands for the largest share of the total time and cost (Figure 1).

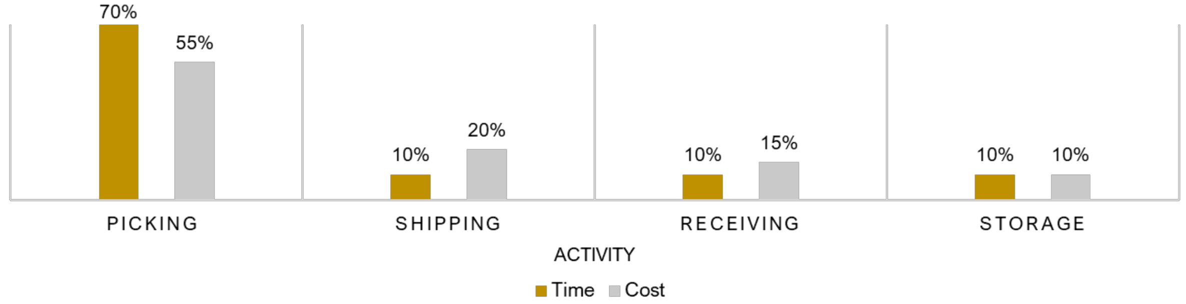

Figure 1. Percentage of annual operating costs in a warehouse (inspired by Bartholdi & Hackman 2011; Habazin et al. 2017 p. 60).

Professionals in warehousing acknowledge order picking as the highest priority for productivity improvements (Le-Duc 2005). Order picking operations have a significant impact on the overall performance since it is a united part of the logistics chain. Inefficiency can cause deficient service besides high operational cost, which consequently affects the whole supply chain.

Order picking requires resources, both in terms of a correct composition of products from a production point of view, such as administrative and physical labour. One other reason why order picking has gained such an interest "is the increased emphasis on quality improvements and customer service, forcing warehouse managers to focus more on minimising product damage and transaction time and improve picking accuracy" (Ong & Joseph 2014 p. 135). In terms of improving the order picking process, an understanding of the process itself is necessary to identify influencing factors and causes to why, and to what extent they affect the operations. It is found to be interesting to study activities within order picking that does not add value to the product, especially within the sawmill and wood processing industry. Since the industry still suffers from low profitability and the outcome could be improved if the value chains would become more decisive (Lindström 2020). Further, the delivery of wooden products is determined by the operation in inventory stocks and warehouses, namely order picking since the process shapes the form of service to the needs of customers.

Research regarding order picking activities within the forest industry is limited, hence it creates an interest in identifying parameters that are non-value adding to the organisation. The limited number of studies are further elaborated in the literature review. Continuing, the key to implementing an effective order picking system is to adapt it to the company's capabilities, space requirements, and technology to maximise the benefits of order picking and its customers (Petersen 2000). In that sense, it becomes appealing to analyse the process of order picking within the forest industry and see if there are certain aspects to be considered to increase productivity and efficiency.

1.3 Aim and research questions

This study aims to identify nonvalue adding activities within the existing inventory management and material handling at a sawmill – and wood company, focusing on the order picking processes. The intent is to explore opportunities for improvement during the process with the support of operations management. To assist in fulfilling the aim, two research questions have been formulated:

- Which activities affect the material flow and how do the activities interact and impact each other?
- Which changes on operation – and company level - can impact the material flow to become more time – and cost-effective?

1.4 Delimitations

This study focuses on the wood-processing facility driven by Sandåsa Timber AB, a Swedish sawmill – and wood-processing company. The company has a wide selection of products that requires large areas of storage place. Different types of products are distributed to multiple customers daily which demands a well-functioning material flow, involving administration and physical handling of packages to a great extent. The study has been limited to the activities that occur between the point a customer places an order until the goods are ready for loading. In terms of theory, the study will focus on adopting principles within the lean and agile value chain and material management and handling such as conducting an ABC-analysis. The study will discuss the basic understanding of order picking principles and inventory layout. However, the study will not intend to suggest a new inventory layout or change the current method of picking orders. The study will focus on how to make the current order picking process more efficient by identifying waste and further discuss suggestions on actions in terms of improving the process of the operations.

1.5 Outline

The study has been divided into eight chapters (Figure 2). Initially, it begins with an introduction with background, problem description as well as aim and research questions. The second chapter is comprised of a literature review with a review of scientific articles and studies in the field that the study intends to investigate. The third chapter presents the theory and relevant models of analysis that have been relevant to the study. Thereafter, methods and procedures for conducting the study are described in the fourth chapter. The fifth chapter is comprised of an empirical background with information about the company in the case, inventory layout, and the order process. Chapter six presents the empirics including an analysis of the results with parallels to the theory section and the empirical background. In the eighth chapter, the analysis is further discussed with parallels to previous studies and the empirical background. Finally, the study's conclusions will be presented concerning the study's aim and research questions including a suggestion for further studies.

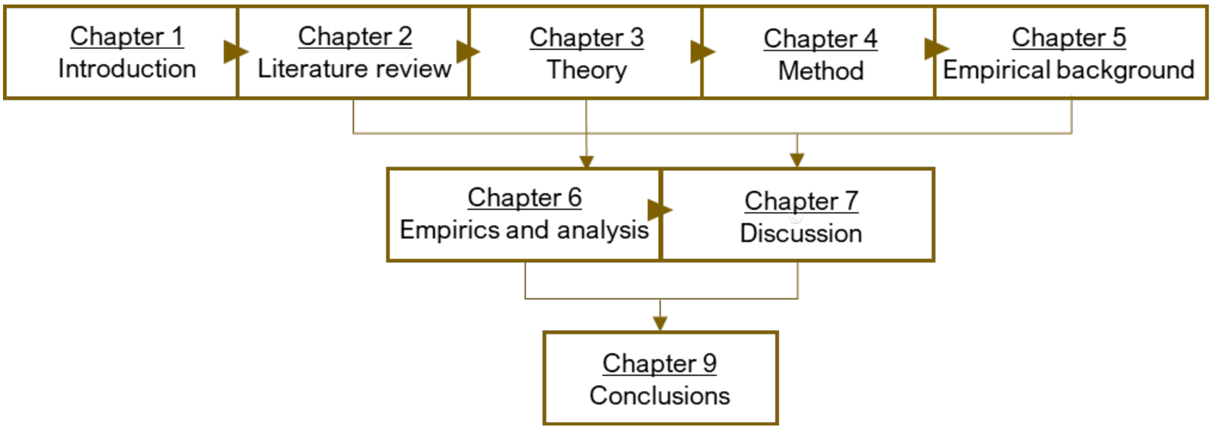

Figure 2. Illustration of the outline of the study.

2 Literature review

The section begins with a literature review of scientific articles and studies in the field that the study intends to investigate. The literature review concludes with a synthesis of identified knowledge gaps, focusing on the sawmilling and wood processing industry.

A literature review was conducted to obtain a picture of how the state of knowledge in the subject area of inventory layout and material management is applied in the forest industry and other manufacturing industries. The databases used in the literature search were SLU Primo, Google Scholar, WebOfKnowledge, Emerald, ResearchGate, and uppsatser.se. Keywords used were business modeling, inventory management, material handling, nonvalue adding activities, value stream mapping, LEAN, agile supply chain, ABC analysis, material costs, material flow, order picking, lead time, and logistics (including Swedish equivalents). The most relevant scientific articles and studies after the performed literature review are summarised in Table 1. The table is followed by an in-depth review of the most relevant ones including other found articles and studies.

Table 1. Selected scientific articles and studies within the literature review

Authors	**Aim**	**Method**	**Conclusions**
(Bild & Svensson 2019)	Find short – and long-term solutions on non-value-added activities in a material handling process.	Case study based on data collected through focus groups and interviews. Conducting a VSM.	In the order picking process, most of the non-value-added activities occurred resulting in the highest cost.
(Broulias *et al.* 2005)	Reduce the overall picking time in a timber goods production and trading company.	Collection of time data and observations to target improvements. Implementation. ABC-analysis.	Need for more systematic management, storage, and arrangement of products and more efficient routing.
(de Koster *et al.* 2007)	Identify typical decision problems in the design and control of manual order-picking processes.	Conducting a literature review focusing on the layout design, storage assignment, routing, etc.	Areas of storage assignments have matured in the last decade. Fast picking environments increases.
(Kevine 2018)	Illustrate the importance of ABC cross analysis for an effective allocation or management of products.	Observations and interviews. Two ABC analysis which resulted in an ABC cross-analysis.	ABC cross analysis is relatively efficient in terms of allocating products in the warehouse.
(Purba & Aisyah 2018)	Increase productivity by improving the working methods of the picking process.	Time and process flow analysis using VSM. Comparing picking methods.	Necessary to study and analyse the flow process. Analyse product by class periodically (demand rate).

Bild and Svensson (2019) conducted a case study with the intent to identify which non-value-added activities in the material handling process that occurs at a third party-logistic provider in Sweden. The researchers performed a VSM and identified non-value-added activities throughout the whole process, from the reception of goods until the goods were distributed. The summary of the performed VSM and non-value-added activities showed that they occurred most frequently during the order picking process. The identified wastes were waiting until the next activity could begin, unnecessary movements to collect products, unnecessarily long transports, and re-work by picking the wrong products. The authors claim that the transports are long because of the product's location. Some products are more frequently picked than others, but it is not something that is considered when storage takes place in previous activities.

Continuously, the authors suggest that the placement of products should proceed from order frequency to reduce transportation. Purba & Aisyah (2018) studied a Spare Part Center in Indonesia to identify and improve value-adding activities, also focusing on using VSM. By mapping the storage and analyst flow processes, including calculating picking time, grouping products by class according to demand rate increases productivity continuously in warehouse management. Since customer demand is ever-changing, and the requirement for fast deliveries, accurate and precise order services increases, the product by class division should be updated periodically. Further, the authors claim that analysing the flow process is necessary to study as the total time of order picking is determined by the traveled distance. Chen & Meng (2010) agrees with the fact that VSM is proven to be a good and useful tool to eliminate waste in a cycle and identify more waste to eliminate in the next cycle as a continuous process.

de Koster *et al.* (2007) conducted an extensive literature overview, reviewing about 140 papers to identify typical problems when decision design and control of order picking processes handled manually. The authors claim that publications in areas of storage strategies like family grouping, for example, is still limited. Although storage assignment impacts the performance of routing, it seems to have been neglected in the literature. Instead, researchers are focusing on discussing routing methods when random storage assignments occur. The authors further claim that many researchers treat demand as given, which is not true. Peculiarly, in fast picking environments which becomes more of a daily practice. Finally, the authors conclude that general design procedures and optimisation models are still lacking within order picking. Researchers should also focus on applying methods that can be generally drawn instead of only focusing on a specific situation or problem.

Broulias *et al.* (2005) conducted a study to reduce the overall picking time in a timber goods production and trading company. The study was divided into three stages, the first stage included measurements of the present situation. The authors divided the picking procedure into four phases: travel time, search time, retrieval time, and return time. 15 order plans were time measured. In stage two, suggestions based on the first measurements were stated. Some of the suggestions were adopted by the case company. The company adopted a simple warehouse management system (**WMS**) to speed up the tracing of products and they also changed the location of products based on an ABC analysis to reduce retrieval time. The authors further suggested extending the storage space to reduce the storage depths. However, this did not occur since it required an additional warehouse. A second measurement was thereafter made (stage three) after the suggestions were implemented, resulting in a reduction of the total picking time by mean 50 %.

ABC analysis has been made in other studies to allocate products with the purpose to avoid wastage of time by doing unnecessary works. Kevine (2018) sought to bring out the effectiveness of an ABC cross-analysis which is a method to classify items into more than just one class (factor). The author performed two ABC-analysis based on the sales value of 20 products and the order frequency value of the same items. The items were then arranged in a matrix consisted of nine classes. The cross-analysis was made to achieve a complete set of information to prioritise certain items and achieve an effective organisation of products in the warehouse. The author found that although certain products are of high value, they are not always highly requested in terms of order frequency. Carrying out an ABC cross analysis is claimed by the author to make the allocation of products more effective and as a result, reduce the expected retrieval time. De Felice *et al.* (2014) also argues that a single ABC analysis is limited because it only accounts for one criterion. The authors further state that many factors could be considered within a cross-analysis to decide a more suitable management method.

Such as frequency of use, production criticality, and damage risks among others. Arnesson & Bergqvist (2018) conducted a study focusing on the placement of products to rationalise order picking activities at a large warehouse distributing car parts and components in Sweden. The authors performed an ABC cross-analysis based on order frequency and weight as weight according to the employees often tend to stop the order picking activity. They further suggested that the important products according to the analysis should be placed near the entrance and far out on the shelves as cost savings are achieved due to less transportation.

Further, searches on scientific articles and literature with different combinations of concepts mentioned previously were made adding "sawmill" to the search. The number of hits is presented in Figure 3. The searches were done in Google Scholar with the restriction that every word must exist in the literature.

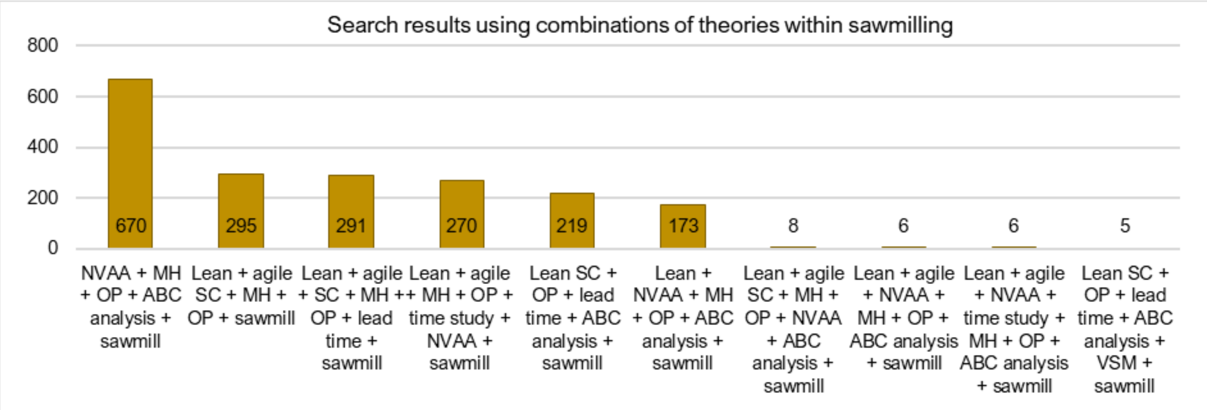

Figure 3. Search results using combinations of concepts within sawmilling.

The search words are presented as abbreviations and the number of articles and literature is viewed as data labels in the diagram. The searches show that very few articles and overall literature have been made on lean and agile supply chains **(LAVC)**, non-value-adding activities, lead times, time studies, material handling, order picking, VSM, and ABC analysis within the sawmilling industry. However, it must be stated that the searches have been made using only on search-web and further, other terms for the chosen concepts could have been used in other articles and literature. Apart from that, it can be claimed that few studies have been made using a combination of lean and agile supply chains, VSM, and ABC analysis with a focus on material handling, order picking, and lead time. In combination with the fact that the sawmill – and wood processing industry operates at a competitive market, it becomes interesting to study how and if, mentioned concepts can be applied at a wood processing company and to what extent material handling and order picking can become more efficient.

Mathematical models, algorithms, and simulations have been developed by several researchers to rationalise the order picking process and increase productivity among warehousing activities (Theys *et al.* 2010; Yu & de Koster 2010; Ene & Öztürk 2012; Chen *et al.* 2015; Altarazi & Ammouri 2018). Analytical models, mathematical programming, and simulation are popular research methods to analyse the combinations of problems within order picking planning (van Gils *et al.* 2018). In terms of simulation techniques, it is particularly useful when redesigning operational rules within order picking according to Chackelson *et al.* (2011). Shqair *et al.* (2014) claim though that the development of mathematical models is difficult because of the randomness in operations and the variety of parameters affecting them. Although it is found to be popular conducting statistical studies involving methods mentioned above, an in-depth literature review will not be conducted regarding these kinds of research. The order picking process at the case company has previously not been studied. Which strengthen the contention that mathematical programming and simulation were not suited to be applied since the current state of the order picking process and influencing factors should firstly be understood. With the support of previous studies and research, the focus will be on identify the process and evaluate it using theories and tools within operations management.

It is made evident through the literature reviews that research regarding order picking is a rather popular process to study since it is the most time consuming and costly task to perform in warehousing and a process to prioritise. As previously mentioned, a lot of the research papers aim to develop algorithms, models, and simulations to comprehend the challenges. Further, a great portion of the reviewed literature focuses on comparing routing methods and order picking methods to determine which one is the most effective and productive, mainly to reduce the travelled distance. However, the apprehension is that studies aiming towards rationalising the existing order picking process, focusing on non-value-added activities without changing the order picking methods and storage assignments is limited, especially within the forest - and the wooden industry. The perception is that sawmill – and wood processing facilities is not built-up as traditional warehouses. This mean that the products are bulky and require larger storage areas, which can imply scattered stockholding and complexity. A knowledge gap is seemed to be been identified concerning rationalising the existing order picking process without implementing or compare certain methods and developing statistical models.

3 Theory

This section reviews the chosen theories and models for analysis within this study. The theory-chapter focuses on operations management, the overall meaning of a lean and agile strategy which is followed by a review of material management and handling. Further on, the concept of order picking, lead-time, and performance measurements are described such as the concept of value stream mapping and adopting an ABC analysis. The chapter concludes with the conceptual framework for this study.

Operations management "refers to the systematic design, direction, and control of processes that transform inputs into services and products for internal, as well as external customers" (Krajewski *et al.* 2015 p. 23). For organisations in both service as well as manufacturing sectors, operations management can be a source to gain competitive advantage since the business is only as effective as its processes. Operations management consists of a wide range of tools, concepts, and models between science and management, aiming at different goals regarding efficiency, quality, customer satisfaction, and competitiveness, among others. With the support of operations management, strategies, and theories have been chosen to address this study's´ objectives. The theory chapter begins with the lean and agile strategy. Motivated by the fact that lean refers to reduce the lead time of processes and agility relates to the coherence between the company and the market (Katayama & Bennett 1999). The lean and agile strategy is followed by the purpose of performing business modelling and VSM to identify which activities that occur and if and how they are valuable to the process being studied. Further on, the principles of material management and handling, including theories within order picking are reviewed followed by a tool, ABC analysis, to categorise products according to importance. The chapter ends with the conceptual framework for this study and how each theory and strategy has been applied.

3.1 Lean and agile strategy

The concept of Lean strategies is to provide a strong infrastructure to support manufacturing methods, reduce the lead time of processes, and minimise the cost from non-value added activities (Sabri & Shaikh 2010). However, lean value chains are not enough, they also need to be agile. Agility relates to the coherence between the company and the market (Katayama & Bennett 1999). Basically, it is a set of capabilities for meeting widely varied customer requirements in terms of price, quality, quantity, specifications, and delivery. In today´s demand and supply volatility, value chains must react quickly when changes occur and even discover changes before they happen (Sabri & Shaikh 2010). A combination of lean, which strives for excellence in execution, and agility, which emphasis planning and controlling variability complement each other. Together they form a hybrid strategy that is further defined as the lean and agile value chain or "leagile" supply chain (Konecka 2010). A comparison of the lean value chain and LAVC have been made by several authors. Sabri & Shaikh (2010) are one of them in whose review is presented in Table 2.

Table 2. Comparison of the lean value chain and leagile supply chain (inspired by Sabri & Shaikh 2010 p. 9 with minor modifications)

	Lean value chain	Leagile value chain
Primary focus	The factory	Customer and supplier
Strategy	Reducing waste, excessive materials, labour, replenishment requirements via pull	Quicker response and flexibility, quickly adapting to changing customer demands
Production environment	Requires relatively stable or predictable demand	Can handle both predictable and unpredictable demand products
Complement techniques	No intermediate storage, Just-in-time shipping and receiving	Frequent deliveries of small quantities, supply chain collaboration
Prerequisites	Timely visibility about inventory and production, automated data collections and real-time communications	Timely and intelligent visibility about inventory and production, automated data collections and real-time communications, tight system integration
Critical-to-success metrics	Inventory turns and asset utilisation	Response time and lead time

The primary focus when adopting LAVC is the customers and suppliers. LAVC enables companies to be flexible in various situations, such as rapidly responding and adapting to customer needs (Sabri & Shaikh 2010). The hybrid strategy is argued to provide important benefits for industries, such as improvements in visibility, lower inventory, faster time to market, and improvements in customer satisfaction.

3.3.1 Guiding principles within the leagile value chain

There are five main principles within the hybrid strategy according to Sabri & Shaikh (2010 p. 10-14). The five main principles are “focus on customer success” (1), “create win-win and a trusted environment for all stakeholders” (2), “eliminate waste and reduce nonvalue-added activities” (3), “institutionalise continuous improvement” (4) and “close the loop between planning and execution” (5). The principles are further explained below.

Focus on customer success

The first principle is being customer oriented. The company shall foster customer-satisfying behaviours and customise product and service offerings based on interactions between the customer and the company.

Create win-win and a trusted environment for all stakeholders

To get the stakeholders supporting the lean and agile initiatives, the company shall look beyond local improvement and strive to eliminate waste and continuously improve the entire value chain. Trust between supplier and customer is therefore important which can be proven through collaboration. Through a collaborative environment, organisations can learn how to become a better supplier to customers and better customers to their suppliers.

Eliminate waste and reduce nonvalue-added activities

This principle spurs companies to free resources to concentrate on value-added activities. Non-value-added activities are referred to as waste that has no value to the customer and further on, is not required to operate the business. The different types of waste are derived from the lean strategy which is further described in section 3.2.2.

Institutionalise continuous improvement

The challenge with any value chain is to identify the main cause of the problem and eliminate it. Hence, proactive elimination of problems and continuous improvement becomes essential. Companies are recommended to establish a single process based on the best practice for any frequent process and share it across the organisation. The opposite way, to let every business unit or operating location develop its own internal custom procedures is against the principle of continuous improvement and standardisation.

Close the loop between planning and execution

The fifth principle is primarily regarding the importance of measuring the performance of the value chain or a certain process within the value chain. A performance measurement system is among others, a tool to motivate people and identify areas of improvement by demeaning benchmarking. The authors claim that any performance measure should have seven parameters; the category and scope of the measure that it is addressing, performance target hat represents both internal – and external focus, a system to capture the actual performance, time period of the value, the accountable for success or failure of the measure, frequency of communicating and capturing and a set of actions plans if the target is not achieved.

3.2 Modelling business processes

Modelling of business processes has become increasingly popular when organising businesses and understanding value-adding processes (Aguilar-Savén 2004). The concept of modelling business processes is referred to by several names in the literature where there are only slight differences in the theories behind and in the execution. Frequently used terms are flow analysis, business process mapping, value flow analysis, and VSM. VSM is more detailed in terms of lead time and flow of both material and information. But the overall purpose is to optimise a process or a value chain by identifying value-adding activities and processes. The definition of processes is many but in essence, the meaning of them is all the same. According to Aguilar-Savén (2004 p. 133), processes are "relationship between inputs and outputs, where inputs are transformed into outputs using a series of activities, which add value to the inputs".

3.2.1 Defining activities

When conducting a VSM or a value flow analysis in general, activities are often divided into three categories (Olhager 2013): value-adding activities, non-value adding activities, and necessary non-value adding activities. Value-adding activities refer to activities that lead to changes in products to fully complete the item. Within the category of non-value-added activities, the main activities are transportation and storage. However, some people claim that transportation and storage are value-adding as they are required to make the product available for the customer. But in general, non-value adding activities refer to those that cause losses in time and costs. The third category, necessary non-value-added activities, comprises activities that support an effective transformation process for the product. For example, planning of procurements, production, and deliveries. These activities might not be value-adding according to the external customer, but they are essential to properly operate the business (Martin & Osterling 2017). The Lean approach is about prioritising these three types of activities. The unnecessary value-adding activities are 1st priority in terms of eliminating them. The outcomes of eliminating these, are faster delivery, improved quality, and a reduced inventory which leads to greater customer loyalty, among others. The 2nd priority is the necessary non-value adding activities by challenging and reduce these. The 3rd priority is the value adding activities, which should be optimised, as necessary.

3.2.2 Non-value-added activities

Non-value-added activities are often referred to as waste, which in the lean philosophy, and according to the Japanese is called *muda* (Trent 2008). However, non-value-adding activities are not necessarily wasteful which contradicts the perception that waste is a synonym to activities that do not add value. Activities that are referred to as waste add neither value nor move information or material closer to the customer. The products or material still need to be moved across the supply chain to the location where the customer wants that product. However, products and materials should not e.g. be moved or processed unnecessarily since it only leads to additional costs. That is the trough definition of waste. Eight types of wastes can be identified within inventory management and handling of material (Table 3).

Table 3. Non-value added activities/wastes according to Lean (Mostafa et al. 2015; Anđelković et al. 2016)

Waste	**Explanation**
1. Overproduction	Replenish, packing and picking products before they are needed
2. Defects	Activities caused by damage, wrong or mislabelled products, mistakes
3. Waiting	Includes waiting for control, picking, waiting for data
4. Unnecessary movement	Movement of employees caused by inefficient routing
5. Unnecessary inventory	Non-optimal use of space, excess of inventory
6. Transportation	Unnecessary transport of materials or products
7. Inappropriate processing	Unnecessary inspections, picking, and packing of orders
8. Unused employee creativity	Wasting the available knowledge, experience or skill of the employees

The seven first mentioned are considered traditional wastes (Trent 2008), as these were the ones which originally was identified. However, later on, an eighth waste was added to the list, *unused employee creativity* (Wahab *et al.* 2013; Mostafa *et al.* 2015). The eight waste was included within this study since human factors and characteristics according to Grosse *et al.* (2015) should be considered to enhance performance and quality when making decisions regarding the management of order picking. The statement by the author is further reviewed in section 3.5.1.

3.3 Material management and handling

Material handling involves loading, moving, and unloading materials, and the term is often used in reference to industrial activity (Ray 2008). In many cases, it is seen that competing industries use the same or similar production equipment, and those who use improved material handling systems can further increase their competitiveness. Implementing a well-functioning materials handling system can be summarised in the following essential requirements:

→ Safe and efficient movement of materials to the desired location
→ Timely movement of materials when they are needed
→ Supply of materials at the desired rate
→ Utilising minimum space when storing materials
→ Implement lowest cost solutions to the activities involving material handling

Further, a well-designed system attempts to achieve improved efficiency by delivering the right quantity at the right place at the right time. Reduce the overall cost, improve customer service, and reduce the damage of material during movement and storage (*ibid.*). When designing and planning the layout of warehouses, the overall aim is to reduce the amount of work-related to order picking (Kevine 2018). This can be fulfilled through appropriate and efficient design, balancing the trade-offs between utilisation of space, speed, distances, handling, access, and cost etcetera (Richards 2014).

3.3.1 Principles of materials handling

Certain fundamental principles have been developed over a period of time by experts to analyse and design solutions to challenges within material handling (Ray 2008). Twenty principles, that was originally stated by Hall (1965), cover different aspects of challenges associated with material handling within industries. Each principle applies to a certain aspect of material handling and some of them are hard to adapt depending on the surroundings and procedures at the individual company. Fifteen principles out of the original twenty are briefly reviewed and further explained in Table 4.

Table 4. Principles of materials handling (inspired by Ray, 2008 p. 9 with minor modifications)

Principle	**Explanation**	**Suggestions**
Planning	All handling activities should be planned	Consider the plant layout before design, plan the correct location for material supply and disposal
System	Integrate handling activities	Avoid/minimise intermediate storage
Material flow	Plan sequence and equipment arrangement for operations	Eliminate obstacles from material flow, combine activities to reduce material movement
Simplification	Eliminate, combine or reduce unnecessary movement	Eliminate re-handling, deliver materials at the correct location the first time
Space utilisation	Optimum use of building volume	Eliminate or minimise temporary storage
Unit size	Increase size, quantity, the weight of loads handled	Examine the possibility of unitising loads
Safety	Handling must be safe	Stack/unstuck materials safely do not overload handling equipment
Equipment selection	Consider all aspects when selecting handling equipment	Compare alternatives based on the cost of handling
Standardisation	Methods and equipment should be standardised if possible	Purchase standard types and sizes of equipment
Motion principle	Stoppage of non-stationary equipment should be minimum	Reduce loading/unload time
Idle time	Minimise unproductive time in terms of equipment and labour	Use indirect labour for materials handling
Obsolescence	Replace obsolete handling methods	Rent or lease new equipment to try out
Control	Use equipment to improve production, inventory control, and order handling	Synchronise materials handling with production
Capacity	Use material handling so that production can achieve full capacity	Make full use of building volume
Performance	Select handling systems with higher efficiency	Select convenient, common and standard equipment

The chosen principles in Table 4 have been selected according to suitability for the individual case within this study. Some of the suggestions may interfere with another. Hence, the principles should be carefully understood, and suggestions may be considered before implementation (*ibid.*).

3.3.2 Lead time

Time-measurements are suitable when analysing and describing flows (Oskarsson *et al.* 2013). Reduction of time often affect costs as well as delivery service in a positive matter. One of the key measurements is lead-time. Lead-times can be defined as the time it takes from the order placement until the customer has received its goods, but the lead-time can also be studied within smaller processes. In other terms, on several levels (Figure 4).

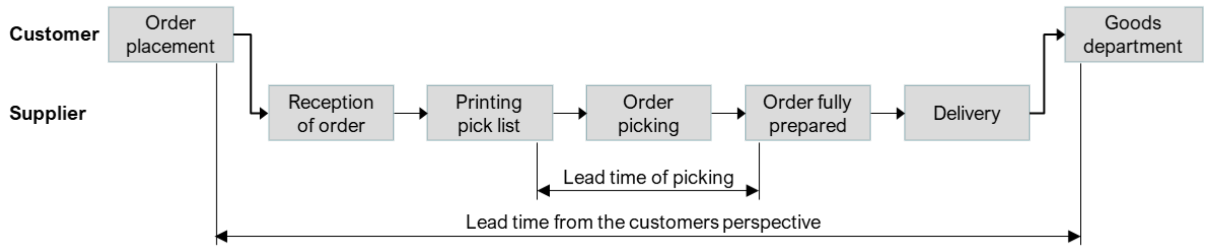

Figure 4. Lead times on several levels (inspired by Oskarsson et al. 2013 p. 189 with minor modifications).

Lead-times for smaller internal processes, such as the lead time of picking, are unusually measured regularly. These are often studied when there is a special need for it (*ibid.*). However, it is argued that order picking accounts for more than 50% of warehouse operations (Tompkins *et al.* 2010), which brings forth an interest on how the process can become more efficient. Further, by shortening lead time, companies can gain a competitive advantage in business because of the given ability to improve the service level to customers (Ouyang *et al.* 2007).

3.4 Order picking

Order picking is not only one of the costliest activities in a warehouse. It is also one of the most labour-intensive functions (Frazelle 2016). It is claimed that 55,4 % of the amount of time order pickers spend, is traveling which makes it the most time-consuming task. 18,4 % of the time is spent on searching and 14,9 % is spent on extracting. There are two general methods within order picking: manual or automatic (Oskarsson *et al.* 2013). When using an automatic method, some form of robots is handling the actual picking which is rather unusual. According to de Koster *et al.* (2007) and Gajšek *et al.* (2017), roughly 80 percent of warehouse operations are performed manually, with human resources. According to Oskarsson *et al.* (2013), there are three main principles of order picking (Table 5).

Table 5. Main principles of order picking (inspired by Oskarsson et al. 2013 p. 136)

Principle	Explanation
Pick by order	The operator fully completes one or more orders on time. If there are few order lines per order, the efficiency can increase if several orders are picked at the same time.
Pick by zone	The order is divided into zones within the storage area. Within each zone, operators oversee picking the items that are stored in that zone. In summary, several operators are working with the same order.
Pick by article	E.g. the daily consumption of one article is picked at the same time. The picked volume is later distributed to different orders.

Which principle to use depends on prerequisites. Pick by zone could e.g. be an alternative if there are narrow aisles in a warehouse with many high-frequent articles that could result in queues (*ibid.*). In addition to these three principles, there are other methods and sub-methods to adopt in a warehouse such as sort-while-pick, pick-to-parts, and pick-and-sort (de Koster *et al.* 2007). In this study, a deeper understanding of these different methods will not be discussed since the aim is to focus on how the current order picking process can be rationalised.

3.4.1 Objectives when optimising the order picking process

Multiple strategies have been developed over the years, with the overall aim to reduce the amount of picking time (Frazelle 2016). Since order picking is the most labour-intensive activity in warehouses, order picking is considered to be the highest-priority area for improving productivity (de Koster *et al.* 2007). When optimizing warehouse design in general and further focusing on order picking, certain objectives often are taken into consideration (de Koster *et al.* 2007 p. 486):

→ “Minimise the throughput time of an order”
→ “Minimise the overall throughput time (e.g. to complete a batch of orders)”
→ “Maximise the use of space”
→ “Maximise the use of equipment”
→ “Maximise the use of labour”
→ “Maximise the accessibility to all items”

Grosse *et al.* (2015) claim that many researchers have developed strategies for planning order picking activities and increasing efficiency by focusing on warehouse layouts, storage, and order picking routes and operating strategies. But that many studies fail to account for human factors or characteristics when planning order picking activities. The authors argue that human factors should be considered when making decisions regarding operations and management of order picking to enhance performance and quality by focusing on working conditions. Since humans are primary actors within the manual order picking process. Grosse *et al.* conclude that incorporating human factors in order picking models, could result in fewer errors and achieving higher workplace quality in order picking.

3.4.2 Performance measurements

Warehouse performance measurement is a way to measure activity performance, service, or program which a warehouse provides (Kusrini *et al.* 2018). There are multiple methods to use when classifying performance measurements at a warehouse, both quantitative and qualitative measures. Different classifications can further be expressed as indicators. Frazelle (2016) classifies performance measures into 25 key performance indicators (**KPI**) throughout warehouse activities. Among these, financial, productivity, utilisation, quality, and cycle time are indicators (Figure 5).

	Financial	Productivity	Utilization	Quality	Cycle Time
Order picking	Picking cost per line	Order lines picked per man-hour	% Utilization of picking labour and equipment	% Perfect picking lines	Order picking cycle time (per order)

Figure 5. Key performance indicators for order picking (inspired by Kusrini et al. 2018 p. 2 with minor modifications).

To measure the performance of order picking, five main indicators are claimed by the authors. Regarding the financial aspect, for example, picking cost per line is measured. According to the research made by Kusrini *et al.* (2018), the most important KPI for order picking was cycle time, as a result of studying five different construction material warehouses located in Indonesia.

3.5 ABC analysis

Studies have shown that ABC analysis can act as a tool to allocate products in warehouses to make material handling more efficient and further reduce the retrieval/order picking time. When creating an ABC analysis, a selected assortment is divided into groups or classes (A, B, and C) depending on a certain value (Oskarsson *et al.* 2013). The general idea behind an ABC analysis is to divide products into the most important items (group A), moderate important items (B), and the least important items (C) within a product range. The ABC classification builds upon the Pareto´s Law, or in other terms, the 80/20 rule (Richards 2014). Pareto´s Law states that roughly 80 % of effects come from 20 % of causes. This concept is not universal, but it can be applied in a surprising number of cases. Therefore, the idea behind the rule is to concentrate resources on the important 20 %. When dividing products into classes, it proceeds from that a certain percentage of products stands for a certain percentage of the chosen value. Within class A, Pareto´s Law is applied, stating that 20 % of the products produce 80 % of sales and thereby are the most important products. Class B contains 35 % of the products which produces 15 % of sales. The remaining 45 % of products produce 5 % of the sales which are stated as C-products. However, it is important to state that the precise classification of products will vary between businesses and different sectors. The proportions above are although very similar in the broad aspect. Richards (2014) further argues that performing a single ABC analysis will only consider one parameter, which can lead to a reduction in productivity as other important factors are set aside. This dilemma has been claimed by other authors, among them, De Felice *et al.* (2014) and Kevine (2018). Hence, ABC cross-analysis has increased in popularity. Cross analysis can consist of two or more single analysis of different parameters to divide them into several classes, the analysis can thereafter be visualized in a nine-box grid if the number of classes is nine (Figure 6).

	High frequency ←		→ Low frequency
Higher sales	AA	AB	AC
↑	BA	BB	BC
Lower sales	CA	CB	CC

Figure 6. ABC-cross analysis with several classes (inspired by Richards 2014 p. 82 with minor modifications).

In the figure above, an ABC cross-analysis have been carried out regarding sales volume and frequency in terms of how often a pick location is visited. I this case, AA products are those that are sold most frequently and generate the most sales. The CA class contains products that sell the least but are sold most frequently. Another way of taking several factors into account is by weighted volumes (Richards 2014). One example is given by the author. By multiplying the annual demand by the number of times the item appears on a pick list, a weighted volume is received which the ABC analysis then will be based on. By adding the frequency, a more appropriate layout design can be achieved in terms of decreasing travel time between the pick location and loading-spot. ABC analysis can be associated with class-based storage, which means that products are clustered into classes according to importance (Chackelson *et al.* 2011). The authors claim that "the principal advantage of this strategy is the reduction of travel time" (Chackelson *et al.* 2011 p. 307).

3.6 Conceptual framework

Based on the literature review and chosen theories, a conceptual framework for this study was conducted to fulfil the aim. The study has been divided into three fundamental steps: fundamental comprehension, identify the process, and analyse the process which is presented as the conceptual framework (Figure 7).

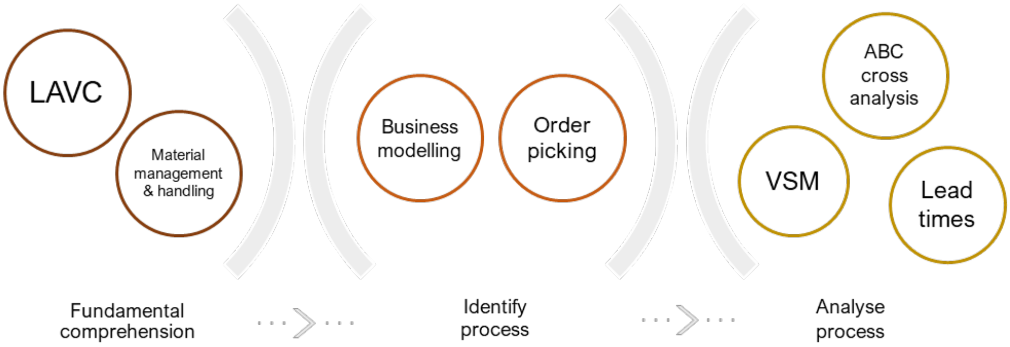

Figure 7. The conceptual framework for the study.

The fundamental comprehension of the concept is obtained by the theories of the lean and agile value chain (LAVC) and material management and handling. Principles within both theories are included to get an understanding of which conditions that must be fulfilled to achieve a leagile and effective material management and handling. Theories of business modelling and the concept of order picking is used when the process is identified. The theory about business modelling acts as guidance to model the process and the author's understanding of order picking acts as guidance to include necessary steps within the order picking process and impacting factors. Further, the process is lastly analysed with the support of theories within VSM, such as activities that are viewed as non-value adding and value-adding. The lead-times are calculated to find similarities and correlations between the properties of each order and order line. An ABC cross-analysis will also be conducted to identify factors or situations within the inventory that affects the order picking process.

4 Method

The method section deals with the approach of the study. The choice of method is presented, the procedure for data collection as well as the unit of analysis and quality assurance in the process.

4.1 Approach

For this study, an abductive method approach was chosen as the theoretical framework was adapted to the results of observations, which approaches an iterative process (Alvesson & Sköldberg, 2017). The abductive approach is a combination of the two main methods used in regards to the method of theory and knowledge building; inductive and deductive research methods (Lancaster, 2004). In a deductive method approach, the researcher develops theories or hypotheses which then are tested through empirical observation. In an inductive approach, theories or hypotheses are formulated to explain the empirical observations. However, Bryman (2017) believes that there are weaknesses and difficulties in strictly adopting a deductive - or inductive approach and that a combination of these can better suit the studied phenomenon; an abductive method approach. In an abductive approach, the researcher links the empirical results with the theoretical framework on which the conclusions then are based. Literature and previous studies are often used in abductive reasoning as a basis for increased understanding of the empiricism analysed.

4.2 Case study

Case research provides an eminent means of studying prominent practices within operations management (Voss *et al.* 2002). With appropriate rigor, combined with relevance, a powerful methodology can be reached within case-based research. Further, it is an appropriate method when the intention is to investigate issues concerning "how" and "why" (Yin, 2009). A case study is based on an empirical study that examines a contemporary phenomenon in-depth and in its real context. Case studies can be associated with certain distinctive features (Denscombe, 2018):

→ A framework	rather than	several units
→ Depth of the study	rather than	broadness of the study
→ The specific	rather than	the general
→ Relations and processes	rather than	results and end-products
→ Comprehensive view	rather than	isolated factors
→ Multiple sources of data	rather than	one method of research

The characteristics of this study are more in line with a case study (left column) which motivated the choice of case study as a research strategy. As the specific process of order picking is examined through multiple sources of data, it is leaning towards depth instead of featuring the broadness of the study. Furthermore, researchers can choose to perform a single case study or a multi-case study that studies several organisations (Yin, 2009). If the researcher intends to study only an individual organisation, a single case study is the best choice. The purpose of this study was to identify nonvalue adding activities within material management and material handling, which motivates the choice of method for this study: a single case study. This allows the author to gain a deeper understanding of the topic being studied (Dyer *et al.* 1991) and the opportunities become greater to go deeper and find a phenomenon that might not have become apparent in a more simplistic method (Denscombe, 2018).

4.2.1 Unit of analysis

This study can be considered an extension of a previous study which was about inventory control and optimal lot-sizing for a selection of products (Gyllengahm 2020). As a continuation, the current analysis focuses on mapping non-value-adding activities in their material handling.

4.2.2 Contributions from the study

Case studies are a "descriptive or explorative basis that helps in the development of theory" (Denscombe, 2018). The results of these types of studies can be generalised in the analytical sense Furthermore, case studies are claimed not to be generalisable to populations or the universe but to theoretical claims (Yin, 2009). Given this study, the data collected is unique in terms of inventory statistics and time requirements. The data has formed the basis for mapping activities within the company's handling of material and further cost calculations that have been performed. However, the approach can be applied to other organisations to identify non-value adding activities and suggestions on how to reduce these activities. Denscombe (2018) argues that although each case is unique in some respects, it is at the same time an example that falls into a broader category. In this aspect, the author claims, the individual case included in the study can be used as an example of how other companies can identify activities and rationalize their handling of material.

4.3 Collection of data

When conducting a case study it is common to use both qualitative and quantitative methods (Eisenhardt 1989). Qualitative and quantitative data can be used alone or together to complement each other and strengthen the study. A combination of the two has been adopted within this study since the research intents to state the actual lead time for order picking and the experience and inputs from the operators. Further, both primary and secondary data were used. Primary data is generated through the research process as a part of the study and secondary data comprises already existing information that is retrieved from internal and external sources (Lancaster 2004). The main data that was collected during the process were primary as a great proportion of the data was adapted to this study. The primary data was mostly retrieved from interviews, time studies, observations, demand for products, and order frequency such as properties of packages that seemed relevant for the analysis. Information about the company was retrieved trough both internal and external sources such as dialogues with the employees and the company’s website.

The collection of data began with focus group interviews, followed by time studies including observations, and later, inventory statistics were studied to search for indications of package properties and to be able to perform an ABC analysis.

4.3.1 Focus group interview

In qualitative research, interviews are valuable to describe activities or certain situations in-depth. The use of interviews is highly worthwhile when investigating the quality of relationships, activities, situations, or materials and gathering information based on experience and insights (Wisker 2008; Fraenkel *et al.* 2012). The chosen method for interviews was trough a focus group. The focus group often consists of a few participants and the groups are fairly homogeneous (Wisker, 2008). A focus group was chosen since the primary aim when conducting a focus group interview is to gain an understanding of a specific issue from the perspective of the respondents (Liamputtong, 2011). Further, there are found to be many advantages by conducting an interview with focus groups (Gorman *et al.* 2005). The method is perceived as transparent for the respondents which encourages contribution to the discussions. The participants are also encouraged to interact with each other, and the respondents have the chance to give immediate feedback or clarification and contribute to the dialogue. Potential problems or risks can emerge within focus group sessions. Such as getting people together, dominating personalities, and respondents that want to be agreeable instead of taking issue. Sensitive facilitation is considered being a helpful tool in these situations. To reduce the risk of not being able to get the participants together, the focus group interview was held during work hours at the facility. The interview was conducted as a semi-structured interview, which implies some degree of predetermined questions but still allowing flexibility in the way certain subjects or issues are addressed (Dunn 2005). Both focus groups and semi-structured interviews allow for an open response (Clifford *et al.* 2010) which suited this study well. Two respondents were part of the focus group, all working as truck operators picking orders daily. Before the interview was held, one observation was made to capture the overall procedure. The interview was recorded since the interviewer then can concentrate on the questions asked and on-going dialogue (Brinkmann & Kvale 2018). The interview was then transcribed for further analysis. The questions that were asked during the interview are stated in Appendix 1. The interview was held in Swedish, but the questions asked have been translated to English in the appendix.

4.3.2 Time studies and observations

Time studies were conducted to track the time order picking takes. The total number of time studies was 10, corresponding to 81 order lines. The activities measured were empty transport and movements of packages, transportation of packages to the loading spot, and required time for verifying packages. The time studies were conducted using the inventory software while each order was picked. The time required for each activity was timed according to Figure 8.

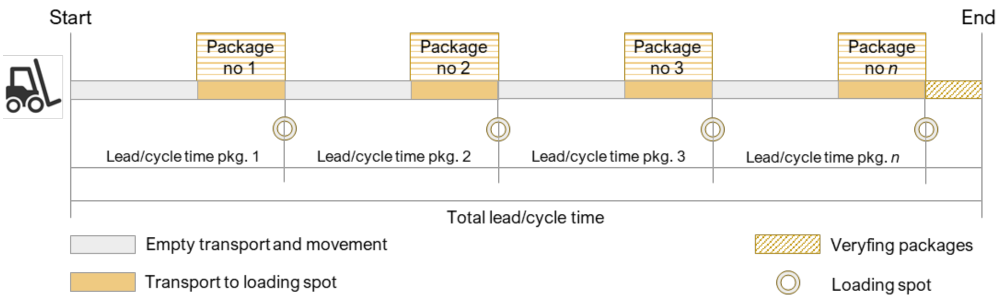

Figure 8. Method for timing activities during order picking.

In the inventory system, the time when the truck operators started was stated, which made it possible to measure the time from the point the operator started until the first reserved package was accessed. In the inventory system, the system keeps track of when a package leaves a compartment and when it is placed in another, including the time the packages are on the truck. The total time for accessing and transporting each package was the time from the point the previous package was left at the loading spot until the current package was left at the loading spot. The time required for verifying the packages was from the point the last package *n* was left at the loading spot until the truck operators marked the load to be completed in the system. Before the actual time was retrieved, a copy of the order before the order picking started was taken to receive the accessibility of each reserved package and how many packages that had to be moved to access them.

The selection of orders to study was strictly random to avoid being selective during the collection of data and time studies. The criteria for choosing the different orders were that the packages had to be reserved which normally occurs the day before the orders get picked. The ones who were fully prepared for order picking were compiled in Microsoft Excel and given a random number using the excel formula (=RAND). The orders were then sorted from largest to smallest and the ten first orders were then used for the time studies and analysis.

4.3.3 Inventory statistics

To carry out an ABC analysis, the demand for products and order frequency was retrieved from the business – and inventory software. For a deeper explanation of the procedure, see section 4.4.2. Further, the interviews and time studies led to an interest in looking at properties of packages such as the number of unnecessary movements and possible explanations to these. With the help of inventory software, a list was retrieved and filtered in Microsoft Excel to be able to sort and categorise them.

4.4 Method for analysing the collected data

After the data was collected through focus group interviews, time studies, and inventory statistics, the data were analysed to conduct a VSM and further, complete the aim with this study which focused on non-value added activities, cause to waste, and improvements (Figure 9).

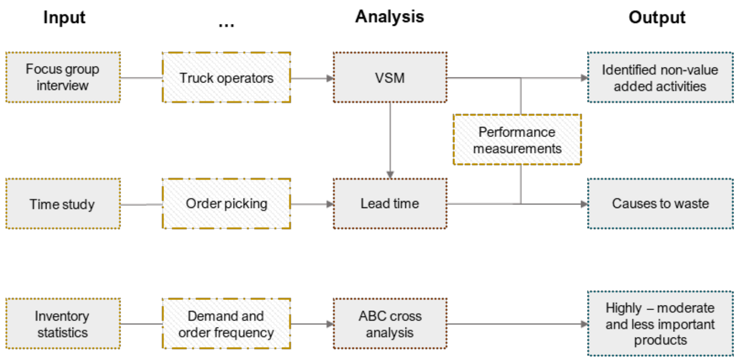

Figure 9. Overview of inputs, main analysis methods, and output within this study.

The model above describes the analysis of data within this study consisting of three main stages: VSM, calculating lead times, and perform an ABC cross-analysis. The analysis led to the identification of non-value-added activities, causes to waste, and classification of products in terms of importance.

4.4.1 Value stream mapping and lead time

Value-stream mapping was conducted to identify certain steps and activities that occur within the process of picking orders. The activities were divided into value-adding activities, non-value-adding activities which are necessary and non-value-adding activities that are not necessary. To create a value-stream map and an overview of the flow, time-studies and focus group interviews were conducted. Both to achieve a comprehensive view of the process as a whole and the required time it takes from retrieving the pick lists until the order has been fully prepared for loading. As a result of the time study, lead times were calculated as previously been described in section 4.3.2. By performing focus group interviews, time studies, and inventory statistics, causes to waste were identified as to why non-value-added activities occur. In addition, it was found to be interesting to look deeper into the properties of the packages. With the help of the inventory software and gathered statistics, packages were filtered according to different attributes. The main attribute that was investigated was the number of times packages been moved. Packages that is been moved more than 15 times were compiled and further analysed regarding possible reasons as to why they been handled numerous times. Possible reasons were identified on the behalf of focus group interviews, the empirical background, and time-studies when truck operators were picking orders. To better visualize the underlying causes of why waste occurs, an Ishiwika diagram was created.

4.4.2 Performance measurements of the order picking process

To measure the performance of the order picking process, three main key performance indicators were used which have been developed and reviewed by Frazelle (2016) and Kusrini *et al.* (2018). The indicators analysed were financial, productivity, and cycle time. Cycle time was an important indicator to use since Kusrini *et al.* (2018) claimed it as the most important one to consider. To calculate the financial aspect, the cost per man-hour was set to 70 € including salary to truck operator, fuel, and maintenance cost. Equations used for calculating the performance indicators can be found in Appendix 2.

4.4.3 ABC analysis of product categories

An ABC cross-analysis was conducted to divide the product range according to their importance and reasoning about inventory layout and material management. Firstly, the products were divided into four categories: impregnated, planed, finger-jointed, and painted products. The ABC analysis was carried out for each category alone. Each product's demand during the period 1st July 2019-31st December 2019 was summarised in Excel-sheets. So was the number of times each product been ordered during the same period. The annual demand and order frequency for each product was then multiplied with each other according to equation 1.

$$D_p \times OF_p \ = WV_p \ (m^3) \tag{1}$$

Where

D_p = Demand for product p
OF_p = Order frequency for product p
WV_p = Weighted volume expressed in cubic metre (m^3)

The equation resulted in a weighted volume expressed in cubic metre. If the equation only was based on volume figures, the analysis had not accounted for order frequency. The order frequency was argued as important as it is presumed to correlate against the number of times each compartment is visited. Initially, the number of products within each category varied to a large extent, hence a selection of products was made after the weighted volume was calculated. The reason why a selection was done, was because several of the products are not produced against stock and are considered as special orders. Depending on the number of products it was within each category, the selection criteria varied (Table 6).

Table 6. Selection criterion and number of products before and after

	Planed products	**Impregnated products**	**Finger-jointed products**	**Painted products**
Minimum weighted volume (m3)	≥ 3000	≥ 600	≥ 30	≥ 15
The original number of products	195	93	54	33
Number of products after selection	38	21	41	24

The minimum weighted volume was determined by the number of original products and the proportion of special ones which most often are manufactured against customer order. Within category planed products, 38 was selected. 21 was selected within impregnated products and 41 respective 24 was selected within finger-jointed and painted products.

The next step was to express the weighted volume in percentage, witch calculation is expressed in equation 2.

$$\frac{WV_p}{\sum_{p=1}^{n} WV_p} \times 100 = WV_p\ (\%) \tag{2}$$

The weighted volume was divided into the total weighted volume and further multiplied with 100. Further, the cumulative weighted percentage was calculated. The cumulative weighted percentage acted as guidance to classify the products into A, B, and C. For a detailed view of the calculations and classification of products, see Appendix 3.

4.4.4 Improvements

By identifying non-value-added activities and causes of these wastes, including performing an ABC cross-analysis, improvements could further be discussed. A studied theory such as principles of LAVC acts as guidance towards improvements and by identifying causes, suggestions on how to make the material flow more efficient could be stated. The improvements include reduction of lead-time and costs if the non-value-added activities are eliminated and how to, at least, reduce the amount of waste by implementing a more efficient material management.

4.5 Delimitations regarding method and empirics

Delimitations within the study have been made. The assignment does not study the whole value chain from incoming raw material until the point the end customer has received its goods. The choice has been made to only focus on the material flow from when the finished products have been transferred to the finished goods warehouse until the point when the goods are fully prepared for loading and further delivery (Figure 10).

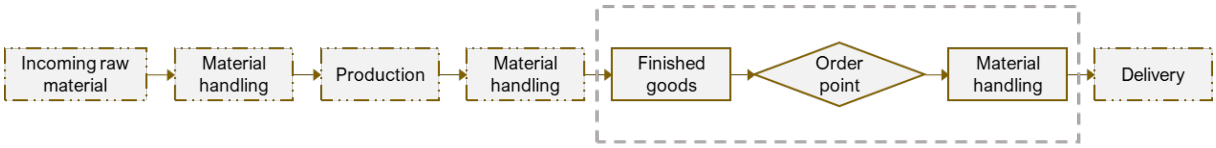

Figure 10. Delimitations of the study.

Shapes with solid lines within the crosshatched rectangle are part of the study. The whole value chain could have been studied to get a complete overview of the entire handling of material. However, Bild & Svensson (2019) studied nonvalue adding activities in the material handling process and found that nonvalue adding activities occurred most often during order picking. The results according to their study have motivated the choice of studying this specific part of the value chain. Continuously, the study had been to comprehensive if the whole value chain been highlighted.

4.6 Quality assurance

In terms of enhancing the quality of a study, the author should account for validity and reliability. It is particularly important in case study research (Voss *et al.* 2002). The aim of establishing validity and reliability in studies, is primarily to ensure that data are replicable and sound, and the achieved results are accurate (Mohajan 2017). Reliability is defined as the stability of findings, whereas validity refers to which extent a certain concept is accurately measured in a study (Heale & Twycross 2015; Mohajan 2017). There are three major types of validity according to Yin (2009): construct validity, internal validity, and external validity. The different types and reliability are further explained in Table 7 and how it was considered within this study.

Table 7. Achieving validity and reliability and how it is applied in this study (inspired by Voss et al. 2002 p. 211; Yin 2009 p. 40)

Criteria	Meaning	Application within this study
Construct validity	Identify suitable operational measures for the concept being studied	Chosen measures within this study have to an extent been inspired by previous studies and theories within warehouse management and the process of order picking. Key respondents have reviewed the summary of the interview results.
Internal validity	Seeking to find a causal relationship where specific conditions are believed to lead to others	The inferences have been based on multiple data collection methods such as interviews, time studies and inventory statistics to consider many aspects and possibilities as to why non-value-added activities occur within the process. Multiple data collection methods have increased the possibility to analyse data through several aspects.
External validity	To which extent the study´s finding can be generalized	Theories and data collection methods that were chosen, have previously been practiced to a high extent in a broad spectrum of sectors. Hence, the methods are generalisable although the initial data are specific for this case.
Reliability	Achieving the same results by demonstrating the operations within the study such as data collection procedures	Applied theories and methods for analysing data have been narrated and protocoled. The collection of data is explained in text, equations, and figures, and detailed views are found in appendixes. By conducting good documentation of observations, a chain of evidence was established.

The validity and reliability of the collected data can be enhanced by using various types of data collection methods (Mohajan 2017). In this study, both qualitative and quantitative data have been used through focus group interviews, time studies, and inventory statistics. By using multiple methods, the probability of discovering the majority of influencing factors and activities are believed to have increased. Hence, increasing both internal – and construct validity. Regarding external validity, it is somewhat challenging to argue that the findings of a single case study can be generalised to others. However, as previously argued (section 4.2.2), the study can act as guidance for other researchers or companies who intends to identify non-value-added activities and find causes to occurrence such as methods to eliminate or reduce these within the same area. Reliable results increase with the use of multiple data sources (Voss *et al.* 2002) which was taken into account within this study.

4.7 Ethical considerations

The way a researcher conducts their research activities is influenced by ethics, which are moral principles and values (Ghauri & Grönhaug 2005). Ethical considerations are significant when performing interviews. The importance of informed consent is high when conducting an interview, such as informing the respondents about the subject and further publication (Brinkmann & Kvale 2018). The focus group participants were therefore informed about the research subjects, the overall purpose and main features of the design. The participants were further informed about voluntary participation and their right to end the interview at any time. Before the interview was held, the participants signed a GDPR form to agree on consent. The participants could read through the transcriptions and further analysis to make sure that nothing was misunderstood. Continuously, they were informed about how the results will be presented in the research. Ethical considerations were present in other parts of the study as well. Especially in making it clear that the data collected through interviews and inventory software only was aimed to answer the aim and research questions within this study.

5 Background for the empirical study

In this section, the organisation studied is described in general. Continuing by describing the inventory layout and inventory software used to manage the inventory. Further, the process of order picking is described to get a fundamental understanding of the activity and how the process is carried out.

5.1 The organisation

The company that is been studied, Sandåsa Timber AB, is active in the sawmill and wood-processing industry. The company has two sawmills and one wood processing facility, all located in the middle part of Sweden (Sandåsa Timber AB, 2020a). The production volume of sawn products amounts to about 210,000 m3 per year with a distribution of 50% spruce and 50% pine. There are several processing units at the wood processing facility: mainly two planing mills, impregnation, finger-jointing, and painting. The company produces many different products that are further refined in various stages depending on the end-product, which can be considered a common scenario for many companies in the Swedish forest sector. The studied company produces both standard and specialty products and offers customers a wide product range (Sandåsa Timber AB 2020b). The specialty products are produced against customer orders, while the standard products are produced against the stock for further delivery when customer orders are received. The wide product range entails that the company needs to maintain large warehouses and storage areas that require both administrative and physical resources to a great extent.

5.2 Inventory management

5.2.1 Inventory layout

At the facility, there are approximately 880 storage places (compartments) that are either placed in timber warehouses, halls, or on outdoor storage areas. In Appendix 4 an overview of the facility is attached including examples of compartments with varied products and lengths. The company strives for different assortments to be stored in different storage areas. Most of the impregnated products are stored in neighbouring timber warehouses for the impregnation and raw material assortments intended for planing are stored near the planer units, for example. Products whose sales volume corresponds to a large part of the total sales, the company strives to keep the product - and length the same in each compartment. That is, the compartments contain the same product and the same length to ease order picking. Many of the products, however, are held in compartments that contain the same product, but with varying lengths.

5.2.2 Inventory software

Since 2014 the organisation has been using SIPal (SawInfo Package Logistics) to manage inventory (Datapolarna, 2020). The software operates the handling of packages from the point the packages arrive at the facility until the packages are delivered to the customer. In SIPal the employees can localise packages and for example, choose which packages the truck operator should pick. Each truck operator has a screen with the software and layout of the inventory areas which acts as a guide when handling, transporting, and picking orders. Accurate placement of packages fully relies on the truck operators since there is no GPS attached to the packages. Stock-taking is continuously carried out, by truck operators themselves and other employees. In Appendix 4, the truck operators' view of the software is attached and further explained.

5.3 Administering and picking orders

The customers place a request at the sales department, either by telephone or mail. The incoming requests turn into an order which is managed in the business system. Some orders are manufacturing-orders while others are distributed through existing inventory (finished goods). The delivery time varies depending on the customer. Most often the delivery time is set to two days. If that is the case, customers place the order at day one, the orders are picked during day two and delivered the day after. The ordered number of packages varies from time to time, and so does the proportion of products. This impacts the planning and routing of deliveries. To fill the lorries, several orders to different customers are loaded onto the same lorry. Usually, there are three different delivery addresses at most. This has a further impact when preparing the orders for loading which are explained further on.

5.3.1 Reservation of packages

The orders are inserted in the business system where product, length, volume, price, and specific instructions are specified if needed. The order confirmation is printed out and so is the order basis which acts as an instruction for the truck operators. The order basis is then sorted into files according to which lorry they will be delivered. Orders that will be delivered firstly in the morning are prioritised as they are loaded onto the lorry the same day the truck operators pick orders. Each file (sometimes consisted of several orders) are then managed in the inventory software SIPal. Each package, with few exceptions, is reserved at the end of day one and the prioritised files are reserved first. In SIPal, reservable packages are matched according to inserted product (according to article number) and length. This means that packages are only shown if they match the product description. See Appendix 4. Accessibility is prioritised when reserving packages, also in which compartments they are stored. Further, the right number of packages (or volume) needs to be correct. Otherwise, the software alerts if the volume overrun or fall below the ordered volume. Often it is desirable to reserve packages that contain a standard number of pieces, so-called “half-packages” which is the term for a standard-sized package once it has been processed. In those cases where a non-standard sized have higher accessibility than a standard-sized package, size is often prioritised before accessibility.

5.3.2 Order picking

When the file is prepared and the packages are reserved, they are collected by the truck operators the morning after. Each truck operator oversees one file/lorry at once. Usually, the truck operators pick one order at a time within each file, preferably they start with the order that contains the largest number of packages. The truck operators strive to keep each customer's orders separate from one and another to ease the unloading once the driver arrives at the customer. While picking the orders, the packages are transported to a specific loading-spot. Usually, the decision of which loading spot to use is depending on where most of the reserved packages are stored. The reason is to avoid unnecessary transportations. Further, the truck operators often begin with the longest packages which have to do with the upcoming loading. The longest packages are preferred to be placed at the bottom when stacking the packages to achieve stability and for the placements of rachets straps when securing the load.

When all packages are picked, prepared, and placed at the loading-spot, the truck operators scan the packages to ensure that all the reserved packages are there and match the product description. Further, the truck operators’ hands in the order basis to the office where the order is checked once again according to product, length, and volume. Thereafter the delivery note is printed out. Once the driver arrives for loading, the truck operators are given the delivery note where they sign it and confirm the number of loaded packages.

6 Empirical findings and analysis

This chapter consists of the empirical findings which are further analysed, aimed to address the research questions stated in chapter one. The analysis is based on the empirics, theoretical framework, and the empirical background.

6.1 Business modelling of the order picking process

The general process of receiving a request and picking the orders was described in the empirical background. The observations and interview gave a detailed view of the order picking process which is visualized in Figure 11 below.

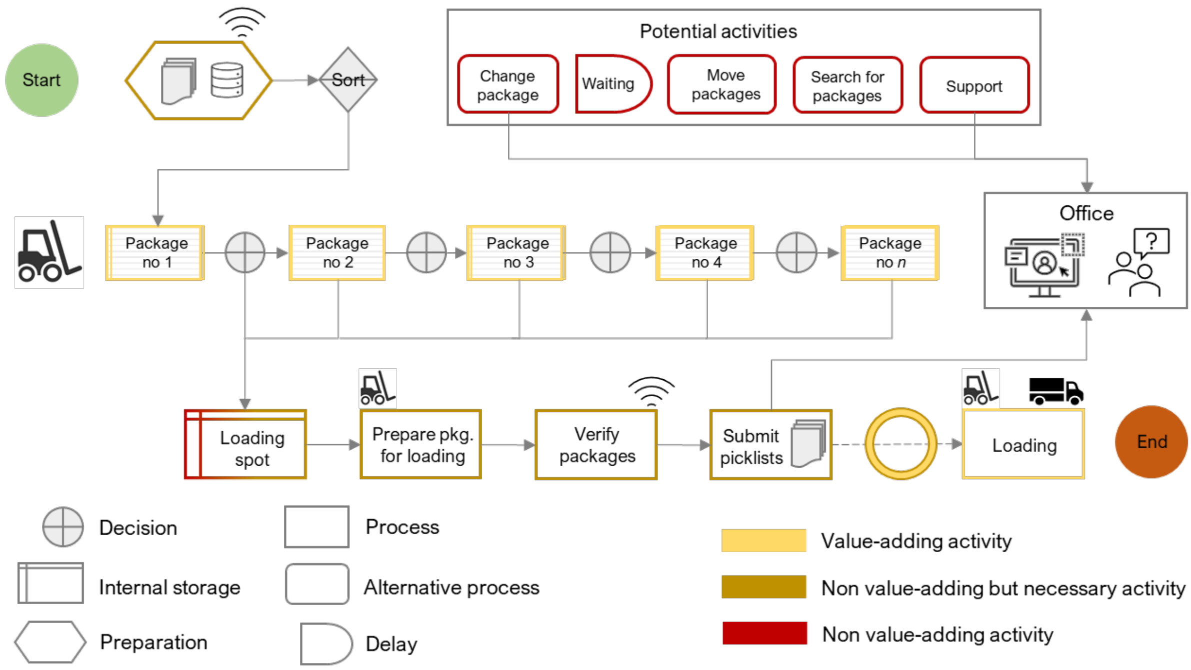

Figure 11. Business modelling of the order picking process.

The truck operators gather the picklist or picklists at the office and open the order in the inventory software. They select which order they will begin with and sort the order to decide which package they should pick first. On the screen in the truck, they sort the packages after length as top priority and dimension as a second priority since the longest and thickest dimensions shall be placed at the bottom when loading for stability and even axel load. Then the truck operators travel to the first package and pick it up, they can either choose to transport the package to the loading spot directly or continue to package no two and three and then transport the three packages to the loading spot at the same time. When all the packages have been transported to the loading spot, the packages are prepared for loading meaning that they are positioned as they will be loaded on the trailer. Next, the packages are verified using the hand unit to ensure that the packages conform to the request. The picklists are then submitted to the office which prints out the delivery notes. When the trailer arrives, the truck operator loads the vehicle and the order is completed to its fullest.

6.1.1 Activities

As seen in Figure 10, the different activities or processes have different colours, representing the type of activity that occurs. The value-adding activities are the picking of packages and loading since they are valuable to the customer. The non-value-adding but necessary activities are the preparation of the order (gathering picklists and open them in the inventory system), preparing packages for loading, verifying packages, and submitting the picklists to the office. Potential activities that can occur during the order picking process are changing packages, waiting, move packages, search for packages, and the need for support from the office and salesmen. All these activities are non-value adding activities. The internal storage, which in this case is the loading spot, is determined to be both a non-value-adding activity and a non-value-adding activity that is necessary. Hypothetically, the packages could have been loaded directly from the warehouse storage on to the trailer. However, since that would have required the truck to wait for all packages to be picked the packages must be prepared at the loading site before the trailer arrives.

The main activities within the category of non-value-added activities are storage and transportation as was described in the theory chapter (Olhager 2013). However, transportation and storage can be claimed to be value-adding since they are required to make the product available for the customer. The actual picking of packages is value-adding, but the transportation is not, however it is necessary. As Martin and Osterling (2017) claim, the necessary but non-value adding activities should be challenged and reduced. As the time studies will well in the section below, transportation occurs to a high extent which certainly entails that the conditions in the inventory should be enhanced.

6.1.2 Lead time

The lead time was calculated for 10 individual orders which corresponded to 81 order lines. The number of order lines within each order varied from 3 to 19, so did the number of packages picked and their accessibility. The time measured was empty transport and movement of unreserved packages and transport of reserved packages to loading spots such as the time required for verifying the packages. A detailed time study and valuable parameters are seen in Figures 13 and 14. The figure below (12), describes in detail how Figure 13 and 14 should be interpreted.

Order no	Product	Access-ibility	No of compart. visited	No of pkg. picked	Empty transport. and movement of unreserved pkg.	% of total time	Transport. of pkg. to loading spot	% of total time	CT for each orderline	PC per orderline (€)	OL picked per man-hour	Pkg. picked per man-hour	No of pkg. moved to acess reserved pkg.
2020A-1	2045095565H4	5	1	1	00:02:05	61%	00:01:20	39%	00:03:25	3,99 €		17,6	4
-	2045145532H4	3-4, 6-8	1	5	00:05:16	64%	00:03:01	36%	00:08:17	9,66 €		36,2	3
-	2022125461JU	34-36	1	3	00:48:45	95%	00:02:50	5%	00:51:35	60,18 €		3,5	33
-	2045170532H4	2-3	2	3	00:04:02	39%	00:06:11	61%	00:10:13	11,92 €		17,6	1
-	2045195532H4	4-6	1	3	00:02:41	70%	00:01:10	30%	00:03:51	4,49 €		46,8	3
-	2045095532H4	1-3, 5-10	1	9	00:10:41	85%	00:01:49	15%	00:12:30	14,58 €		43,2	1
-	*Verifying*								00:01:46	2,06 €			
TOTAL	**6**		**7**	**24**	**01:13:30**	**80%**	**00:16:21**	**18%**	**01:31:37**	**106,89 €**	**3,9**	**15,7**	**45**

Number of products

Proportion of empty transport and movement of unreserved pkg. out of the total picking time

Proportion of transport of pkg. to loading spot out of the total picking time

Pkg. picked per man-hour (60 minutes)

Pkg. moved in order to access the reserved

Figure 12. Interpretation of the time studies.

The figure above represents a complete order, consisting of six different products which are the same as six order lines. The accessibility is the position of each package within the order line, which made it possible to calculate how many packages had to be moved to access the reserved ones. The number of compartments visited is shown, as is the number of packages picked. The percentage of empty transportation and movement of packages such as transport of packages to the loading spot is expressed out of the total time. Packages picked per man-hour was calculated, the order lines marked with red text are ranked as low productivity, and the orange text symbols order lines that are moderate in terms of productivity.

Order no	Product	Access-ibility	No of compart. visited	No of pkg. picked	Empty transport. and movement of unreserved pkg.	% of total time	Transport. of pkg. to loading spot	% of total time	CT for each orderline	PC per orderline (€)	OL picked per man-hour	Pkg. picked per man-hour	No of pkg. moved to acess reserved pkg.
2020A-1	2045095565H4	5	1	1	00:02:05	61%	00:01:20	39%	00:03:25	3,99 €		17,6	4
-	2045145532H4	3-4, 6-8	1	5	00:05:16	64%	00:03:01	36%	00:08:17	9,66 €		36,2	3
-	2022125461JU	34-36	1	3	00:48:45	95%	00:02:50	5%	00:51:35	60,18 €		3,5	33
-	2045170532H4	2-3	2	3	00:04:02	39%	00:06:11	61%	00:10:13	11,92 €		17,6	1
-	2045195532H4	4-6	1	3	00:02:41	70%	00:01:10	30%	00:03:51	4,49 €		46,8	3
-	2045095532H4	1-3, 5-10	1	9	00:10:41	85%	00:01:49	15%	00:12:30	14,58 €		43,2	1
-	Verifying								00:01:46	2,06 €			
TOTAL	6		7	24	01:13:30	80%	00:16:21	18%	01:31:37	106,89 €	3,9	15,7	45
2020A-2	2022070528HK	5	1	1	00:03:59	88%	00:00:32	12%	00:04:31	5,27 €		13,3	4
-	2045145532H4	1-2	3	4	00:09:14	70%	00:03:57	30%	00:13:11	15,38 €		18,2	0
-	2045220532H4	1	1	1	00:01:10	74%	00:00:24	26%	00:01:34	1,83 €		38,3	0
-	2045170532H4	5	1	1	00:01:10	28%	00:03:03	72%	00:04:13	4,92 €		14,2	4
-	2045195532H4	1	1	1	00:00:36	20%	00:02:20	80%	00:02:56	3,42 €		20,5	0
-	2045095558H425	2-4	1	3	00:02:14	59%	00:01:33	41%	00:03:47	4,41 €		47,6	1
-	2045070558H425	2	1	1	00:00:26	33%	00:00:53	67%	00:01:19	1,54 €		45,6	1
-	1045145632H4A	1	2	2	00:05:10	38%	00:08:30	62%	00:13:40	15,94 €		8,8	0
-	1045170532H4A	1-3	3	5	00:07:15	69%	00:03:17	31%	00:10:32	12,29 €		28,5	0
-	2045220532H4A	5	1	1	00:02:03	47%	00:02:18	53%	00:04:21	5,08 €		13,8	4
-	1028070658H4AB	2	1	1	00:02:57	56%	00:02:17	44%	00:05:14	6,11 €		11,5	1
-	1028120658H4AB	1-2	2	4	00:02:07	38%	00:03:24	62%	00:05:31	6,44 €		43,5	0
-	2020095528HS	14	1	1	00:07:09	93%	00:00:32	7%	00:07:41	8,96 €		7,8	13
-	2034120538H4	2	1	1	00:03:00	57%	00:02:14	43%	00:05:14	6,11 €		11,5	1
-	Verifying								00:06:02	7,04 €			
TOTAL	14		20	27	00:48:30	54%	00:35:14	39%	01:29:46	104,73 €	9,4	18,0	29
2020A-3	1028145H4AB	1-2, 11	3	4	00:05:55	47%	00:06:42	53%	00:12:37	14,72 €		19,0	8
-	1150150458SA	23	1	1	00:04:45	94%	00:00:18	6%	00:05:03	5,89 €		11,9	22
-	1028095658H4AB	1, 9	2	2	00:05:04	94%	00:00:18	6%	00:05:22	6,26 €		22,4	8
-	1022045658H4BAB	6	1	1	00:02:03	87%	00:00:18	13%	00:02:21	2,74 €		25,5	5
-	Verifying								00:01:51	2,16 €			
TOTAL	4		7	8	00:17:47	65%	00:07:36	28%	00:27:14	31,77 €	8,8	17,6	43
2020A-4	2045145532H4	3	1	1	00:03:33	98%	00:00:04	2%	00:03:37	4,22 €		16,6	2
-	2045070532H4	2	1	1	00:04:14	98%	00:00:04	2%	00:04:18	5,02 €		14,0	1
-	2045170532H4	1-2, 6	2	3	00:05:48	68%	00:02:42	32%	00:08:30	9,92 €		21,2	3
-	2045195532H4	14	1	1	00:01:02	16%	00:05:22	84%	00:06:24	7,47 €		9,4	13
-	2045220532H4	1	1	1	00:02:03	67%	00:01:00	33%	00:03:03	3,56 €		19,7	0
-	Verifying								00:04:10	4,86 €			
TOTAL	5		6	7	00:16:40	55%	00:09:12	31%	00:30:02	35,04 €	10,0	14,0	19
2020A-5	1070070658H4A	5	1	1	00:05:36	79%	00:01:27	21%	00:07:03	8,23 €		8,5	4
-	1045145632H4A	1	1	1	00:04:35	76%	00:01:27	24%	00:06:02	7,04 €		9,9	0
-	2045220532H4	1	1	1	00:01:00	59%	00:00:42	41%	00:01:42	1,98 €		35,3	0
-	2045070532H4	1	1	1	00:00:48	53%	00:00:43	47%	00:01:31	1,77 €		39,6	0
-	1022045658HKAB	1	1	1	00:05:41	91%	00:00:34	9%	00:06:15	7,29 €		9,6	0
-	1045195632H4A	1	1	1	00:01:32	59%	00:01:03	41%	00:02:35	3,01 €		23,2	0
-	2028070568H4	2	1	1	00:00:38	19%	00:02:40	81%	00:03:18	3,85 €		18,2	1
-	2023120568ÄR	1	1	1	00:01:11	43%	00:01:34	57%	00:02:45	3,21 €		21,8	0
-	1045095658H4AB	4	1	1	00:01:41	70%	00:00:43	30%	00:02:24	2,80 €		25,0	3
-	2045070758H4FK27	1	1	1	00:01:54	49%	00:02:01	51%	00:03:55	4,57 €		15,3	0
-	2045095532H4	1	1	1	00:02:28	90%	00:00:16	10%	00:02:44	3,19 €		22,0	0
-	1045120658H4AB	1	1	1	00:01:18	83%	00:00:16	17%	00:01:34	1,83 €		38,3	0
-	Verifying								00:06:34	7,66 €			
TOTAL	12		12	12	00:28:22	59%	00:13:26	28%	00:48:22	56,43 €	14,9	14,9	8

Moderate: pkg. picked per man-hour

Low: pkg. picked per man-hour

Figure 13. Part I – Time study for each order and order line including key performance indicators.

Order no	Product	Accessibility	No of compart. visited	No of pkg. picked	Empty transport. and movement of unreserved pkg.	% of total time	Transport. of pkg. to loading spot	% of total time	CT for each orderline	PC per orderline (€)	OL picked per man-hour	Pkg. picked per man-hour	No of pkg. moved to acess reserved pkg.
2020B-1	2047075460U	1-3, 14-20	1	13	00:22:39	75%	00:07:28	25%	00:30:07	35,14 €		25,9	11
-	2045070560U	21-23	1	3	00:12:25	61%	00:07:51	39%	00:20:16	23,64 €		8,9	20
-	2023100460SKF	1-3, 10-11	3	5	00:09:57	58%	00:07:14	42%	00:17:11	20,05 €		17,5	6
-	Verifying								00:04:38	5,41 €			
TOTAL	3		5	21	00:45:01	62%	00:22:33	31%	01:12:12	84,23 €	2,5	17,5	37
2020B-2	2022145528P21	3	1	1	00:05:50	97%	00:00:11	3%	00:06:01	7,02 €		10,0	2
-	2022120528HK	5, 6	2	2	00:10:18	83%	00:02:07	17%	00:12:25	14,49 €		9,7	9
-	2022145528HK30	2	1	1	00:05:54	96%	00:00:16	4%	00:06:10	7,19 €		9,7	1
-	2022170528HK	1	1	1	00:06:04	94%	00:00:23	6%	00:06:27	7,53 €		9,3	0
-	1034145658H4AB	2	1	1	00:03:01	72%	00:01:10	28%	00:04:11	4,88 €		14,3	1
-	1045045658H4AB	2	1	1	00:03:10	79%	00:00:51	21%	00:04:01	4,69 €		14,9	1
-	1045095658H4AB	3-4, 6	2	3	00:10:03	76%	00:03:10	24%	00:13:13	15,42 €		13,6	7
-	1045120658H4AB	1, 6	2	2	00:04:16	83%	00:00:54	17%	00:05:10	6,03 €		23,2	5
-	1045145632H4A	2, 3	2	2	00:08:19	72%	00:03:10	28%	00:11:29	13,40 €		10,4	3
-	2045045538H4	6	1	1	00:06:20	97%	00:00:11	3%	00:06:31	7,60 €		9,2	5
-	2045095558H425	1	1	1	00:02:57	76%	00:00:56	24%	00:03:53	4,53 €		15,5	0
-	2045070558H425	2-5	1	4	00:05:13	62%	00:03:09	38%	00:08:22	9,76 €		28,7	1
-	2045095532H4	3	1	1	00:04:35	84%	00:00:52	16%	00:05:27	6,36 €		11,0	2
-	2045120532H4	3	1	1	00:01:41	73%	00:00:38	27%	00:02:19	2,70 €		25,9	2
-	2045220732H4F66	1	1	1	00:07:25	97%	00:00:12	3%	00:07:37	8,89 €		7,9	0
-	2022120528P16	3	1	1	00:05:53	86%	00:00:56	14%	00:06:49	7,95 €		8,8	2
-	2020120568ÄR	7, 9	1	2	00:11:21	88%	00:01:30	12%	00:12:51	14,99 €		9,3	7
-	2022095568H	1-2	1	2	00:01:59	53%	00:01:44	47%	00:03:43	4,34 €		32,3	0
-	1028120658H4AB	1	1	1	00:02:51	42%	00:03:55	58%	00:06:46	7,89 €		8,9	0
-	Verifying								00:05:48	6,77 €			
TOTAL	19		23	29	01:47:10	77%	00:26:15	19%	02:19:13	162,42 €	8,2	12,5	48
2020B-3	2045195732H4F66	1	1	1	00:01:02	76%	00:00:20	24%	00:01:22	1,59 €		43,9	0
-	2045220732H4F66	2	1	1	00:02:34	54%	00:02:12	46%	00:04:46	5,56 €		12,6	1
-	2045220732H4F72	4	1	1	00:04:37	66%	00:02:21	34%	00:06:58	8,13 €		8,6	3
-	2020095568ÄR	1, 1	2	2	00:01:54	74%	00:00:41	26%	00:02:35	3,01 €		46,5	0
-	2063200420J	5, 8	1	2	00:14:57	84%	00:02:52	16%	00:17:49	20,79 €		6,7	6
-	2032150461J	2, 13-16, 19, 21	2	7	00:22:53	61%	00:14:42	39%	00:37:35	43,85 €		11,2	16
-	Verifying								00:10:51	12,66 €			
TOTAL	6		8	14	00:47:57	59%	00:23:08	28%	01:21:56	95,59 €	4,4	10,3	26
2020B-4	10125125458SA	13	1	1	00:11:06	70%	00:04:46	30%	00:15:52	18,51 €		3,8	12
-	2020120568ÄR	1	1	1	00:02:24	62%	00:01:27	38%	00:03:51	4,49 €		15,6	0
-	1028095658H4AB	1	1	1	00:02:01	85%	00:00:22	15%	00:02:23	2,78 €		25,2	0
-	1034145658H4AB	2	1	1	00:03:01	76%	00:00:57	24%	00:03:58	4,63 €		15,1	1
-	1028145658H4AB	1	1	1	00:02:49	64%	00:01:37	36%	00:04:26	5,17 €		13,5	0
-	1045145632H4A	2	1	1	00:03:06	87%	00:00:27	13%	00:03:33	4,14 €		16,9	1
-	2045070532H4	9	1	1	00:08:28	80%	00:02:09	20%	00:10:37	12,39 €		5,7	8
-	2022095828HKVG	7	1	1	00:08:35	67%	00:04:16	33%	00:12:51	14,99 €		4,7	6
-	Verifying								00:04:21	5,08 €			
TOTAL	8		8	8	00:41:30	67%	00:16:01	26%	01:01:52	72,18 €	7,8	7,8	28
2020B-5	1045195632H4A	3	1	1	00:03:16	61%	00:02:06	39%	00:05:22	6,26 €		11,2	2
-	1045170632H4A	2	1	1	00:02:28	71%	00:01:00	29%	00:03:28	4,04 €		17,3	1
-	2045195532H4	1, 7	2	2	00:09:40	75%	00:03:14	25%	00:12:54	15,05 €		9,3	6
-	1028145658H4AB	10	1	1	00:08:34	77%	00:02:30	23%	00:11:04	12,91 €		5,4	9
-	Verifying								00:03:02	3,54 €			
TOTAL	4		5	5	00:23:58	67%	00:08:50	25%	00:35:50	41,81 €	6,7	8,4	18

Moderate: pkg. picked per man-hour

Low: pkg. picked per man-hour

Figure 14. Part II – Time study for each order and order line including key performance indicators.

The figures above represent each order (2020A-1 to 2020A-5 and 2020B-1 to 2020B-5) and belonging order lines. The product, the accessibility of the packages, visited compartments and the total number of packages picked are shown. Such as the percentage of the total time the empty transport and movement and transport of packages to loading spot correspond to. The key performance indicators are presented as CT (cycle time) for each order and order line, PC (picking cost) per order line, OL (order lines) picked per man-hour, and packages picked per man-hour. Another parameter was also included, the number of packages that had to be moved to access the reserved ones. By analysing the lead times, it becomes clear that the empty transports and movement of unreserved packages stand for the majority of time each order line takes in total which is not surprising since packages have to be moved to access the reserved ones. To better visualise the different parameters, scatterplots were created. In Figure 15, the cycle time per order line and the number of packages picked is shown including a linear trendline.

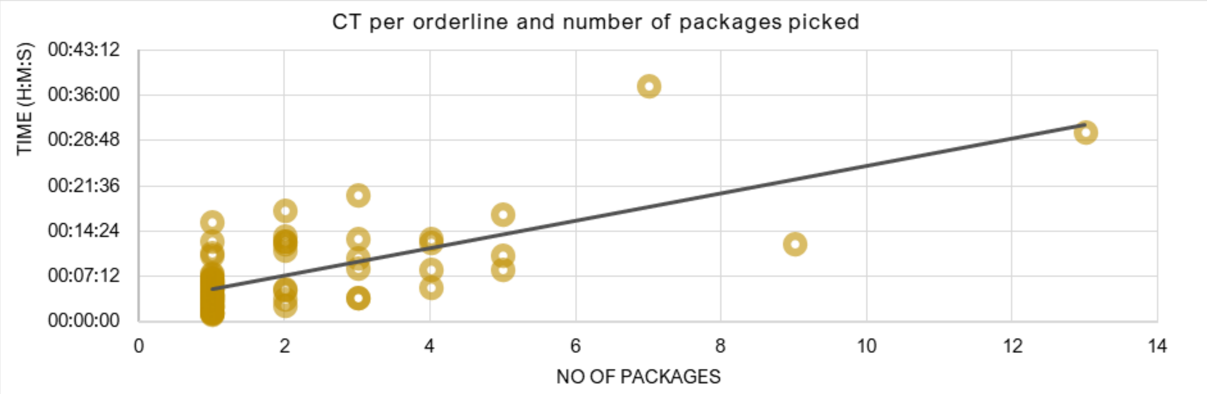

Figure 15. Cycle time per order line and the number of packages picked (including linear trendline).

Each mark represents an order line with the number of packages picked at the x-axis and the cycle time at the y-axis. 13 packages were the most that were picked for one individual order line. As can be seen by adding a trendline, the required time increases with the number of packages. However, there are some exceptions. Looking at the marks at x-axis value 3 for example (number of packages), the required time varies between 3,5 minutes and 20,25 minutes although the number of packages picked is the same in total. Although the trendline strongly indicates that the total time required increases with the number of packages, it cannot be precluded that there is another reason as to why the time varies. Another scatterplot was then created, presenting the cycle time per order line and the number of packages that were moved to access the reserved ones (Figure 16).

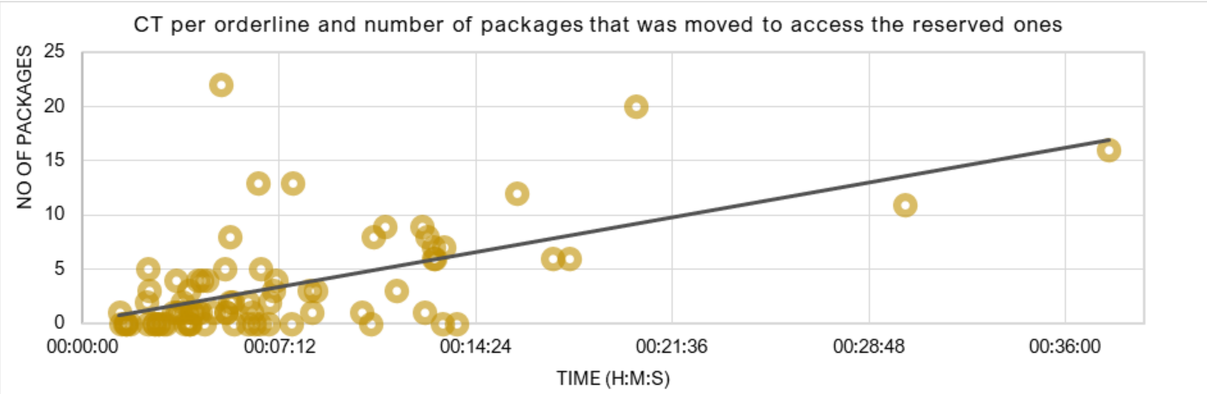

Figure 16. Cycle time per order line and the number of packages that were moved to access the reserved ones (including linear trendline).

The number of packages that had to be moved represents the y-axis and the cycle time is represented by the x-axis. As can be seen, most of the order lines required less than five packages to be moved to access the reserved ones. However, there are still order lines that required many unnecessary moves. Even though the order line that required 22 moves required a relatively short amount of time, the trendline strongly indicates that the time required increases with the number of packages. The last scatterplot that was made focused on the average accessibility of each order line and packages picked per man-hour (Figure 17).

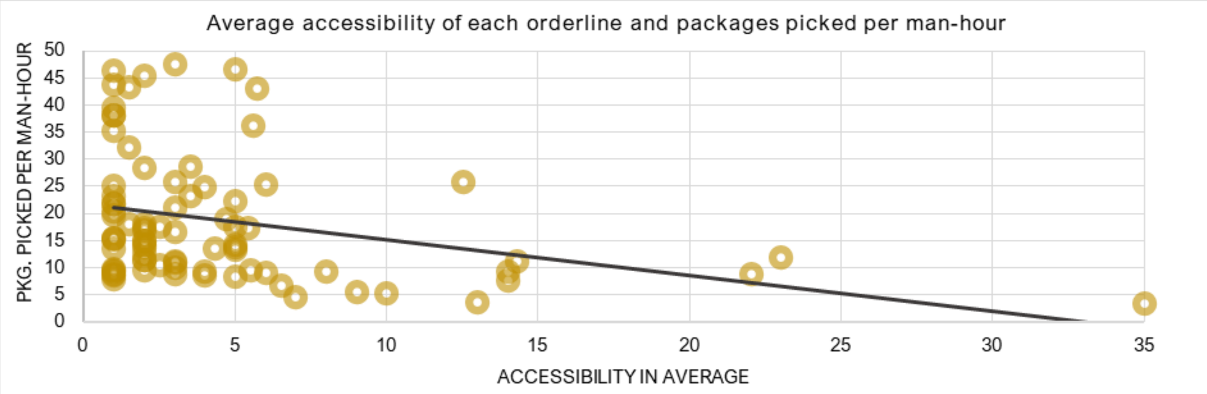

Figure 17. Average accessibility of each order line and packages picked per man-hour (including linear trendline).

The y-axis represents the packages picked per man-hour and the accessibility on average is expressed at the x-axis. Most of the order lines had average accessibility of less than five. The packages picked per-manhour strongly varies, however, the trendline shows that the packages picked per man-hour decreases as the accessibility in averages becomes worse.

6.2 Identified wastes within the order picking process

The eight wastes which were reviewed in section 3.3.2, were identified through interviews and observations. The occurrence of the unnecessary activities was rated between low, moderate, and high occurrence (Figure 18).

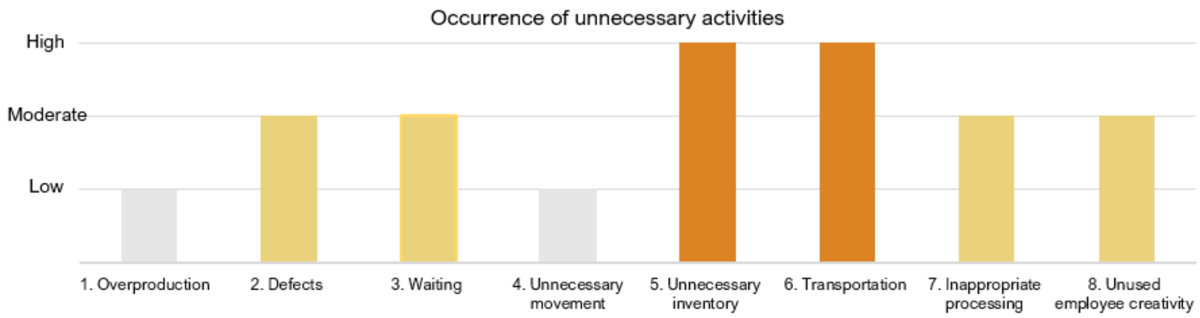

Figure 18. The occurrence of unnecessary activities within the order picking process.

Waste 1 and 4, overproduction and unnecessary movements were ranked as low. Waste 2-3 and 7-8 were ranked as moderate and waste 5 and 6, unnecessary inventory and transportation were seen to occur most often. Each waste is further discussed in the sections below (6.2.1-6.2.8).

6.2.1 Overproduction

The main question asked during the interview was if the picking of orders and preparation of loads always occur the day before the goods are delivered. According to the truck operators, that is the case for most deliveries. With the exception if orders are being forgotten or if the customer pays the load in advance. In those cases where the loads are paid in advance, the packages are being reserved and those packages need to be picked for the invoice to be correct. In addition, the question was asked if there are products that have been stored for a longer period that inhibits the order picking process. The truck operators feel that it does occur as a result that some lengths are not demanded for those customers who only requests even lengths.

6.2.2 Defects

Defects can arise on packages, such as incorrect packages due to production faults and incorrect labelling. If the reserved and picked package has a minor defect and some wooden pieces are damaged, the truck operators make a notation in the picklist of the amount as well as placing another label on the package so the customer knows it is been subtracted from delivery note. If the defect and damage are not acceptable, the truck operators need to switch the package to a new one. The initial thought is to why the packages have become defected from the first place and why they have made it to the finished goods storage areas. The truck operators mean that you need to be observant and notice if packages are defected or damaged to avoid these situations where packages need to be switched during both orders picking and loading or not at all. It creates more unnecessary work if packages need to be switched and they most re-do the picking. The truck operators also feel that it is hard to evaluate if packages can be sent or not if unsureness arises since they all have different preferences. If the truck operator is feeling unsure, the package is often transported to the office where the salesmen make the final call if the package can be sent. Additional defects can arise due to mixed products within compartments. According to the truck operators, different dimensions stored in the same compartment can cause damage to the goods. Products with thinner dimensions are more likely to be deformed if thicker and heavier products are placed on these, the pieces will slightly bend and can eventually become in very bad shape.

6.2.3 Waiting

Waiting does occur during order picking, such as waiting for the system to start at the beginning of the workday and sometimes during the workday if the system stops to work or lacking connection. Sometimes the truck operators must wait for the computer to restart which in some cases can take about an hour. The initial thought is that the system requires updating. However, an update during work hours is often avoided since the truck operators must wait for it to be completed and during that time the truck operators cannot pick any packages since it is not synchronised within the system. One suggestion from the truck operators is looking at the possibility to complete the update after the workday has ended to avoid waiting and standstills.

6.2.4 Unnecessary movement

The question was asked if the truck operators feel that it is easy to find packages that should be picked to the order. The response was that it is easy if the packages are reserved and if they are stored where they should be stored according to the inventory system. If the packages are not located at the correct compartment, the truck operators usually look for the package in the compartments nearby to see if the packages have been misplaced. If that is not the case, the truck operators contact the office to let them know that the package is missing, and the truck operators reserve a new package by themselves. Sometimes the office re-book the package but for the most time, the truck operators do it themselves. While contacting the office, the truck operators often communicate that the missing package should be moved to a fictitious compartment called “to-find”. If the truck operators, later, finds the missing package, they re-locate the package in the inventory system to the correct compartment and position. The reason why the truck operators want the missing package to be moved to the fictitious compartment is to avoid re-booking the package which causes repeated frustration and unnecessary movement.

6.2.5 Unnecessary inventory

The respondents think that the current structure of the storage areas and compartments works well. However, there are specific problematic storage areas. In one of the warehouses “C”, where the products are stored below the roof, most of the compartments consist of mixed products and lengths which causes unnecessary transportation and movement of packages. During high-season, the truck operators responsible for production must make use of the warehouse and transport material there just to find space for the uncovered packages that cannot be stored outside. So is the case for impregnated products that also must be stored inhouse. During high-season, the focus is to raise the storage-levels which causes an extensive number of packages. This makes it problematic to find compartments where they can temporarily store packages to access the reserved ones. The great extent of material stored in the warehouse causes disorder and it makes it hard to organise the warehouse. Many times, the truck operator may place a package randomly just to store it and continue with the next package on the picklist. The truck operators try to keep the warehouse organised, but the motivation decreases as it becomes disarranged easily and fast. There is one more warehouse at the facility that is also a problem, warehouse "A". A lot of small packages (non-standard volume ones) are transported to the warehouse when a certain amount has been painted. The so-called leftovers are then stored in the warehouse. It also leads to difficultness to identify which package you should pick since labels on the packages sometimes are lacking. Packages are also incorrectly placed in the inventory system in comparison to the actual location of the package. According to the truck operators, sometimes it can take approximately 40 minutes to access the reserved package since the location of the package is incorrect and many packages must be moved.

6.2.6 Transportation

Both truck operators claim that unnecessary transportation does exist during order picking, especially packages. The truck operators believe that accessibility is one of the main causes as to why packages need to be transported and moved more than once. In compartments where there are mixed lengths and products, many packages must sometimes be moved to pick the right package that is been reserved. Small packages (non-standard volume ones) are often moved to get access to the correct one which also is very time-consuming. The reason is that they are not being reserved. The questions about temporary storage were also asked during the interview, questioning if there are situations where packages must be temporarily stored to, later, be placed at the correct location. The respondents claimed that there are compartments in which assignment is to act as a buffer. If compartments are full of a specific product, the coming packages are stored in the buffer compartments, but they are never moved back to its primary location. The truck operators believe that it is better to reserve packages within the buffer compartments to empty these to be able to store other packages there once it is needed. The buffer compartments are better off if they are empty (if possible) since it allows the truck operators to temporarily store packages there to access the right package in the compartments next aside. Sometimes the truck operators need to transport packages a long distance only to find a compartment where they temporarily can put the package aside.

6.2.7 Inappropriate processing

There are unnecessary activities that are repeated during order picking. One of these is the need to reset the hand unit used for verifying each order once all packages have been prepared for loading. Sometimes the hand units must be reset several times a day due to bad connection which is both time-consuming and frustrating according to the truck operators. The need for resetting is also apparent with the computers in each truck. The computers seem to work better if they are updated with the latest version, however, an update takes a long time and forces the truck operators to wait while the update is running. Further, the question was asked if the truck operators sometimes must prepare and repack several times and why that might be needed. The response was that it occurs very often. Customers can change their orders when the load is fully prepared for loading. Sometimes customers want to add one package or switch one package to a different length or product. In some cases, it cannot be done if there is no room for one more package. Sometimes it also happens that one or more packages cannot be loaded if there is a lack of space. This occurs most often when loading foreign trailers since they are lower in height. Communicating with truck drivers that packages must be removed and that they need to receive and sign a new delivery note is sometimes hard. Which further results in an unnecessary amount of time spent on loading.

6.2.8 Unused employee creativity

Overall, the truck operators have a good understanding of the inventory software, however, some functions are a bit problematic and often avoid. In some cases, the truck operators are given the task to reserve packages themselves, for example, special orders like painted products. The truck operators experience that the article number of the ordered package does not agree with the product ordered, even though the package is manufactured according to the request. It makes it difficult to reserve packages as it requires searching in the software, especially when there are a lot of different products and abbreviations and there is a possibility to pick the wrong package. According to the truck operators, it is better if the salesmen reserve the packages or write down the package number manually if it is a package that should be processed further for an order. Sometimes the salesmen reserve packages that the truck operators during order picking found to be unsellable due to damage or fault. It falls naturally since the salesmen cannot keep track of damaged goods unless it is noted in the software when reserving the packages. The truck operators often report to the office when damage or inaccurate packages are reserved and switch the package to another. However, often these packages are reserved multiple times even though the truck operators have reported that they are not sellable to the office. This causes waste since it is both time-consuming and leads to unnecessary movement. When this kind of feedback is reported, the packages should be noted as damaged or possibly moved to another storage area to avoid time-consuming movements.

The question was asked if the truck operators feel that their suggestions for improvement are being accepted and leading to changes in procedures. One truck operator thinks that it mostly is about solving the problem there and then if, for example, a package needs to be re-booked. The suggestions or challenges faced are often brought up as short-term to continue the order picking now instead of long-term solutions. One truck operator has brought up some suggestions on how to ease the order picking process, some of them have been implemented and some of them have not. One of the suggestions that have not been implemented is to keep track of which products should be manufactured and loaded to a specific customer each week regarding special requests. For example, products that should be exactly cut in different lengths that are not standard module lengths.

6.3 Summary of identified wastes and causing factors

An Ishikawa diagram for the order picking process was created to summarise the identified wastes and causing factors as to why inefficiency occurs (Figure 19).

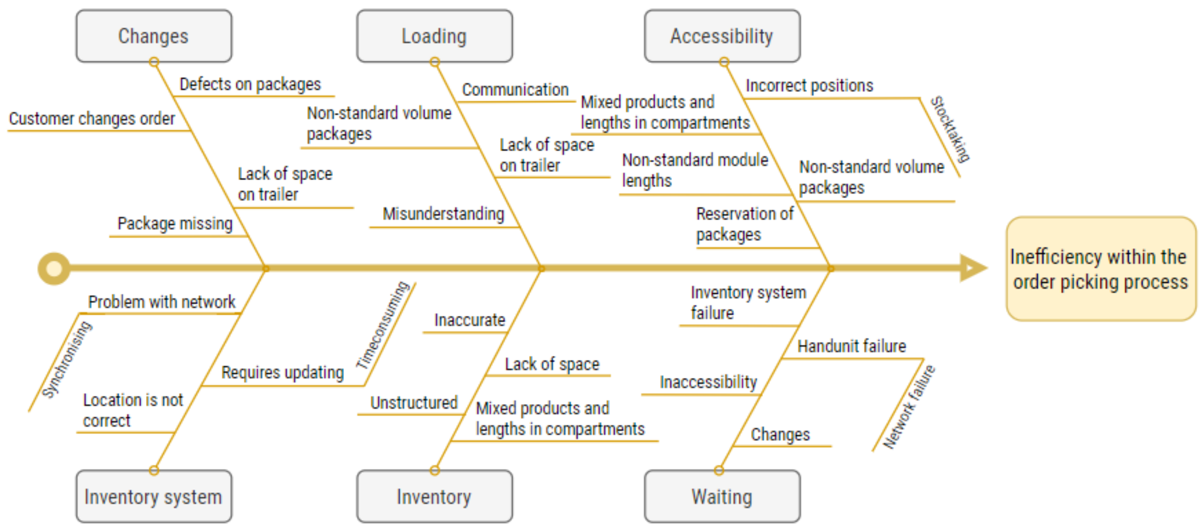

Figure 19. Cause and effect - or Ishikawa diagram for the order picking process.

The six main factors that lead to inefficiency are changes, loading, the inventory system, inventory layout, waiting, and accessibility. Changes occur when a customer wants to change the order when packages are missing or are defected. Lack of space on the trailer also leads up to changes since one or more packages must be removed. The loading process was not studied or timed, however, since the truck operators perform the loading the time for order picking becomes less and affects the number of order lines picked per day. As was the case for situations leading to changes, lack of space on the trailer also is time-consuming. Non-standard volume packages also are time-consuming since the truck operators must puzzle for stability. Both factors mean that is must be communicated to the drivers which sometimes is hard since they might not understand the need for it. Regarding the inventory system, the main time-consuming activity is a problem with the network which results in non-synchronising the packages picked. Continuous, the position of the packages sometimes is not correct according to the physical location which corresponds to the inventory layout. The inventory is in some areas very unstructured and inaccurate. Besides that, high volumes lead to a lack of space which makes it time-consuming to pick and temporarily store packages. One more factor is the mixed products and lengths in compartments, leading to unnecessary movements and causing defects in some cases when dimensions are mixed. Waiting does also exist during order picking which is caused by hand unit and inventory system failure, changes, and inaccessibility meaning that packages are missing. Accessibility and movement of packages occur very often as also was stated during the time studies since many packages had to be moved to access the reserved ones. This statement created an interest in looking deeper into these parameters within the existing inventory. In the next section, this is discussed further.

6.3.1 Accessibility and movement of packages

With the help of inventory statistics, a list of packages that have been moved more than 15 times was retrieved. The total amount of packages that fulfilled the criteria was 733. It was found interesting to also study the accessibility out of the 733 packages. The number of packages with accessibility within the interval 1 to 5 was compiled with the number of times packages been moved (Figure 20).

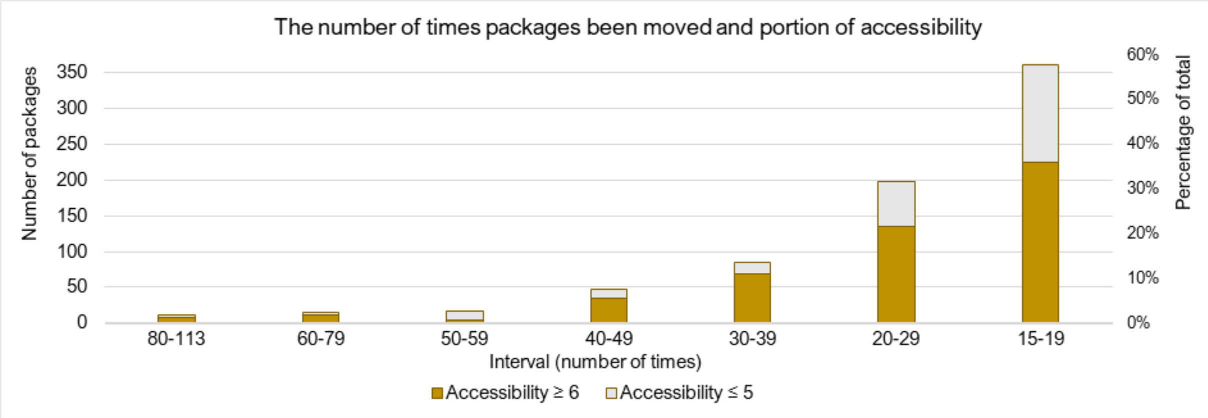

Figure 20. The number of times packages been moved and the portion of accessibility.

Most of the packages have been moved between 15 and 19 times and approximately 200 packages have been moved between 20 and 29 times. The highest number of times a package been moved was 113. The proportion of packages with the best accessibility (1-5) increased with the number of packages. The combination of high accessibility and the number of times packages been moved indicates that these packages will continue to be moved unnecessarily. Furthermore, the completed list of the 733 packages was studied to find possible causes as to why the packages been moved more than 15 times (Figure 21).

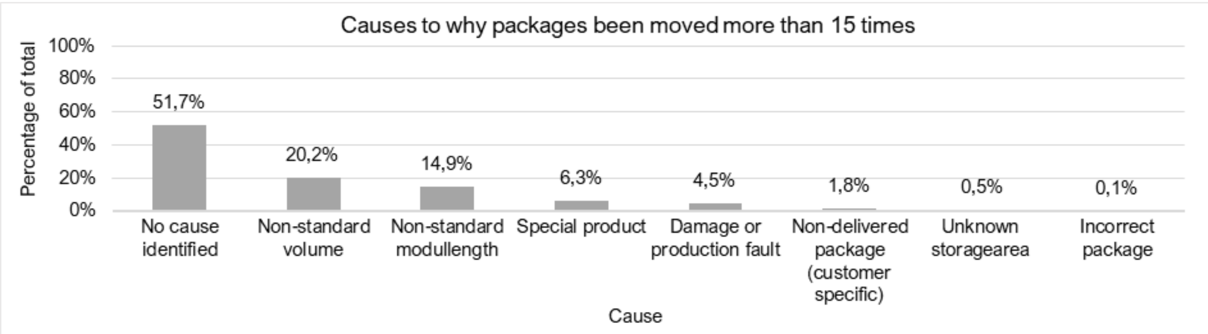

Figure 21. Identified causes as to why packages been moved more than 15 times.

No cause was identified for 51,7 % of the investigated packages that is been moved more than 15 times (733 in total). According to the statistics, 20,2 % of the volume of the packages is non-standard, meaning that the number of pieces is less than what the standard is set to be when producing it. Furthermore, 14,9 % of the packages are not standard module lengths which were found to be the second primary cause. Special products stood for 6,3 % and 4,5 % of the packages were commented to be damaged or incorrect due to production faults.

Packages with non-standard volume and module lengths correspond to 35,1 percent which is equal to 257 packages. Two primary causes have been identified as to why the proportion is that large. Packages that are not non-standard volumes are less than 1,6 cubic metre. Smaller packages are sometimes unwanted from the customers' point of view since they request "half-packages", meaning standard volume. Another reason is the preparation of loads before loading, especially when loading foreign trailers. Smaller packages can make it trickier to load, both in terms of space and distributing weight as smaller packages often imply the need to puzzle. In terms of foreign trailers, loading templates are often used which eases the preparation and loading of packages. In these loading templates, it is important to note packages that are smaller as they are placed at the top of each stack to ensure stability and maximising the utilisation of space. This is also a part of the principles of materials handling (Ray 2008), the motion principle which suggests reducing loading and unloading time. By using the loading templates the amount of time needed can be reduced. Further on, the perception may be that many of the customers will not accept smaller packages which may always not be the case. Hence, the smaller packages will not be reserved and the number of them will not be reduced.

The problem with non-standard module lengths is the fact that they are not shown in the inventory system when reserving packages. As previously been described in the empirical background, reservable packages are matched according to inserted product (according to article number) and length. If the average length is not a module one, although 99 percent of the pieces are, the package will not appear in the system and consequently continue to be left in stock and be moved again and again. As a result of repetitive handling, the risk for obsolescence and damage increases which can lead to unsellable packages or even worse, be sent to a customer. The packages that were not non-standard module lengths were further investigated. The difference between the packages' maximum length and the average length was calculated. 91 packages were found to differ between 1 and 178 millimetres between the maximum and average length. Looking at the individual packages, the main cause is that one or a few more pieces are 1 decimetre shorter than the actual length which probably is a production error. Out of the 91 packages, 27 has accessibility better than five. These packages have been moved between 1 and 29 times, with an average of about 10 times. The suggestion is that these packages should be altered since the probability is very high that all pieces in the packages are the same length. By altering them, the packages will appear when reserving packages and they will not continue to be moved unnecessarily.

6.4 ABC analysis

Products were divided into A, B, and C-classes within each segment (planed -, impregnated -, finger-jointed -, and painted products). The classification was based on demand and order frequency as previously been described in the method-section. The classification of products is seen in Figure 22-25. For a detailed ABC-analysis, see Appendix 3.

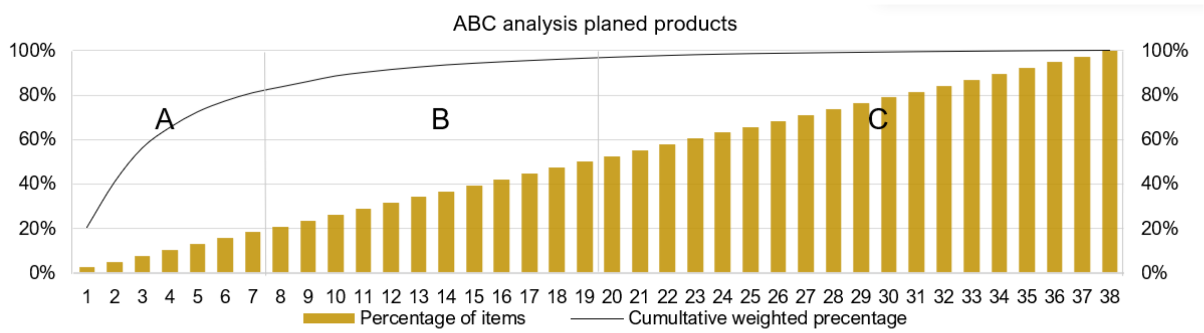

Figure 22. ABC analysis of planed products divided into A, B, and C categories in accordance with demand and order frequency.

Seven products are classified as A, corresponding for 18 percent of the items in total (38). 32 – and 50 % are B respectively C products.

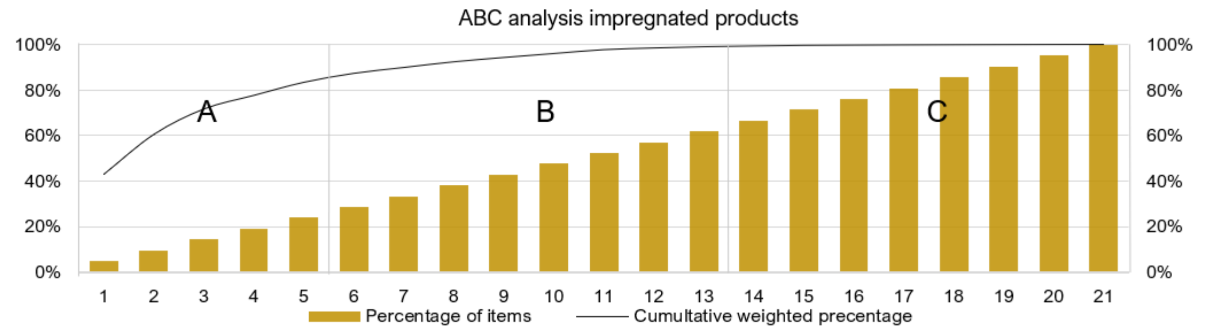

Figure 23. ABC analysis of impregnated products divided into A, B, and C categories in accordance with demand and order frequency.

Five products are classified as A within the impregnated segment, corresponding for 19 percent of the items in total (21). 33 – and 57 % are B respectively C products.

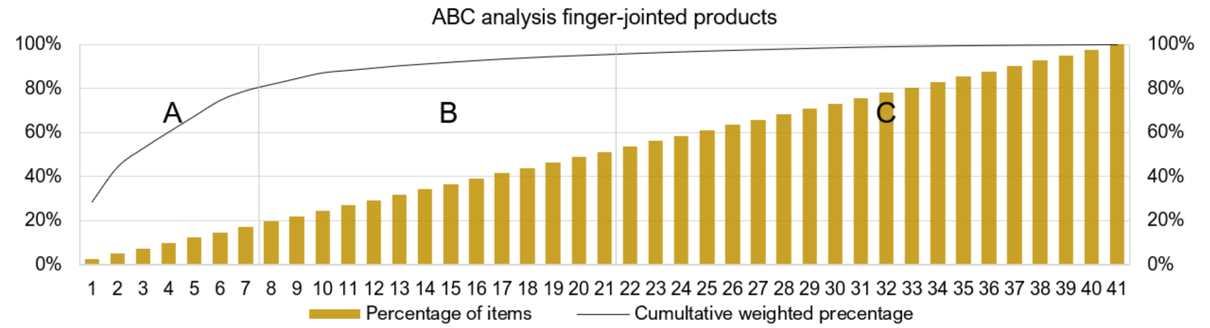

Figure 24. ABC analysis of finger-jointed products divided into A, B, and C categories in accordance with demand and order frequency.

Seven products are classified as A, corresponding for 17 percent of the items in total (41). 34 – and 79 % are B respectively C products.

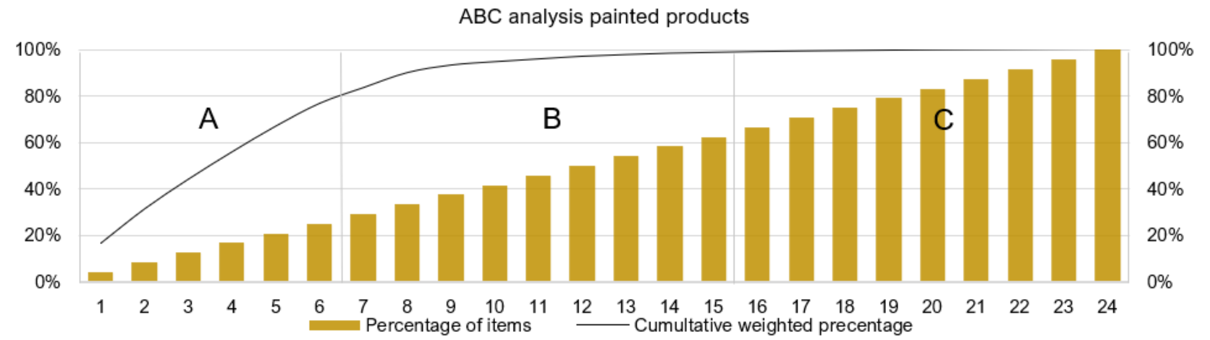

Figure 25. ABC analysis of painted products divided into A, B, and C categories in accordance with demand and order frequency.

Within the painted products, six products are classified as A, corresponding for 25 percent of the items in total (24). 29 – and 46 % are B respectively C products.

By using weighted volumes, order frequency and demand were taken into account which can act as a foundation to achieve a more appropriate layout design (Richards 2014) and further prioritise products. Within this study the ABC analysis was performed to further look deeper into the inventory layout, focusing on compartment content.

After the ABC analysis was conducted the location of the products was retrieved to find if the products are stored in compartments containing specific lengths of the same product (SL), mixed lengths of the same product (ML), mixed products (MP) or combinations of these since products often are stored in multiple compartments. The A, B, and C classified products were then categorised in accordance to compartment content (Figure 26). A detailed compartment content for each product is seen in Appendix 3.

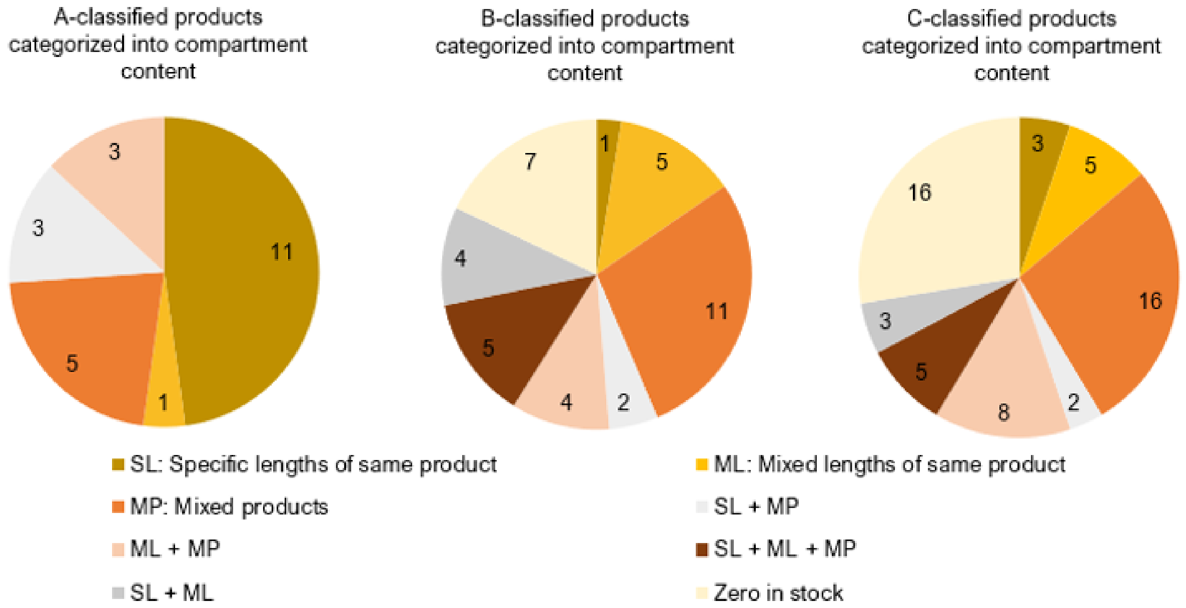

Figure 26. A, B, and C classified products categorised in accordance to compartment content.

The categorisation states that approximately 50 % of the A-products are stored in compartments with specific lengths containing the same product. That is not the case however for B – and C classified products. Many of the packages are stored in compartments consisting of mixed products. It is also quite normal for products to be stored in a combination of these categories. Meaning that one compartment can contain specific lengths of the same product, another compartment contains mixed lengths of the same product as well as mixed products.

Theoretically, the optimal strategy would be to keep products and specific lengths separate to avoid unnecessary movements of packages. However, that can be difficult to apply in real contexts since it requires storage area and possibly affects the travelled distance since the storage areas extend. Further, it can contradict the objective for efficient order picking: maximising the use of space (de Koster *et al.* 2007) and requirements of utilising minimum space when storing materials (Ray 2008). For example, if C-products are stored in compartments containing specific lengths, the compartments can remain un-filled, and, in that sense, the storage capacity is not utilised to its fullest. Resources should instead be focused on the A and B products which are highly and moderately important in terms of order frequency and demand. A-products should, for example, be prioritised and stored in compartments consisting of specific lengths since they are ordered most frequently and stands for approximately 80 percent of the volume sold. Meaning a higher degree of visits within these compartments. During the retrieval of the product´s location, many products are held in SL, ML, and MP combined. Currently, there was storage space free within all SL compartments. Implying that products, specifically held in MP should be moved to the SL compartments since there is available storage. Further, the number of compartments containing mixed lengths with the same products including compartments with mixed products can be reduced without having to extend the storage area. Rearranging products following the ABC analysis could be beneficial in that matter, hence reducing the number of unnecessary movements and transportation of packages.

6.5 Summary of empirical findings applied to material management, handling and order picking

6.5.1 Achieving a leagile value chain

Sabri and Shaikh (2010) developed five main principles within the hybrid strategy to achieve a leagile value chain. The principles were reviewed in section 3.2.1 and are further discussed below in relevance to the case company and the order picking process.

Focus on customer success

The company as such should foster customer-satisfying behaviours and customise service offerings. One of the immediate thoughts is that order picking plays a great part in offering service against the companies. The products should be delivered at the right place at the right time and live up to the customer's request containing the correct composition. One request could be to shorten the total lead time from the point a customer places their request until the packages have arrived at the site. To achieve a decrease in the total lead time, the order picking must become more effective than it is today by improving the conditions around it.

Create win-win and a trusted environment for all stakeholders

The company shall look beyond local improvement and eliminate waste trough out the entire value chain by getting the stakeholders to support the lean and agile initiatives. By collaboration, the organisation can learn how to become a better supplier to customers. As was discussed in the principle above, a decrease in the total lead time could make the company a better supplier if the customer appreciates that but still can adapt to changes. One of the challenges that were discussed during the interview was the uncertainty if the customer accepts smaller packages. The truck operators would like to send smaller packages to a higher degree to reduce unnecessary moves. The suggestion is to have a dialogue with the customers to which extent they accept smaller packages, perhaps smaller packages are demanded in those cases where the products are not requested regularly at the customers´ facility. The truck operators also stated that some lengths are not demanded, however, some customers do not request certain lengths. In those cases, a suggestion is to sell and reserve lengths that have the best accessibility but still remain an even distribution of lengths in the stock. Today the decision of which lengths that should be sold is determined in the business system where the accessibility of the packages is not shown. If the accessibility could be integrated with the business system a win-win situation could be achieved since the company reduces the required time for order picking and belonging cost while decreasing the total lead time for the customers.

Eliminate waste and reduce nonvalue-added activities

The wastes and non-value adding activities have been reviewed previously, with the purpose to free resources and concentrate on value-added activities. Some activities are non-value adding but necessary to prepare the loads to its fullest. None of these activities can be eliminated to its fullest, but they can be minimised and, in some respects, avoided. For example, can the transportation and unnecessary movements of packages decrease and so the waiting that occurs. More time can be spent by picking up the reserved packages and the packages picked per man-hour can increase if the inventory layout is more thought out. In this case, it is important to think about activities that make the experience from the customers negative. As was stated earlier, excessive handling of one package will increase the risk of damaging the goods. Hence, it is important, besides the financial and time-consuming aspect, to reduce the extent of material handling to keep the customer satisfied with the quality.

Institutionalise continuous improvement

Proactive elimination of problems and continuous improvement becomes essential in achieving a leagile value chain. By regularly listening to the truck operators and on their suggestions, such as regularly perform stocktaking and keeping track of the inventory content, problems and waste can be prevented to a higher degree. The authors also recommend companies to share the best practice across the organisation. By involving the truck operators responsible for production, they can create an understanding of the order picking process and ease the process by being alert and increase the accessibility for packages instead of moving material to that compartment and inhibit the order picking. Order picking does not only exist at the wood processing facility, but it also occurs at the other two facilities the organisation owns. Even though the conditions at those sites are not explored within this study, certain initiatives could perhaps be adopted since the same inventory system is used.

Close the loop between planning and execution

The fifth principle is primarily regarding the importance of measuring the performance of the value chain or a certain process within the value chain (Sabri and Shaikh 2010). As was stated in the theory chapter, Frazelle (2016) and Kusrini *et al.* (2018) reviewed key performance indicators throughout the order picking. The financial, productivity and cycle time measures were used within this study and could further be applied when continuously improving the order picking process. By studying the different measures, causes of inefficiency were identified which strengthens the fact that warehouse performance measurements do indicate problems that need to be solved.

6.5.2 Solutions to achieve principles of materials handling

According to Ray (2008), well-functioning materials handling systems call for certain essential requirements which were summarised in section 3.4. The same author has reviewed the principles of materials handling which originally was stated by Hall (1965). In Table 8, the selected principles (11) are deducible to the individual case that is been studied as a result of the empirical background, interviews, time studies, and observations. For an explanation of the selected principles, see section 3.4.1.

Planning

According to Hall (1965) and Ray (2008), the plant layout should be considered before the design of the correct location for material should be planned. Within the company, products should be allocated according to the ABC analysis where demand in terms of quantity and order frequency was considered. The additional Figure (23) showed that many of the A-classified products are stored in both SL, ML, and MP compartments. Products may be arranged to prioritise A-products and keep them in SL compartments instead of a variety of different combinations. Planning of orders with manufactured products should be emphasised. If products are manufactured to a specific customer and order the product shall be allocated to ease the order picking process and avoid unnecessary transportations and movements.

System, simplification and space utilisation

Hall (1965) and Ray (2008) suggest that intermediate and temporary storage should be avoided, minimised, or eliminated. Further, re-handling should be eliminated by delivering materials at the correct location the first time. The suggestion for the case company is to encourage the production trucks to pick orders that are being manufactured and transport them directly to the loading spot to avoid temporary storage and fill compartments which sooner are picked by the truck operators. Another suggestion is to reserve packages from buffer compartments first to create space for moving packages around to access reserved ones. It could be a part of making use of existing compartments to avoid combinations of SL, ML, and MP for the same products.

During the collection of data, it was found to be storage space available in SL compartments which indicates that space is not utilised to its fullest.

Material flow and unit size

Eliminate obstacles from material flow, combine activities to reduce material movement and examine the possibility of unitising loads is suggestions made by the authors. The suggestions for the company are to encourage the truck operators to pick several orders at the same time to a higher degree than is done today. Possibly encourage the loading planner who reserved the packages to gather similar orders with the same products to support the truck operators to increase productivity. By picking multiple orders at the same time, with similar products, the transportation and movements of packages can theoretically decrease. As was clarified during the investigation of accessibility and the number of times packages have been moved, the packages that are non-standard average length should be adjusted (if the length is incorrect). Non-standard volume packages could be reserved to a higher degree if the customer accepts and it is possible within the loading template since they are moved extensively. It should also be added that sometimes the package's position is not correct according to the computer. By carrying out stocktaking regularly the position of the packages will be more accurate hence be equivalent to the actual position and accessibility. Leading to that the packages with the best accessibility are the ones who get reserved.

Motion principle

The suggestion made by Hall (1965) and Ray (2008) is to reduce the loading and unloading time. As previously discussed, changes and non-standard volume packages affect the loading time negatively. The suggestion is to inform and educate the salesmen about the circumstances for loading foreign trailers (since these are the most time consuming) and how non-standard volume packages affect the loading process in terms of space and stability. According to the truck operators, the perception of non-standard volume packages differs which makes it useful to note how small or big the packages are on the picklist. The loading templates that are used when loading foreign trailers come in handy and should continue to be used and detailed so there will not emerge surprising elements.

Idle time

The idle time is apparent during order picking, especially when the truck operators must wait for the computer to restart if a failure occurs. One suggestion was to update the software since the initial thought is that the inventory software works better if it is updated to the latest version. Since updating leads to standstills, it seems to be a good idea to update the software after work hours so the truck operators can focus on order picking during the day.

Obsolescence

According to the authors behind the principles, their understanding of the principle obsolescence is to replace obsolete handling methods. Within the order picking process, modern tools such as the inventory software and hand units to verify the load are used and they are helpful. However, during the time studies, it became apparent that the hand unit and the inventory system can lose network connection during the order picking and verification. Possibly could the network improve if more connection points were installed. If that is not the main cause for failure of the hand units, perhaps a new hand unit should be tested and see if a new model works better.

Control

According to the authors, materials handling should be synchronised with production which could be applied at the company. The suggestion is to encourage truck operators at production to pick orders that are about to be produced and transport them directly to a loading spot. Often a customer places a request for one product that is about to get planed. When the product is being manufactured the truck operator at the production unit can directly prepare the load. It will eliminate temporarily storage for that order and the truck operators can focus on picking another order. Products that are manufactured specifically for an order could be noted with a reference to a larger extent and stored at the same location. By gathering the packages, the truck operators do not spend an excessive amount of time to prepare the load. In some cases, the trailer can perhaps be loaded directly to the compartment.

Capacity

The suggestion from Hall (1965) and Ray (2008) is to make full use of building volume. The suggestion can certainly be adopted at the company by making full use of existing compartments since there was free storage in SL compartments during the collection of data. By utilizing the storage space in compartments, mixed compartments can decrease to some extent and perhaps make the accessibility better and warehouses can be more organised. Packages that have been moved multiple times with high accessibility should perhaps be further investigated. If they are in good condition they should preferably be reserved when the next opportunity comes up. If they are damaged or defected, they should be moved to another storage area that is not visited as often to stop the unnecessary movement of that package.

6.5.3 Objectives with the order picking process

The objectives when optimising the order picking process, discussed by de Koster *et al.* (2007), is rather unfilled after been conducting a time study, held interviews, and analysed the process. The use of space is not maximised which was discussed during the ABC analysis since products with high order frequency are held in compartments with mixed content, even though there was available storage space within the SL compartments. The overall throughput time varied when comparing different orders and order lines. For some products, the packages picked per man-hour was high, indicating that there is potential for the throughput time to decrease and be minimised. The packages picked per-man hour correlated with the accessibility to packages which implies that the maximisation of accessibility to all items is lacking which especially was made clear during the ABC analysis. By rearranging the inventory and allocating products according to their importance, the accessibility can increase with the combination of reserving smaller packages more often. One other objective according to de Koster *et al.* (2007) was to maximise the use of labour, by incorporating and engaging the truck operators responsible for production, intermediate and temporary storage of packages can increase. Meaning that the truck operators could pick orders directly when packages are produced. Except for the objectives discussed by the authors, Grosse *et al.* (2015) claimed that human factors should be considered to enhance performance and quality. The truck operators mentioned that frustration can occur during the order picking process when unsellable packages continue to be reserved even though it is been communicated to the office. Many non-value-adding activities can decrease if the dialogue between the truck operators and office increases and becomes better. An understanding of the loading process and factors inhibiting it from the truck operator's perspective can make it much more efficient and release time for picking orders.

7 Discussion

In this section, the empirics and the analysis are discussed with parallels to the problem background and literature review in section two. Further, the suitability of methods and procedures is discussed.

7.1 Empirics and analysis

7.1.1 Material handling and flow efficiency

Through time studies, interviews, observations, and inventory statistics the material flow was shown to be affected by several activities and parameters. These activities corresponded to be both value-adding ones, non-value-adding but necessary and strictly non-value-adding. The performance of a simplified VSM made it possible to evaluate which steps in the process that contributed or inhibited efficiency. The main activities that led to inefficiency were unnecessary movements of packages and transportation followed by waiting, changes, inventory and inventory system, and accessibility. Searching for products did not occur as often according to the truck operators, which did occur more often in the study made by Broulias *et al.* (2005). To speed up the tracing of products, the company adopted a simple WMS. If the case company within this study did not have an inventory system, the required time for searching packages would probably be much more of a problem. Searching for packages is not eliminated, however, it might occur fewer times if stocktaking is being performed more regularly and the inventory system matches the physical location of products better. Except for adopting a WMS in the study made by Broulias *et al.* (2005), the authors changed the location of products based on an ABC analysis to reduce retrieval time. It became clear within this study that the required time for accessing packages was high, especially since multiple packages often had to be moved to access the reserved ones. After performing the ABC analysis, and analysing in which compartments they are stored, it was shown that less important products are stored in compartments containing the same product and same length. While the most important products are widely scattered and stored both in SL, ML, and MP compartments. The recommendation is that products shall be rearranged following the analysis while still making use of the existing SL compartments that were not full during the collection of data. Broulias *et al.* (2005) further suggested that the storage space should be extended to reduce the storage depths, it was not adopted by the company since it required an additional warehouse. It certainly would have decreased the low accessibility at the case company if the storage area were extended and more products could be held in SL compartments. However, it is not realistic due to the high number of products and their bulkiness. Instead, the focus shall be on utilising the height and existing compartments that are not full. In other words, make use of the existing resources. It is worth mentioning that the inventory stocks change depending on the season. In that sense, it is a good idea, suggested by Purba and Aisyah (2018), to analyse products by class periodically according to the demand rate. The demand and order frequency were studied during the period 1st July 2019-31st December 2019, if the interval had changed to the spring, the outcome of ABC analysis could have been different.

Conducting a VSM is not only limited to increase efficiency, but also be used to enhance product quality. The quality of products was mentioned during the interview in the means that defects do occur. Heavier dimensions that are stored upon thinner dimensions causing the pieces to be crooked. For those reasons, increasing the utilisation of existing compartments can help to avoid stacking thicker dimensions on thinner ones. Lumsden (2006) addressed that a higher degree of handling can increase the risk of damaging the goods, hence affects the value of the product which can be applied for this industry. As well as the storing of packages and the content in compartments. To look beyond the order picking process and look at the inventory as a whole, the material does affect the overall profitability. It was shown that many packages are moved multiple times, due to varying factors (Figure 21). The actual movement of a package increases the risk for damages, but the properties of the material itself make it even more important to store it accurately and reduce the average inventory turnover. The belief is that a well thought out storage policy, minimising the excessive handling of packages, and decreasing the average number of days a package is stored at the facility will reduce obsolescence. To reduce obsolescence and damage, the evaluation of the order picking process is vital. By thoroughly explore the process and identifying factors affecting it, the margins should hypothetically increase since the flow of material becomes more efficient (Frazelle 2016).

7.1.2 Trade-off between being strictly lean and strictly agile

In order to achieve a well-functioning operational strategy for value chains, concurrent improvement in both internal operating efficiencies and customer service level is required (Lambert 2008). By combining lean and agile models, focusing on the factory as well as the customer, advantages can be reached to a greater extent (Reiner 2009; Sindi & Roe 2017). It has become apparent during the study that activities within the order picking process, are not value-adding in terms of the strictly lean-approach. However, these activities might be valuable to the customer. Verifying packages for instance, are determined as a non-value adding but necessary activity within this study. To develop, verification should not be necessary if the truck operators were sure that the right packages were picked immediately. However, the activity is necessary meaning that packages are checked once again to ensure that the right product, and the right volume are delivered to the customers. As a result, the company can achieve a low rate of products returned to remain or achieve a high service level to customers (Hugos 2018).

Both the lean and agile strategy requires minimisation of total lead-time from the point a customer places a request for a product until the products are delivered (Christopher & Towill 2001). However, minimisation of the total-lead time for picking orders must also take the service level to customers in remembrance. Some activities that should be eliminated according to the strictly lean approach, could according to the agile strategy be vital in terms of reaching customer success. For example, the verification of packages before loading. The leagile value chain shall handle both predictable and unpredictable demand and further value frequent deliveries of small quantities rather than no intermediate storage, just-in-time shipping, and receiving (Sabri & Shaikh 2010). As suggested, there is seen to be potential for orders to be picked in direct connection to production by truck operators to avoid temporary storage. However, it is not about eliminating intermediate storage completely, it is about decreasing the storage and increase efficiency within the order picking. Without intermediate storage, the company falls behind in achieving flexibility and quickly adapting to changing customer demands which affects their satisfaction.

To summarise, the lean and agile strategy is interesting by those means that the strategy includes the lean philosophy combined with customer success and service level. By adopting the strategy, companies do not have to strictly choose one or another. Companies may still need to consider the trade-offs when analysing processes and tempting to achieve a leagile value chain. As Lindström (2020) claimed, the development of value chains can be decisive for organisations within the forest sector to increase profitability and solvency. However, it is interesting to look beyond local improvements and look at the opportunities to create value for the customer and supplier and the interactions between these two. A collaborative environment, learning how to become a better supplier to customers and better customers to suppliers, could certainly, act as guidance on how the value chain can develop. In the end, it is the customer that decides which supplier to turn to and companies who acts in a competitive environment must both increase its internal efficiency but not oversee the service to customers. It is simply a trade-off between being strictly lean and strictly agile to achieve a successive value chain.

7.2 Choice of method and procedures

7.2.1 Focusing on the order picking process

De Koster *et al.* (2007) argued that researchers should focus on applying methods that can be generally drawn instead of only focusing on a specific situation or problem. Although the focus within this study was on specific problems within the order picking process, it should be stated that factors causing non-value-adding activities also affect the overall management of material at the facility. Low accessibility and packages that are non-standard volume and non-standard-lengths also affect the truck operators responsible for production, since they also must prepare packages before production starts. Thus, decreasing productivity. The exploration of the order picking process has certainly led to suggestions that will make the overall material handling more efficient. The statement made by de Koster *et al.* (2007) is agreeable, but in this study, it appears by focusing on a specific situation also can lead to methods that can be generally drawn. Such as decreasing the number of packages that have been moved many times by correcting the packages that are non-standard-lengths due to production faults such as increasing the sales of non-standard volume packages. The authors further claimed that storage assignments seem to have been neglected during their literature review, although it impacts the performance of routing (*ibid.*). As been mentioned the focus was on the actual order picking process and not so much on the activities around it such as the inventory layout. However, many of the activities identified are caused by the inventory layout which was settled by conducting an ABC analysis analysing the compartment content.

7.2.2 Collection of data through interviews, time studies, and observations

The initial thought was to conduct time studies and time each activity within the order picking process such as the dialogue with the office, changing reserved packages to another one, communicating with other truck operators, etc. However, a lot of different activities are carried out and there are no distinct lines between the activities that occur. That made it difficult to measure since it was shown to be great complexity. The cycle time for picking individuals orders and belonging order lines was still measured but without deriving it to specific motions. Except for empty travels and unnecessary movements of packages and transportation of reserved packages to loading spot. Instead, the observations became more valuable in terms of identifying both motions and factors that affect the process. Both negatively and positively. The observations contributed to the analysis of the process to a great extent since many of the activities were not heard during the interviews. It cannot be precluded that the amount of time each motion take would have been both interesting and valuable within this study, as well as measurable and comparable if suggestions were implemented. However, the cycle time of the order picking process, as well as inputs from observations and interviews, still made it possible to analyse the process.

Since the order picking process showed great complexity, in combination with that the inventory layout and storage areas are scattered, the time studies, observations, and interviews were felt to be the right approach. Especially since the order picking process has remained somewhat a non-investigated area at the company. Theys *et al.* (2010), Yu & de Koster (2010), Ene & Öztürk (2012), Chen *et al.* (2015), and Altarazi & Ammouri (2018) have been developing mathematical models, algorithms, and simulations to rationalise the order picking process. Although they are popular research methods to analyse problems within order picking planning (van Gils *et al.* 2018), it was felt to not suit the aim of this study since the current state of the order picking process and influencing factors had not been identified in depth before. The choice to not adopt or create a mathematical model, algorithm, or simulation was strengthen during the literature review. Shqair *et al.* (2014) claimed that it is difficult because of the randomness in operations and the variety of parameters affecting them which certainly was the case within the studied organisation.

7.2.3 Performing a VSM

Creating a value stream map is common within operations management and when optimising processes in organisations. Both Bild & Svensson (2019) and Purba & Aisyah (2018 performed a VSM in their studies when identifying non-value-added activities and improving value-adding ones. Value stream maps are often detailed, and the lead time is derived from each activity that occurs. As previously was mentioned, a lot of different activities were carried out and there were no distinct lines between the activities that occurred. That made it quite tricky to perform a detailed VSM accordingly to the maps that the authors did. Instead, the order picking process was mapped out more simply and the summary of the lead times acted as a complement to the model. However, the order picking process was mapped out and gave an overview of which activities that occur and which ones that are value-adding, non-value-adding but necessary, and completely non-value-adding. In that sense, business modelling or value stream mapping has proven to be a good and useful tool to eliminate waste in a cycle and identify more waste to eliminate in the next cycle, which was stated by Chen & Meng (2010).

7.2.4 Parameters used in the ABC analysis

Two ABC singles analyses could have been conducted and then merged to attain the traditional way of conducting an ABC cross-analysis as De Felice *et al.* (2014), Arnesson & Bergqvist (2018), and Kevine (2018) exemplifies. In this study, a weighted volume was retrieved by multiplying demand and order frequency which fills the same purpose. Kevine (2018) found that although certain products are of high sales value, they are not always highly requested in terms of order frequency. Within this study, the demand in quantity was used instead of sales value. However, the authors´ conclusion is found to be the same in this study. Although the demand for one product was higher than another, the order frequency leads to a higher weighted volume in comparison, leading to an increase in importance from an ABC-classification perspective. This strengthens the fact that a single ABC analysis, accounting for only one criterion, becomes limited as also been claimed by De Felice *et al.* (2014). In this study two criteria were chosen, however, De Felice *et al.* (2014) argue that many factors could be considered, for example, the risk of damage. The truck operators mentioned that defects on packages can arise if heavier dimensions are placed on products with thinner dimensions. With that said, damage risk could perhaps be included to identify if products with a higher risk are currently placed in mixed compartments containing heavier dimensions to decrease obsolescence. Arnesson & Bergqvist (2018) performed an ABC analysis based on order frequency and weight as weight often tended to stop the order picking process according to the employees. With that said, the ABC analysis could be used in a variety of ways. Based on Arnesson & Bergqvist (2018) analysis, their suggestion was to place the most important products near the entrance to achieve cost savings. This study was delimited to not focus on inventory layout more than the ABC analysis and compartment content. However, besides increasing the number of SL compartments the important products shall be placed near the entrances but another factor must be included within this company and the facility layout. The inventory layout shall also be based on which products that often are requested together. Placing important products near the entrances is a start, but transportation might not become less.

8 Conclusions

In this section, the conclusions are presented that refers to address the aim of the study and associated research questions. The section concludes with suggestions for further studies.

8.1 Aim, research questions, and further studies

This study aimed to identify nonvalue adding activities within the existing inventory management and material handling at a sawmill – and wood company, focusing on the order picking processes. The intent was to explore opportunities for improvement during the process with the support of operations management.

8.1.1 Which activities affect the material flow and how do the activities interact and impact each other?

The material flow was showed to be affected by several activities and parameters, the main activities were the retrieval of packages and unnecessary movement of packages. Changes, loading, accessibility, the inventory, and inventory system and waiting were identified as causing factors that lead to inefficiency within the order picking process. Changes occurred, among others, if packages have defected, the customer changed the order, and if packages were missing. The accessibility of packages is crucial for efficiency. Incorrect positions, non-standard volume, and length packages such as mixed products and lengths in compartments worsen the accessibility and thereby worsening the material flow. Failure of the inventory system and hand units leads to waiting, hence affecting the packages picked per man-hour. The inventory was identified as a time-consuming parameter. Inaccurate positions of packages, lack of space, unstructured warehouses, and mixed products and lengths in compartments led to great excessive handling of material.

8.1.2 Which changes on operational – and company level – can impact the material flow to become more time – and cost-effective?

The main activities that decrease the efficiency of order picking are the retrieval of packages and thereby unnecessary movement of packages and loading. The excessive number of packages that must be moved has the potential to decrease. By rearranging products according to the ABC analysis and be better at utilising the existing compartment the accessibility can become greater. Stocktaking should be carried out more regularly to ensure that the location of the package conforms with the system, thus eliminating inaccuracy and missing packages. Further, by regularly have a dialogue with customers if they accept non-standard volume packages, unnecessary movements can decrease since these packages often are moved several times. A suggestion to the company is to oversee the possibility to sell lengths according to accessibility if a specific length is not requested to increase the number of packages picked per man-hour and reduce the picking cost. To minimise the waiting, updating the inventory system could possibly be carried out after work hours. The temporary storage of packages does occur often. By engaging the truck operators responsible for production, some orders can be picked directly to the production line if the products are manufactured in the near term. Thus, decreasing unnecessary transportation. By continuing to adopt performance measures, causes that lead to inefficiency can be identified, thus be eliminated or minimised.

8.1.3 Further studies

It would have been interesting to proceed with another ABC analysis according to damage risk as well as which products often are requested together. By analysing products that often go together, the inventory layout could be explored to a higher degree and see if there is potential to reduce transportation. Continuously, it would be interesting to explore the possibilities for changing the location of loading spots or expand the number of loading spots to check if the current ones are optimal. According to the results of this study, transportation was shown to occur to a great extent. For that reason, the truck operators distance travelled and how often they visit the same storage areas would have been interesting to explore and see if it could be rationalized to some degree. Lastly, the three main principles of order picking should further be explored and see if the order picking process could become more efficient by adopting one or another.

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Personal messages

Lindblom, Mattias
Truck operator, Sandåsa Timber AB
In-person at the worksite [2020-04-01]

Lovén, Joakim
Truck operator, Sandåsa Timber AB
In-person at the worksite [2020-04-01]

Appendicies

Appendix 1. Interview guide

Interview guide in English

Tells briefly about the Lean philosophy and the waste and non-value adding activities that can occur in the material handling process.

Questions about the order picking process

- What factors control which products/packages you start with when ordering?
- Do you feel that reserving packages facilitates order picking? Are there currently products that are not booked that should be booked and vice versa?
- The load can consist of several orders to different customers. Do you pick one order at a time or do you work in parallel with several orders at the same time?
- Do you always pick up packages from the finished goods warehouses or do you pick packages in direct connection with production?
- Do you see the benefits of picking directly in connection with production? Is there a dialogue between you and the truck operators responsible for production units?

Questions related to waste and non-value adding activities

Overproduction

- Do you always pick - and prepare orders and loads the day before the delivery is due?
- Do you find that there are products that have been in stock for a long time that hamper the order picking process?

Defects

- Can damages occur on packages, or can packages/products be incorrect or incorrectly specified?
- How does this affect your order picking?
- Do you see that it occurs on specific products or specific storage places?

Waiting

- Is there a lot of waiting in the order picking process? For example, waiting to be able to pick or waiting for information?

Unnecessary movement

- Do you find it easy to find products/packages to pick?
- If the package is not where it should be. How do you go about it then?

Unnecessary inventory

- Do you think the structure of the storage areas and warehouses is good today?
- Do you see that some products should be stored in a different place than they do today?

Transportation

- Does unnecessary transport occur in order picking? For example, packages must be moved several times.
- What might be the reason that packages must be moved multiple times?
- Do situations arise where packages are stored temporarily in one place and then need to be moved to their proper place?

Inappropriate processing

- Are there activities that you need to repeat unnecessarily? For example, verify the weld several times?
- Does it happen that you must prepare and repack several times? In such cases, why might it be needed?

Unused employee creativity

- Do you feel that you have a good understanding of SIPal?
- Are there any factors that SIPal and thus the load scheduler does not see that you see outside at the storage areas and in warehouses? That should be kept in mind.
- Do you feel that your suggestions for improvement are being accepted and leading to changes in procedures?

Other questions

Do you have any other comments you would like me to bring? Who has not been brought up during the interview?

Interview guide in Swedish

Berättar i korta drag om Lean filosofin och de slöserier och icke-värde adderande aktiviteter som kan uppstå i materialhanteringsprocessen.

Frågor om orderplockningsprocessen

- Vilka faktorer styr vilka produkter/paket ni börjar med att plocka på beställningen?
- Upplever ni att bokningen av paket underlättar orderplockningen? Finns det idag produkter som inte bokas som bör bokas och vice versa?
- Lasset kan bestå av flera beställningar till olika kunder. Plockar ni en order i taget eller jobbar ni parallellt med flera beställningar samtidigt?
- Hämtar ni alltid paket från färdigvarulagret eller händer det att ni plockar paket i direkt anslutning till produktion?
- Ser ni fördelar med att plocka i direkt anslutning till produktion? Finns det en dialog mellan er som framplockare mot truckförare som kör mot produktion?

Frågor med härledning till slöserier

Överproduktion

- Plockar ni alltid ihop och förbereder ordrar och lass dagen innan leveransen skall ske?
- Upplever ni själva att det finns produkter som stått längre i lager och hämmar orderplockningsprocessen?

Defekter

- Kan skador uppstå på paket, eller kan paket/produkter vara felaktiga eller felaktiga specade?
- Hur påverkar det er orderplockning?
- Ser ni att det uppstår på särskilda produkter eller på särskilda lagerplatser?

Väntan

- Uppstår det mycket väntan i orderplocknings-processen? Exempelvis väntan på att kunna börja plocka eller väntan på information?

Onödig rörelse

- Upplever ni att det är lätt att hitta produkter/paket som ni ska plocka?
- Om paketet inte finns där det ska vara. Hur går ni tillväga då?

Onödigt lager

- Tycker ni att uppbyggnaden av lagret och lagerstrukturen är bra idag?
- Ser ni att vissa produkter bör lagras på ett annat ställe än vad de gör idag?

Transport

- Uppstår det onödig transport i order-plockningen? Exempelvis att paket måste flyttas flera gånger?
- Vad kan vara orsaken att paket måste flyttas flera gånger?
- Uppstår det situationer där paket lagras provisoriskt på en plats för att sedan behöva flyttas till sin rätta plats?

Onödigt arbete

- Finns det aktiviteter som ni måste upprepa i onödan? Exempelvis verifiera lassen flera gånger?
- Händer det att ni måste plocka om lass flera gånger? I sådana fall, varför kan det komma att behövas?

Ej utnyttjad kreativitet hos anställda

- Känner ni att ni har en bra förståelse för SIPal?
- Finns det faktorer som SIPal och därmed utlastningsplaneraren inte ser som ni ser ute på plan? Som bör tas i åtanke.
- Känner ni att era förslag på förbättring mottags och leder till att rutiner förändras?

Övriga frågor

- Har ni några andra synpunkter ni vill att jag tar med mig? Som inte har fått tagit plats under intervjun?

Appendix 2. KPI equations

2.1 Cycle time: order picking cycle time per order

The order picking cycle time per order line was retrieved by calculating the time from when the previous order line was finished until the next order line was completed. The calculation of the cycle time per order line is expressed in the equation below.

Cycle time for package no 1:

$$(P_{1\,accessed} - OP_{start}) + (P_{1\,loading\,spot} - P_{1\,accessed}) = CTP_1$$

Where

$P_{1\,accessed}$ = time when forklift access package no 1
OP_{start} = time when order picking started
$P_{1\,loading\,spot}$ = time when package no 1 was left at the loading spot
CTP_1 = cycle time for package no 1

Cycle time for package no *n*:

$$(P_{n\,accessed} - P_{n-1\,loading\,spot}) + (P_{n\,loading\,spot} - P_{n\,accessed}) = CTP_n$$

Where

$P_{n\,accessed}$ = time when forklift access package no *n*
$P_{n\,loading\,spot}$ = time when package no *n* was left at the loading spot
$P_{n-1\,loading\,spot}$ = time when package no *n* - 1 was left at the loading spot
CTP_n = cycle time for package no *n*

Cycle time for order:

$$CTP_1 + CTP_2 \dots CTP_n = CT_{order}$$

Where

CT_{order} = cycle time for order

2.2 Financial: picking cost per line

The picking cost per line was calculated with the equation below:

$$PC_{hour} \times CT_{order} = PC_{orderline}$$

Where

PC_{hour} = picking cost per hour
CT_{order} = cycle time per order line
PC = picking cost per line

The picking cost per hour (set to 70 euro) was multiplied with the cycle time of picking the order line.

2.3 Productivity: order lines picked per man-hour and packages picked per man-hour

The number of order lines picked per man-hour was calculated with the equation below:

$$\frac{\sum_{n=1}^{n} OL}{CT_{orderline}} - = OL_h$$

Where

OL = number of order lines
CT_{order} = cycle time per order line
OL_h = order lines per hour

The number of packages picked per man-hour was calculated with the equation below:

$$\frac{\sum_{n=1}^{n} P}{CT_{orderline}} - = P_h$$

Where

P = number of packages
CT_{order} = cycle time per order line
P_h = packages per hour

Appendix 3. ABC-analysis

3.1 ABC analysis and compartment structure – planed products

Planed products										
Number	Product	Demand 20190701-20191231	Order frequency	Weighted volume	Weighted percentage	Cumultative weighted precentage	Classification	Percentage of weighted volume	Percentage of items	Compartment structure SL, ML or MP*
1	2045195532H4	3135	335	1050135	20%	20%	A	81%	18%	SL + MP
2	2045145532H4	2872	364	1045470	20%	41%	A			SL + MP
3	2045095532H4	2092	374	782432	15%	56%	A			SL + MP
4	2045220532H4	1827	259	473229	9%	65%	A			SL + MP
5	2045170532H4	1375	261	358965	7%	72%	A			SL + MP
6	2045120532H4	1139	221	251720	5%	77%	A			SL
7	2045095530H4	1667	114	190060	4%	81%	A			SL
8	2020120568ÄR	881	149	131263	3%	83%	B	15%	32%	SL + ML + MP
9	2045045530H4	935	137	128151	2%	86%	B			ML
10	2028070568H4	875	146	127811	2%	88%	B			SL + ML + MP
11	2045245532H4	1096	73	80006	2%	90%	B			SL + ML + MP
12	2045070530H4	596	114	67912	1%	91%	B			ML
13	2045070538H4	480	118	56590	1%	92%	B			-
14	2022145528HK	396	126	49867	1%	93%	B			SL + ML + MP
15	2023120568ÄR	438	86	37690	1%	94%	B			ML
16	2022170528HK	341	97	33029	1%	95%	B			SL + ML
17	2045045538H4	302	98	29630	1%	95%	B			ML + MP
18	2045070545H4	597	46	27477	1%	96%	B			SL + MP
19	2022120528HK	280	93	26066	1%	96%	B			ML
20	2022095528HK	249	92	22880	0%	97%	C	4%	50%	ML
21	2022095568H	339	62	21033	0%	97%	C			ML
22	2070195532H4	495	41	20280	0%	98%	C			SL + ML + MP
23	2070170532H4	441	39	17190	0%	98%	C			SL + ML + MP
24	2045095565H4LP	542	25	13557	0%	98%	C			SL + ML
25	2022045528HK	117	94	10989	0%	99%	C			MP
26	2020540568RL36	191	44	8388	0%	99%	C			SL
27	2058155532H4	283	28	7919	0%	99%	C			ML
28	2070220532H4	277	27	7492	0%	99%	C			SL + ML + MP
29	2045145530H4	239	31	7406	0%	99%	C			ML + MP
30	2022195528HK	133	53	7032	0%	99%	C			ML
31	2022070528HK	128	53	6789	0%	99%	C			ML
32	2021095565HDK	399	14	5592	0%	99%	C			ML + MP
33	2020095568ÄR	138	38	5257	0%	100%	C			ML + MP
34	2021095568R	260	20	5206	0%	100%	C			SL + ML + MP
35	2045045545H4	174	27	4700	0%	100%	C			ML + MP
36	2045095565H4	128	34	4367	0%	100%	C			ML + MP
37	2022120528P21	110	32	3516	0%	100%	C			ML + MP
38	2070245532H4	160	20	3208	0%	100%	C			SL + ML
Total		26129		5130306	100%			100%	100%	

SL	Contains specific lengths of the same product
ML	Contains mixed lengths of the same product
MP	Contains mixed products
-	Zero packages in stock

3.2 ABC analysis and compartment structure – impregnated products

Number	Product	Demand 20190701-20191231	Order frequency	Weighted volume	Weighted percentage	Cumultative weighted precentage	Classification	Percentage of weighted volume	Percentage of items	Compartment structure SL, ML or MP*
Impregnated products										
1	1028120658H4AB	2169	331	717981	43%	43%	A	83%	19%	SL
2	1045145632H4A	1048	276	289180	17%	61%	A			SL
3	1045170632H4A	806	228	183744	11%	72%	A			SL
4	1034145658H4AB	647	153	98941	6%	78%	A			SL
5	1045195632H4A	530	179	94888	6%	83%	A			SL
6	1045095658H4AB	387	168	64966	4%	87%	B	14%	33%	SL + ML + MP
7	1028145658H4AB	421	101	42556	3%	90%	B			ML
8	1045120658H4AB	340	121	41102	2%	92%	B			SL + ML
9	1022095658H4AB	287	109	31316	2%	94%	B			SL + ML
10	1045070658H4AB	258	112	28855	2%	96%	B			SL
11	1095095658H4A	258	108	27816	2%	98%	B			SL + ML
12	1045220632H4A	185	66	12226	1%	98%	B			MP + ML
13	1045045658H4AB	145	63	9153	1%	99%	C	3%	57%	SL
14	1028045658H4BAB	97	57	5507	0%	99%	C			MP + ML
15	1070070658H4A	111	41	4571	0%	100%	C			SL + ML
16	1045120658H4A	175	10	1748	0%	100%	C			SL + ML + MP
17	1028095658H4AB	57	26	1472	0%	100%	C			ML + MP
18	1022120658HKAB	48	23	1095	0%	100%	C			MP
19	1034120658H4AB	55	19	1036	0%	100%	C			MP
20	1022095658HKAB	40	23	924	0%	100%	C			MP
21	1022120658H4AB	42	17	715	0%	100%	C			SL + MP
Total		8104		1659790	100%			100%	100%	

SL Contains specific lengths of the same product
ML Contains mixed lengths of the same product
MP Contains mixed products
\- Zero packages in stock

3.3 ABC analysis and compartment structure – finger-jointed products

Finger-jointed products										
Number	Product	Demand 20190701-20191231	Order frequency	Weighted volume	Weighted percentage	Cumultative weighted precentage	Classification	Percentage of weighted volume	Percentage of items	Compartment structure SL, ML or MP*
1	2045070758H4FK27	186	87	16217	28%	28%	A	79%	17%	SL
2	2045095758H4FK27	132	69	9093	16%	44%	A			SL
3	2045195732H4F	231	21	4854	8%	53%	A			ML
4	2095220758HS	354	12	4252	7%	60%	A			SL
5	2045245732H4F	159	26	4128	7%	67%	A			SL
6	2045195732H4F72	194	21	4083	7%	75%	A			MP
7	2045045758H4FK27	64	39	2511	4%	79%	A			MP
8	2045220732H4F72	148	11	1625	3%	82%	B	16%	34%	MP + ML
9	2045220732H4F66	82	19	1558	3%	85%	B			MP
10	2045145732H4F	113	13	1463	3%	87%	B			MP
11	2045195732H4F66	49	13	633	1%	88%	B			MP
12	2075220758HS	203	3	609	1%	89%	B			-
13	2045220732H4F12	151	4	604	1%	90%	B			MP
14	2075100760SF	92	5	462	1%	91%	B			SL + MP
15	2022100768SF60	115	4	461	1%	92%	B			-
16	2045220732H4F60	42	10	421	1%	93%	B			-
17	2045145732H4F66	40	10	397	1%	93%	B			-
18	2045220732H4F84	28	12	335	1%	94%	B			ML + MP
19	2070220758HS	104	3	312	1%	95%	B			-
20	2045145737H4F	29	9	265	0%	95%	B			MP
21	2075150760SF	62	4	249	0%	95%	B			-
22	2045220732H4F	41	6	247	0%	96%	C	5%	49%	-
23	2045145737H4F60	27	9	240	0%	96%	C			-
24	2060220732H4F	73	3	220	0%	97%	C			-
25	2045170732H4F60	25	8	203	0%	97%	C			MP
26	2045195732H4F30	64	3	191	0%	97%	C			SL
27	2070220732H4F	44	4	176	0%	98%	C			-
28	2045195732H4F60	29	6	172	0%	98%	C			MP
29	2022150760SF	57	3	170	0%	98%	C			MP
30	2045120732H4F	33	5	163	0%	99%	C			MP
31	2045145732H4F60	26	6	153	0%	99%	C			MP
32	2095145758H4F	30	4	118	0%	99%	C			MP
33	2045170732H4F66	20	5	100	0%	99%	C			MP
34	2045170732H4F	19	5	93	0%	99%	C			MP
35	2045170732H4F72	27	3	80	0%	100%	C			-
36	2048248732H4F	60	1	60	0%	100%	C			-
37	2075150732SF	25	2	51	0%	100%	C			-
38	2095195758HSF	20	2	40	0%	100%	C			-
39	1095145758H4FA	38	1	38	0%	100%	C			-
40	1048198732H4F	34	1	34	0%	100%	C			-
41	1048148732H4F	32	1	32	0%	100%	C			-
Total		3385		57116	100%			100%	100%	

SL	Contains specific lengths of the same product
ML	Contains mixed lengths of the same product
MP	Contains mixed products
-	Zero packages in stock

3.4 ABC analysis and compartment structure – painted products

Painted products										
Number	Product	Demand 20190701-20191231	Order frequency	Weighted volume	Weighted percentage	Cumultative weighted precentage	Classification	Percentage of weighted volume	Percentage of items	Compartment structure SL, ML or MP*
1	2022145828HKVG	89	35	3112	17%	17%	A	77%	25%	ML + MP
2	2022145828P21VG	92	30	2747	15%	32%	A			MP
3	2022120828HKVG	82	29	2372	13%	44%	A			ML + MP
4	2022120828P02VG	81	27	2192	12%	56%	A			MP
5	2022120828P21VG	76	27	2060	11%	67%	A			ML + MP
6	2022170828HKVG	70	26	1815	10%	77%	A			MP
7	2022120828P10VG	57	22	1256	7%	84%	B	21%	29%	MP
8	2022095828HKVG	52	23	1198	6%	90%	B			ML + MP
9	2022145828P02VG	40	15	605	3%	93%	B			MP
10	2022195828HKVG	24	11	269	1%	95%	B			MP
11	2022120828HKVGM	25	9	221	1%	96%	B			MP
12	2022145828P10VG	27	8	213	1%	97%	B			MP
13	2022070828HKVG	17	8	135	1%	98%	B			MP
14	2022145828HKVGM	16	7	114	1%	99%	C	2%	46%	MP
15	2022120828P21VGM	13	5	65	0%	99%	C			ML + MP
16	2022170828HK	16	4	64	0%	99%	C			-
17	2022045828HKVG	7	6	42	0%	99%	C			MP
18	2028170828HK	36	1	36	0%	100%	C			-
19	2022145828HKVM	8	4	33	0%	100%	C			MP
20	2022195828HKVGM	10	3	30	0%	100%	C			-
21	2028170828HKF65	11	2	21	0%	100%	C			-
22	2022145828P21VGM	9	2	18	0%	100%	C			SL + MP
23	2022145828P10VGM	6	3	17	0%	100%	C			MP
24	2022045828P30V	8	2	16	0%	100%	C			-
Total				18580	100%			100%	100%	

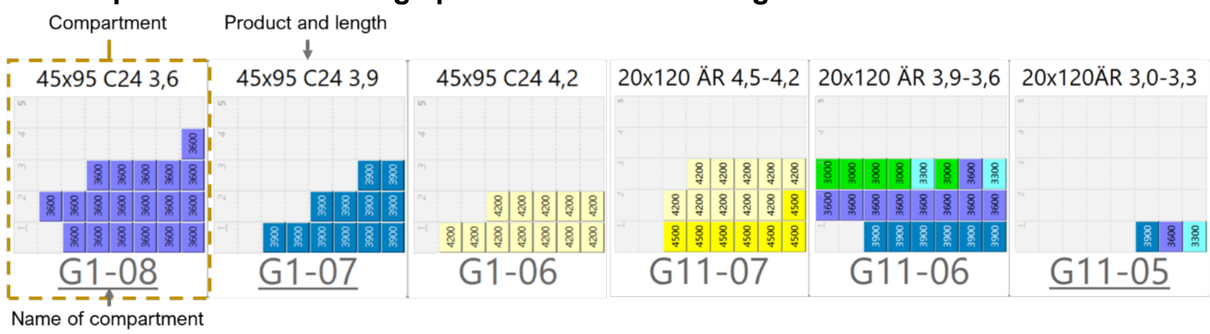
SL Contains specific lengths of the same product
ML Contains mixed lengths of the same product
MP Contains mixed products
- Zero packages in stock

Appendix 4. Screenshots and figures supporting the empirical background

4.1 Overview facility layout

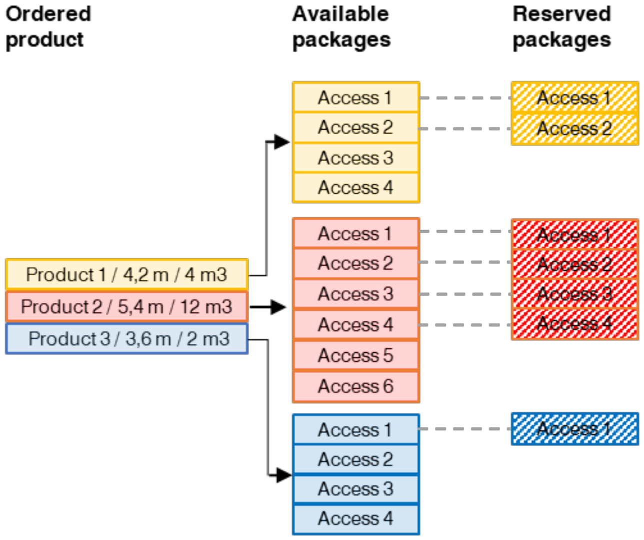
Screenshot over the facility layout, production units, and storage areas retrieved from the company inventory software. Colours represent the different dimensions of each package.

4.2 Compartments containing specific and various lengths



Screenshot over compartments. Colours represent the different lengths of each package. Compartments G1-08 to G1-06 contains specific lengths in each compartment, 3,6; 3,9; and 4,2 metre. Compartments G11-07 to G11-05 contains a mix of different lengths as can be visually seen as the colours differ within the compartments.

4.3 Reservation of packages



Reservation of packages according to product, length, volume, and accessibility.

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