Material flow improvements

An investigation of the picking process at Scania

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Ludvig Lindén
Lund, May 2022

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ABSTRACT

Title: Material flow improvements – An investigation of the picking process at Scania

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Problem description: At Scania in Oskarshamn, there is a phenomenon referred to as external picking. External picking is in the context of this report defined as the process where stock-keeping units, not intended for the main production lines, are picked at one of Scania's Oskarshamn facilities. These items are intended for various organizations within Scania, but also external business partners.

The external picks are currently managed by different departments with different processes, based on the recipient. Scania believes that there is potential to improve and streamline these processes. Thus, the company has requested help to (1) investigate and map the material flow related to the external picking processes, (2) examine the involved organizations, and (3) develop suggestions for increased efficiency.

Purpose: The purpose of this master thesis is to propose improvements for the process of external picking at Scania's production unit in Oskarshamn and to provide suggestions on how such changes can be implemented.

Research questions:
RQ: How can Scania's process of external picking be improved?

- ***RQa****:* *What do the material flow and processes related to external picking currently look like?*
- ***RQb****:* *What are the problems and drawbacks of the current solution?*
- ***RQc****:* *Which changes can be done to improve the current logistical setup?*
- ***RQd****:* *What changes should be done and how can they be implemented?*

Methodology: An exploratory study was desired since the previous knowledge about the phenomenon was limited. As the goal was to explore and describe the phenomenon, and the data collection would primarily consist of interviews and observations, a case study was conducted.

Conclusion: The material flow related to the external picking can be arranged into four categories, based on recipient/customer and involved organizations. To improve the external picking process, Scania should, e.g., improve the level of digitalization, implement assistive devices, standardize processes, appoint a process owner, and restructure the organizational responsibilities.

Keywords: External picking process, Parallel material flows, Organizational responsibilities, Internal logistics, Automotive industry, Supply chain

SAMMANFATTNING

Titel: Materialflödesförbättringar – En undersökning av plockprocessen hos Scania

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Problembeskrivning: Hos Scania i Oskarshamn finns det ett fenomen som kallas externa plock. Externa plock är i detta examensarbete definierat som den process där artiklar, som ej är avsedda för huvudproduktionen, plockas i en av Scanias lokaler i Oskarshamn. Dessa artiklar är avsedda för olika organisationer, både inom Scania och för externa affärspartners.

De externa plocken utförs idag av olika avdelningar med olika processer beroende på vem kunden är. Scania tror att det finns potential för förbättring och effektivisering av dessa processer. Därav har företaget bett om hjälp för att (1) undersöka och kartlägga materialflödet kopplade till den externa plockprocessen, (2) granska de involverade organisationerna och (3) utveckla förslag för förbättrad effektivitet.

Syfte: Syftet med detta examensarbete är att föreslå förbättringar för den externa plockprocessen hos Scanias produktionsenhet i Oskarshamn, samt att föreslå hur dessa förbättringar kan implementeras.

Forskningsfrågor:
FF: Hur kan Scanias externa plockprocess förbättras?

- ***FFa**: Hur ser materialflödet och processerna ut relaterat till externplock?*
- ***FFb**: Vilka problem och svårigheter finns med den nuvarande lösningen?*
- ***FFc**: Vilka förändringar kan göras för att förbättra den nuvarande logistiska lösningen?*
- ***FFd**: Vilka förändringar borde göras och hur kan de implementeras?*

Metod: En utforskande studie var önskvärd då den tidigare kunskapen om fenomenet var begränsad. Eftersom målet var att utforska och beskriva fenomenet, och datainsamlingen primärt skulle bestå av intervjuer och observationer så ansågs en fallstudie lämplig.

Slutsats: Materialflödet kopplat till den externa plockprocessen kan delas in i fyra kategorier baserat på mottagare/kund och de inblandade organisationerna. För att förbättra plockprocesserna kopplade till dessa fyra flöden så borde Scania exempelvis öka digitaliseringen, implementera hjälpmedel, standardisera processer, tillsätta en processägare och omstrukturera de organisatoriska ansvarsområdena.

Nyckelord: Extern plockprocess, Parallella materialflöden, Fordonsindustri, Organisatoriska ansvarsfördelningar, Internlogistik, Försörjningskedja

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ABBREVIATIONS

DL = Door Line

GP = Group Manager

IP = Instrument Panel

KPI = Key Performance Indicator

LC = Logistics Center

LSV = Laxå Special Vehicles

LVL = Low Volume Line

MC = Manufacturing Cabs

PO = Purchase Order

RQ = Research Question

SKU = Stock-keeping Unit

TC = Technical Center

TL = Team Leader

1 INTRODUCTION

This chapter provides an introduction to the thesis and the context in which the study was performed. The background is described, the problem formulated, and the purpose stated. Next, the research questions and the specific focus of the study are addressed, whereafter the target group is being established. Finally, an outline of the report is presented.

1.1 Background

With an ever-changing business landscape, organizations must engage in continuous improvement initiatives to cultivate their processes and retain their competitiveness. To meet the increasing demand for customized products and services, organizations tend to expand their range of products and service offerings. While this may lead to interesting business opportunities, it also increases complexity which, if not managed properly, can prove to be fateful.

It is well known that supply chain complexity might hamper performance. As pointed out by Bozarth et al. (2009), complexity in the supply chain can arise from within a manufacturing plant (stemming from e.g. the number of supported parts) or via the plant's connection to up- and downstream partners (stemming from e.g. the number of customers).

For a long time, order picking has been recognized as one of the most influential factors with regard to labor and cost in warehousing operations. Moreover, the management and design of the order picking process have become increasingly complicated due to recent trends such as customization, digitalization, and smaller lot-sizes (De Koster et al., 2007). It is therefore not surprising that organizations continually seek to improve their picking processes.

1.2 Problem Formulation

Scania CV AB, hereafter referred to as Scania, is a world-leading provider of transport solutions, including trucks, buses as well as product-related service offerings. The company is the 6^{th} biggest in Sweden with regards to the number of employees, the 5^{th} biggest with regards to revenue (Ekonomifakta, 2019), and is a subsidiary of the Volkswagen Group. The company's global presence is strong, with about 50,000 employees in around 100 different countries. In addition to the production facilities located in Europe and Latin America, regional product centers are present in Africa, Asia, and Eurasia, see Figure 1.1.

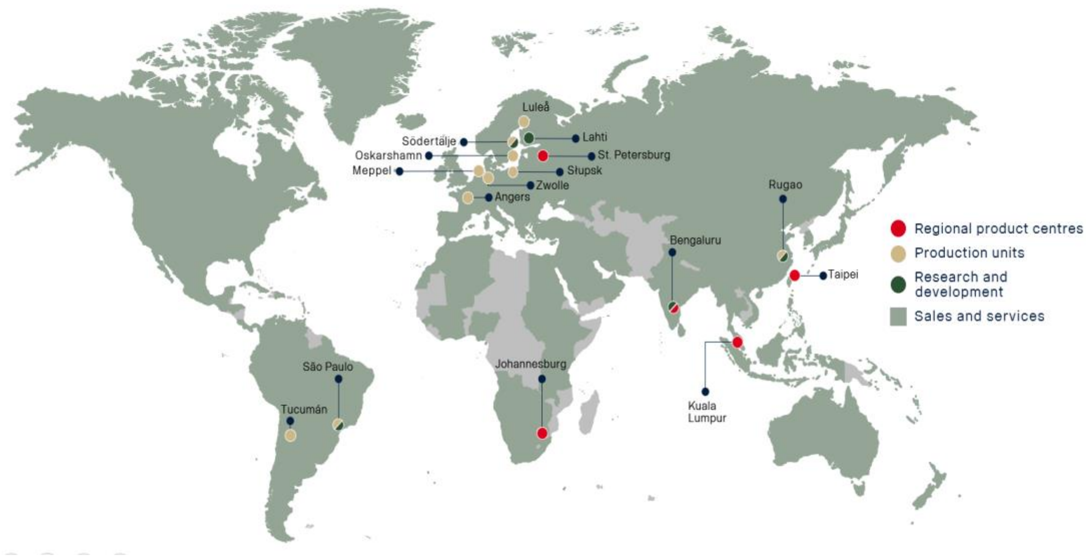


Figure 1.1: Scania's global presence.

This thesis will focus on Scania's production unit in Oskarshamn, which is responsible for the production of truck cabs. As part of Scania's broad range of transport solutions, special vehicles are produced at other production facilities. Consequently, the logistics organization at Scania Oskarshamn is not only required to pick production materials for the main production lines. The number of recipients has increased over the years, leading to increased complexity.

At Scania in Oskarshamn, there is a phenomenon referred to as external picking. External picking is in the context of this report defined as the process where stock-keeping units (SKUs) not intended for the main production lines are picked at one of Scania's Oskarshamn facilities. The recipients of these goods, in this thesis referred to as internal customers, are other parts within Scania's organization or external business partners. Internal customers are in this report defined as parties (unrelated to the main production lines) that demand parts or sub-assemblies to construct truck cabs, i.e. receivers of the SKUs that have gone through the external picking process. A list of the internal customers, together with their geographical location is provided in Table 1.1.

Table 1.1: List of the internal customers and their geographical location.

INTERNAL CUSTOMER	LOCATION
Chassis factories	Södertälje, Sweden
	Angers, France
	Zwolle, Netherlands
Low volume line	Oskarshamn, Sweden
The Arena	Oskarshamn, Sweden
"Partner X"	"Somewhere", France
Laxå Special Vehicles	Laxå, Sweden
Scania Parts Logistics	Oudsbergen, Belgium

The external picks are currently managed by different departments with different processes, based on the recipient. Customer requirements such as delivery time and packaging need to be considered. The situation at hand is further complicated by the fact that external picking might not be possible to perform while the ordinary operations, for the main production lines, are ongoing. Moreover, the utilization of digital solutions is very limited, the traceability is low, and information about the processes is inadequate. As a consequence of the modest information available, quantified performance is not tracked in a structured manner.

Scania believes that there is potential to improve and streamline these processes. Thus, the company has requested help to (1) investigate and map the material flow related to the external picking processes, (2) examine the involved organizations, and (3) develop suggestions for increased efficiency.

1.3 Purpose of the Study

The purpose of this master thesis is to propose improvements for the process of external picking at Scania's production unit in Oskarshamn and to provide suggestions on how such changes can be implemented.

1.4 Research Questions

To fulfill the purpose, a set of research questions have been developed. The set consists of one main research question (RQ) and four sub-questions (RQx).

RQ: How can Scania's process of external picking be improved?

The main research question is virtually a translation of the purpose, and by answering this question, the purpose of this thesis will essentially be fulfilled. Since RQ is rather broad, it has been divided into sub-questions to facilitate the research process.

RQa: What do the material flow and processes related to external picking currently look like?

RQb: What are the problems and drawbacks of the current solution?

RQc: Which changes can be done to improve the current logistical setup?

RQd: What changes should be done and how can they be implemented?

These four sub-questions can be seen as building blocks of the main question. By addressing and answering each of the sub-questions, the main question can be answered. The relationship between the research questions and the deliverable is depicted in Figure 1.2. To understand the impact and consequences of making adjustments to the external picking process, extensive knowledge about the current process is required, hence RQa and RQb are fundamental. RQc relates more to the change itself; what is possible to change, and how will Scania benefit from changing it. There is an important difference between knowing how to improve a process in theory, and actually being able to realize it. RQd has been formulated to address this and ensure that the provided recommendations are feasible to implement and thus valuable for Scania.

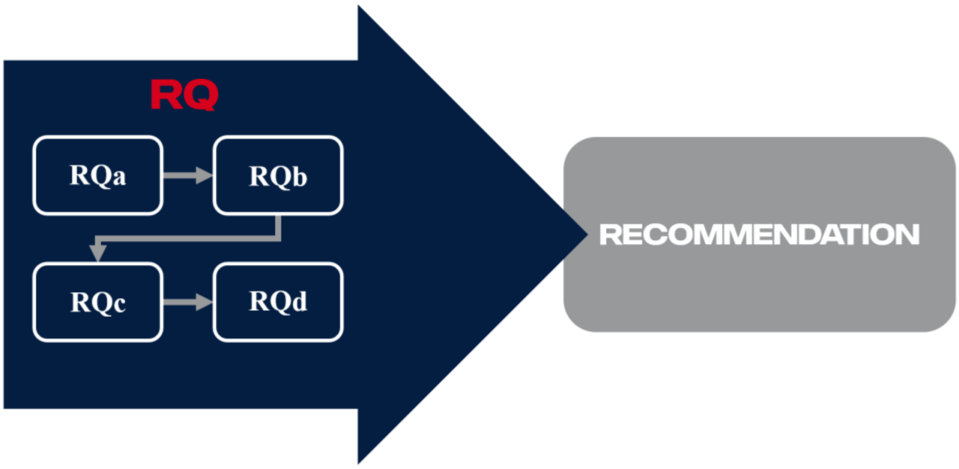


Figure 1.2: Illustration of the relationship between the main research question, the sub-questions, and the deliverable.

1.5 Focus and Delimitations

The focus of this report is limited to the outbound flow of material from Scania's truck cab production facility in Oskarshamn to internal customers, and the processes taking place to pick and pack said material. All material flows to internal customers except one – the knock down flow – will be examined. The knock down flow is included in the concept of external picking but it is currently not "active", i.e. there is no material flow to map or analyze, why this flow will be excluded in this study. Moreover, the focus will be on the picking processes in proximity to the production lines and, therefore, the process at Scania's logistics center (LC), a separate facility 2.5 km away from the main production, will not be analyzed.

Material flows related to the main production lines are considered out of scope and will thus not be investigated. Specifically, the report will focus on the utilization of resources such as floor space and personnel. It will also address the organizational structure as well as the use (or need) of equipment with regard to these material flows.

How the material is handled before it enters the premises of Scania will not be investigated. Thus, for the purpose of this study, it is assumed that SKUs requested for external picking are always in stock. Similarly, once the material leaves Scania's premises, it falls out of scope. That said, the transport modes and the distribution process will not be analyzed. The focus and delimitations are illustrated in Figure 1.3 – red illustrates the limits of this thesis.

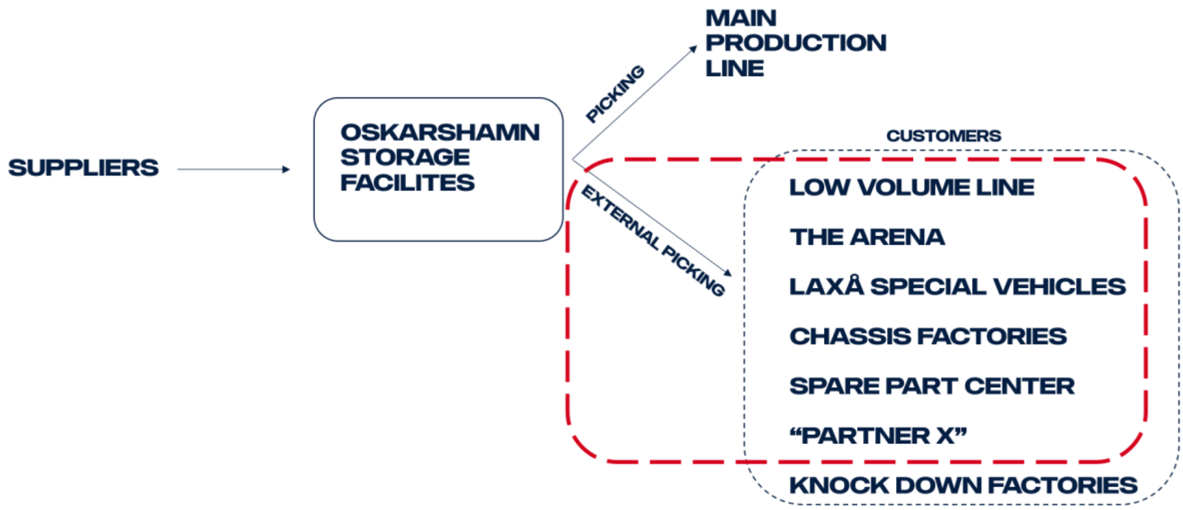


Figure 1.3: Focus of this thesis.

1.6 Target Groups

This thesis is mainly directed to, and of interest to, three distinct groups. Firstly, this thesis targets the Department of Industrial Management and Logistics at LTH, as well as any other individual who wants to further develop the knowledge of the phenomenon examined. Secondly, the case company Scania, which developed the assignment in response to a real challenge present within their operations, is targeted. Thus, the findings of this thesis are intended and expected to be of value to the organization. Thirdly, the report should be of value to any organization interested in the field of logistics and supply chain management that may find the result of this thesis relevant for their operations.

1.7 Outline of the Report

The outline of this master thesis and the focus of the subsequent chapters are explained in Table 1.2.

Table 1.2: Outline of the report.

CHAPTER	FOCUS
1 Introduction	This chapter provides an introduction to the thesis and the context in which the study was performed. The background is described, the problem formulated, and the purpose stated. Next, the research questions and the specific focus of the study are addressed, whereafter the target group is being established.
2 Methodology	In this chapter, all aspects related to how the study has been conducted are covered. First, the research approach and the design of the study are discussed in depth. This is followed by a detailed account of the methods employed to collect data. Moreover, it is discussed how to obtain credibility in this study and what ethical aspects need to be considered.
3 Literature Review	In this chapter, relevant literature for this thesis is reviewed and compiled. Firstly, theory about mapping and methodologies for realizing process improvements are presented. This is followed by theory regarding order-picking and key performance indicators.
4 Empirical Study	This chapter aims to provide the reader with a comprehensive overview of the empirical data gathered in this thesis. Starting on a more general level, the internal customers, the overarching setup at Scania Oskarshamn, and the organization involved in the cab assembly process are described. This is followed by a detailed account of the material flow, thus addressing RQa and to some extent RQb.
5 Analysis	This chapter delves into the challenges identified in the previous chapter by applying theory to evaluate the current process and setup, thus complementing the empirical study to answer RQb. Further, the analysis is a combination of qualitative and quantitative, ultimately aiming to unravel which changes can be done to improve the current logistical setup, thus answering RQc.
6 Recommendations	Based on the analysis, this chapter includes our recommendations regarding how Scania can improve their external picking and how implementations can be conducted – thus answering RQd. The recommended actions are divided into three categories; Order-picking process, Organizational, and Flow-specific.
7 Conclusion	In this final chapter, the thesis is concluded. Firstly, the purpose fulfillment is addressed and answers to the sub-questions are summarized. Following is a discussion regarding the generalization and credibility of the results. Next, we highlight the limitations of the study and propose future areas of research. Finally, a short section with concluding remarks is provided, thus bringing this thesis to its end.

2 METHODOLOGY

In this chapter, all aspects related to how the study has been conducted are covered. First, the research approach and the design of the study are discussed in depth. This is followed by a detailed account of the methods employed to collect data. Moreover, it is discussed how to obtain credibility in this study and what ethical aspects need to be considered. Finally, a summary of the methodology applied for this thesis is provided.

2.1 Approach

When conducting research in the field of logistics, a good first step is to understand what kind of research approach is suitable. Thus, in this section, three commonly used approaches will be described based on the comprehensive review conducted by Kovác and Spens (2005). The definition of ‘research approach’ used in this thesis is the one provided by Kovác and Spens (2005, p.133); “[...] the way of conscious scientific reasoning”. The purpose of presenting these different approaches is to allow the reader to better understand the reasoning behind the logic and decisions made throughout this thesis.

In the study by Kovác and Spens (2005), articles published between 1998 and 2002 in the three major logistics journals *International Journal of Logistics Management*, *International Journal of Physical Distribution & Logistics Management*, and *Journal of Business Logistics* were examined regarding approaches. They proceed to discuss the (1) Deductive approach, (2) Inductive approach, and (3) Abductive approach. In this section, these three approaches are discussed, followed by a motivation for what is suitable for this study.

2.1.1 Deductive approach

The deductive approach is regularly referred to as one of the most common research approaches utilized in logistics studies and it is typically of a quantitative nature (Golicic et al., 2005; Kovác & Spens, 2005). This way of reasoning starts with generalizations and seeks to find if they apply to specific instances (Hyde, 2000). The deductive approach is thus suitable for testing existing theories and less appropriate for creating new science (Kovác & Spens, 2005). Woodruff (2003), according to Golicic et al. (2005), illustrates the deductive approach as shown in Figure 2.1.

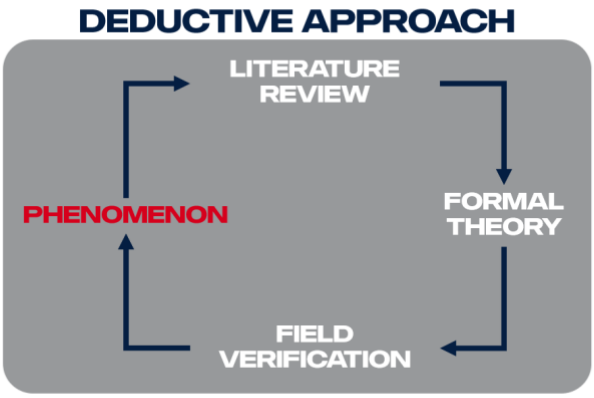


Figure 2.1: Illustration of the deductive research approach (Source: Golicic et al., 2005).

2.1.2 Inductive approach

The inductive research approach is historically less common and is the opposite of deductive, meaning that it starts with observation of a specific case, and seeks to establish generalizations (Hyde, 2000; Kovác & Spens, 2005). In contrast to the deductive approach, inductive reasoning is typically of a qualitative nature (Kovác & Spens, 2005). Considering that the inductive approach aims to "[...] generate meanings from the data set collected in order to identify patterns and relationships to build a theory" (Dudovskiy, n.d.), it can be considered more appropriate than the deductive approach to explore new phenomena and to create new science. Woodruff (2003), according to Golicic et al. (2005), illustrates the inductive approach as shown in Figure 2.2.

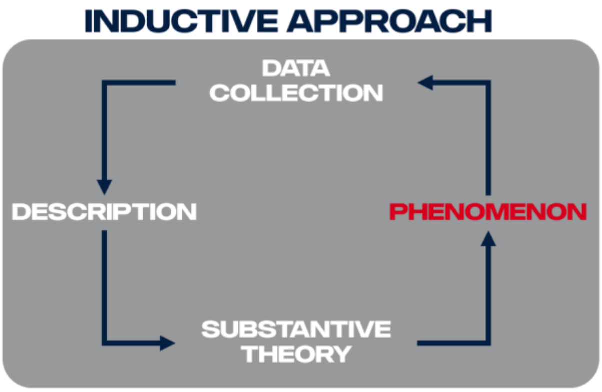


Figure 2.2: Illustration of the inductive research approach (Source: Golicic et al., 2005).

2.1.3 Abductive approach

The abductive approach can be described as a combination, or a balanced approach, of the inductive and deductive approaches. Kovác & Spens (2005) explain that this approach is a result of the insight that the greatest advances in research neither followed the pure deductive approach, nor the pure inductive approach. Consequently, the abductive approach does not bring any subsequent new depth, but rather 'allows' researchers to track back and forth between the two aforementioned approaches. Woodruff (2003), according to Golicic et al. (2005), illustrates the abductive approach as shown in Figure 2.3.

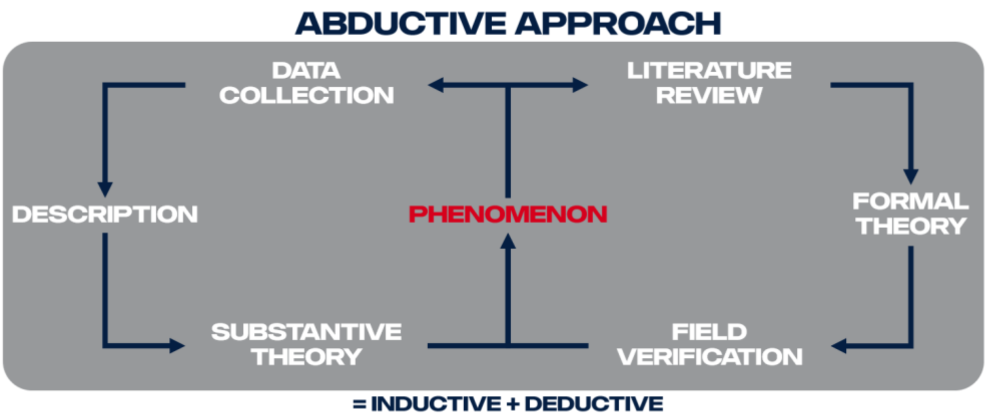


Figure 2.3: Illustration of the abductive research approach (Source: Golicic et al., 2005).

2.1.4 Choice of Approach

Considering the research question for this thesis (how Scania's process of external picking can be improved), the inductive approach is the most suitable since the study is primarily of a qualitative nature. To answer the main research question, the current situation needs to be understood and, with that as a starting point, it is needed to seek solutions and generalizations. This falls well in line with the inductive approach; *observe a specific case and seek to establish generalizations*. Consequently, the deductive approach (to see if generalizations apply to specific situations) is not appropriate for this study. The one anomaly from the inductive approach is for RQc (which changes can be done to improve the current logistical setup) to which the abductive approach has been applied. This is due to the mixed nature which calls for a combination of the approaches to both examine the current situation as well as to see if generalized theories can be applied.

2.2 Research Design

In this section, the rationale behind choosing the applied research method will be presented and argued for. The ambition is to do so in a comprehensive and structured manner, and the intention is to justify the selected research method. Furthermore, this section will address the design of the study and define the unit of analysis.

2.2.1 Selection of research method

After evaluating the adequacy of different research methods for this study, case study research has been chosen due to the following reasons:

I. Case studies lend themselves useful in the early stages of research when the certainty with respect to knowledge is low (Malhotra & Grover, 1998).
II. Case studies are appropriate when the research question is formulated as "how", the researcher has little control over the events, and the focus is on a contemporary phenomenon (Yin, 2009).
III. Case studies are utilized when the interaction with the world is of an unstructured nature and the goal of the research is to be descriptive (Fisher, 2007).

The external picking process is managed by several different departments within Scania's logistics organization and no individual employee has an understanding of all the different flows related to this phenomenon. Thus, the certainty with respect to knowledge is considered low. Looking at Malhotra and Grover's (1998) maturity cycle of research, Figure 2.4, it can be seen that case studies are especially effective in the early stages of research when the certainty with respect to knowledge, as for this phenomenon, is low. Further, the authors state that case studies usually are qualitatively oriented, that the variables are not predefined, and that they encompass in-depth examinations of a phenomenon in its natural setting. All of the aforementioned characteristics are true for this thesis, why a case study is considered an appropriate method of choice.

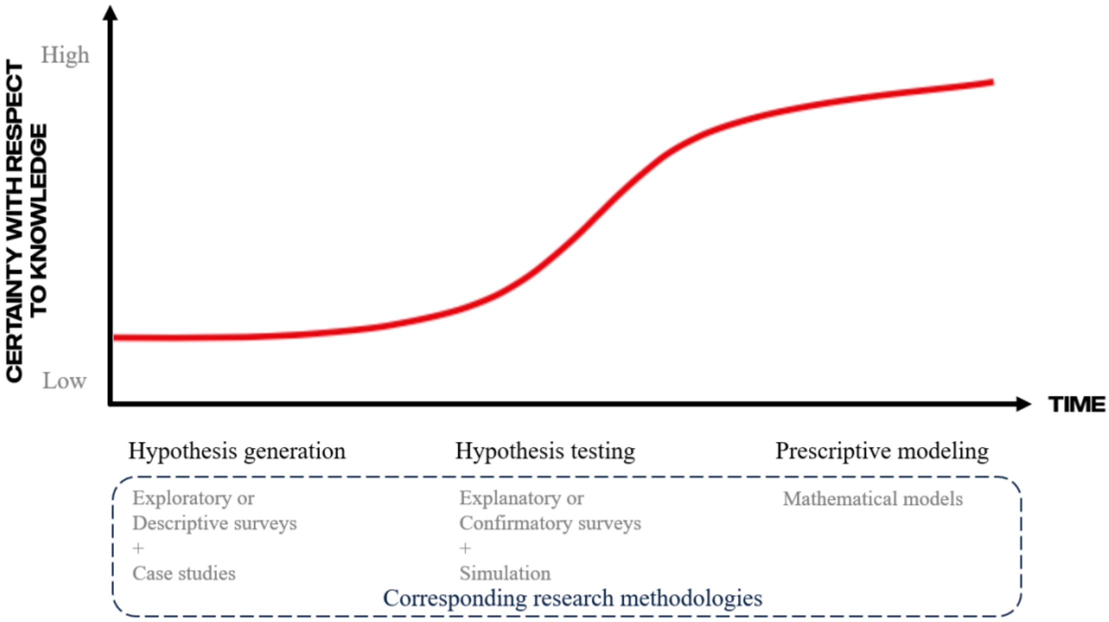


Figure 2.4: Maturity cycle of research, based on Malhotra & Grover (1998).

The main research question is a "how" question, we as researchers have no control over the events happening in the external picking process, and the studied phenomenon is unquestionably contemporary. In other words, all three criteria by Yin (2009) apply to the main research question, suggesting that case study research is an adequate choice of method for this master thesis.

Lastly, the choice of methodology is supported by Fisher's (2007) model of empirical research in operations management, Figure 2.5. The model is used to categorize methods of empirical research based on how structured the interaction with the world is, and what the ultimate goal of the study is. Since data collection will be of a more unstructured nature, relying on interviews and observations rather than data, and the intention is to describe the process of external picking rather than prescribing a remedy for it, this study places itself in the lower right quadrant of Fisher's model. Consequently, the choice of applying case study research is validated.

INTERACTION WITH THE WORLD	GOAL OF THE RESEARCH: PRESCRIPTIVE	GOAL OF THE RESEARCH: DESCRIPTIVE
HIGHLY STRUCTURED: Data & Algorithms	**ENGINEERING** Software implementation of algorithm deployed in a company and run daily	**OPERATIONS MANAGEMENT ECONOMETRICS** Statistical analysis of large data sets to discover drivers of success in operations
LESS STRUCTURED: Interview & Observations	**PRINCIPLES** Ohno invents Toyota Production System, inspired by the principles of U.S. supermarkets	**CASE STUDIES** Interview and observe managers Research cases

Figure 2.5: Model of Empirical Research in Operations Management (Source: Fisher, 2007).

2.2.2 Design of the case study

Having decided to use a case study, the logical subsequent course of action is to design the study. The design of the study can be described as “the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of study” (Yin, 2009, p.24). Furthermore, the design also relates to whether the study employs a single-case or multiple-case approach. This master thesis will focus solely on Scania Oskarshamn and is thus a single-case study. While this approach provides an in-depth understanding of a phenomenon, the methodology has limitations regarding the generalizability of results (Voss et al., 2002). Nevertheless, Stuart et al. (2002) argue that in-depth case studies are effective when trying to uncover further areas of research and explore new territory, which is exactly what this study aims to do.

A case study should always demonstrate that its means of measuring are valid, no matter the overarching design or approach (Stuart et al., 2002). It is further emphasized by both Voss et al. (2002) and Yin (2009) that case researchers must take measures to maximize the quality of the research by designing the study so that validity and reliability are ensured. Williams (2007) reasoned along the same line and suggests that researchers should spend time on-site to interact with the people pertinent to the study. How the quality of this study will be addressed is further elaborated on in section *2.5 Credibility of the Study.*

2.2.3 Unit of analysis

There seems to exist some ambiguity between the meaning of ‘unit of analysis’ and the case itself, and Grünbaum (2007) claims that the distinction between the two is unclear. The author even proceeds to argue that the relationship has become tautological. In the same vein, Patton (2002), according to Grünbaum (2007), argues that the case is in fact identical to the unit of analysis. Since the unit of analysis defines what the case study is focusing on (what the case is), it can be whatever the researcher decides it to be, e.g. an individual, a group, an organization, or a city.

This thesis studies the flow of material related to the external picking process at Scania Oskarshamn, scrutinizes the shortcomings of the current setup, and proposes improvements for increased efficiency. Thus, the unit of analysis is defined as the case itself; Scania’s external picking process at the manufacturing plant in Oskarshamn.

2.3 Literature Review

The literature review is a fundamental part of any research project, and its role in the scientific research process is paramount. A well-performed literature review supports the goal of contributing to the subject field and mitigates the risk of reinventing the wheel (Höst et al., 2006). The literature review should draw on and evaluate a range of different sources, including books, academic journals, and web-based resources, to fulfill its ultimate purpose of summarizing the state of the art within that subject field (Rowley & Slack, 2004). To achieve a proper structure and ensure comprehensiveness of the review, the 4-step approach suggested by Rowley and Slack (2004) has been used. The four components are: (1) evaluating information resources, (2) searching and locating information sources, (3) developing conceptual frameworks and mind mapping, and (4) drawing together the literature review. Each step is further explained in the following subsections.

2.3.1 Evaluating information resources

When reviewing literature to help answer research questions, a wide range of information sources can be used. Thus, evaluating the literature can be challenging. Both academic and professional literature can be useful, however, the former has a firmer theoretical basis, and thus the core of the literature review should consist of articles from scholarly and research journals. In addition to this, books are useful as they provide a summary of current ideas, and in many disciplines, these are updated regularly. Lastly, effective sources to access a wide range of information are web resources. To ensure that sources are good and relevant, Rowley and Slack (2004, pp.33-34) provided aspects to consider, see Table 2.1. These two lists have been used thoroughly throughout the literature review of this thesis.

Table 2.1: Checklist to evaluate books and web resources, based on Rowley and Slack (2004).

CHECKLIST: EVALUATING BOOKS	Relevant to the research topic
	Written by an authoritative author (the biographical details given in the book will summarize the authors experience in the field)
	Up-to-date (as signaled by the publication date)
	Published by a reputable publisher in the discipline
	One that includes extensive reference to other associated literature
	Is clearly structured and well presented, and easy to read
CHECKLIST: EVALUATING WEB RESOURCES	Who is the intended audience?
	What is the frequency of update?
	Which organization is the publisher or web site originator?
	What is the web resource developer's claim to expertise and authority?
	Are there links or references to other relevant web, electronic, or print sources?
	What do reviews or evaluations of the site say?

2.3.2 Literature searching and locating information sources

Several different tools can be utilized to build the literature review (Rowley & Slack, 2004). To locate books held by libraries, library catalogs have been used in this study. Moreover, to locate articles and web pages, search engines and databases such as Google Scholar and LUBsearch (which is a collective entry point to all of Lund University's libraries' joint resources) have been used. Due to the high level of development of Google's search algorithms, the common practice throughout this literature review has been to use keywords to look for articles in Google Scholar. If an article is inaccessible through the web page provided by

Google Scholar, LUBsearch has been used as an entryway after finding the doi-address through Google Scholar.

There are four strategies to use when gathering information and developing a search strategy that Rowley and Slack (2004, pp. 35-36) provided, which are illustrated in Table 2.2. These have been used to different extents throughout the literature search process, but primarily *citation pearl growing* has been utilized.

Table 2.2: Four strategies for literature search, based on Rowley and Slack (2004).

FOUR SEARCH STRATEGIES	
	Citation pearl growing: This is an easy approach for newcomers to a topic, which starts from one or a few document and, in those documents, find suitable terms to use as keywords to find other relevant documents.
	Briefsearch: Commonly used as good starting point for further work by retrieving a few documents crudely and quickly.
	Building blocks: By using synonyms and related terms the search statements are extended. This leads to a possibly lengthy search where all relevant terms are used to construct a comprehensive set of documents.
	Successive fractions: Can be used to reduce a large or too large set of documents in order to make it manageable. This is done by searching within an already retrieved set of documents and successively remove those considered insignificant or irrelevant.

2.3.3 Developing conceptual frameworks and mind mapping

Concept mapping can help to identify key concepts in a research area, or among already collected documents, in the following ways (Rowley & Slack, 2004, p. 36):

- During the literature search, it can help to identify additional search terms.
- As a preparation for writing the literature review, it can be used to clarify thinking about the structure of the review.
- It can help to understand the theory as well as concepts and their relationships.

For this thesis, it has been applied to structure the literature review and to early on get a holistic view of what should be included and covered.

2.3.4 Drawing together the literature review

The final phase of conducting a literature review is to compile all the literature in a comprehensive manner. It is suggested that the creation of the literature review itself can be divided into five steps (Rowley & Slack, 2004, pp. 37-38). These are presented in Table 2.3.

Table 2.3: Five steps to create a literature review, based on Rowley and Slack (2004).

FIVE STEPS IN CREATING A LITERATURE REVIEW	***Scanning documents:*** Provides a familiarity with the broad spectrum of documents, and the grouping of documents with similar themes. May give insights regarding key themes to include in the literature review.
	Making notes: Leads to a distillation of key themes and messages.
	Structuring the literature review: Organize concepts and documents in accordance with key themes.
	Writing the literature review: Can commence once a broad structure has been resolved. Should integrate three different types of materials: - *Distillation and understanding of key concepts* - *Quotations (used for special impact)* - *Distillation of positions, research findings or theories*
	Building the bibliography: A list of all the sources referred to. The construction of this is an ongoing process.

2.4 Data Collection

This section aims to account for the different techniques used to gather data throughout this master thesis. Interviews with key employees from Scania and observations of the picking processes constitute the foundation of the data collection. In addition, already existing data from Scania's internal systems have been gathered. Following is a detailed explanation of how each technique has been applied.

2.4.1 Interviews

Interviewing, a technique for collecting qualitative data, is frequently used in case studies (Williamson, 2002; Williams, 2007). That is true also for this case study, where a majority of the data has been gathered through interviews with employees possessing relevant knowledge about the phenomenon. A general benefit of conducting interviews is that they often provide in-depth information pertaining to the participants' experiences and perspectives on a specific topic (Turner, 2010). It is further mentioned by Höst et al. (2006) that interviews can be conducted in a master thesis to collect feedback regarding a suggested solution. Williamson (2002) categorizes interviews according to structured, unstructured, and semi-structured depending on the level of freedom the researcher has to adapt and tailor questions throughout the interview, see Table 2.4.

Table 2.4: Types and characteristics of interviews, based on Williamson (2002).

TYPE	CHARACTERISTICS
Structured Interview	Each respondent is asked exactly the same questions in the exact same sequence. Useful when it is important to enable comparison between respondents.
Unstructured Interview	Each answer generates the next question. Used to explore a subject or to collect extensive data in a case study.
Semi-Structured Interview	Uses a standard list of questions but allows the interviewer(s) to ask follow up questions. Combination of the other two types, but closer to an unstructured than a structured interview.

To grasp the complexity and attain a holistic understanding of the external picking process, interviews were initially held with employees from different organizational levels in an unstructured manner. This approach harmonizes with the one suggested by Williamson (2002), who means that unstructured, exploratory interviews are appropriate in the early stages of research when the researcher neither has good knowledge of the subject nor the types of participants to involve. As the understanding became deeper, interviews became more specific, targeting certain employees with key knowledge. At this stage, semi-structured interviews were conducted to guide the conversation to particular topics while maintaining the freedom to ask follow-up questions.

Several different qualities of the interviewer can play a significant role in establishing cooperation from the interviewee, and Turner (2010) claims that it can be difficult for a novice investigator to engage in qualitative research. In the words of Williamson (2002, p.245): "Interviewers should be neutral and dispassionate, but at the same time personable, empathetic and enthusiastic so that participation is encouraged". It is also important that the interviewer is nondirective, i.e. he or she should take caution not to lead the interviewee towards a "correct" answer, or to express any personal opinions (Cannell et al., 1981). These qualities have been considered and sought throughout the interviews.

2.4.2 Observations

To capture the subconscious actions and habits of the employees working with the external picking, which may not be reflected in the interviews, observations have been made. This rationale is supported by Kellehear (1993), who argues that the combination of observations and interviews may increase the validity of the findings since one method can reveal critical aspects of the phenomenon which the other method then can explore. Following the same logic is Baker (2006), who means that observations can be invaluable in a study because when researchers observe people in their natural setting, understanding of the phenomenon from 'their' point of view is gained.

Researchers usually employ one of four main techniques when conducting observations: ad libitum, focal, scan, and behavior (Martin & Bateson, 1986, cited in Williamson, 2002, p.275). A short description of each technique is provided in Table 2.5.

Table 2.5: Observation types and their respective characteristics, based on Williamson, (2002).

TYPE	CHARACTERISTICS
Ad libitum	Non-systematic observation technique, useful when researchers are new to the topic they are studying.
Focal	A group or individual is chosen, whereafter all behaviors or physical characteristics are recorded over a specific period of time.
Scan	A group or individual is quickly scanned, and information recorded, at regular intervals.
Behavior	Researchers choose a particular behavior of interest and records who does it, and when it is displayed.

At the early stages of the research, observations were conducted with the ad libitum approach to build an initial understanding of the various flows and processes pertinent to the study. Once a fundamental understanding had been attained, the approach shifted to a focal one. In this part of the study, contact was established with several pickers working within the different flows (oftentimes through team leaders (TLs) and group managers (GPs)), whereafter the researchers of this study accompanied them as they carried out their tasks.

2.4.3 Internal systems

Both aforementioned data collection methods are of a more qualitative nature. While this falls well in line with the purpose of the study and the phrasing of the research questions, quantitative data is to some extent necessary to achieve depth in the analysis. Thus, Scania's internal systems have been utilized to collect data about picking errors. The internal systems have further been useful to access documents concerning building layouts. One of the main advantages realized when collecting data from a company's documentation is that the process is unobtrusive, i.e. the data is not created as a result of the study (Yin, 2009).

2.5 Credibility of the Study

To ensure that the study would be credible, three overarching aspects were considered: *validity*, *reliability*, and *objectivity*. These three aspects are highly relevant for attaining rigor in qualitative studies (Bashir et al., 2008; Denscombe, 2010). In this section, these three concepts are addressed.

2.5.1 Validity

The concept of validity can be summarized to the phrase "That you measure what you intended to measure". However, on closer inspection it can be divided into three subcategories: (1) construct validity, (2) internal validity, and (3) external validity. Firstly, construct validity "[...] pertains to the degree to which the measure of a construct sufficiently measures the intended concept" (O'Leary-Kelly & Vokurka, 1998, p.387). Secondly, internal validity pertains to the degree "[...] to which we can establish a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships" (Stuart et al., 2002, p.430). Lastly, external validity pertains to "[...] the domain to which a study's findings or presumed causal relationships may be generalized" (Stuart et al., 2002, p.430). See Figure 2.6 to further understand the concept of validity.

A way to improve validity when conducting qualitative research is to use several different perspectives to explain a phenomenon (Björklund & Paulsson, 2012; Noble & Heale, 2019). This can be done through the triangulation principle which means that methods, theories, or observations are combined when conducting research. By applying triangulation, fundamental biases which arise when only a single method or observation is used can be avoided. Moreover, this principle induces the benefit of offering the readers of a study a more balanced explanation of the phenomenon or certain situations (Noble & Heale, 2019). The triangulation principle has persistently been sought throughout this study.

2.5.2 Reliability

The concept of reliability refers to the degree to which results are consistent over time, how reliable the measuring instruments are, and whether the results can be reproduced under a similar methodology. Bashir et al. (2008) explain that three types of reliability are commonly referred to in research:

(1) The degree of consistency of results
(2) The stability over time
(3) The similarity within a given time period

The reliability of a research study can be improved by using control questions when conducting interviews or surveys. This has been considered throughout the data collection phase – the same questions were asked to multiple interviewees to attain reliable answers. These questions ensure that aspects can be investigated once again which allows the researchers to study both reliability and validity simultaneously instead of looking at them in an isolated manner (Björklund & Paulsson, 2012). The relation between reliability and validity is illustrated in Figure 2.6.

Figure 2.6: Illustration of validity and reliability (Source: Björklund & Paulsson, 2012).

2.5.3 Objectivity

Objectivity pertains to the absence of bias in the study and research process, i.e. that the study is free from personal opinions. It is important that researchers are impartial and neutral in terms of how they affect the outcome of the study and that the processes conducted throughout the research are fair and even-handed. However, it needs to be recognized at a fundamental level that all research is subject to some level of influence from the researchers, and this cannot be avoided completely. Data does not only sit and wait to be discovered, but is produced by researchers through their process of analysis and interpretation (Denscombe, 2010). Consequently, this impacts the prospect of objectivity and Denscombe (2010, pp.301-302) explains that it raises two questions; firstly, about "[...] the involvement of the researcher's 'self' in the interpretation of the data", and secondly about "[...] the prospects of keeping an open mind and being willing to consider alternative and competing explanations of the data".

In response to the difficulties with maintaining objectivity, there are a few things that researchers conducting qualitative research should keep in mind. Björklund and Paulsson (2012) explain that by clearly stating and motivating choices and assumptions throughout the research process, higher levels of objectivity can be achieved. Denscombe (2010) explains that researchers should be on guard and distance themselves from their everyday judgments and should come clean about how their research agenda has been shaped by personal experiences. Moreover, he says that (1) analysis of data needs to be approached with an open mind, (2) researchers should avoid neglecting data that do not fit the analysis, and (3) they need to examine rivaling and alternative explanations. The propositions from Björklund and Paulsson (2012), as well as from Denscombe (2010), have been kept in mind throughout the process of conducting this thesis.

2.6 Research Ethics

When conducting research within the operations field, some ethical aspects need to be considered. Gallo (2004) explains two principles that operations researchers should be aware of; the 'responsibility' as well as the 'sharing & cooperation' principles. The application of the former (the responsibility principle) in operations research is e.g. to not only take into account the view of the 'client' – in the case of this thesis the logistics development department at Scania in Oskarshamn. The points of view of all stakeholders who might directly or indirectly be affected by the activities and outcome of this thesis should not be neglected. The second principle (sharing & cooperation) calls for more open distribution of the results produced by research activities independently of whether it is just ideas, or complete algorithms and software. The rationale for this is twofold according to Gallo (2004). Firstly, the final result is not only the authors' product, but the tip of an iceberg built on a large pre-existing body of knowledge. Considering the utilization of results from scientific and professional communities, he means that it is the researchers' duty to ensure that results can come to gain for the whole community. Secondly, Gallo (2004) claims that the trend of increasing privatization of ideas tends to turn public investments into private gains, which should be avoided.

Another aspect of research ethics that is of importance is to protect the parties involved in the study and Yin (2014, p.78) presented a few ways this can be performed:

I. **Gaining informed consent** from all the people participating in the study to ensure that they know the nature of the study and that they want to be a part of the study.
II. **Avoiding any and all deception** from the researchers – especially important in the data collection phase.

III. **Protecting the privacy and confidentiality** of participants to ensure that they will not unwittingly be put in an undesirable situation.

These aforementioned aspects by Yin (2014) and Gallo (2004) have been considered and evaluated continuously throughout the work of this thesis. Moreover, to protect Scania's business secrets, the name of a specific business partner has been anonymized with “Partner X”. Considering that Scania is a subsidiary of Traton Group, a publicly traded company on the stock exchanges in Stockholm and Frankfurt (Nasdaq Stockholm and Frankfurter Wertpapierbörse), the protection of confidential information is particularly important.

2.7 Conclusion of Methodology

This section aims to provide an overview of the methodology applied in this master thesis. As the goal was to explore and describe the phenomenon, and the data collection would primarily consist of interviews and observations, a case study was conducted. The inductive research approach was applied, with some complementary use of the abductive approach. The research commenced with a thorough literature review to get a solid theoretical base. This was followed by a phase of data collection where interviews were conducted, observations were made, and internal sources were utilized. Throughout the entire process of this thesis, methods for bolstering credibility have been considered to attain a rigorous and trustworthy study.

3 LITERATURE REVIEW

In this chapter, relevant literature for this thesis is reviewed and compiled. Firstly, theory about mapping is presented and different types of maps are described. Secondly, methodologies for realizing process improvements and the challenges related to this are discussed. This is followed by a section regarding order-picking with a number of subsections about important factors pertaining to the picking process. Lastly, theory about key performance indicators is provided before the major take-aways from this section are summarized.

3.1 Mapping

Before delving into the details of mapping, we must first define what constitutes the essence of a map. Gardner and Cooper (2003) describe maps as a spatial representation of the environment. In this instance, representation refers to something that stands for the environment that it portrays, and is both a likeness and a simplified model. A similar definition is provided by the International Cartographic Association (2021): “A map is a symbolized representation of geographical reality, representing selected features or characteristics, resulting from the creative effort of its author’s execution of choices, and is designed for use when spatial relationships are of primary relevance”. Consequently, maps can be seen as external aids facilitating the investigation, analysis, and discussion of spatial issues.

The level of detail and scope of maps can differ significantly; both individual processes and entire supply chains are frequently mapped by organizations. However, no map can represent everything (Fabbe-Costes et al., 2020), and it is suggested that an appropriate course of action is to first map individual processes and later on superimpose them on a supply chain map (Lambert & Cooper, 2000). The effectiveness of a particular map is a consequence of the selectivity with which it represents a system, and traditional features of a “good” map are that it is interpretable, recognizable, and easy to disseminate (Gardner & Cooper, 2003).

Process maps are regularly used to enhance understanding of a certain process’s characteristics and to generate useful data (Kumar & Phrommathed, 2006). Furthermore, they are known to increase transparency and visibility of the studied processes, and in many organizations, the development of such maps is considered a stepping stone to realizing improvements (Klotz et al., 2008). The development of strategic supply chain maps can entail a myriad of benefits. A well-executed one can, to name a few, enhance the strategic planning process, facilitate the distribution of key information and provide a basis for supply chain analysis (Gardner & Cooper, 2003). Similar to the process maps, supply chain maps increase visibility, but they can also result in improved resilience (Mubarik et al., 2021).

One approach to mapping was developed by Damelio (2011), who related three different kinds of maps to three different levels of performance, see Table 3.1. Each map has different characteristics and is thus effective in different situations. The relationship map is used for the highest level of performance, i.e. organization. It visually depicts the parts of an organization and the supplier-customer relationships existing between them. Relationship maps should not explicitly show work activities, but rather focus on the input/output or linkages among organizational parts. The cross-functional process map, commonly referred to as a swimlane diagram due to its appearance, is aimed at the process level and captures the workflow in organizations by visualizing the work taking place within each part. Lastly, the flowchart is used to map activities on a job level. Damelio (2011, p.8) describes the flowchart as "a graphic representation of the sequence of work activities used to create, produce, or provide a *single* specific, unique output". This type of map provides the highest level of detail with regard to the work activities, and it can be developed to allow the categorization of activities into value-adding or non-value-adding.

Table 3.1: Level of performance and map types (Source: Damelio, 2022).

LEVEL OF PERFORMANCE	MAP USED	"VIEW" OF WORK EMPHASIZED
Organization	Relationship map	**Organization:** The supplier-customer relationships that exist between "parts" of an organization
Process	Cross-functional process map, also known as a "swimlane diagram"	**Workflow:** The *path* of work that "crosses" several functions, plus the *architecture* that connects the relevant activities, people, information systems, and other resources along that path.
Job/Performer	Flowchart	**Activity:** The value-creating or nonvalue-creating work performed

3.2 Process Improvements

Continuous improvements and refinements of processes are frequently sought by organizations in the pursuit of competitive advantage, although the expected results are often absent, leaving managers perplexed. While all change projects are difficult, process-based change is emphasized as particularly complicated (Hammer, 2007). The challenge of redesigning business processes is twofold; *technical*, in the sense that it is difficult to achieve a radical improvement of the current design, and *socio-cultural*, due to the serious organizational effects a major process redesign often entails (Reijers & Mansar, 2005). Hammer (2007, p.3) summarized this appropriately in the following quote:

> *"Companies will invest in retraining employees to work in a new process, but they balk at footing the bill for helping people understand how the process works as a whole. If employees don't know the context in which they work, they will be prone to making decisions that aren't in the best interests of the entire process. Similarly, leaders will try to create processes without altering managerial responsibilities. That's problematic, too. A high-performance process extends across functional boundaries, so a senior executive must supervise it. Without such a person, the process won't gain traction within the organization."*

The maturity of a certain process is often highlighted as especially important to achieve excellence, and several authors have developed propositions and frameworks addressing this (see e.g. Hammer, 2007; Lockamy III & McCormack, 2004; Netland & Alfnes, 2011). This section begins with a description of Hammer's (2007) Process and Enterprise Maturity Model and proceeds with a discussion of the inherent complexity and recurring trade-offs faced by managers when working with process improvements.

3.2.1 Hammer's Process and Enterprise Maturity Model

In 2004, after observing a considerable number of companies trying to rejuvenate themselves by redesigning their business processes, and failing despite their great efforts, Michael Hammer set out to develop a road map for process implementation. This resulted in the creation of the Process and Enterprise Maturity Model (PEMM), a framework that aids executives in comprehending, planning, and assessing process-based transformation efforts. Hammer (2007) argues that two distinct groups of characteristics are required for a process to perform well: *process enablers*, which pertain to individual processes, and *enterprise capabilities*, which apply to entire organizations. The five process enablers and four enterprise capabilities included in PEMM are presented in Table 3.2. Considering that the unit of analysis for this thesis is the external picking process, i.e. an individual process, a more granular view of the process enablers is provided than for the enterprise capabilities.

Table 3.2: Process enablers and enterprise capabilities, based on Hammer (2007).

PROCESS ENABLERS	**Design:** How a process is to be executed. a) Purpose - how the process is designed to fit with suppliers and customers processes. b) Context - how well understood the process's inputs, outputs, suppliers, and customers are. c) Documentation - how well documented the process is.
	Performers: The people who executes the process. a) Knowledge – how well the performers understand the process. b) Skills – which skills the performers possess. c) Behavior – what the performers attitude towards the process is.
	Owner: The senior executive who are responsible for the process and its results. a) Identity – who the owner is. b) Activities – how the owner works with the process. c) Authority – how the owner can influence the process.
	Infrastructure: The systems that support the process a) Information Systems – how advanced the IT systems supporting the process are. b) Human Resource Systems – how hiring, development, reward, and recognition systems are utilized in relation to the process.
	Metrics: The measures used to track the process's performance. a) Definition – how the process's metrics have been derived. b) Uses – how the process's metrics are used by managers.
ENTERPRISE CAPABILITIES	**Leadership:** Senior executives who support the creation of processes.
	Culture: The values of customer focus, teamwork, personal accountability, and a willingness to change.
	Expertise: Skills in, and methodology for, process redesign.
	Governance: Mechanisms for managing complex projects and change initiatives.

To evaluate the maturity of a certain process, i.e. how capable it is of delivering higher performance over time, Hammer (2007) proposes the use of a five-level scale ranging from P-0 to P-4. The logic of the sub-scores is that if all five process enablers are at the P-1 level, the process itself is at the P-1 level; if all five process enablers are at the P-2 level, the process itself is at the P-2 level; and so forth. In a situation where only four out of five enablers have reached a certain level, the process cannot be considered to be on that level – it will belong to the level below. Different process levels correspond to different characteristics:

- P-0: The process works erratically.
- P-1: The process is reliable and predictable.
- P-2: The process delivers superior results.
- P-3: The process delivers optimal performance.
- P-4: The process is 'best in class'.

Hammer (2007) further claims that companies using PEMM find it effective to not treat all propositions of the model as binary. Instead, he suggests an approach where all aspects are graded according to largely true (statement is at least 80% correct), somewhat true (statement is between 20% and 80% correct), or largely untrue (statement is less than 20% correct). For an extensive explanation of the criteria for different levels, we refer to the article by Hammer (2007).

3.2.2 Complexity of process redesign

The ultimate goal of redesigning a process is often to realize improvements with respect to time, cost, quality, or flexibility (Reijers & Mansar, 2005). Ideally, the newly designed process decreases the time required to complete it and the cost required to execute it, while improving the quality of the deliverable(s) and the ability to react to changes in requirements. However, that is seldom the case. The relationships between (1) quality and cost, (2) flexibility and cost, and (3) customization, manufacturing cost, and delivery lead times are of a contesting nature (Hallgren et al., 2011). Similarly, Reijers and Mansar (2005) argue that improvements along one performance dimension generally have a negative effect on another, and refer to a model called the *devil's quadrangle* (Figure 3.1) to illustrate the competing nature of the trade-offs. It should also be acknowledged that competition is present even within the dimensions. For example, Wilding (1998) claims that the trade-offs between labor costs, transportation costs, inventory costs, and response time to customers are becoming increasingly complex.

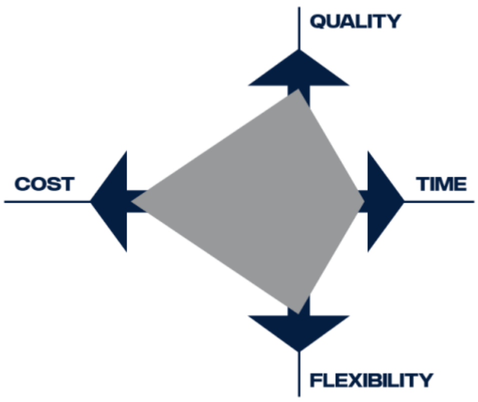


Figure 3.1: The devil's quadrangle (Source: Reijers & Mansar, 2005).

The inherent complexity of both supply chains and internal operations is a peril that must be addressed. If not managed properly, the complexity may impede the development of a process or even undermine it; several authors (e.g. Bozarth et al., 2009; Shäfermeyer et al., 2012; Serdarasan, 2013) emphasize the relationship between performance and complexity management. The sources and drivers of supply chain complexity are numerous. Examples include the number of customers, heterogeneity in customer needs, number of products, number of parts, one-of-a-kind/low volume batch production, number of suppliers, globalization, and incompatible IT systems (Bozarth et al. 2009; Serdarasan, 2013). At the process level, nonroutine, difficulty, uncertainty, and interdependence are driving complexity (Karim et al. 2007).

Fortunately, there is extensive literature both on how to master complexity and how to succeed with implementations in general. Persson (1995) developed nine principles for logistics process redesign. The fifth principle, *simplify structures, systems, and processes*, is directly related to complexity. Within this principle, standardization of methods and processes is mentioned as an effective tool to reduce complexity. Principle six, *differentiate*, refers to measures that find new and more effective ways of categorizing and grouping products, systems, and processes. After establishing an appropriate categorization, different methods and principles can be applied to each group to elevate the performance.

Reijers and Mansar (2005) compiled a set of best practices for redesigning business processes and divided them into seven categories based on what the process is oriented towards. Two of the categories are *business process operation*, which focuses on how to implement the workflow, and *organization*, which considers the allocation of resources as well as the resources involved. Some of the best practices appurtenant to these categories are presented in Table 3.3. According to McKinsey (2015), the success rate of transformation projects is significantly higher when companies have a systematic process for identifying, sharing, and improving upon best practices. Other fundamental success factors when redesigning processes include open communication from senior management about the transformation's progress, employee understanding of how his or her work relates to the organization's vision, and employee participation in the identification of errors (McKinsey, 2015; Kotter, 1996).

Table 3.3: Best practices for business process redesign, based on Reijers and Mansar (2005).

CATEGORY	BEST PRACTICE	WHY?
BUSINESS PROCESS OPERATION	Order types: Determine whether tasks are related to the same type of order and, if necessary, distinguish new business processes.	May yield faster processing times and less cost. Distinguishing sub-flows of many different flows may also yield efficiency gains.
	Task elimination: Eliminate unnecessary tasks from a business process.	Increase processing speed and reduce order-handling cost.
	Triage: Consider the division of a general task into two or more alternative tasks, or the integration of two or more alternative tasks into one general task.	Improve quality of the process, utilize resources more efficiently. Similar advantages as the "order types" best practice.
ORGANIZATION	Order assignment: Let workers perform as many steps as possible for single orders.	The employee will get acquainted with the assignment and need less setup time. May improve the quality of the service.
	Split responsibilities: Avoid assignment of task responsibilities to people from different functional units.	Reducing the overlap of functions should lead to better quality of the execution and reduce conflict.
	Numerical involvement: Minimize the number of departments, groups, and persons involved in a process.	Should lead to less coordination problems. Similar advantages as the "split responsibilities" best practice.

3.3 Order-Picking

Order picking is defined as the process of retrieving products from storage (or buffer areas) in response to a specific customer request, and consists of tasks such as lifting, moving, picking, packing, etc. (De Koster et al., 2007; Lee et al., 2015). Order-picking can represent up to 55% of the total warehouse operating cost, and thus many companies look to cut costs within this labor-intensive process. The order-picking process is important due to the high cost (which in turn leads to high supply chain cost), but also because it is important to avoid delays and unsatisfactory service. Thus, many professionals within operations argue that picking is the highest priority area for productivity improvements. For the order picking process to function efficiently, it is of importance that it is robustly designed and controlled in an optimal way (De Koster et al., 2007). The aforementioned 55% of the total warehouse operating cost can on a general basis be further broken down into sub-segments, see Table 3.4 (Bartholdi & Hackman, 2019).

Table 3.4: Breakdown of order-picking (Source: Bartholdi & Hackman, 2019).

ACTIVITY	% ORDER-PICKING TIME
Traveling	55%
Searching	15%
Extracting	10%
Paperwork and other activities	20%

Several objectives are important when analyzing order-picking. As learnt by the segmentation in Table 3.4, traveling represents more than half of the cost induced by this process. Thus, this sub-segment is often the first candidate for improvement and a lot of resources are generally allocated to reducing this non-value adding time (Bartholdi & Hackman, 2019; De Koster et al., 2007). In addition to traveling, De Koster et al. (2007, p. 486) present other important objectives:

- Improving picking accuracy (to avoid picking errors)
- Reduce total cost (both investments and operating costs)
- Minimizing the throughput time of orders
- Minimize the overall throughput time (e.g. to complete a batch of orders)
- Maximize space utilization
- Maximize equipment utilization
- Maximize labor utilization
- Maximize item accessibility

In the following subsections, different aspects of designing and controlling order-picking processes are explained.

3.3.1 Forward-reserve allocation

To improve the order-picking, forward-reserve allocation can be used in a warehouse. This means that the picking stock (forward area) is separated from the bulk storage (reserve area) to increase the picking speed (De Koster et al., 2007; Bartholdi & Hackman, 2019). However, the size of a forward area is restricted, and the smaller the area is, the shorter the average travel times for the order-pickers will be. It is therefore important to decide how much of each SKU should be allocated in the forward area. When storing SKUs in different areas of the warehouse, regular internal replenishments from the reserve area to the forward area are required. This implies a trade-off between additional replenishment efforts and reduction of pick efforts. In certain cases, it can even be advantageous to store some SKUs solely in the reserve area, e.g. if the demand quantities are low. In addition to choosing which SKUs, and the quantity of each SKU, to store in the forward areas, there is another difficulty – replenishments are commonly restricted to times at which there is no order-picking activity to avoid congestion (De Koster et al., 2007).

3.3.2 Order-picking strategies

Order-picking systems can be differentiated into two categories; part-to-picker and picker-to-part. The former of the two categories, part-to-picker, includes automated storage and retrieval systems (AS/RS) which in most cases use aisle-bound cranes that retrieve unit loads (commonly pallets) and transport them to a picking location. At this point, the order picker takes the required amount, after which the remaining load is transported back to storage again (De Koster et al., 2007). The latter of the two categories, picker-to-part, is the most common and means that order pickers walk or drive along aisles to pick SKUs. It can be performed in different organizational variants, and can be divided into three strategies (De Koster et al., 2007; Parikh & Meller, 2008):

- **Picking by order (discrete picking)** means that one picker is responsible for picking all the items that a single order consists of during a pick-tour.
- **Picking by article (batch picking)** means that multiple customer orders (called the batch) are picked simultaneously by one picker. This means that several orders are grouped (batched) together and one picker is responsible for picking all items that are included in the group of orders. A drawback of this strategy is that items have to be sorted into orders either while picking or later downstream.
- **Picking by zone (zoning)** means that a storage area (e.g. a pallet storage area or an entire warehouse) is split into multiple parts (zones), and each of these parts has an assigned picker(s). Zoning can further be divided into two types; progressive zoning and synchronized zoning. The former means that an order is picked in one zone and then passed on to another zone(s) to be complemented with more articles. The latter of the two types implies that the order is picked in parallel in different zones.

3.3.3 Routing

As mentioned in the introduction of section *3.3 Order-picking*, traveling to retrieve orders does not add any value and is the most expensive activity related to order-picking. Moreover, travel time is significant because it affects customer service through its impact on how soon an order is ready for shipping (Bartholdi & Hackman, 2019). One way of reducing the travel time without the need for drastic investments is to look into routing (Dukic & Oluic, 2004). Petersen (1999, p.1054) explains routing as follows: "Routing policies determine the route of a picker for a picking tour, specifically the sequence in which items are to be picked". Different policies of how routing should be conducted range from simple heuristics to optimal procedures. Optimal routing results in less travel time but is highly complex to develop and implement, while heuristic routing benefits from its simplicity and that it is familiar to most experienced pickers. Another benefit of routes based on heuristics is that it forms fairly consistent routes which help to minimize the risk of missed picks, which would have more severe consequences compared to the picker needing to take a few extra steps (Petersen, 1999).

In practice, the most common way of solving the problem of routing is heuristics, and De Koster et al. (2007) explain that this is due to some disadvantages of optimal routing:

- An optimal algorithm for routing is not available for every warehouse layout.
- Optimal routes can seem illogical to the pickers, which results in them deviating from the specified routes.
- A standard optimal algorithm cannot consider aisle congestion while it may be possible for heuristic methods to avoid (or at least reduce) it.

Five heuristic routing strategies as well as an example of an optimal route are illustrated in Figure 3.2. There are however a few problems with these strategies that need to be taken into account. Firstly, De Koster et al. (2007) explain that a lot of the research where these strategies have been developed assumes that the aisles are narrow enough to allow pickers to retrieve products from both sides of the aisle without changing position. Secondly, he explains that a problem may arise if SKUs are stored at several locations in the warehouse. In that case, there is a need for a decision about which locations the articles should be retrieved from. Thirdly, when conducting the literature review for this subsection, it has been noticed that more or less all literature is based on the assumption that the warehouse configuration is rectangular and consists of aisles with consistent depth.

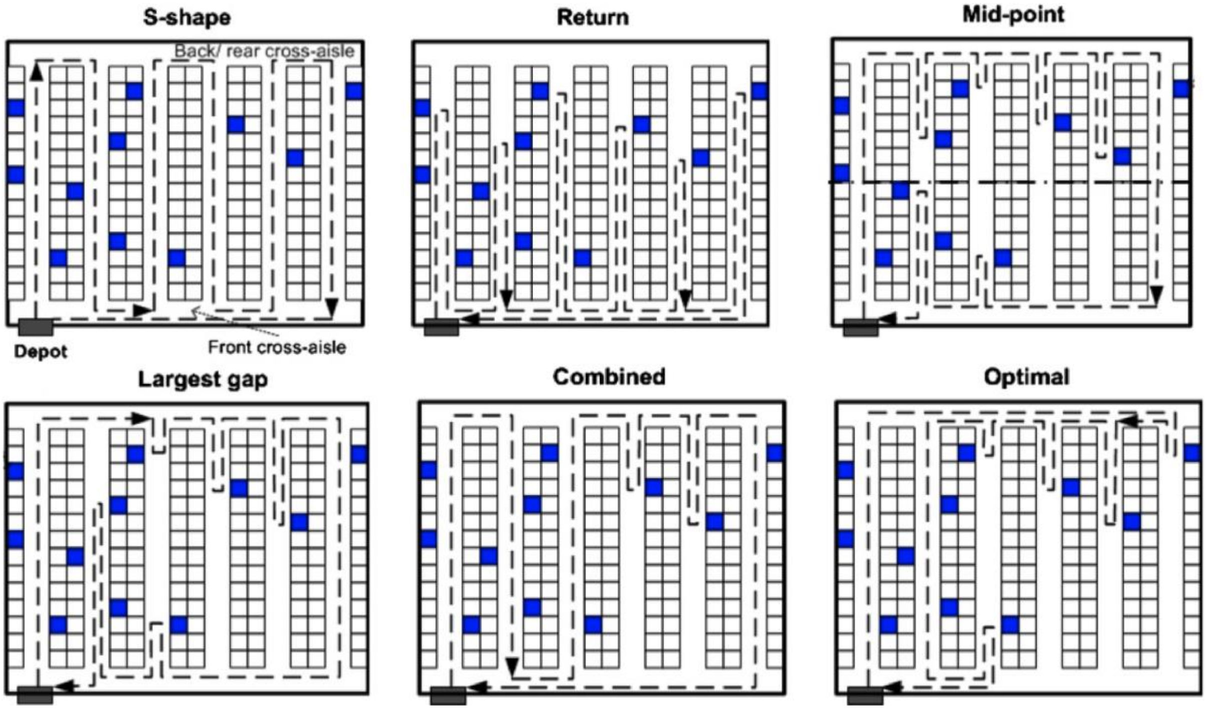


Figure 3.2: Routing strategies (Source: De Koster et al., 2007).

3.3.4 Assistive devices

Even though there is an ongoing trend to automate and digitalize industrial processes, manual material handling still plays an important role in many industries. Automation levels are quite low within warehousing and processes such as order-picking or packaging still rely heavily on manual labor. To quantify it – data in 2018 showed that more than 10.8 million people were employed within the warehouse-transport-storage sector in the European Union (Glock et al., 2021, p.3446). To utilize human labor in the best possible way, different assistive tools can be used to make the picking process both more efficient and accurate, but also more sustainable with regard to ergonomics (Glock et al., 2021). Assistive devices are in this thesis defined in accordance with Glock et al. (2021, p.3447) as “technical devices that assist humans in warehousing tasks, but that do not fully automate or substitute the manual process of materials handling”. This subsection will cover different types of technologies and tools which can be used as assistive devices.

Mobile and wearable technologies are devices that both send and receive data that can be carried or worn by the personnel working in a warehouse. *Mobile* means that the user carries the device, while *wearable* means that the user wears the device, e.g. on the head or the wrist. The difference between the two is in other words that wearables can be used hands-free, which enables the user to perform tasks that require the hands without compromising system interaction. Examples of mobile technologies are vehicle-mounted computers, tablets, and handheld scanners. Wearable devices are e.g. smart glasses, smart gloves, and voice headsets. An important example of a benefit that these two kinds of technologies bring is that they eliminate the need for pickers to walk back and forth to their working station to enter or access data, which allows the pickers to reduce their travel distances. Consequently, this enables more efficient warehouse operations (Cyzerg, n.d.). However, Scheuermann et al. (2016) explain that if handheld devices impede workers in any way, it can result in decreased motivation to use such devices. Therefore, wearable devices are an interesting option for companies conducting manual material handling.

A mobile technology that is commonly used in warehouse operations is scanners. It is an effective tool to improve both picking speed and accuracy in comparison to more traditional methods (Glock et al., 2021). Moreover, it is a suitable technology to use at the entrance and exit of the warehouse to keep data updated in real-time of what is in inventory, and thus in theory removes the need for traditional stocktaking (Connolly, 2008).

One useful wearable technology is pick-by-voice which is a sophisticated way to help workers collect SKUs for an order. Each picker wears a headset with an attached microphone, together with a belt-mounted wireless computer. Via the headset, the picker gets instructions by a spoken voice about pick locations and what quantities to pick. When a pick is being conducted, the picker reads out loud a check string provided at the pick location into the mic so the system can check that it is the correct SKU (Connolly, 2008; Glock et al., 2021). This technology allows for dramatically higher picking accuracy in comparison to a paper-based system (Connolly, 2008; Cyzerg, n.d.). In one study it was shown to reduce picking errors by 71%, from 5.26 to 1.51 per thousand picks (Glock et al., 2021).

Another technology to help pickers locate SKUs is pick-to-light, also known as 'pick-by-light'. This is an approach that requires indicators to be permanently mounted at each SKU location. To attract the picker's attention, indicator lights are used, commonly in combination with a small display to communicate the requested quantity. Each picker works in a particular zone and for each order, all the indicators light up (Connolly, 2008). Research shows that this technology both increases pick frequency as well as significantly reduces the number of picking errors (Stockinger et al., 2020).

Smart glasses are a wearable technology that is relatively new and seems to have a promising future. In 2019, DHL implemented 'vision picking' in their warehouses worldwide. Markus Voss, COO and CIO of DHL Supply Chain, talked about the development of smart glasses as follows: "The possibility of object recognition is also particularly promising for us in industrial applications. With the corresponding software, it is no longer just possible to read out barcodes, locate products and display the corresponding storage compartment; in future, also complex objects can be identified with the smart glasses" (DHL, 2019). In a previous press release, DHL (2017) disclosed that smart glasses lead to a 15 percent productivity increase for their pickers. Moreover, a case study within the automotive industry, conducted by Fang and An (2020) showed that picking efficiency increased by 50 percent while picking errors decreased by 65 percent when implementing smart glasses compared to the previous method of pick-by-paper.

A wearable technology that can be seen as a substitute for traditional handheld scanners is smart gloves. It is a glove with a small scanning unit attached to the top of the hand that is connected to a smartwatch, see Figure 3.3. A study by Scheuermann et al. (2016) showed less physical fatigue and better user acceptance of the smart glove compared to handheld scanners.

Another benefit they found was that travel distance can in some cases be reduced by 50 percent. The underlying reason was in these cases that pickers might need to pick several items, and if they only had one hand available (due to the scanner being in one hand) they would need to make two runs to that location. Moreover, they found that the number of errors was reduced by 66% when using smart gloves compared to traditional scanners. However, the type of error is not explicitly defined in Scheuermann et al. (2016).

Figure 3.3: Smart glove (Excerpt from Figure 1 in Scheuermann et al., 2016).

3.4 Key Performance Indicators

In 1954, an approach called "management by objectives" was introduced which meant that employees and their boss would agree upon a set of goals to work towards achieving throughout a year. Today, goals dominate the modern workplace and in 95% percent of organizations, employees set goals for themselves or their teams. Sull and Sull (2018) explain that goals should be "FAST". This means that "Goals should be embedded in **Frequent** discussions; **Ambitious** in scope; measured by **Specific** metrics and milestones; and **Transparent** for everyone in the organization to see" (Sull & Sull, 2018).

Following the principle of the aforementioned FAST goals, specific metrics and milestones should be utilized to measure the goals. However, the use of performance measures is nothing new – organizations have tracked success for centuries. Although, the way these measures are designed and used has changed tremendously during the last few decades. From the development of the modern accounting framework in the Middle Ages up until recently, financial criteria have been the foundation of performance assessment (Kennerley & Neely, 2003). Albeit, today's competitive environment calls for a more balanced approach, giving attention to financial and operational measures alike. As pointed out by Kaplan and Norton (1992, p.71): "The traditional financial performance measures worked well for the industrial era, but they are out of step with the skills and competencies companies are trying to master today". The financial measures are criticized for a number of reasons, including their lack of strategic focus, their inability to provide information concerning customer needs, and their inclination towards history rather than the future (Neely, 1999).

Adages such as 'what gets measured gets done' and 'you get what you measure' imply that the implementation of appropriate measures will ensure alignment between actions and objectives. That raises the question; what determines the appropriateness of a measure? In general, quantitative measures are preferred considering that qualitative evaluations such as good or poor are vague (Beamon, 1999). Chae (2009) describes the development of key performance metrics (KPIs) as a daunting task, considering that listing potential KPIs itself appears to be inexhaustible. He further argues that while the common perception is that 'more is better', the opposite is true for supply chain performance measurement – companies should start with a small number of essential KPIs. Beamon (1999) identifies four key characteristics of effective performance measurement systems:

(1) Inclusiveness, which pertains to the measurement of all relevant aspects.
(2) Universality, which allows for comparison under various conditions.
(3) Measurability, meaning the required data must be measurable.
(4) Consistency, in terms of measures consistent with organizational goals.

Several authors (e.g. Gunasekaran et al., 2001; Chae, 2009; Huan et al., 2004) divide performance measures pertinent to the supply chain in accordance with the Supply Chain Council's supply chain operations reference (SCOR) model: plan, source, make/assemble, and delivery/customer. Considering the scope of this thesis, the make/assemble and delivery/customer KPIs will receive the most attention. Some examples of appropriate performance measures within these categories as identified by researchers are: fill rate, perfect order fulfillment (Huan et al., 2004), response to the number of urgent deliveries (Gunasekaran et al., 2001), and on-time departure to customers (Chae, 2009). We can also distinguish some warehousing-specific performance indicators, such as order picking time, picking accuracy, and order processing cost (Staudt et al., 2015).

3.5 Conclusion of Literature Review

This section aims to summarize the key take-aways from this chapter. Three types of maps can be useful for this thesis; (1) relationship maps can be used to illustrate the material flows, (2) cross-functional process maps (swimlane diagrams) can be used to illustrate information flows as well as how organizations are responsible for different parts of the material flow, and (3) flowcharts can be used to step-by-step illustrate how processes are executed.

Process improvement is difficult but facilitating tools and frameworks exist. An example of this is Hammer's process and enterprise maturity model. The literature also provides a number of best practices and principles for attaining process improvements. Order-picking is highlighted as a time-consuming task, the performance of which is influenced by factors such as strategies, routing, and the use of assistive devices. To realize improvements it is crucial to have adequate KPIs in place. Examples of proper performance measurements include perfect order fulfillment and picking accuracy.

4 EMPIRICAL STUDY

This chapter aims to provide the reader with a comprehensive overview of the empirical data gathered in this thesis. Starting on a more general level, the internal customers, the overarching setup at Scania Oskarshamn, and the organizations involved in the external picking process are described. This is followed by a detailed account of four separate flows: (1) Technical Center, (2) Laxå Special Vehicles, (3) Spare parts, and (4) "Partner X". Each flow is described in terms of material flow, organizational responsibility, picking process, and challenges, thus answering RQa and to some extent RQb. Further, building on the understanding attained through interviews and observations, maps have been constructed for each flow – acting as illustrative summaries of the gathered information.

4.1 Context to External Picking

4.1.1 Internal customers

As explained in section *1.2 Problem Formulation*, a number of different internal customers receive items through the external picking process. Their geographical locations are illustrated in Figure 4.1. What distinguishes these customers is that they can order production material on an article level, in contrast to regular customers who can only order a complete cab. In the following bullet points, the recipients are described briefly:

- Cabs that for various reasons cannot be produced at the main production lines are produced at the low volume production line (**LVL**), located at the Technical Center in Oskarshamn. The majority of these cabs are intended for military trucks and are produced at LVL due to specifications such as big roof rails/roof loading areas and racks for ammunition and radio equipment.
- **The Arena** is also located at the Technical Center in Oskarshamn and is used to test new engineering solutions before they go into commercial production.
- **Laxå Special Vehicles (LSV)** is a company wholly owned by Scania that produces truck cabs for specific usages where the majority are crew-cabs or low-entry cabs. These are e.g. intended for fire trucks and garbage trucks.
- In Oskarshamn, only the cabs are produced and to assemble the truck, the cabs are shipped to the **chassis factories** to be mounted. The items that are included in the flows relevant to this thesis are sent when something is damaged in the assembly process at those factories. These factories are located in Södertälje, Zwolle, and Angers.
- Scania works hard to provide a high level of customer service. Some customers have service agreements guaranteeing that they will be provided spare parts within 24 hours to avoid stranded trucks. Therefore, Scania has a spare part center (**Scania Parts Logistics**) in Oudsbergen, Belgium, where all relevant items are stored. When an item is shipped from this center, it has to quickly be restocked with items from Oskarshamn.
- **"Partner X"** is a French business partner which specializes in security and defense vehicles. They do not build all components required for their trucks but instead purchase from suppliers – one of which is Scania. From Scania, "Partner X" purchases instrument panels as well as other various components needed inside the cab.

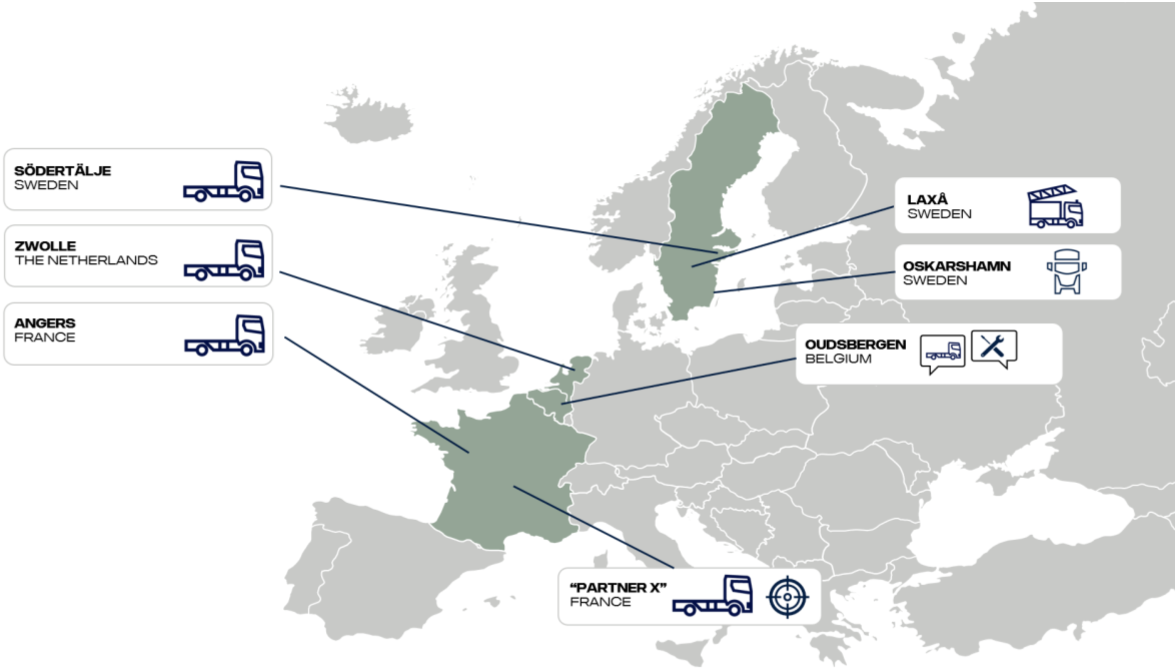


Figure 4.1: Location of internal customers.

4.1.2 Oskarshamn setup

Material is shipped between facilities in Oskarshamn – either to fulfill the need of that specific customer (as is the case with the Arena and LVL) or as a step towards reaching the final customer. The main production only runs during the daytime and is divided into MB (manufacturing body) and MC (manufacturing cab). MB is highly automated and no picking occurs here. MC, however, is heavily dependent on human labor, both in terms of the production and the replenishment of material to production lines. The material flow within MC generally follows the same steps:

(1) Deliveries from suppliers are temporarily stockpiled in the inbound area.
(2) The pallets are transported into the highbay storage area by conveyor belts.
(3) Material is withdrawn from storage and put on a "logistics platform".
(4) Material is picked at the platforms and placed on tugger trains.
(5) The trains deliver material to the production lines.

Naturally, there are some exceptions. For some items which are very rarely used, it would not make sense to keep an entire pallet in stock. Such slow-moving SKUs are kept in boxes in a dedicated box storage. Some other items are too bulky to fit in a regular EUR-pallet – such SKUs are kept in special big pallets in a dedicated big pallet storage area. Noteworthy is that each platform is responsible for serving a particular line with material and that the frequency of which the train departs is predetermined as a consequence of the takt time used. Humans are unquestionably the core of the cab assembly process, although MC has implemented some different technologies and automated solutions to improve plant performance. For instance, an automated storage and retrieval system (AS/RS) conveniently transports full pallets to a pick-up location via conveyors upon request, two AGVs are used to remove empty boxes from platforms, and both pick-by-voice and pick-to-light are available for pickers. To clarify, 'full pallet' is in this thesis defined as a pallet containing a single kind of item.

Production material requested outside of MC can take one of three different paths to exit the facility:

(1) It is placed on the "moving floor", a system for quickly loading palletized goods onto trailers.
(2) It is placed in Slussen, an area where pallets are temporarily stored before being loaded on a trailer.
(3) It is placed in a container outside of MC before being transported by forklift, truck, or tractor.

The moving floor is used when pallets are destined for the Logistics Center (LC). LC serves multiple logistical purposes and is an important player in the reception, storage, and shipment of goods. On average, trucks run between MC and LC every eighth minute. All production materials bound for destinations outside of Oskarshamn are sent via LC, where it is registered and consolidated. The pallets placed in Slussen/trailers contain a mix of items and are bound for the Technical Center (TC). Pallets placed in the container that are relevant for this thesis are either (1) full pallets or dangerous goods bound for TC, or (2) dangerous goods bound for the logistics center. Each of the four main Oskarshamn facilities is depicted in Figure 4.2, and the layout inside of MC is illustrated in Figure 4.3. Who is responsible for transporting the goods depends on where it is shipped from. Some transports are managed by Scania themselves, while others are managed by external parties. However, this is outside the scope of this thesis, thus the subject of transportation will not be elaborated on further.

Figure 4.2: Main facilities of Scania Oskarshamn.

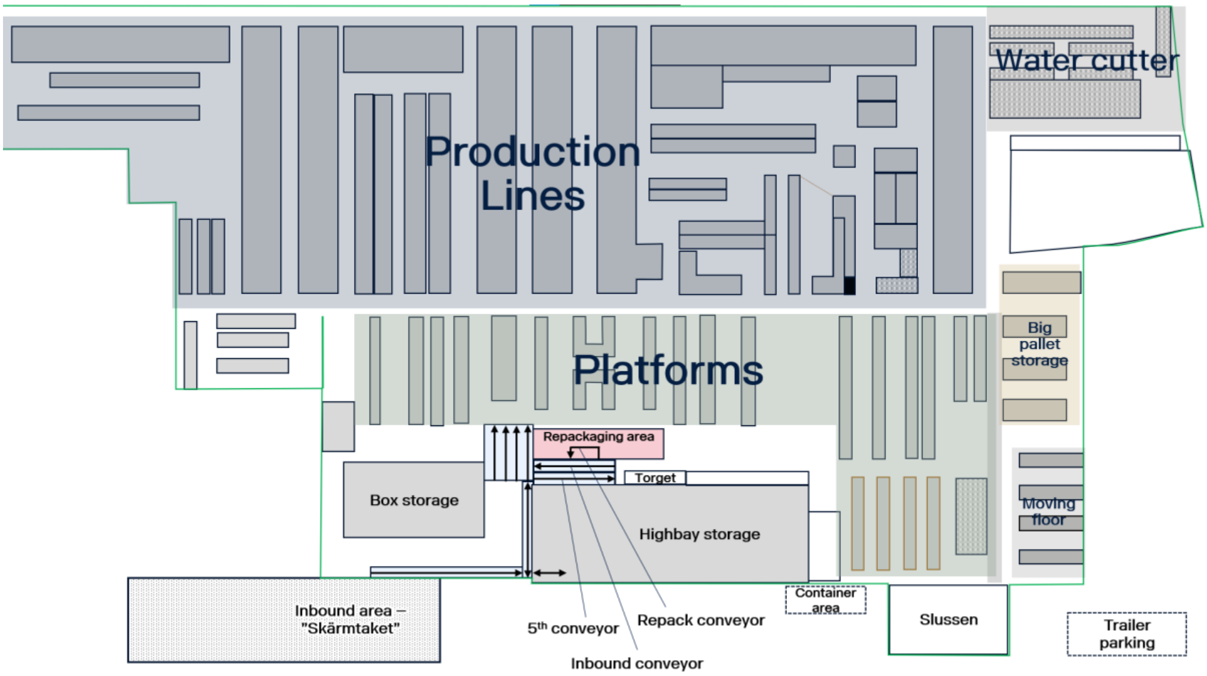


Figure 4.3: Layout of MC.

4.1.3 Organization

With approximately 50,000 employees worldwide, Scania is a massive organization consisting of countless divisions and departments. Illustrating the entire organizational structure would be an inexhaustible task, not to mention redundant for this thesis. However, focusing on Scania Oskarshamn, and more specifically the organizations related to the external picking process, the number of organizational layers becomes manageable. To visualize the departmental responsibilities and functions, Figure 4.4 has been developed. Not all functions within the organizational structure are included in the figure. Each branch is divided to a level where at least one of the interviewees is employed. In the figure, the functions that the authors of this thesis have been in contact with are illustrated with a darker color, whilst the functions that have not been interviewed are more transparent.

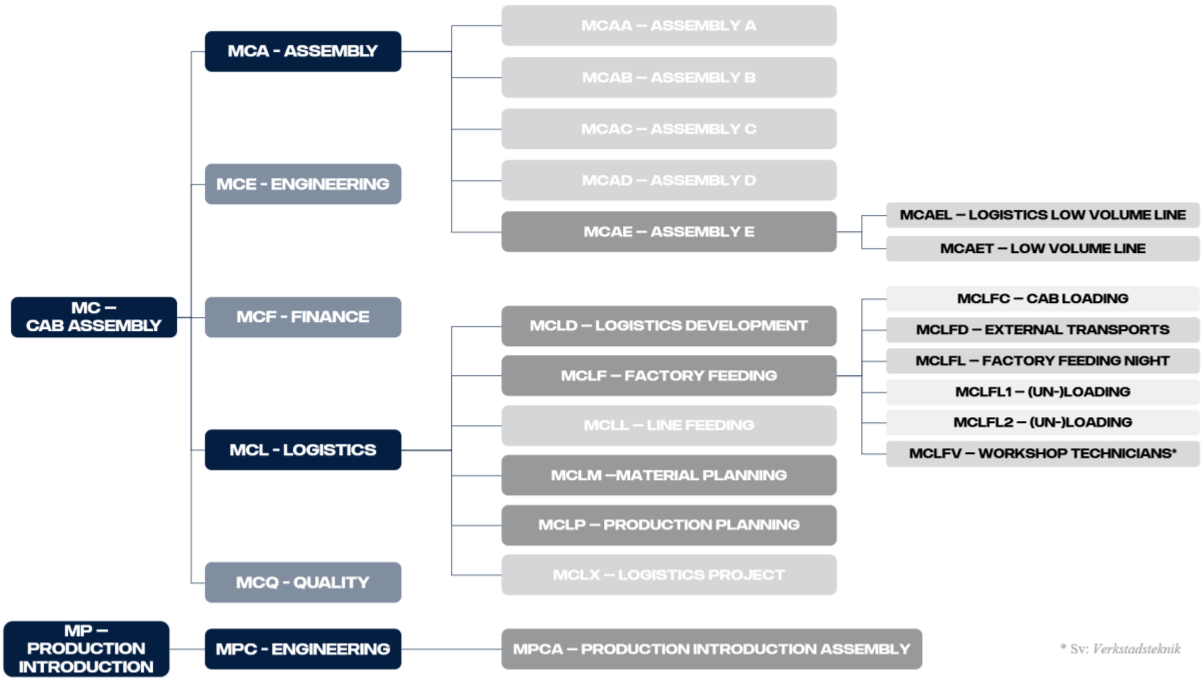


Figure 4.4: Organizational structure of MC.

Several different functions are involved in the process of external picking. Omitting support functions such as material and production planning, we can say that three distinct functions are involved in the actual picking of mixed pallets: MCAEL (Logistics Low Volume Line), MCLFL (Factory Feeding Night), and MCLFV (Workshop Technicians). Oftentimes, one organizational unit is responsible for the picks to one specific internal customer, but there are examples of when two different functions work in parallel with identical tasks. This is the case during nights when employees from MCAEL and MCLFL pick orders destined for the LVL and the Arena side-by-side. The organizational responsibilities will be further elaborated on and discussed in the following section.

4.2 Material Flows and Processes to Internal Customers

Empirical data in this study have predominantly been gathered through interviews. During the interviews, key information related to each of the studied flows have been discovered. A list of interviewees, their role in the company, and the focus of the interviews are provided in Appendix A. To improve the validity of the study by utilizing the triangulation principle, observations were made. Lastly, internal systems were utilized to gather quantitative data regarding picking errors. The empirical data is presented in the following subsections.

The flows to some of the internal customers are identically managed at Scania's Oskarshamn facilities and are thus merged in the maps included in this section. This is explained and elaborated on in the relevant subsections. Four distinctive flows have been identified: (1) Technical Center (TC), (2) Laxå Special Vehicles (LSV), (3) Spare parts, and (4) "Partner X". For each of the internal customers the material flow, organizational responsibilities, picking processes, and challenges are presented.

4.2.1 Technical Center

The Technical Center (TC) flow is entangled in all flows except for the Spare parts flow – why the TC flow will be the first one covered in this section. The reason for this is that all instrument panels (IPs) that will not be mounted on a cab produced at the main production lines are assembled at the low volume production line (LVL), i.e. all cabs produced at TC, Laxå Special Vehicles, and "Partner X" receive IPs from the LVL. When referring to the TC flow, it entails the material flow to both the LVL and the Arena. The reason that the LVL and Arena flows are bundled together and called the 'TC flow' is due to all the material being transported together from MC to TC and being stored in shared storage areas before production (the LVL and the Arena are located in buildings next to each other, see Figure 4.5). Noteworthy is that both LVL and the Arena can be seen as scaled-down versions of the main production lines. I.e., when items are picked from e.g. line 4 or its platform at MC, the material is used at line 4 at LVL.

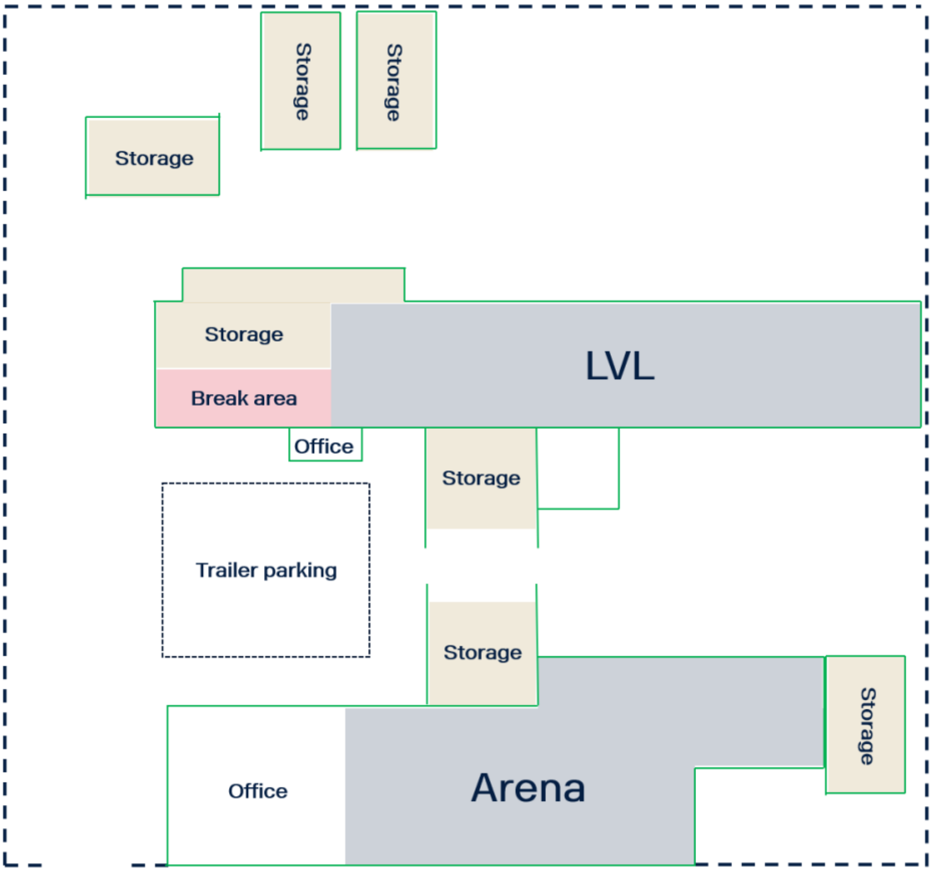


Figure 4.5: Map of Technical Center.

Material flow

The materials requested by TC arrive there in a few different ways depending on different factors such as (1) are TC requesting a full pallet or a mixed pallet and (2) are the items stored on a big pallet or an ordinary EUR-pallet. As can be seen in Figure 4.6, TC receives items from MC as well as the logistics center (LC). If TC requests a full big pallet containing army-specific items, it is shipped straight from LC. From MC, the flow can be divided into the two categories (1) full pallets and (2) mixed pallets:

(1) The former is quite simple, the full pallet arrives at the 5th conveyor. From there, the pallet is moved by forklift to Torget before it is transported to the container area. Finally, pallets are transported by either forklift, truck, or tractor to TC. This transport is not scheduled for specific times but instead is conducted when MCLFD (External Transports) are driving their routes around MC and notice that pallets are waiting in the container. Before the items arrive at the 5th conveyor, they can have two different origins; (A) If the SKU is also used at the main production lines, the pallet arrives from the automated highbay storage. (B) If the SKU is solely used at TC, the pallet goes straight from the inbound area to the 5th conveyor. The reason the pallets go via MC and not straight to TC from the supplier is that TC does not have a proper goods arrival area where the goods can be registered.

(2) When the requested quantity of an SKU is not equivalent to a full pallet, it gets a bit more complex. The items are then manually collected by pickers at MC, either from the main production lines or the logistics platforms. Alternatively, if the item requested is water cut, it is picked at the water cutting station. A picklist contains items from one line/corresponding platform for one pallet, and when the picks are finished, the pallet is placed in Slussen. From there, all finalized pallets are loaded onto trailers, which then transport the goods to TC. This transport is conducted every morning around 07.00. To avoid congestion and mitigate the risk of delaying production, the material is transported to TC approximately 24 hours before it is scheduled to be used.

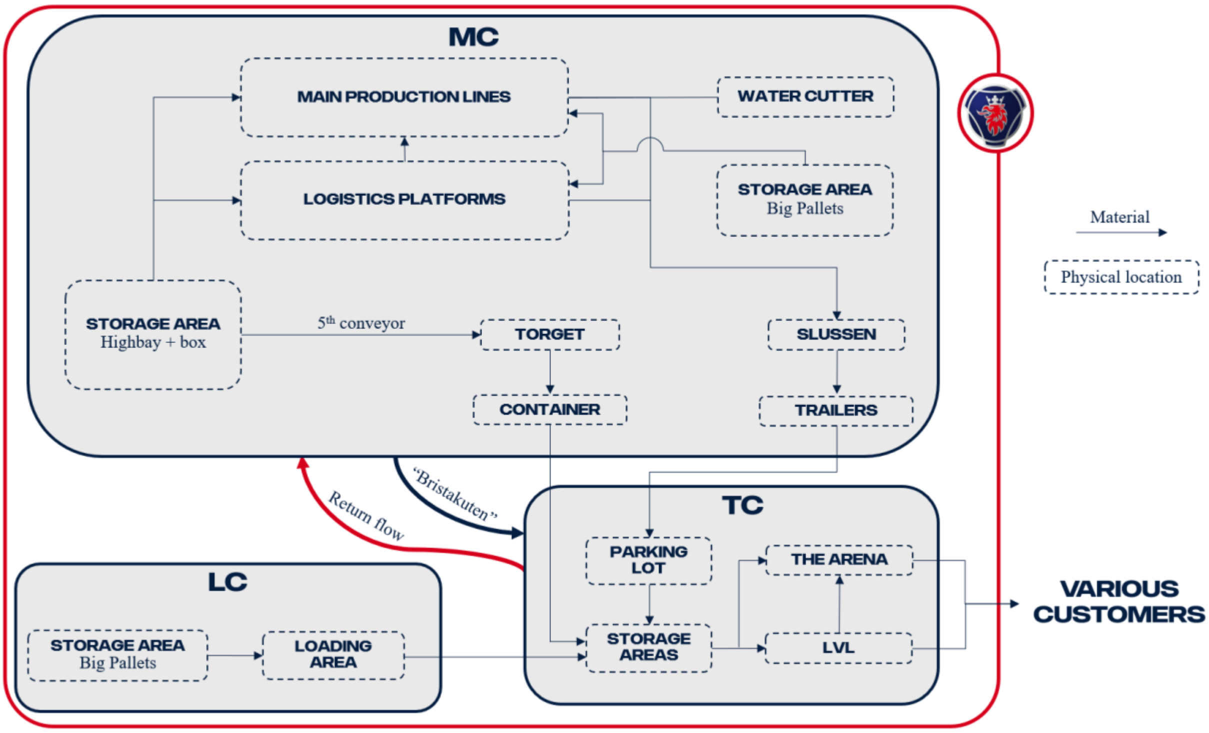


Figure 4.6: Relationship map illustrating the material flow to TC.

In addition to these two flows from MC, there is also the emergency shortage flow. This is an ad-hoc solution that comes into play if something is missing when the pallets arrive for production at LVL or the Arena. The organization responsible for this is referred to as "Bristakuten". To avoid stalling production, they quickly drive to MC, collect the missing item(s), and drive back. On the other hand, if TC receives a surplus of items, this results in a return flow of material back to MC. Small items are gathered in a pallet and sent back to MC once a week. Bigger items are left in the pallet they arrived in, and thus shipped back the same day they are noticed at TC. The pallet with the remaining items is marked with a label to notify the personnel at MC that it contains returning items.

Goods arriving from LC are unloaded from the truck and put into one of the storage areas. The trailers arriving from MC with the manually picked items are parked in the parking lot at TC. From there, the pallets are unloaded and placed in storage as well. Once the trailers are empty, they remain in the same location to allow pallets that have been emptied during the day to be loaded. In the afternoon/evening when the trailers are filled with empty pallets, they are transported back to MC to be reused for the same flow the following day. The full pallets transported from the container area also go straight into one of the storage areas. Moreover, it should be mentioned that due to space constraints at the Arena, they cannot stock-keep all required items. Therefore, personnel from the Arena pick items such as windshields and ceiling storage shelves from LVL.

Organizational responsibilities

To understand the organizational responsibilities pertaining to the TC flow, a cross-functional process map was constructed from the information gathered in interviews, see Figure 4.7. As can be seen in the figure, the order is received by production planners (MCLP), who schedule the production and shipments. This is followed by a series of questions that determine when, and by whom, the items will be picked.

Full pallets are managed by OLO if they are army-specific big pallets. Otherwise, they are managed by one of the line feeding teams (MCLLB) who simply lifts the pallet of the 5th conveyor. The pallets that contain mixed items are managed differently if they are intended for LVL or the Arena. For both of them, items are picked by the day shift as well as the night shifts depending on what line they are intended for. However, as illustrated in Figure 4.7, the same line can be picked by either shift depending on whether the items are destined for LVL or the Arena. The day shift consists of three pickers from MCAEL and the night shift consists of five pickers (also) from MCAEL as well as five pickers from MCLFL.

Another important crossroad in Figure 4.7 is whether LVL produces a complete cab or only an IP. If only an IP is produced it is then transported to LC before being shipped to the customer, and if it is a complete cab, it is shipped straight from TC to the customer.

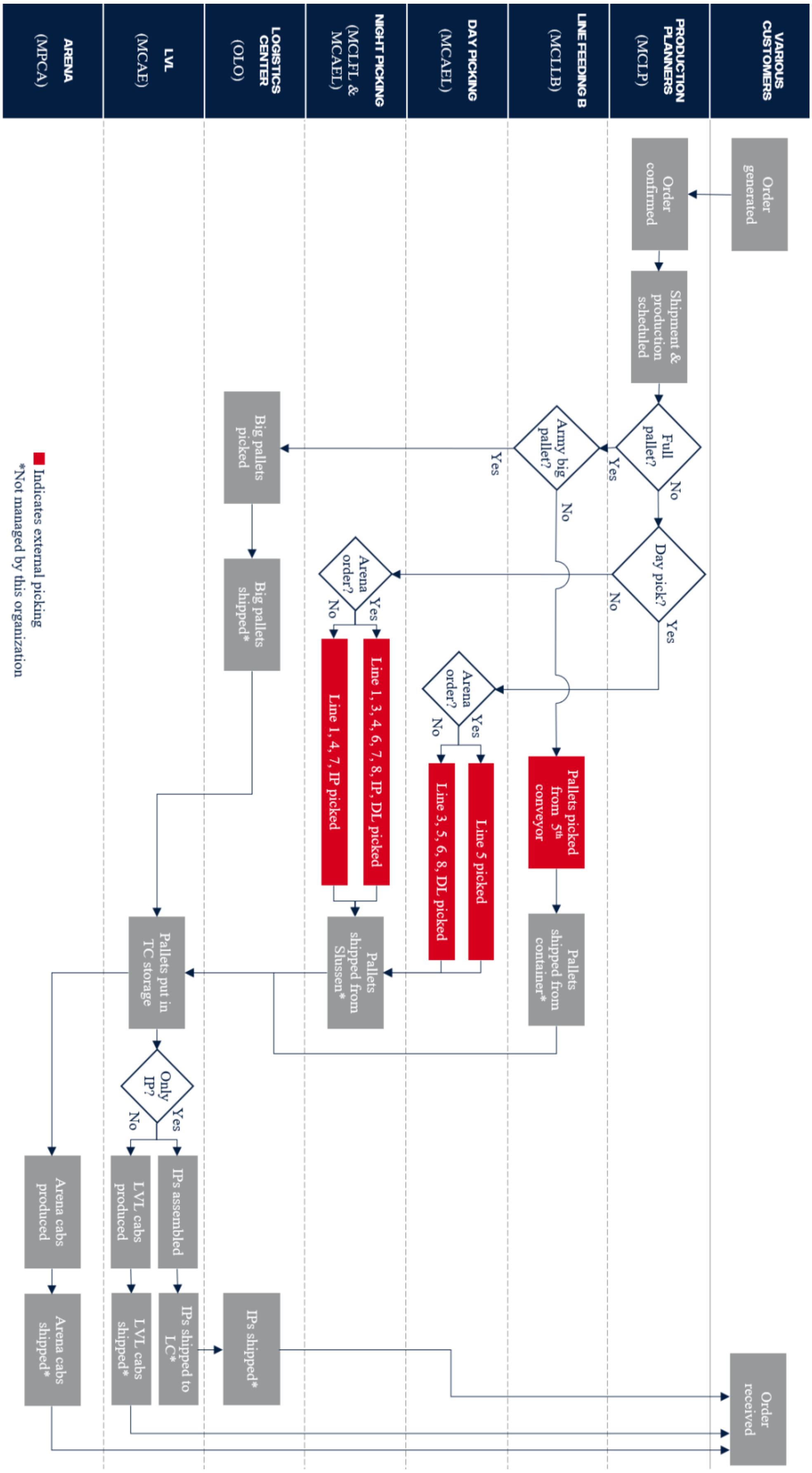


Figure 4.7: Cross-functional process map illustrating organizational responsibilities for the TC flow.

Picking process

As can be seen in Figure 4.7 above, the external picking process is highlighted in red. To get a comprehensive understanding of the process, interviews and observations have been conducted. The mixed pallet flow between MC and TC utilizes customized pallets, see Figure 4.8. These pallets are used in a circular flow. This means that when the trailer is emptied at TC during the day, it is loaded with previously emptied pallets before it returns to MC. Therefore, one of the initial steps for the night shift is to take off the empty pallets. These are then used by the night shift (and the following day shift) to pack picked items. The external picking process is illustrated in the flowcharts in Figures 4.9a and 4.9b. As explained pertaining to the cross-functional process map, the picking is conducted during both day and night, which is why the flowchart is segmented accordingly.

Figure 4.8: Pallets used between MC and TC.

The way the picking process for TC essentially works is that one picklist includes items to be picked and placed into one single pallet, and all materials are from one line or the corresponding platform. Sometimes a pallet can contain items intended for several cabs (meaning they are co-packed), or they simply contain items for a single cab. Noteworthy is that the picking process is conducted by using pen and paper, and if three cabs are co-packed, the picker manages three different picklists simultaneously. The day and night shifts are responsible for picking different lines/platforms for the two different recipients (LVL or the Arena). Information regarding which shift picks items for what lines, and which lines are co-packed, is summarized in Table 4.1. In contrast to LVL, the Arena does not have dedicated storage where they stock commonly used items. Therefore, pallets bound for the Arena contain more items per cab and consequently only one cab fits per pallet. Another reason that surfaced during the interviews is that due to frequent sequence changes in their production schedule, co-packing simply would not work.

Table 4.1: Summary of picking procedures per production line.

LINE	RESPONSIBLE SHIFT	CABS PER PALLET
LVL line 1	Night	4
LVL line 3 (Tilt line)	Day	2 or 3
LVL line 4	Night	2
LVL line 5	Day	All cabs for that shift (5-7)
LVL line 6	Day	All cabs for that shift (5-7)
LVL line 7	Night	1
LVL line 8	Day	2
LVL IP	Night	1
LVL Door line	Day	2
Arena line 5	Day	1
Arena (all lines except 5)	Night	1

The picking process is not identical for the day and night shifts, and some tasks are unique to the night shift. One such task is e.g. if TC has received a surplus of items and returned them to MC. Then the responsibility to either return the items to the platform/line or scrap them falls upon the pickers from the night shift. Moreover, a task unique to the night shift is a task called "buy-off". This means that if there is available manpower, one employee is responsible for choosing one finalized pallet at a time and ensuring that all picked items are correct. This employee repeats this task throughout the whole shift.

There are also differences in how the picking is conducted by the two shifts. Firstly, the pickers from the night shift drive around with their own forklifts and bring their pallet around with them. However, that is not possible for the day shift pickers due to production being up and running during their work hours and therefore it would lead to too much congestion. Instead, they have dedicated spots where they place their pallets depending on which line/platform they are picking from. To transport items from the platforms to the pallets they use trollies. Secondly, there is also a difference between the shifts regarding whether the items are picked from the production line or the corresponding platform. The night pickers have to pick some items originating from the box storage at the production lines since they are only stored there and not at the platforms. On the contrary, items that are stored in sequence at the production lines have to be picked at the platform. For the remaining items that are neither of these two categories, the night pickers can individually choose where to pick from. This is quite different from how the day pickers do it, who only pick at the platforms except for line 5, which they pick at the actual line. The reason that almost all picking during the day shift is conducted at the platforms is due to congestion at the actual lines when the production is running. However, there might also be congestion at the platforms when the tugger trains are there to be loaded. When that happens the day pickers have to wait for their turn since the main production lines have priority.

The performance of the pickers is mainly measured in terms of accuracy (picking errors). One interviewee explained that the number of errors occurring each month is continuously tracked and that the performance of the day and night pickers is measured separately. It was also explained that each of the picking teams has separate targets for errors per month. Indirectly, the picking performance is also measured in terms of stop minutes at LVL. The production line can come to a halt for several reasons, including a shortage of material stemming from picking errors. Regarding this KPI, the day and night pickers have a common target: no stop minutes at the production lines due to shortages caused by picking errors.

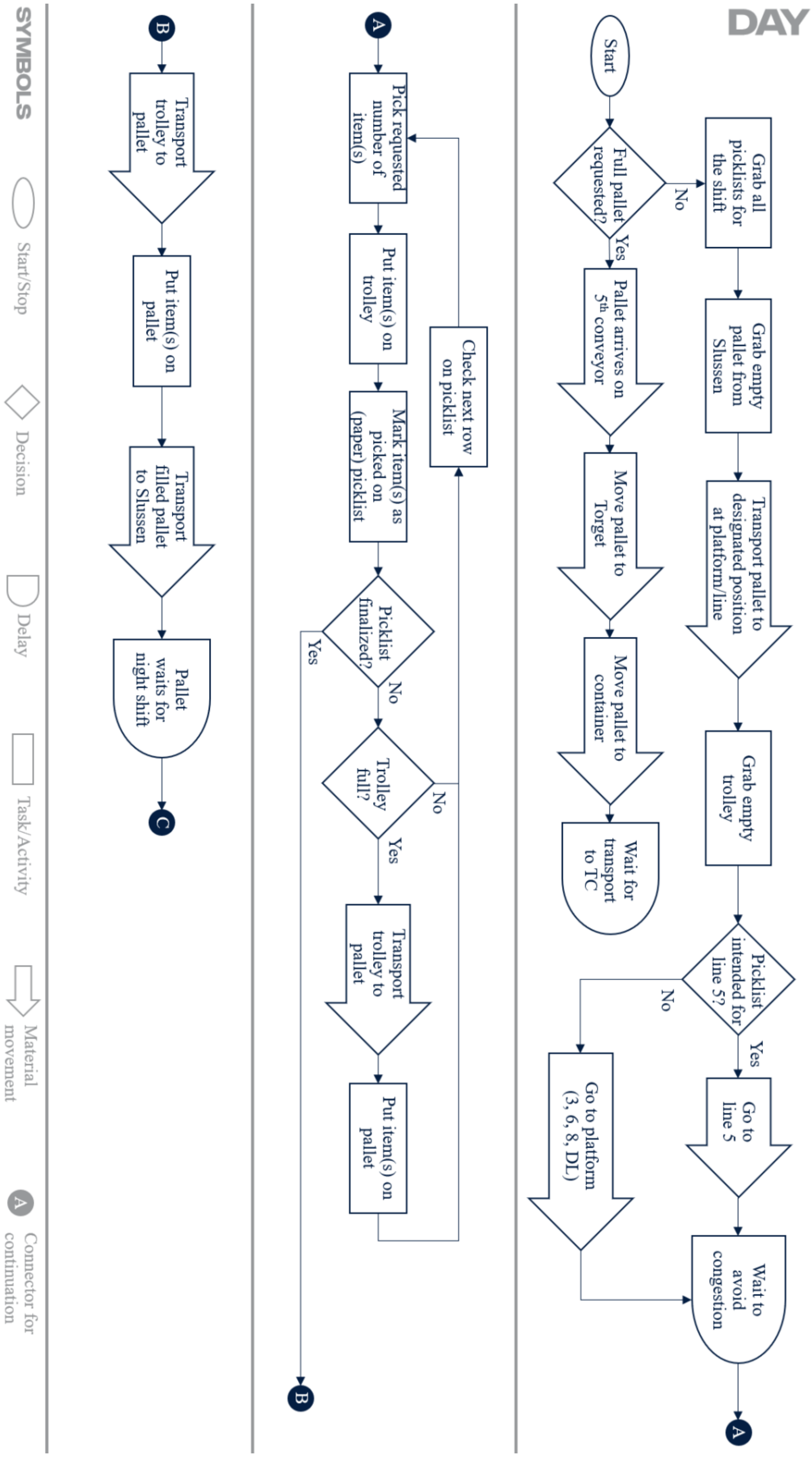


Figure 4.9a: Flowchart illustrating the external picking process during daytime for TC.

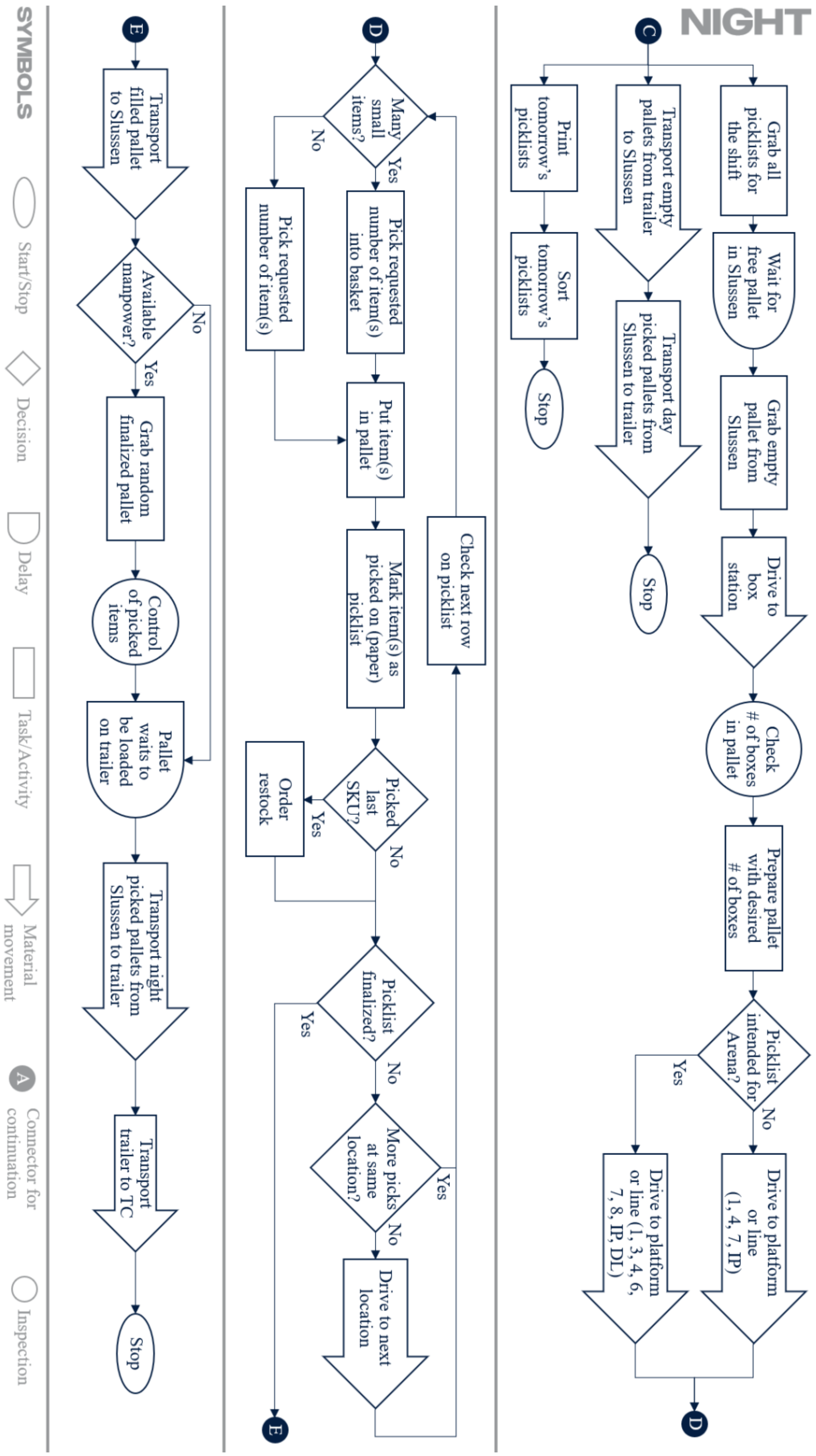


Figure 4.9b: Flowchart illustrating the external picking process during nighttime for TC.

Challenges

Throughout the interviews, challenges and improvement ideas were frequently discussed. Here we will compile the thoughts and opinions expressed by the interviewees. A recurring theme was the lack of digital solutions. The Scania employees that work with picking to the main production lines have assistive technologies such as pick-by-voice and pick-to-light, but no such technology is available for the staff picking material intended for the LVL or the Arena. Interviewees express that it would be desirable for pickers involved in the external picking process to use these existing technologies.

Another issue raised by both the day and night shift picking teams was the sheer quantity of papers required for the picklists. A rough estimate brought up was that two full boxes of A4 paper are consumed per week. All picklists are printed at the beginning of the night shift. The items are then picked during the following day and night shifts, see Figure 4.10. The process of printing and sorting the picklists takes about one hour for the employee responsible for that task. It was explained that one of the reasons for it being so time-consuming is that all picklists are printed in order by what cab they are intended for, while the picking is conducted by one picker per production line/corresponding platform. Therefore, the employee has to sort all picklists from "per cab" to "per line/platform". Moreover, this outdated paper and pen solution make it inflexible when changes are done to the production schedule. For these reasons, the interviewees explained that a developed digital solution would be desirable.

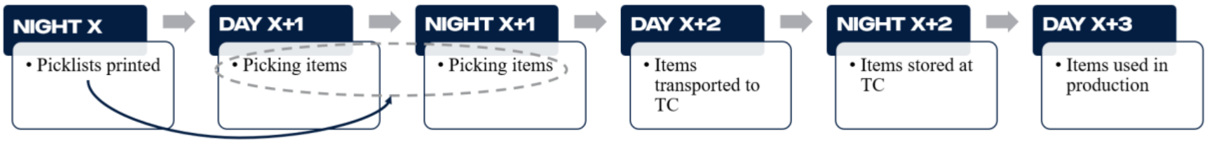


Figure 4.10: Time chart of material flow to TC.

A challenge that also was brought up by more than one interviewee was picking errors. If an item is mispicked or completely missing, it can possibly halt the entire production at TC. Therefore, if that occurs, a car is sent by "Bristakuten" which drives to MC to collect the correct or missing item in order to get it to the LVL as quickly as possible. It is explained that this is a more cumbersome process compared to when items are missing at the main production lines since it is located in the same building as the main storage area. Moreover, it is believed that the items most commonly mispicked or missing are the ones intended for the IP line and that this is due to large quantities of small similarly-looking items. Another interviewee explained that the large quantities and similar characteristics of the IP SKUs make the picking of that line the most time-consuming and described it as the primary bottleneck for the picking process. Furthermore, it is believed that the night shift commits the most picking errors and that a reason for this is stress – they work about 6,5 to 7 hours per shift whilst the day shift work 8 hours.

One difficulty that came up with regards to the night picking was the difficulty to standardize the picking process. It was explained that all pickers decide themselves whether to first pick at the production line or the corresponding platform. However, during the day shift, pickers either only pick at the line or the platform, depending on which production line their picklist concerns. Moreover, there are requests from the personnel at TC that items should be placed in specific, pre-determined locations in the pallet (the one illustrated in Figure 4.8). The team from the day shift explained that they have pictures of where to place the items in the pallet and that the placement is conducted accordingly. Regarding the night shift, it was explained that the items are placed more on a random basis and that it is up to the picker to determine where in the pallet he/she places the items. Related to where to place items in the pallet, the day shift team explained that they avoid placing items on the lowest shelf in the pallet due to complaints from the LVL personnel regarding ergonomics. In addition, the day shift team explained that it makes the ergonomics better for them too. However, the night pickers are not as concerned with placing items on said shelf. The reason for this is that, as opposed to the day shift and the personnel at LVL, the pallet is lifted by a forklift when they handle the material. Consequently, ergonomics is not an issue when considering only their tasks.

Another challenge with regards to the TC flow is the limited floor space in the direct proximity to the LVL and the Arena. The interviewees have thus explained that it is of importance for them to utilize the floor space as efficiently as possible. Moreover, the floor space needs to be used in a flexible manner due to product proliferation. During one of the interviews, it was expressed that a potential improvement with regard to space utilization is to apply kitting to a greater extent. Kitting, a procedure for bunching SKUs, is appropriate when there is an affinity among items, i.e. when items are frequently ordered/used together. This is regularly applied in relation to the main production lines but is used to a limited extent for the TC customers. However, it is mentioned that the entire pallet of picked items could be considered a large kit.

The return flow from TC to MC is brought up by the night shift picking team as a problematic process. They explain that the time it takes to bring an item back to its location at the correct spot is far more time-consuming than it is to originally pick. Moreover, it can be difficult since some of the already stored SKUs are in sequential order. Furthermore, the items might have gotten scratched, or damaged in some other way, during the transport to or from TC. Therefore, items are in some cases scrapped because it is either cheaper than to bring them back into storage or the item is unusable due to damage.

The last challenge brought up was that it can be difficult for the group manager of the night shift to attend the meetings where the group manager of the day shift and production planners meet due to their different work hours. It was explained that in order to establish better communication, it would be desirable to find a suitable time that allows for all individuals to be able to attend.

4.2.2 Laxå Special Vehicles

Laxå Special Vehicles (LSV) produces 1,500 trucks per year. Consequently, great volumes of material are shipped to LSV and trucks depart daily from Scania Oskarshamn. Moreover, as mentioned in subsection *4.2.1 Technical Center*, LSV also receives IPs assembled at the LVL. Since that material flow is already covered, this subsection only goes into depth about the remaining parts of the material flow to LSV. However, the IP flows are included in this subsection’s maps to avoid confusion.

Material flow

Material destined for LSV originates from either MC or the logistics center (LC), see Figure 4.11. All SKUs from MC are brought to the repackaging area where it is put on pallets. The material is picked from the box storage, highbay storage, production lines/corresponding platforms, or the water cutter. The pallets from the highbay storage arrive on the 5th conveyor. If a full pallet is requested by LSV, it is immediately transported to Torget. If only a few items from a pallet are requested, the pallet continues to the repack conveyor. From there, the requested item(s) are put in a new pallet, and the original pallet is returned to the highbay storage. When a pallet is filled with requested items, it is placed at Torget. From there it is moved to the moving floor and then shipped to LC. However, if the pallet contains items classified as "dangerous goods" (e.g. airbags or fire extinguishers), the pallet is transported to LC via the container area instead of the moving floor. The reason is that different organizations, with different certifications, are responsible for the transport from these two locations. If LSV requests a full big pallet, it is picked from the storage area at LC.

LSV also has a return flow back to Scania in Oskarshamn. This is for redundant material that they have realized that they do not need. This material arrives at LC before it is forwarded to MC. Upon arrival to MC, the pallets are brought to the repackaging team which sends the pallets back into the highbay storage by placing them on the inbound conveyor. This solution is feasible since LSV is not allowed to return a pallet containing a mix of items.

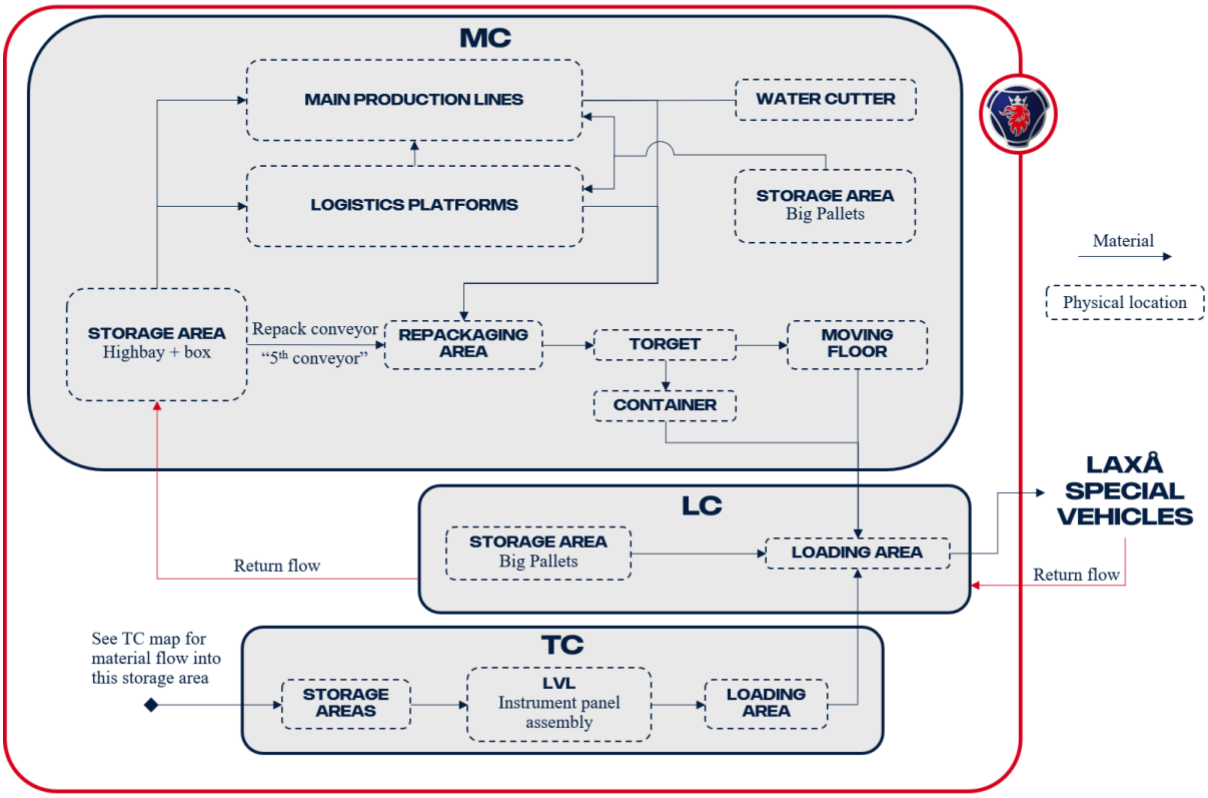


Figure 4.11: Relationship map illustrating the material flow to Laxå Special Vehicles.

Organizational responsibilities

A cross-functional process map has been constructed for the material flow to LSV to understand the organizational responsibilities, see Figure 4.12. Similar to the TC flow, it starts with the customer, for this flow it is LSV, placing an order. The material planners (MCLM) check whether the material is available and if it is, the order is passed on to the production planners (MCLP). They confirm the order as well as schedule the assembly of the IP and shipment of the order. For this material flow, it is only one question determining who picks what SKUs – if it is a full big pallet or not. Consequently, the responsibility is divided between the MCLFV pickers and the personnel at LC. As can be seen in Figure 4.12, the responsibility for the IPs falls on MCAE, but that is covered in subsection *4.2.1 Technical Center*.

Picking process

As LC is not included in the scope of this thesis, only the process at MC, conducted by the two pickers from MCLFV, is mapped in a flowchart. The understanding needed to construct a map of the flow was attained by conducting several interviews and observations.

If a full pallet is not requested, but the material is stored on a pallet in the highbay storage, the pallet arrives on the 5th conveyor. Instead of being taken off the conveyor, it loops around to the repack conveyor. From there, the pickers take the requested item(s) and put them in a new pallet. If they pick a box from a pallet, they need to replace it with an empty box for the automated storage solution to work. No such extra task is required if it is an ordinary pallet with collars. If the item requested is not in the highbay storage, it is stored either in the box storage or at the production lines/platforms. In those cases, the pickers go to that location and bring it back to the repackaging area to put it in a pallet. When a pallet is finalized, it is placed at Torget. Once two pallets are waiting at Torget, the pickers call for a forklift to transport the pallets to the moving floor. However, if items are classified as dangerous goods, they are transported via the container area. A flowchart illustrating the picking process is provided in Figure 4.13.

The use of KPIs is described as nearly non-existent with respect to the LSV flow. Picking errors are measured, but there is no apparent plan for how to utilize the data to improve the process. Concerns regarding the reliability of this data are expressed by some interviewees. Measures such as capability (in terms of cabs picked per unit of time) or picking time (to fulfill an order) are not tracked. Furthermore, no formal targets are in place for the picking process. One of the interviewees expressed the wish to develop and work with proper KPIs.

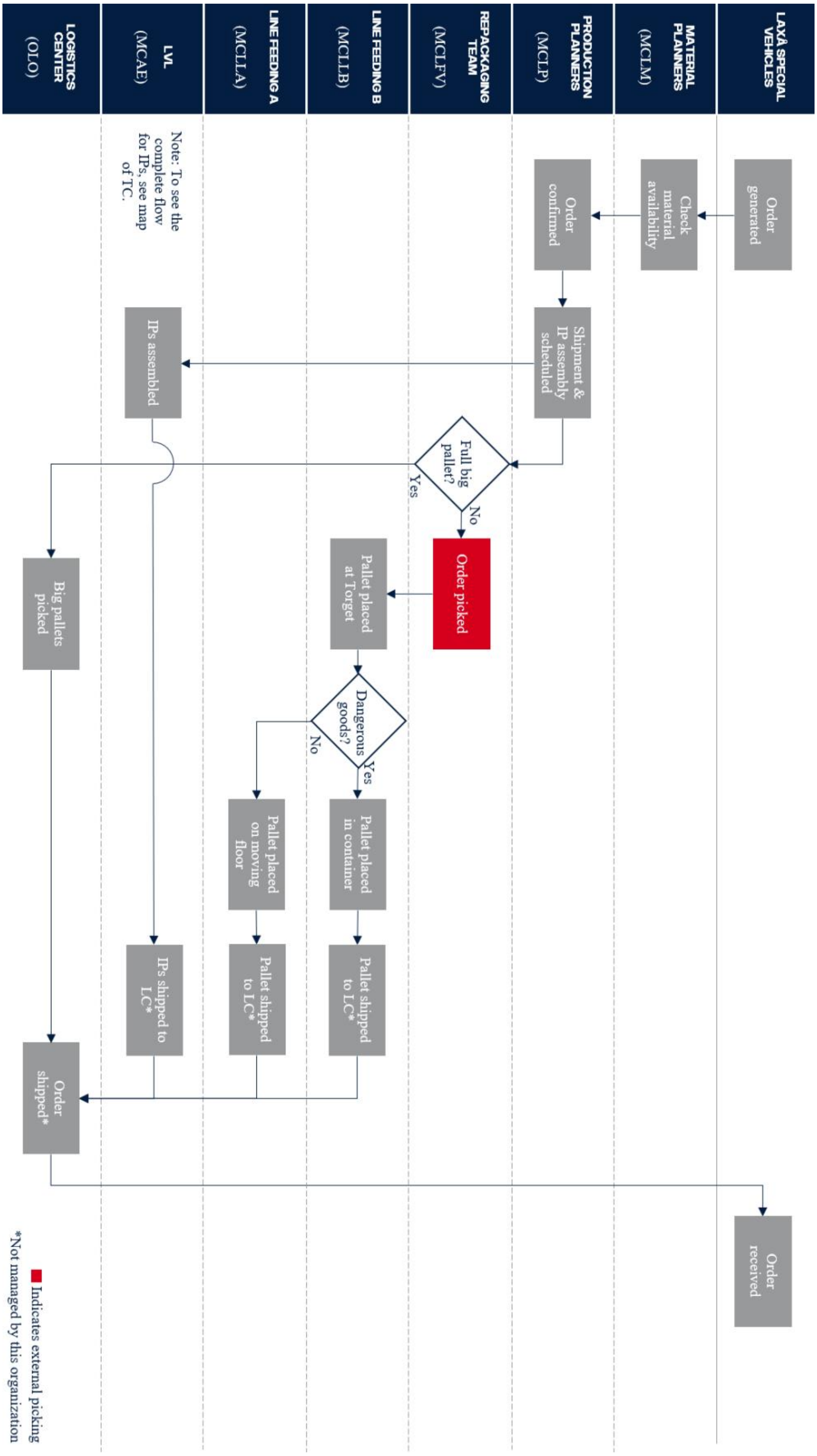


Figure 4.12: Cross-functional process map illustrating organizational responsibilities for the Laxå Special Vehicles flow.

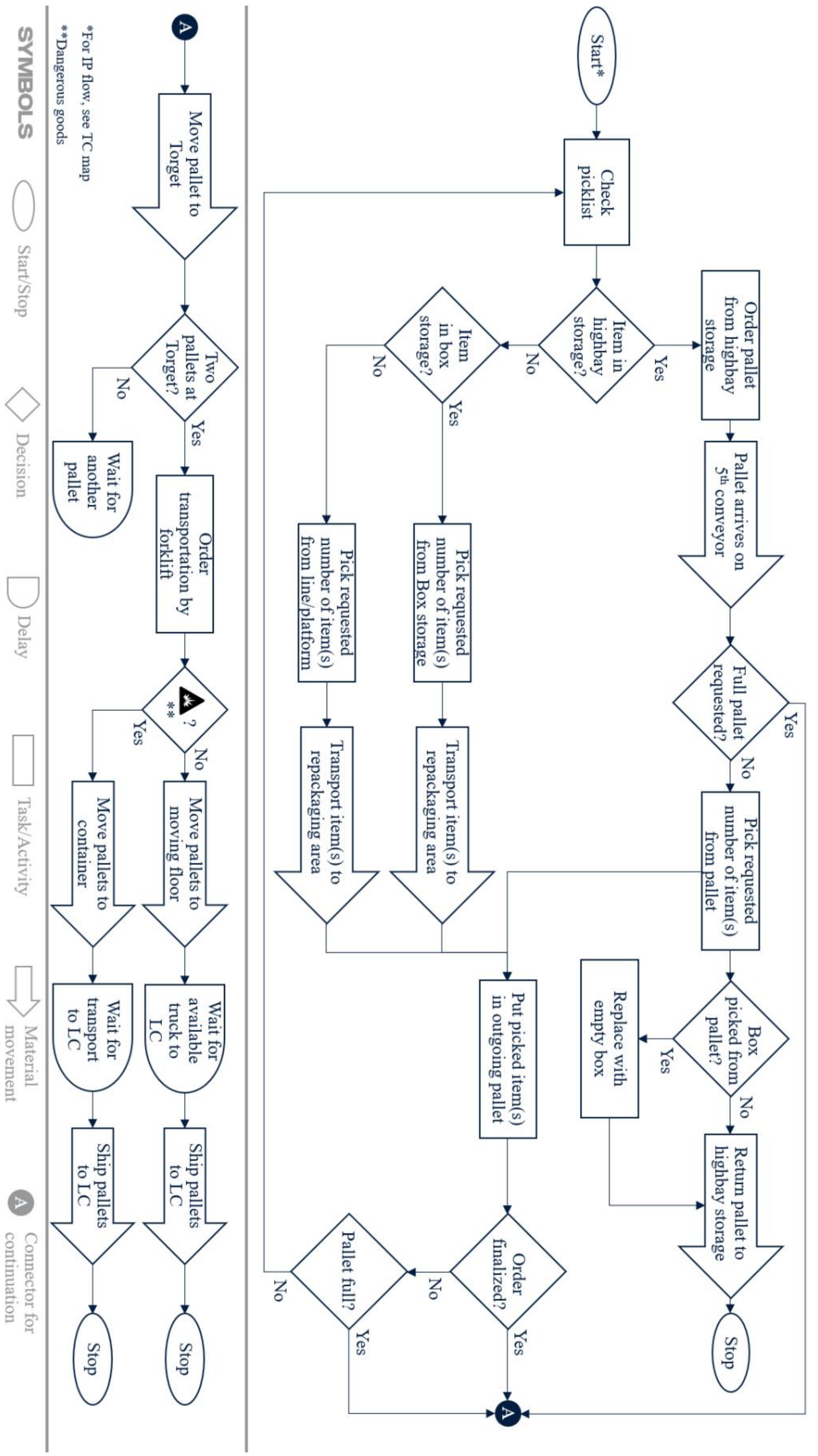


Figure 4.13: Flowchart illustrating the external picking process for Laxå Special Vehicles.

Challenges

Throughout the interviews, several employees expressed concern and frustration about the frequent “emergency orders” originating from LSV. The emergency orders are placed when LSV realizes that they are missing a critical item that would severely affect their production schedule. There is a general belief that it might be too easy for LSV to alter their orders and claim that they are in urgent need of additional items. The lack of information sharing is thought to be a source of discontent. Employees feel frustrated when the workload spikes and they do not know whether it is because they have done something wrong or if the problem is on the customer’s end. Due to the current situation where items seem to disappear somewhere between MC and LSV, the pickers have started to take photos of the picked items to strengthen their claim that the items are in fact picked. Nevertheless, the two employees responsible for picking items to LSV occasionally devote the first two hours of their workday, i.e. 25% of the working hours, to picking emergency orders received the day before.

Questions are raised about whether a formal procedure for reporting errors, defects, etc. should be established (e.g. by using EQ, Scania’s system for quality deviations). It was discussed that by implementing a routine for how LSV should report deviations and place emergency orders, several benefits are thought to be achieved. First and foremost, the interviewees believe it would provide the pickers with valuable information regarding why sudden peaks in workload occur and allow them to take mitigating actions. For instance, if the material is damaged during transportation to LSV, they could pack it differently the next time. Secondly, an interviewee explained that it can clarify which organization should carry the costs induced by the emergency orders. As of today, MCLFV takes responsibility for the additional costs resulting from extra labor and transportation.

Another aspect considered inconvenient is the policy for how items from different purchase orders (POs) can, or rather cannot, be co-packed. An example from one of the interviewees relates to noise absorbents. When two noise absorbents are ordered on different POs, the pickers are not allowed to pack them together even though there is sufficient space in the pallet and both are to be shipped via the logistics center. This seems to stem from a lack of system support at the LC. In addition, LSV’s routines and material planning are questioned. It was explained that uncommon SKUs could be ordered two days in a row. The interviewees believe that it would be beneficial if LSV consolidated upcoming orders to minimize the picking time.

A recurring theme in the interviews was that of the return flow from LSV to MC. Similar to the material flow entailing the emergency orders, this flow puzzles the interviewees. Why this flow exists is ambiguous and different explanations have been provided. In one interview, it is described that LSV can return outdated articles. Another interviewee attributes this to the agreement between LSV’s and Scania’s material planners that full pallets should be ordered to the greatest extent possible. Consequently, the interviewee is under the perception that LSV orders full pallets even when they are aware that they will not consume all items. Regardless of the underlying reason why LSV returns items, employees are in unison that the procedures must be refined to avoid unnecessary labor.

During one interview, an issue surfaced that can be considered an indirect interference with the operations at the main production lines. If the repackaging team picks four items from a pallet that originally contains eight items, and returns it to the highbay storage, there are only four left in the pallet. Later, when this pallet is brought to the platform and eventually to the main production lines, this might be problematic because the tugger trains run with eight cab intervals, meaning it transports materials intended for eight cabs per run. Consequently, when the train delivers a pallet to the line, one of the pallets is only containing half of the expected material. Therefore, a shortage will occur before the next run of the train is conducted. However, an important factor to understand is that this is not an issue with pallets that contains high quantities, e.g. if a pallet contains 100 SKUs. The interviewee explains that the problem only occurs when there is a “low” multiple of eight in a pallet, such as eight or sixteen.

The same interviewee further explained that the indirect interference with the operations at the main production lines was more common in the past and that they have worked on ways to avoid it. One such example was to examine if the pallet could go straight to the production line after items are picked by the repackaging team. However, this was not implemented because it bypasses their first-in-first-out policy and because it can be difficult when items are batched with other items when stored at the production line. Therefore, it was difficult for them to set up a standard due to different product characteristics, e.g. whether they are transported to the line in pallets or batched at the platform before the transportation to the line. The interviewee explained that the probable reason for the previous improvement was thorough scrutiny of the orders from LSV, where Scania tried to send more full pallets if possible. However, this problem has in later days become more common again. It is believed by the interviewee, that this is a consequence of perhaps less strict scrutiny of the orders received, but also that LSV’s systems are not synchronized with Scania’s systems. This means that if the quantity stored on a pallet is changed, and updated in Scania Oskarshamn’s systems, it is not automatically updated in LSV’s system. Consequently, even if LSV believes that they have ordered a full pallet, it might only be e.g. half a pallet with the new standard quantities.

4.2.3 Spare parts

Due to similarities in material flow and picking processes, four different recipients have been grouped and are in this thesis collectively referred to as the Spare parts flow. The customers are the three chassis factories in Södertälje, Angers, and Zwolle, and the spare parts center (Scania Parts Logistics) in Oudsbergen. While the recipients are geographically dispersed, the subsequent actions needed at Scania Oskarshamn to meet customer demands are largely the same. It should also be noted that the similarities between the Spare parts flow and the Laxå Special Vehicles (LSV) flows are many. Yet, some differences are too fundamental to neglect, why the flows have been mapped separately.

Material flow

The internal material movement pertinent to the Spare parts flow is resembling that of the LSV flow, with the key difference being that instrument panels are not a part of this flow. In addition, the order characteristics are dissimilar; while LSV frequently requests full pallets, the customers appurtenant to the Spare parts flow oftentimes order a single SKU. The reason why this order pattern emerges can be deduced from the name itself – when a truck is in need of a spare part, that specific demand must be met in terms of article and quantity. Considering that virtually anything can be damaged or have intrinsic defects, a huge variety of SKUs are requested by these customers. This implies that items can be picked from all locations where inventory is kept. The Spare parts material flow is depicted in Figure 4.14.

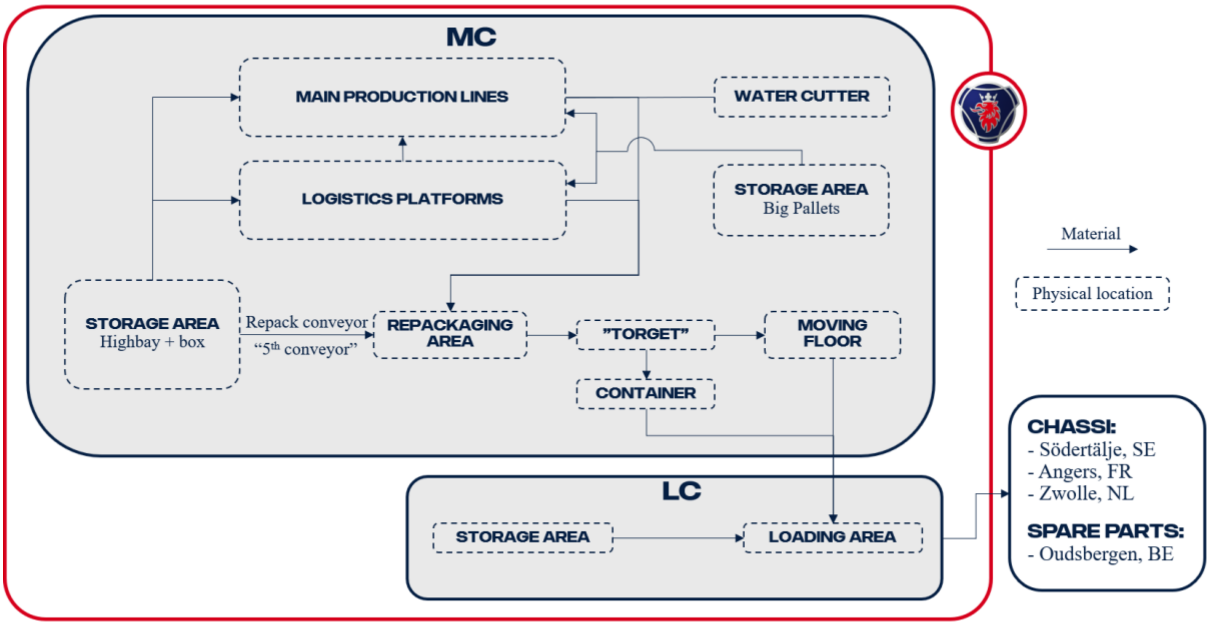


Figure 4.14: Relationship map illustrating the material flow to the chassis factories and the spare part center.

Organizational responsibilities

Since no production is taking place within the Spare parts flow, the production planners are not involved in the process. Instead, the order is sent immediately to "Bristakuten", a sub-group of employees belonging to MCLFV. They forward the order to another part of MCLFV which then picks and packs the requested parts. Similar to how the pallets bound for Laxå are handled, the pallets are placed by MCLLB/A in the container or on the moving floor, from where it is shipped via LC to the customer. A cross-functional process map illustrating the organizational responsibilities related to the Spare parts flow is provided in Figure 4.15.

Picking process

While it is true that the types and volumes of items requested by customers in the Spare parts flow differ from those of LSV, the picking process itself is identical. Hence, the corresponding flowchart is identical. Nevertheless, the map is provided once again in Figure 4.16 to avoid confusion and attain consistency in the chapter.

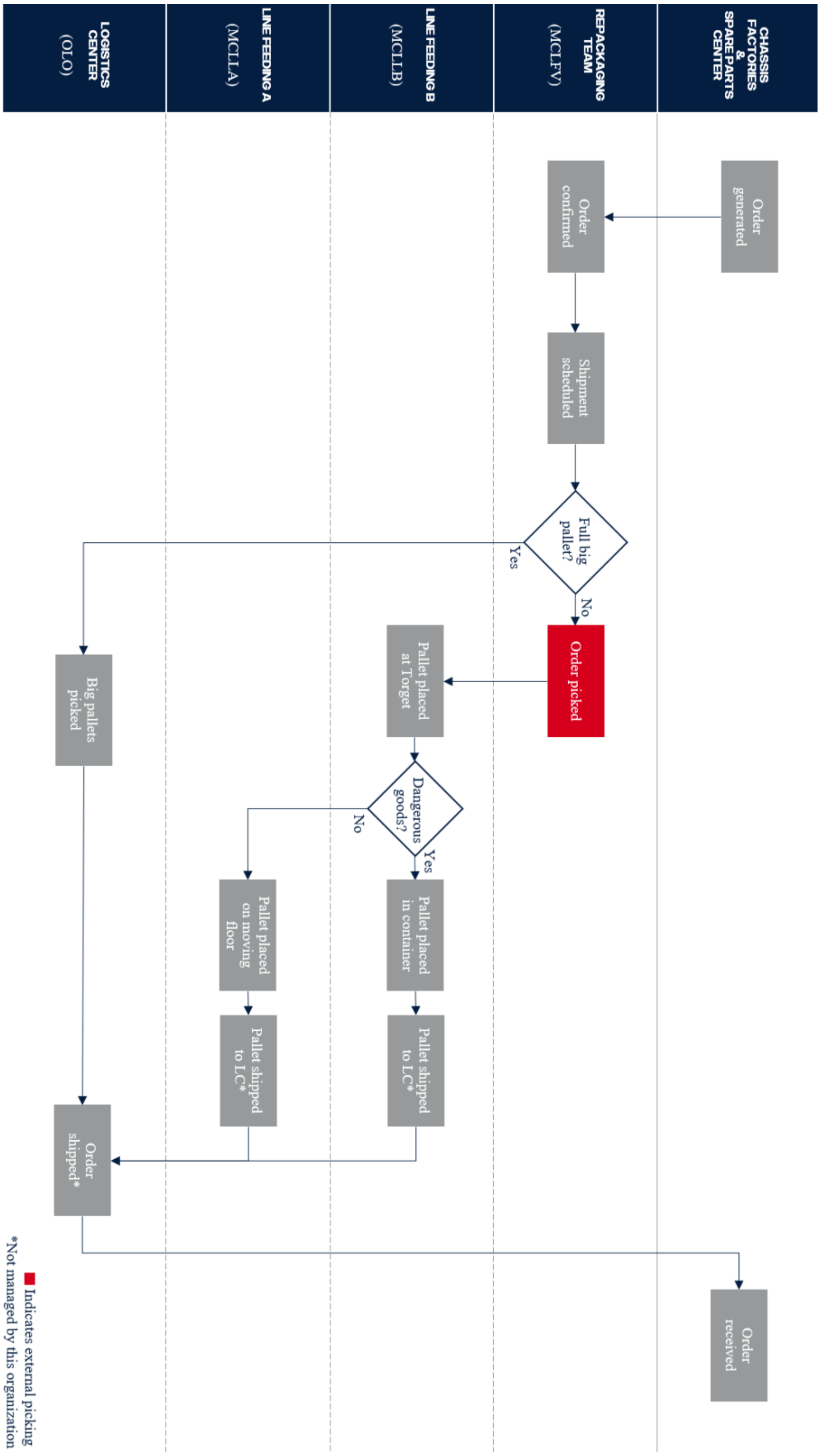


Figure 4.15: Cross-functional process map illustrating organizational responsibilities for the Spare parts flow.

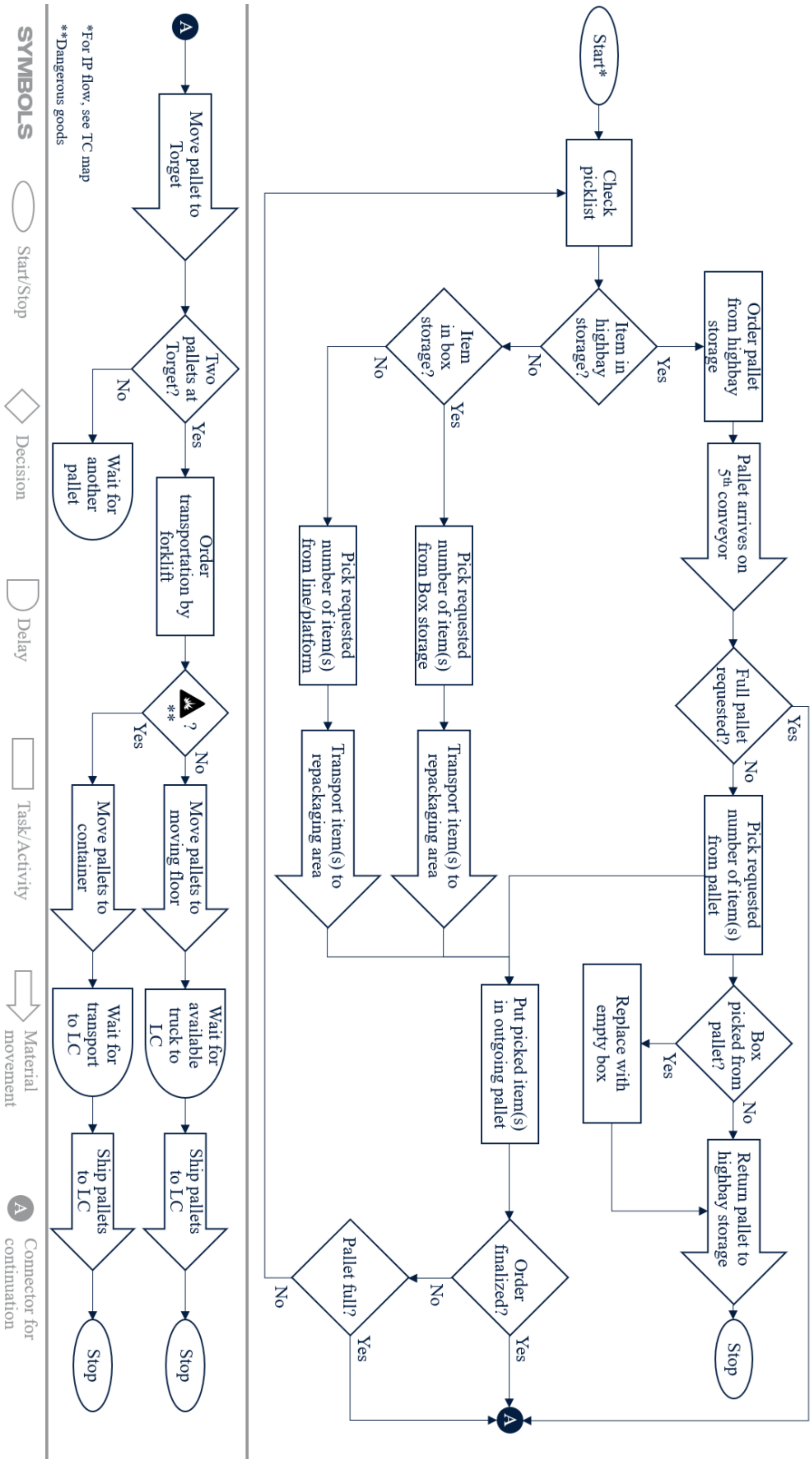


Figure 4.16: Flowchart illustrating the external picking process for chassis factories and the spare part center.

Challenges

During the interviews, it was emphasized that delivery speed is of the essence when a spare part is requested. Thus, Scania has established routines for attaining high customer service towards the chassis factories and the spare part center. The benefits of being able to quickly respond to the demand for spare parts are described as twofold; it minimizes delays in the chassis factories and ensures that the spare part center can deliver upon its promise to provide customers with spare parts within 24 hours. Scania's pursuit of high customer service consequently results in additional requirements for the pickers. For example, SKUs requested within the Spare part flow must be shipped from MC no later than 11 AM the day after they are ordered. While the interviewees generally described this as a well-functioning process, some thoughts are disclosed that indicate that the urgency can be burdensome. On special occasions, the conveyors from the highbay storage can get congested, leading to subsequent delays of pallets bound for the repackaging area. If the delays are substantial, jeopardizing the promise of shipment before 11 AM, the SKUs can be picked directly from the production lines. However, the occurrence of this is emphasized as very uncommon.

The variety of SKUs involved in the Spare parts flow is described as a challenge, mainly due to the inconvenient nature of some items. An example that resurfaced during multiple interviews is when one of the chassis factories places an order for a new door. When a door is to be picked, 4 employees must cooperate to manually carry the door and pack it in a big pallet. This is cumbersome and time-consuming, not to mention ergonomically unsound.

4.2.4 "Partner X"

"Partner X" is a relatively new customer, and the procedures are not as established as for the other flows. An example of a primitive solution with respect to this picking process is that the picklists are not yet available in the regular systems – they have to be constructed manually in Microsoft Excel. The volumes shipped to this external partner are rather small (roughly estimated, the volume corresponds to less than 0.1% of the material to the main production) and once the relationship is fully up and running, an order will be placed every other week. Considering that "Partner X" specializes in security and defense vehicles, the SKUs requested range from standard components used in Scania's main production, to army-specific items stored in connection to the LVL. Furthermore, "Partner X" is one of the recipients of instrument panels assembled at the LVL.

Material flow

The SKUs needed to fulfill an order by "Partner X" can be grouped into three categories: (1) standard items, (2) army items, and (3) IP items. Standard items are picked from platforms and lines at MC, and later on, placed on the moving floor. The army items are picked from storage areas and production lines at TC. Material required to produce an instrument panel is shipped to the TC storage area in accordance with the TC relationship map (Figure 4.6), whereafter the IPs are assembled. Regardless of the origin, all pallets bound for "Partner X" are transported via LC before reaching their final destination in France. According to one of the interviewees, the total volume shipped per order amounts to about 26 pallets. The different paths the material can take before ending up at “Partner X” are illustrated in the relationship map provided in Figure 4.17.

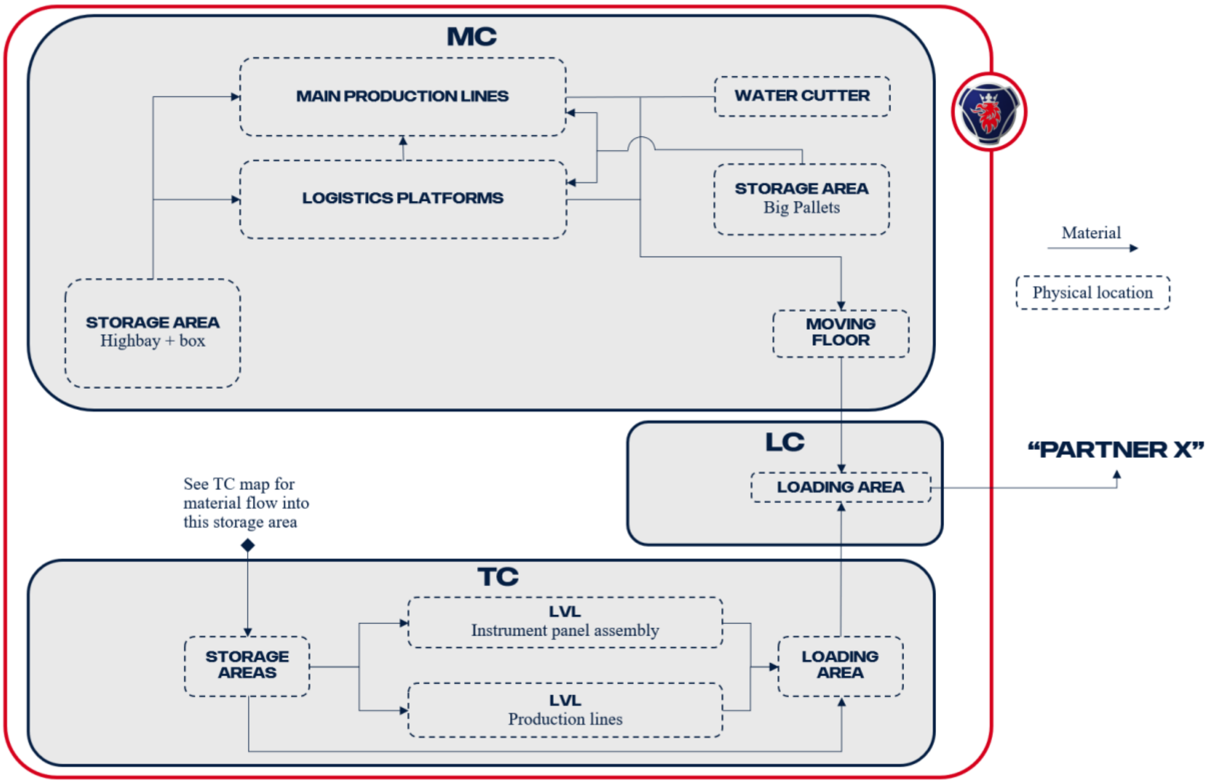


Figure 4.17: Relationship map illustrating the material flow to “Partner X”.

Organizational responsibilities

When “Partner X” places an order, the customer responsible production planner receives it and responds with a confirmation. After scheduling the shipment of the order and the production of the IPs, an article list is created. The article list is sent to one of the more experienced employees from MCAEL who transform it (by using Microsoft Excel) into a picklist similar to the ones used for miscellaneous other picks. This list is divided into military SKUs (to be picked at LVL) and ordinary SKUs (to be picked at MC), whereafter the latter is sent to the night pickers working at MC (MCLFL and MCAEL). This has to be done as the system infrastructure currently lacks the ability to create picklists for “Partner X”-orders. All pallets not containing IP parts are shipped to LC. After the IPs have been assembled, they are also shipped to LC. Employees working at LC register the pallets before finally sending them to “Partner X”. The workflow across the organization is illustrated in the cross-functional process map in Figure 4.18.

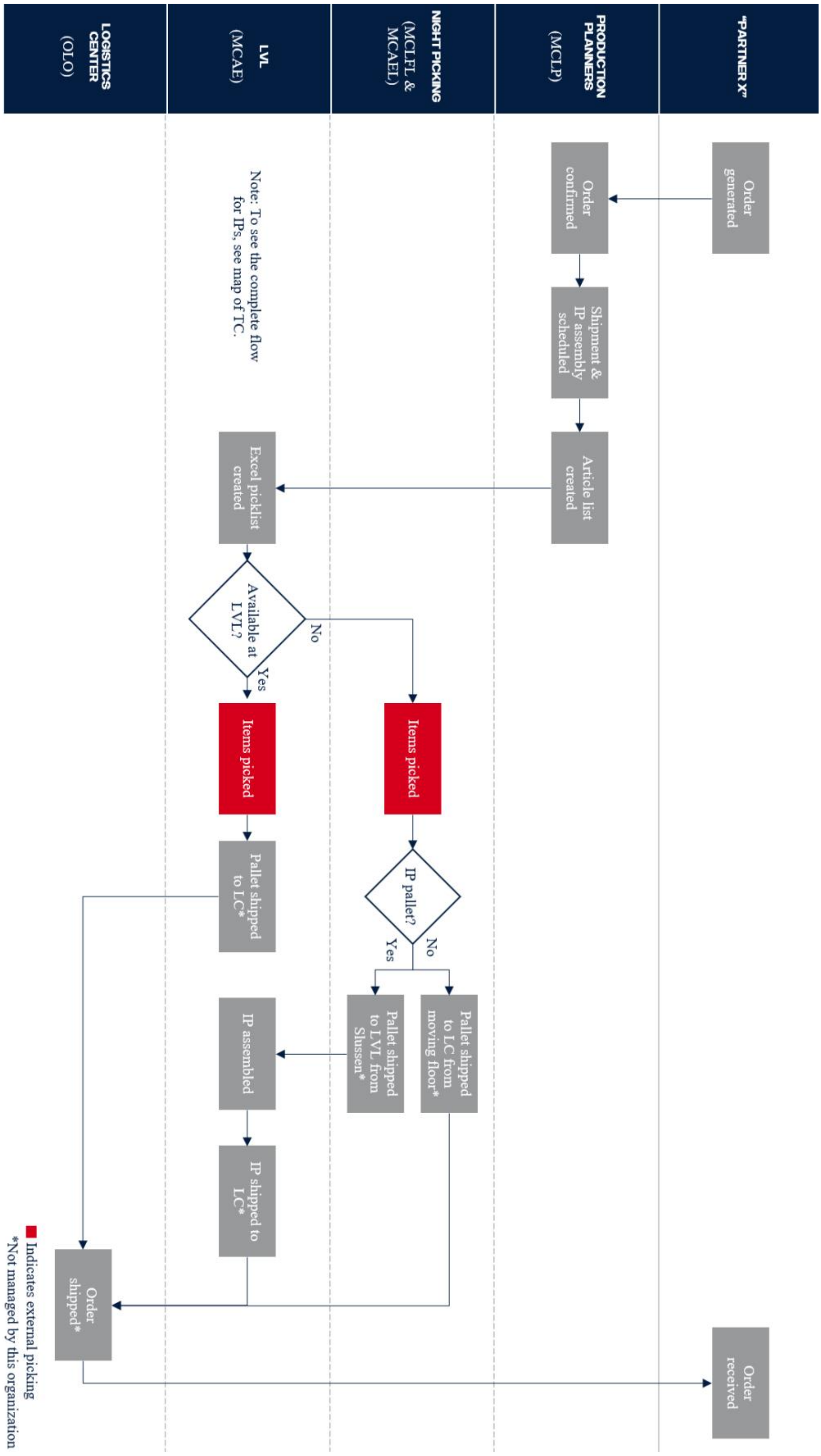


Figure 4.18: Cross-functional process map illustrating organizational responsibilities for the "Partner X" flow.

Picking process

After conducting interviews with relevant employees and observing the "Partner X"-pickers in action, a flowchart for the picking process has been constructed, see Figure 4.19. Since the picking occurs at two different locations, the flowchart is divided accordingly. Items for "Partner X" are picked from all lines at MC by the night shift. It was explained that all pallets are not necessarily picked during the same night – the work can be spread out over an entire week. The picking at LVL is conducted during the daytime. The procedures are similar, but differences do exist. For example, the activity of locating a suitable pallet was especially emphasized during the interview with the picker working at the LVL, who described this as a somewhat time-consuming and cumbersome process. Moreover, the use of a basket to swiftly collect smaller items is protocol among the night pickers at MC. Meanwhile, this practice has not been adopted by their LVL counterparts. Considering that no scanners are used, and no digital log of the picked items exists, the interviewed "Partner X"-picker at the LVL explained that finished pallets are photographed as a precautionary measure to have proof that they are in fact picked. No comparable method is in place for the pallets picked at MC.

Challenges

With regard to the "Partner X" flow, the lack of system support was highlighted as a major inconvenience. The current setup with a particular employee creating the picklists is described as vulnerable. Having a process heavily dependent on the expertise of one single person is an obvious peril. If that employee gets sick, operations might come to a halt. The human factor is also thought to be a risk factor in terms of accuracy. When manually constructing the picklist in Microsoft Excel, it is easy to type in a number wrong. One of the interviewees explained that this is especially true when new articles are introduced.

The human vs technology aspect recurs in other parts of the interviews; several interviewees touch upon the subject of assistive devices pertaining to the picking process. The opinions on whether such devices would be beneficial diverge – some interviewees are positive due to expected effects such as improved accuracy and traceability, while others view it as an unnecessary inconvenience. Among the skeptics, the importance of having both hands free is emphasized.

Another recurring subject is how the items are packed. It is described that the volume is not optimized and that there might be unrealized improvement opportunities concerning the number of pallets shipped. Currently, each picklist corresponds to one pallet. Before beginning the actual picking, the picker must quickly look through the picklist, assess the pallet size needed, and locate an appropriate pallet. Once a particular pallet has been chosen and packed with items, it is not replaced if the picker should realize that a smaller pallet would be feasible.

Some interviewees raise the question of whether the relationship between Scania and "Partner X" makes sense for Scania's business. Thoughts are expressed that the Oskarshamn facilities are neither equipped nor prepared to pick and ship low quantities of individual SKUs to another non-Scania company in this manner. This is explained as one of the underlying reasons why solutions are ad hoc and developed to fit into pre-existing routines.

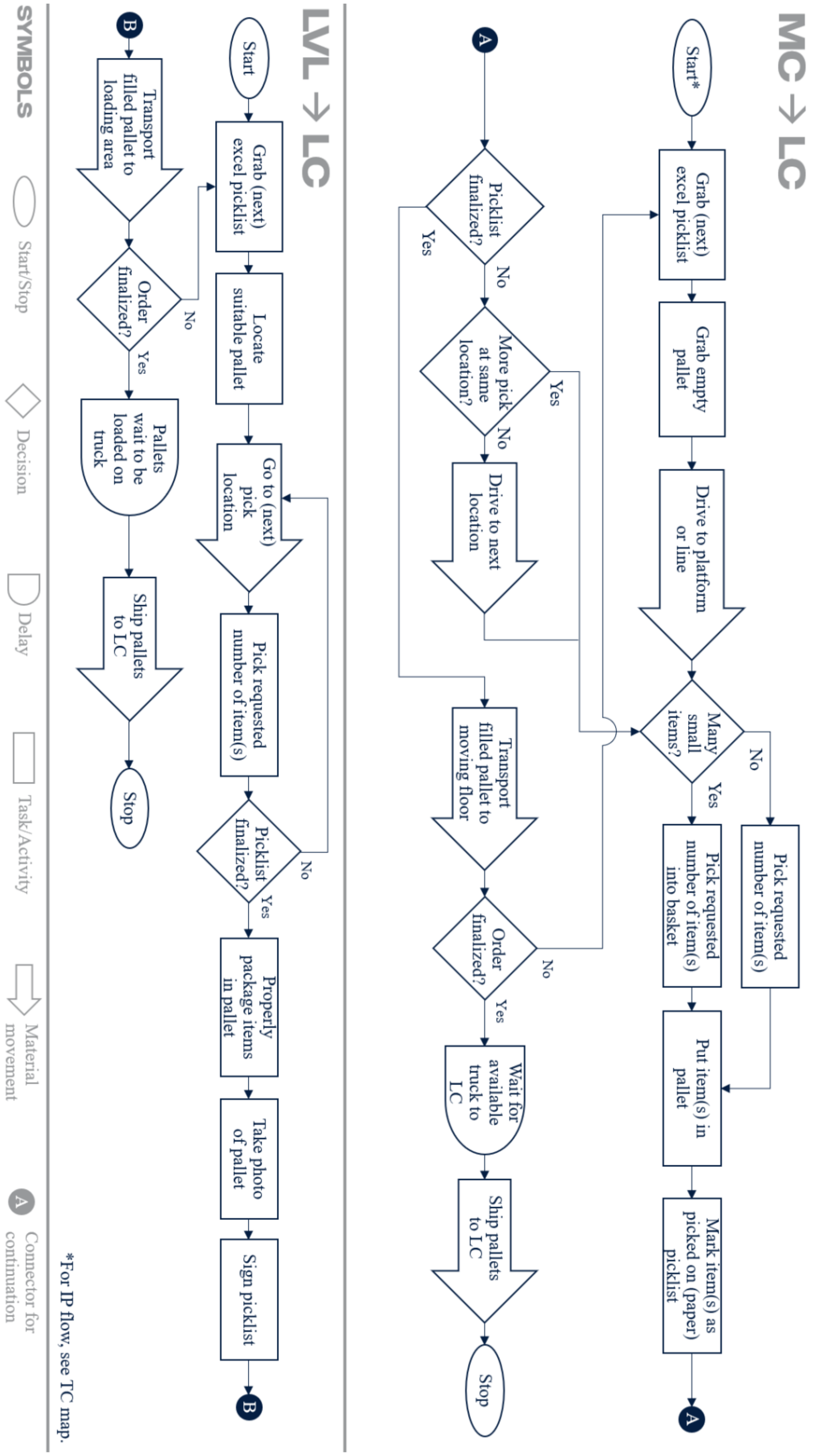


Figure 4.19: Flowchart illustrating the external picking process for "Partner X".

4.3 Conclusion of Empirical Study

Some themes and similarities between the different flows can be identified. First of all, the absence of assistive devices is palpable within all external picking processes and the level of digitalization is low compared to processes connected to the main production. Papers are printed in abundance, primitive solutions such as photographing picked items have been implemented by the pickers themselves, and efficiency has been sacrificed to improve ergonomics. Moreover, the picking errors associated with external picking are a challenge and constitute the only KPI used in relation to external picking. The frequency of picking errors and the consequences they entail differ between the flows. What causes these differences has been speculated upon by interviewees and will be further investigated in-depth in chapter *5 Analysis*.

The vague organizational responsibilities, characteristic of all external orders, are yet another source of frustration. How the responsibilities for the flows are divided are summarized in Table 4.2. Numerous interviewees explain that they do not know why the external picking processes are structured or managed as they are and there is a general perception that the processes are not optimally designed. Interviewees involved in different flows describe that the design probably stems from changes in requirements and demands from customers. It is thought that when a new process has been implemented, the responsibility has been allocated to the organization that, at the time, seemed to have sufficient resources to perform the task. Consequently, a somewhat shared perspective amongst the interviewees is that the holistic view has been neglected.

Table 4.2: Picking responsibility depending on the customer.

CUSTOMER: / RESPONSIBLE:	TC	"Partner X"	LSV (Laxå)	Spare parts
Day picking (MCAEL)	x			
Night picking (MCAEL + MCLFL)	x	x		
LVL picking (MCAEL)		x		
Repack team (MCLFV)			x	x

To summarize, the problems and drawbacks identified within the four material flows can primarily be divided into two categories: the *order-picking process* and the *organizational structure*. However, some challenges are not shared between the flows. Thus, a third category, *flow specific,* is used. These three categories are the foundation for the structure of chapter *5 Analysis*.

5 ANALYSIS

This chapter delves into the challenges identified in the previous chapter by applying theory to evaluate the current process and setup, thus complementing the empirical study to answer RQb. Further, the analysis is a combination of qualitative and quantitative, ultimately aiming to unravel which changes can be done to improve the current logistical setup (RQc). The chapter commences broadly with a comprehensive analysis of the order-picking and the organizational structure. Lastly, the spotlight is redirected to each of the four flows to enable analyses of flow-specific challenges in a more isolated manner.

5.1 Analysis of the Order-Picking Processes

This section includes (1) a comparative analysis between the current external picking process at Scania and the theory gathered in the literature review, (2) a discussion pertaining to standardization of the external process, (3) an analysis of picking errors, (4) a discussion and analysis regarding digitalization, and (5) an analysis of the process maturity.

5.1.1 General comparison between literature review and empirical data

To complement chapter *4 Empirical Study*, this subsection presents a comparative analysis between the reviewed literature and the current situation at Scania. This comparison includes the topics of (1) Forward-reserve allocation, (2) Order-picking strategies, and (3) Routing policies. In the literature review, the topic of assistive devices is also included in section *3.3 Order-Picking*, however, in this chapter, it will instead be discussed in the separate subsection *5.1.4. Digitalization*.

Forward-reserve allocation

The way Scania utilizes platforms to quickly get material to the main production lines can be considered a forward area, which is resupplied by the bulk storage (e.g. highbay storage). This does not only allow for faster picking of material heading to the main production lines but also the material intended for Technical Center (TC) and “Partner X”. This can be compared to the remaining two material flows (Laxå Special Vehicles and Spare parts) which in contrast is primarily picked from the bulk storage (highbay storage). However, there are no forward areas explicitly intended for the external picking process in today’s setup.

Order-picking strategies

The order-picking strategy is interesting since it is not the same for all four material flows. When looking at the picking of items intended for TC, an order is picked in different parts of MC simultaneously (or at least within a 24-hour window depending on the line and customer) by different pickers who are assigned a specific line/platform. Moreover, an order in the TC flow consists of items intended for one complete cab. This means that the TC flow is being picked using zoning, and more specifically synchronized zoning. However, it can be argued that a combination of zoning and batch picking is conducted since, as explained in Table 4.1, some of the lines/platforms are co-packed, meaning that up to 7 cabs are picked simultaneously by one picker in his/her dedicated zone. Moreover, the synchronized zoning strategy is also applied when picking the material intended for "Parter X" – different zones are being picked at MC with one additional zone (the LVL) compared to the TC flow. Another similarity to the TC flow is that pallets are co-packed and thus batch picking is also applied. The reason why co-packing is possible is that each order from "Partner X" contains material for several cabs, i.e., the items are part of the same purchase order. However, different from the TC flow, the workload can be spread out over a week before all pallets have to be accumulated at the Logistics Center (LC). In contrast to the two aforementioned flows, the picking strategy when picking items for the LSV or Spare part flows is discrete picking. Due to the challenge of not being able to co-pack different purchase orders, only one order is picked at a time, and the pickers complete a full order before beginning on the next one.

Routing policies

The last comparison between the reviewed literature and empirical data for this subsection is regarding routing. In the four flows, there are different strategies regarding where items should be picked. The LSV and Spare part flows have quite specific heuristics of how to execute the picking; primarily pick from the highbay storage, and if items are not available there, go to e.g. line or platform. For the TC flows it is a different story. The picking process during the day has quite a clear routing; pick material from the platforms except for items intended for line 5 which are picked from the production line at MC. However, the night picking is less structured and the pickers themselves can choose which locations to go first, and they can even choose if they want to pick some items at line or platform. Thus, to some extent, it can be argued that the pickers from the night shift do not have a routing policy at all. The "Partner X" flow is such a small flow and the picking at MC is conducted by the same organizations as the TC flow's night picking and can, for the purpose of this routing analysis, be considered identical. Lastly, the routing policy for the picking at the low volume production line (LVL) intended for "Partner X" is considered unimportant due to the small quantities and short distances in that building, and therefore an (if possible) reduction in travel time for this process is deemed insignificant.

The predefined heuristic routing policies presented in the literature review from De Koster et al. (2007) are difficult to utilize in this case study for the same reasons that were brought up in that subsection in the literature review; (1) the picking areas at Scania in Oskarshamn do not consist of symmetrical aisles in rectangular spaces and (2) items can be stored at more than one location. However, these policies can be used as inspiration e.g. if developing a routing policy for the TC night shift pickers.

5.1.2 Redesign of the external picking process

As concluded in the literature review, subsection *3.2.2 Complexity of process redesign*, nonroutine is a driving force of process complexity. Standardizing the picking process, whether it is for one particular part of the external picks or the external picking process as a whole, could thus entail drastic improvements. In the empirical study, it was found that the night picking process conducted at MC is the most unstructured. Consequently, this will receive the most attention in this subsection. While some of the night pickers are of the opinion that the challenge of standardizing the picking process is insurmountable, we argue that it is necessary to investigate this and try to implement some aspects.

As found in the literature review, an important principle for logistics process redesign is to simplify structures, systems, and processes by following standardized methods. Furthermore, the day pickers have already developed a more standardized process, implying that it in fact is feasible. This relates both to where items are picked and how items are placed in the pallets. During nights, the pickers have the freedom to pick some items from either platform or line. We believe that it would be beneficial in terms of efficiency and accuracy to agree on a standard procedure for where to pick certain items. The rationale is that efficiency is improved by the elimination of a step (the picker does not have to assess and choose between pick locations), and that accuracy ought to be improved when one article is always picked from the same location. Likewise, agreeing on a standard for where to place the picked items is believed to be important; partially for the pickers' sake but most importantly to facilitate for the employees working at the production lines at TC. This can be considered a form of kitting, where each box in the pallet always would contain the same articles. When items are placed in the same way over and over again, it should be easier for the picker to detect errors or irregularities. Furthermore, it saves the line workers precious time when they do not have to search for the picked items within the pallet. Potentially, the development of a standardized picking process can be further aided by the implementation of digital assistive technologies.

Broadening the discourse to encompass all four flows, the best practices for business process operations discussed in the literature review becomes relevant. The general theme of the three practices (order types, task elimination, and triage) is to examine the tasks involved in a process and determine if they should be divided, integrated, or removed altogether. It is fair to say that digitalization could render several tasks superfluous. For example, the tedious task of printing and sorting picklists for the TC picks could be eliminated. In the same manner, the picker-developed technique of taking photos of picked items as proof of performed work could be removed. The removal of tasks should increase the process efficiency and reduce the order-handling cost. If we take a holistic approach and consider the act of picking items as a task itself, the call for distinguishing new business processes becomes evident, in accordance with the *order types* best practice. The new process would then integrate picking activities across the four flows, thus taking advantage of the *triage* best practice. However, this entails a need for major organizational restructuring. To not deviate from the topic of process redesign, the organizational aspects will be further discussed in section *5.2 Analysis of the Organizational Structure.*

5.1.3 Picking errors

As explained in section *4.3 Conclusion of Empirical Study*, Scania experiences challenges related to picking errors associated with some of the material flows to internal customers. It is explained that this is not an issue regarding the Spare parts and “Partner X” flows, which is why only the TC and LSV flows are analyzed in this subsection. Moreover, as can be seen in Table 4.2, these flows include picks from all responsible picking teams except for the one picking items at LVL intended for “Partner X”, in which only one single picker works at a time.

Consequently, this analysis will include the majority of all relevant aspects of external picks to achieve a comprehensive understanding of the challenge related to picking errors.

Analysis of picking errors in the TC flow

For the TC flow, data regarding picking errors were obtained for the time period 2021-01-01 to 2022-03-08. In Figure 5.1, the number of picking errors per line is illustrated together with the responsible shift. As explained in subsection *4.2.1 Technical Center*, some lines (IP, L1, L4, and L7) are only picked by the night shift. From the figure, it can be seen that IP is the line with the most picking errors, more specifically 38% of all errors. Moreover, we can see that L1, L4, and L7 have about the same level of picking errors. By the blue color, it can also be concluded that the night shift is responsible for all four lines with the most errors, and in total the night shift is responsible for 87% of all picking errors conducted in the TC flow. Therefore, by looking at this figure, the speculations that surfaced during the interviews regarding (1) the majority of picking errors occurring during the night shift and (2) instrument panel (IP) items are the most frequently incorrectly picked category of items, can be confirmed.

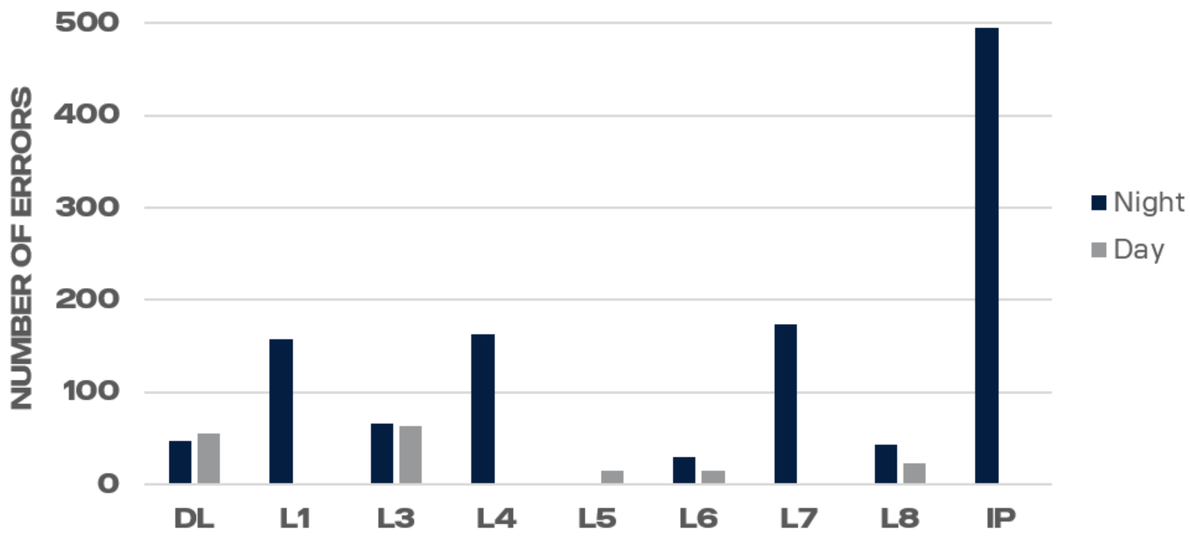


Figure 5.1: Picking errors in the TC flow (Data period: 2021-01-01 to 2022-03-08).

To get a better understanding of what factors cause picking errors, items that during the aforementioned period were incorrectly picked 10 or more times were studied. As can be seen in Figure 5.2, 11 of these 14 items are IP items, 2 are L7 items, and only 1 is an L4 item (all these lines are picked by the night shift). On closer inspection of the items, some interesting findings have been made by analyzing storage locations, item characteristics, and the picking error reports. In the following bullet points, common reasons for mispicks are described:

- The three last digits in the article number are identical for two items that have similar appearances and are stored at addresses close to each other.
- The two last digits in the article number are identical for two items that are stored in boxes next to each other in a rack.
- All digits are the same except the last, and the only physical difference is whether the item is oriented for the right side or left side of the cab, i.e. the items are mirror versions of each other.

- The items have both mirrored versions as well as different versions depending on whether the cab is intended for right-hand or left-hand drive, i.e. there are four versions of the same item.

To summarize the bullet points, the reasons that items are mispicked are that they (1) have similar appearances, (2) have similar article numbers, and (3) are stored close to each other. Most commonly it is a combination of at least two of these three reasons. Examples of these situations with some of the items included in Figure 5.2 are shown in Appendix B.

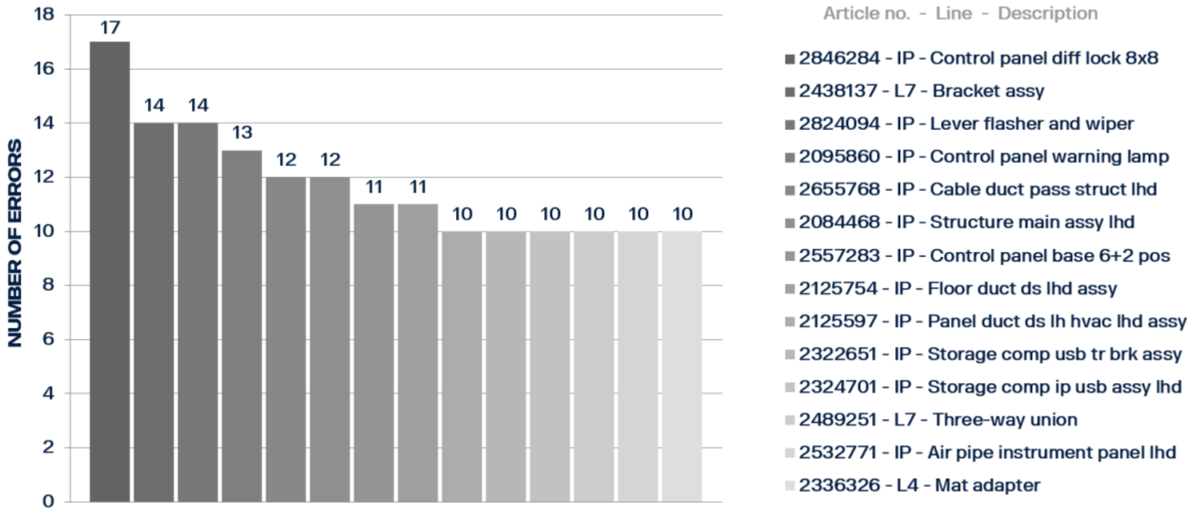


Figure 5.2: Items incorrectly picked 10 times or more (Data period: 2021-01-01 to 2022-03-08).

One of Persson's (1995) nine principles, presented in the literature review, can be utilized in this analysis – to differentiate items into groups or categories. By doing this, different methods can be applied in order to elevate performance. In the interviews, the picking of IP items was explained to be a bottleneck. Furthermore, the IP items were thought to suffer mostly from picking errors (which was proved true in Figure 5.1). As can be seen in Figure 5.2, eleven of the fourteen most incorrectly picked items are IP items. Therefore, to be able to conduct a more in-depth analysis, the items are categorized into 'IP' and 'other lines' in the following parts of the analysis of picking errors in the TC flow.

When once again expanding the analysis by using the whole dataset, and not only the most incorrectly picked items included in Figure 5.2, two kinds of picking errors are used: "mispicked" and "not picked". The latter include both "not picked at all" and "wrong quantity picked". The results provided by the analysis of the complete dataset are presented in Figure 5.3. It can be concluded by these numbers that, in general, IP items are more commonly mispicked, while items from other lines are more commonly not picked. The underlying reasons that IP items are bigger victims of mispicks seem to be that they are small and come in several different variants with similar appearances.

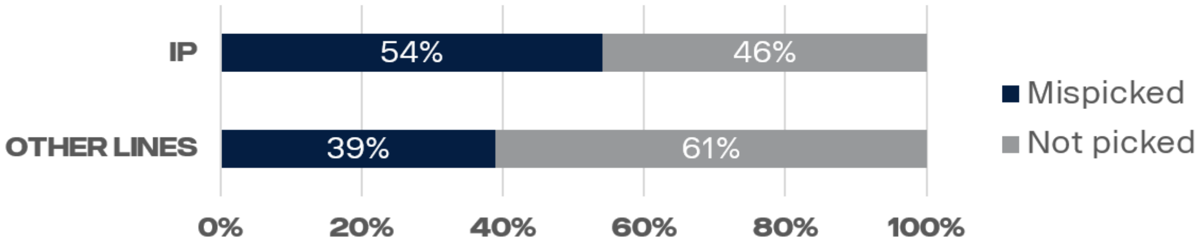


Figure 5.3: Distribution of picking errors for the two categories of items (Data period: 2021-01-01 to 2022-03-08).

In an ideal world, “not picked” would be divided into “not picked at all” and “wrong quantity picked” to enable better and more tailored recommendations, but they are bundled together in the available data. The reason for this is that there is no option in the system for the operator to choose “wrong quantity received”. Therefore, they choose the same option for the two different errors. The only way to distinguish is by reading every comment for each “not picked” error. This system limitation makes the data somewhat unreliable when trying to divide the two since it relies on operators being detailed in the comment of the picking error reports. With this reservation of data reliability, an analysis of a subsample was conducted to investigate the distribution between “wrong quantity” and “not picked at all” within the error type “not picked”. It showed that for IP items, about 5% of the “not picked” errors were indeed “wrong quantity” errors, while the corresponding number for “other lines” was closer to 14%.

The analysis of the subsample shows that the “not picked at all” errors are remarkably more common, and thus for both IP and other lines, it is a serious issue. When talking with people involved in the TC picking process, the primary reason for this error type is believed to be that several items are picked simultaneously, and afterward, several rows are marked as picked on the paper list. Therefore, sometimes too many or incorrect rows are accidentally marked as picked.

Analysis of picking errors in the LSV flow

The data for the LSV flow is unfortunately not of the same quality as for the TC flow. There is no system that gathers information, or where errors are reported on a regular basis. Instead, the errors are reported to a production planner (MCLP) via email who gathers the data in a Microsoft Excel document to at least have some history of past events. However, this has only been done since June 2021. Unfortunately, with the data in this document, it is not possible to conduct the analysis intended for the picking errors in order to achieve a comprehensive understanding similar to what is provided for the TC flow. Although, when manually looking through the comments regarding the picking errors, a few insights are attained. However, these findings should be taken with a pinch of salt considering that the amount of data is small and it is not always possible to distinguish what kind of errors have occurred. With this in mind, the distribution of picking error types is presented in Figure 5.4. It should be mentioned that this only includes the data points in which the error type was distinguishable.

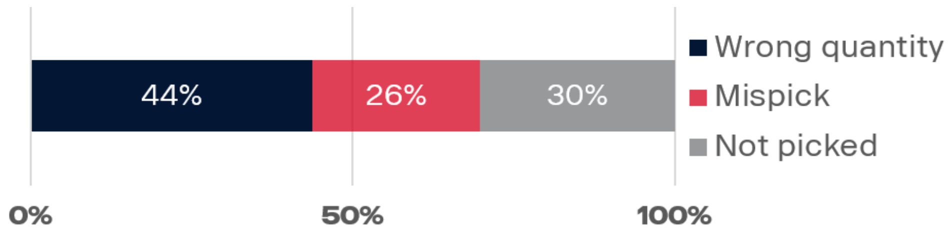


Figure 5.4: Distribution of picking error types (Data period: 2021-06-21 to 2022-03-07).

5.1.4 Digitalization

As concluded in chapter *4 Empirical Study*, an overarching theme for the external picking and the material flows is the low level of digitalization and lack of assistive devices. The material flows investigated have various levels of digital solutions but all flows are substandard in this regard compared to other operations at Scania. Therefore, in this subsection, various ways of digitalization are discussed.

The IT system as a whole has room for improvements to support the material flows to internal customers. Firstly, to save time during the night shift of the TC picking, the IT system should be able to sort the picklists per line and not per cab. By removing the need to manually sort the picklist, about one hour of work per night shift would be saved. Moreover, if the sorting process is automated, it would reduce the risk of lists getting in the wrong order, getting mixed between lines, or worst case getting lost. Secondly, to make the process of picking easier and consequently more efficient as well as to reduce the risk of picking errors, a feature should be introduced that bundles together all picks that will be executed at one line. Today, if five cabs intended for LVL are co-packed in one pallet at line 6 and all of them require a specific item, the picker has to both look at and put a checkmark on six different papers. This induces the risk of picking incorrect quantities e.g. if the picker loses count of the papers. Therefore, it would be more efficient to instead have a single list on which the total quantity is stated. Thirdly, the “Partner X” flow would also benefit from added features in the IT system. Not needing to manually work in Microsoft Excel to create the picklist would reduce the risk of errors and mistakes. During an interview, there were speculations that this is in the pipeline for the IT department, which, if true, is promising for this material flow. Lastly, the LSV and Spare part flows would benefit if the IT system would be able to merge POs into single shipments – meaning that two POs could be co-packed to save time and reduce the required amount of pallets.

Another area of the material flows to internal customers that needs to be improved with regards to digitalization is the data gathering for the LSV flow. During the analysis of the picking errors, it was noticed that the data is substandard compared to what can be expected and the data for the TC flow. By ensuring that errors can be reported (at least) to the same standard as for the TC flow, better insights and consequently changes would be possible.

If the IT system would be developed to better support the external picking processes, it would allow for digital assistive devices to be used by the personnel. Such a change would be an important tool to help reduce the number of picking errors, both considering mispicks, wrong quantities, and when items are entirely forgotten/missed by the picker. Today, the personnel responsible for picking items intended for the main production lines have access to the technologies pick-by-voice and pick-to-light. The pick-by-voice technology is used at platforms and pick-to-light is used to pick items for the IP. These tools would be useful for the personnel that pick items intended for TC and “Partner X” since they regularly pick at locations that already have these technologies installed, and thus the implementation would be relatively smooth. However, it is noteworthy that the pick-to-light technology will only be available when it is not utilized by the pickers for the main production line. This means that from a practical perspective, it will only be utilizable during the night shift. Considering that the main production is only running during the daytime and the IP items are only picked during the night shift, this implementation would not require drastic changes to the picking schedule.

Other technologies that are available on the market that would be of interest for different parts of the external picking process are the remaining mobile and wearable technologies mentioned in subsection *3.3.4 Assistive devices* – scanners, smart gloves, and smart glasses. As explained in section *4.2 Material Flows and Processes to Internal Customers* all pickers working with external picking use paper and pen during their work process. It was explained by several pickers that handheld scanners are not desirable since they want and need both hands available to do their job. Therefore, a solution with wearable technologies should be desirable for the process of external picking at Scania.

Both smart gloves and smart glasses are feasible alternatives that would help to get rid of the current paper and pen solution. The results presented in the literature review explained that smart glasses can drastically improve picking efficiency and decrease picking errors in the automotive industry. The information presented in the literature review also showed that smart gloves are a promising solution with similar improvement figures. During this case study, we have learnt that similar technologies are being used, or at least tested, in other parts of Scania, e.g. by the organization OLS which manages a logistics center in Södertälje.

These two aforementioned wearable technologies also bring another benefit that would somewhat solve a challenge that was presented related to the TC flow – changes in the production schedule after the picklists have been printed. Instead of having the picklist printed during the first hour of the night shift and being unchangeable for the upcoming 24 hours, having it digitally would hypothetically make it possible to change the picklist up until the picker starts to pick an affected order.

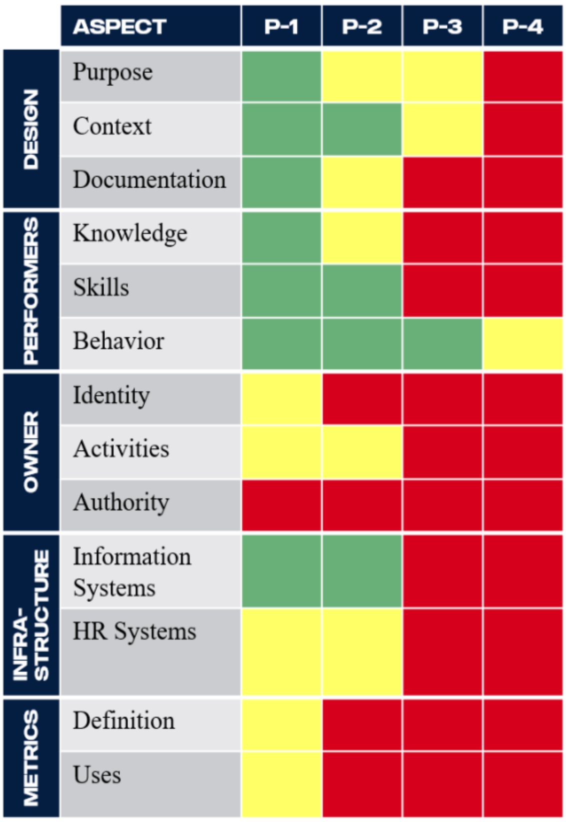
A limitation of the technologies available today is the difficulty to help with the issue of picking incorrect quantities since only a barcode on a box/pallet/storage location would be scanned and not each individual SKU. However, this is where the potential future capability of smart glasses, *object recognition*, becomes extra interesting. More specifically, it would be suitable when analyzing the possibility of implementing smart glasses in the picking process conducted by MCLFV (who pick and pack items as part of both the LSV and Spare part flow) due to two of their challenges. Firstly, as was shown in the data presented in Figure 5.4, the error type that occurs the most is that LSV receives the incorrect quantity of an item. The other challenge that would be resolved by this capability is the issue regarding items seemingly disappearing between Scania and LSV (LSV claiming they do not receive items that Scania claims are sent). If, or when, this capability is realized it can keep count of the number of items that have been picked as well as act as digital “proof” that the item has been picked.

During interactions with individuals from the MCLD team, we have learnt that with today's logistical structure at the production facility in Oskarshamn, items are considered consumed already when they leave the storage areas (either highbay, box, or big pallet storage). I.e., when items are picked at line or platform intended for the internal customers there is no need to change the inventory levels. However, we have also understood that there is a discussion to change this so that items are not considered consumed until they are picked and mounted onto a cab. Such a change would require that items picked for the external flows would need to be registered when picked, which is an important reason to get rid of the current pen and paper solution and implement some sort of digital capability.

5.1.5 Process maturity

To assess the maturity of the external picking process, the Process and Enterprise Maturity Model (PEMM) described in the literature review has been utilized. The framework (and the insights it provides) will serve as a foundation for further discussion regarding areas of improvement. Despite each of the four flows having its unique characteristics, the similarities in how they are managed allow us to apply PEMM for the external picking process as a whole. In accordance with the model, cells were colored based on ‘largely true’ (green), ‘somewhat true’ (yellow), and ‘largely untrue’ (red). This means that differences across flows could be neglected as a holistic assessment was sought. The results are provided in Table 5.1, whereas the comprehensive exhibit including the requirements for each level is provided in Appendix C.

Table 5.1: Results of applying PEMM to the external picking process.



The general aim of process improvement is to reach level 4 and attain a ‘best in class’ process. However, we acknowledge that the external picking process is not a core process for Scania, and therefore deem the pursuit of P-4 gratuitous. Instead, we argue that a modest goal is more appropriate and suggest that the target should be to attain a ‘reliable and predictable’ process by reaching a situation where all statements for P-1 are ‘largely true’ (green). Perhaps the goal can be even more ambitious – to make all statements ‘somewhat true’ (yellow) for P-2. Merely by looking at Table 5.1, it is evident that the greatest efforts are needed in relation to the categories *Owner* and *Metrics*. Some work is needed with regard to *Infrastructure*, while the aspects under *Design* and *Performers* are already at an adequate level. In the following discussion, the focus will be put on those aspects not reaching the aforementioned target.

As the name suggests, *Owner* relates to everything associated with the process owner. The first aspect within this category is “identity”, which refers to who the process owner is. To improve upon this aspect and attain the target, responsibilities would have to be straightened out. Ownership exists for the sub-processes (the picking within each flow) but the external picking process as a whole lacks an owner. First of all, to reach P-1, a group or an individual must be informally charged with improving the process. Thereafter, P-2 is attained by creating an official process owner role. We argue that this is absolutely necessary if the process is to deliver sustained performance. The second aspect, “activity”, relates to what the owner does. This is difficult to assess, considering today’s setup with partial ownership of the process. However, our overall evaluation points to the need of documenting the process and communicating it to all the performers in a more systematic manner. Lastly, the “authority” aspect pertains to the influence possessed by the owner in relation to the process. The reason for the consistently red boxes regarding this is the absence of a formal owner; without explicit ownership, no one has control over the process development.

When weighed together, the information systems have sufficient functionality to support the process. There is, however, an anomaly too significant not to mention. This deviation is related to the “Partner X” flow, where picklists are neither created nor distributed through the main system. Sooner or later, this issue must be addressed by Scania. The human resource systems are on a decent level, but some effort is required to completely reach P-1. To do so, functional managers should continuously reward the attainment of functional excellence and the resolution of functional issues. Currently, we have seen signs that the functional managers encourage the pickers by praising their performance. It might be appropriate to implement a more explicit carrot to foster the performers' motivation.

The utilization of performance metrics within the external picking process is deficient, to say the least. Picking errors (a quality metric) are to some extent measured, why the “definition” aspect is marked yellow on P-1. In addition, managers are attempting to use the metric to identify root causes of faulty performance and drive functional improvements. An example of this is when the night manager is made aware of a picking error, tries to understand why the error occurred, and takes mitigating actions to prevent the same error from happening again. Consequently, the “uses” aspect is also marked ‘somewhat true’ on P-1. To attain a green mark on P-1 for both aspects, Scania would need to adopt some basic cost metrics and expand the use of metrics as a tool to track performance. While this ought to be rather straightforward, more work is required to approach P-2. Be that as it may, it is on this level we believe the benefits of working with KPIs will truly manifest. When it comes to the "definition" aspect, P-2 corresponds to having end-to-end process metrics derived from customer requirements. Concerning "uses", managers should compare the metric to benchmarks and customer needs, and use it to set performance targets, in order to reach P-2. By doing so, it will become apparent where there is room and/or need for further improvement.

5.2 Analysis of the Organizational Structure

Given the current setup with multiple organizations responsible for external picking, we believe that there are significant gains to realize. This is reflected in the interviews, with several interviewees questioning the division of responsibilities across organizations. Thus, the question is not if the responsibilities should be redistributed, but rather how they should be redistributed. In this section, we will review the organizational best practices provided in section *3.2 Process Improvements* based on Reijers and Mansar (2005), assess their appropriateness for Scania, and discuss the implications of adopting a certain best practice. Thereafter, the interviewees' ideas regarding organizational restructuring will be discussed.

5.2.1 Organizational best practices

The *order assignment* best practice relates to letting workers perform as many steps as possible for single orders. This is to some degree already the case for many of the external picks, with one employee conducting all picks from a specific picklist. Although, if we approach the issue with a different perspective, potential improvements can be distinguished. If we do not consider one picklist to correspond with one order and instead assume that all SKUs that are to be picked from one particular line/platform that day are correlated, the responsibilities are no longer as clear-cut. For instance, during each 24h period, many different employees pick from the same line at different times, and who is responsible for a specific line/platform can differ from one day to the other. Would it be beneficial to explicitly designate pickers from the same team to different lines and let the same person perform all picks from that line for a longer period of time? Even more enthralling, could this practice be extended across functional boundaries, in the sense that the same picker is responsible for picking all items from a specific line regardless of the internal customer? There is no indisputable answer to these questions. Most certainly the implementation of this would be difficult and require some major consideration, although we argue that the potential benefits are too important to disregard.

The expected consequences of giving one picker responsibility for all picks from one line are improved quality and efficiency since the picker will become sort of an expert on his/her line. On the downside, flexibility is reduced in terms of resource allocation, and worker satisfaction can deteriorate. To address the question of dissatisfaction, we acknowledge the need for work rotation, so that the picker attains some variety of tasks. A solution to this could be to divide pickers into groups of two or three and let them switch responsibilities at regular intervals. This is somewhat similar to today's setup but instead of rotating on all lines, the picker is always responsible for the same 2-3 lines. The implementation of this practice would also require an analysis of the time it takes to pick from each line so that the labor is split fairly amongst the groups and pickers.

The second organizational best practice discussed in the literature review is *split responsibilities,* which means that the assignment of task responsibilities to people from different functional units should be avoided. Regarding this, we argue that Scania has a lot to learn. The picking of mixed pallets conducted at MC, intended for TC, is managed by one group of employees during the daytime (MCAEL), and two groups of employees (MCAEL + MCLFL) during nighttime. Similarly, the items bound for "Partner X" are picked at LVL during daytime (by MCAEL) and at MC during nighttime (by either MCAEL or MCLFL). When a process is this scattered, the likelihood that tasks become a source of neglect and conflict is great. None of the interviewees conveyed that an actual conflict is ongoing. However, a general mindset of "we vs them" was apparent, with the performance of the day and night pickers being tracked separately and employees talking in terms of "we do this – they do that". Establishing a more unified organization, with all employees pulling in the same direction and learning from each other instead of competing, should improve the quality of the process.

Numerical involvement is the third and final organizational best practice highlighted in the literature review. This dictates that the number of departments, groups, and persons involved in a process should be kept to a minimum. Moreover, this practice goes hand in hand with the split responsibilities practice – by reducing the number of subjects involved in a process, the occurrence of shared responsibilities is decreased. A major strength of applying this practice is that coordination issues become less frequent. Given the current situation at Scania, this is highly relevant. It was explained by the night manager that coordination was difficult, especially since other employees working with the external picking held coordination meetings during the mornings when she was asleep. Furthermore, the situation where the night manager is not the boss for all night pickers (some pickers belongs to MCAEL) was described as odd. We believe that something has to be done, either by merging the two organizations picking items for TC (MCAEL + MCLFL) so that all pickers report to the same manager, or by at least separating the two functions so that one of them conducts all day-picks, and the other all night-picks.

5.2.2 Redistribution of responsibilities

The interviewees' ideas associated with organizational structuring take one of two directions; to expand the use of night picking or to take measures to remove the night picking. Either way, it implies great changes to Scania's organization. The first idea is related to the reallocation of some of the picking intended for LSV to the night shift. Implementing this in a manner so that picks from the repack conveyor are conducted during days and picks from lines/platforms are conducted during nights would reduce the travel time. If we develop this idea further to not only divide the picks according to day and night but instead based on pick locations, the strategy becomes similar to what the theory refers to as zone-picking. Practically, this means that the order-picking is based on location instead of the customer. This would allow the pickers from MCLFV to be more stationary at the repack conveyor while the pickers from MCAEL and MCLFL (the day and night pickers in the TC flow), who are already at the lines and platforms, can take responsibility for the picks at those locations.

Changing to a location-based picking strategy brings benefits, but the solution also entails some drawbacks. First of all, it might require increased manpower at MCAEL and MCLFL, ultimately leading to increased hourly costs as night personnel is more expensive. Furthermore, it becomes a question of quality. Implementing this would cause further division between the picking organizations and be the opposite of what was suggested by the best practices, hence affecting the accuracy. Nevertheless, if we consider a situation where this is combined with the idea of having pickers responsible for a particular line, the quality ought to improve. It results in a situation where responsibilities are split in a fashion that allows each picker to focus on the picks that he/she knows best, i.e. the repackaging team only conducts picks from the repack conveyor while the specialized and dedicated line/platform pickers perform those picks.

Idea number two, removing the night picking altogether, is more in line with the practice of *numerical involvement* since it has the potential of reducing the number of organizations involved. The interviewee conveying this idea explained that the main production work in two shifts during the day and posed the question: could not the day pickers do the same? It is undeniably a compelling thought, however, it leads to another question: is it practically possible to conduct all picks during the daytime? Previously, production was up and running at night, albeit at a reduced speed. Yet the night pickers managed to complete their picks. This leads us to believe that more picking could occur in parallel with production during the daytime.

To evaluate whether the night picking could be removed, or at least reduced, the expected consequences will be investigated. If more picks were to be performed during the days, issues related to congestion would become more frequent. Scania could also expect increased picking time for the external picks since the pickers would have to wait for trains, forklifts, etc. to leave the picking areas. Longer times imply increased costs, although, the consequent reduction of night personnel entails reduced costs. From a cost perspective, this becomes a question of trade-offs, i.e. the cost of having day pickers wait to perform their tasks vs the savings in hourly labor costs. Each employee relocated from the night shift to the day shift corresponds with an average yearly saving of 100 000 SEK, a reduction of approximately 15%. The question is then – would the newly assigned day picker spend more than 15% of their workday waiting? To be able to answer this question, data concerning picking and waiting times is a prerequisite. An interesting analysis to make would be to identify which platforms/lines/items can be picked during the daytime and redistribute the responsibilities of these picks to the day shift. However, with the current lack of KPIs and performance metrics, this analysis cannot be performed at this stage.

How the remaining two dimensions of the devil's quadrangle (flexibility and quality) will be influenced by only picking during the daytime is also difficult to determine. The flexibility can be expected to reduce since pickers have to pick during very specific times. Furthermore, the locations from where picks are to be made would be more explicit than during nights, implying reduced flexibility. The effect of this could be improved quality, considering that routine and standardization are established. On the other hand, quality could deteriorate if the timeslots are too narrow so that the pickers have to conduct their picks hastily.

5.3 Flow-Specific Analyses

5.3.1. Technical Center

Forward picking area at TC

In one of the interviews, it was explained that if looking at TC as an isolated unit, the ideal solution for LVL and the Arena would be to store all material in proximity of the production lines at TC and not at MC. Obviously, this is not possible due to space constraints, but stock-keeping big quantities of identical items in different buildings (MC and TC) would also induce extra costs. However, we do not think the idea should be rejected entirely. Today, a few items that are commonly incorrectly picked or easily damaged during transport are being kept in stock as spare parts at TC, in addition to items unique to the production at TC. We find this interesting and in the following paragraphs, it is analyzed whether this idea can be developed into a forward picking area for some items.

As explained regarding the picking errors in the TC flow, the items can be categorized as IP or other lines. What differentiates IP items are factors such as; (1) IP items are the most incorrectly picked SKUs, both in total but also when looking at which specific items are incorrectly picked the most times, and (2) picking IP items is perceived as the number one bottleneck in the TC picking process. For the same reasons, it can be argued that the IP items are suitable to store in a forward area at TC. The benefits of implementing this would be for example:

- It would allow the night pickers at MC to get rid of their primary bottleneck.
- It would reduce labor costs since IP items would be picked during the daytime instead of nighttime.
- It would allow for faster rectification of errors and consequently saved money due to less work for Bristakuten.
- It would reduce the return flow from TC to MC which in turn reduces the time that needs to be spent returning items by the night pickers. In addition to the financial benefits, this change would probably reduce the number of scrapped items (due to them being damaged in transport or too time-consuming to return), thus also being environmentally beneficial.

There are however some challenges with introducing a forward area of IP items at TC:

- The items still have to be transported from MC to TC. This means that it needs to be determined who will pick the items at MC and who should transport the items.
- As explained in subsection *4.2.1 Technical Center*, one of the challenges with this flow is the limited floor space at TC and thus it can be difficult to introduce a new storage area.

A solution for the first challenge would be to have the repackaging team from MCLFV (the same team who pick and packs items for the LSV and Spare part flows) responsible for picking and packing items from the highbay storage. From there, the pallets would follow the same path as the full pallets do after they arrive on the 5th conveyor; go via Torget to the container. The issue of transport is out of scope for this thesis, but to briefly mention it, it could be handled by the same organization as the full pallets going to TC.

The second challenge can potentially be sorted by putting up new warehouse tents. A couple of these are already in use, and there is enough space outside to accommodate another one. A different and more long-term solution would be to investigate the possibility of moving the staff break area at LVL into a separate space (e.g. a construction barrack, similar to what is already used for LVL's office space) since that space is advantageously located in relation to the production line. Moreover, when investigating this matter regarding the space constraint, it has to be said that IP items are more suitable to stock-keep in a forward area than items from other lines since the items are generally small, e.g. buttons and switches. An appropriate solution would be to only put small to medium-sized items that are frequently used there. The bigger IP items can still be picked at MC, but the forward area of the smaller to medium-sized items might enable the big items remaining at MC to be co-packed. This would ensure that the forward area does not have to take up too much space.

A space-efficient solution would be to utilize paternoster, a storage solution utilizing rotating shelves, which is suitable for when items need to be stored in a tighter footprint. Paternosters can also be combined with a pick-to-light solution which would help decrease the currently high levels of picking errors. However, it is important that the paternoster can store Scania's standardized boxes in order to avoid double handling (in the form of repackaging).

An investment analysis has been conducted to see the financial impact of implementing a forward pick area with a paternoster at TC. The initial investment would be approximately 400 thousand SEK, including the purchase of the paternoster and the work of initially stocking up with items (excluding the cost of the actual items). The savings that can be expected are:

- Reduced labor costs since a paternoster allows pickers to drastically reduce their travel distance, and thus their picking time.
- Reduced labor costs since picking can be conducted during daytime at TC instead of nighttime at MC since day picking at TC obviously will not obstruct the operations at the main production lines.
- Reduced cost by not needing to send Bristakuten to MC to quickly pick items needed in production.
- Reduced leasing costs by potentially only needing three instead of four trailers to transport the mixed pallets between MC and TC.

In addition to these cost savings, a couple of other benefits have been highlighted during the investment analysis that were not possible to include due to the difficulty of quantifying them. These are for example (1) reduced risk of stopping production due to material shortage induced by mispicks, (2) reduction of scrapped items since it will be easier to return items into storage if mispicked, (3) the night picking team at MC remove their biggest bottleneck which can lead to more efficient operations in other areas, and (4) the paternoster will not consume all space that is freed up at TC and therefore even more area becomes available for either stock-keeping of goods or working area for other processes.

By doing this change, a couple of new costs would be induced. For the example used in this analysis, a construction barrack is used to replace the break room, so there will be costs related to renting that. Moreover, the cost of picking at MC would occur when MCLFV would pick the boxes e.g. from the highbay storage to send them to TC. Lastly, transportation costs would also appear if the transportation were conducted similar to how the full pallets are transported today. However, we argue that this cost will be neglectable since these routes are already regularly being driven. All numbers included in this analysis are provided by Scania or taken for the data analysis of picking errors with one exception (online research for the cost of a suitable paternoster) and all assumptions are based on the literature review.

With annual savings of about 230 thousand SEK and an initial investment of about 400 thousand SEK, the payback time is less than two years, as can be seen in Figure 5.5. This means that even if it is discovered that one paternoster is not enough to hold all items deemed suitable for a forward area, investing in a second one would lead to a payback time of less than four years, which is still quite good.

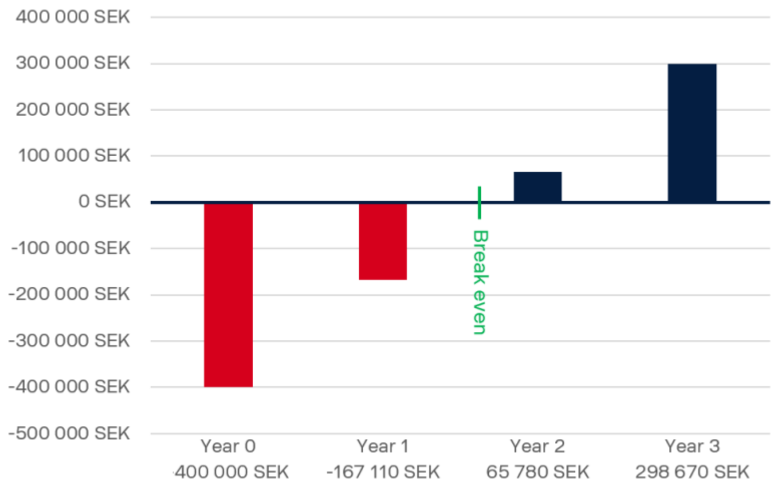


Figure 5.5: Payback time for introducing paternoster in a forward area at TC.

Lowest shelf issue

Related to the issue about the space constraint at TC, and what was discussed in subsection *4.2.1 Technical Center* about not loading on the lowest shelf in the pallets to avoid poor ergonomics – different solutions were discussed with people involved in the picking as well as the employees receiving the pallets at TC. It was found that in general, the TC personnel find it reasonable to have only one or two big items on the lowest shelf which are easy to grab to avoid needing to crawl on the floor to reach smaller items at the back of the shelf. However, we consider it an ergonomic risk to reach down to pull out and lift big and potentially heavy items from said shelf. Therefore, two different solutions for this issue have been developed.

The first one only affects the personnel at TC and is simply to raise the pallets at TC to improve the reachability of the lowest shelf. Already today, some pallets are placed on pallet trolleys to enable better mobility of the pallets. We believe that by extending the use of trolleys and introducing trolleys with greater height, the personnel could more easily reach into the pallet. However, this change would still leave a bad ergonomic situation for the day pickers at TC.

The second solution is a bit more complex and entails modification to the pallets. By mounting rails in the pallet to enable the lowest shelf to be pulled out similar to a drawer, it would allow for better reachability of items located deeper on the shelf. Thus, even small items can be placed there and there will be no need for crawling on the floor. Since these pallets are owned by Scania themselves and used in a circular flow, this modification is considered reasonable. It is however important that the rails can be locked during transport to avoid the shelves from opening.

As can be seen in Figure 4.8, the pallets consist of three shelves. Thus, by implementing one of these two changes, it would be possible to reduce the number of pallets shipped to TC each day and the frequency of pallet changes at the production lines. For example, it might be possible to co-pack pallets that currently only hold items for one cab, or to fit items for even more cabs in pallets that are already co-packed – potentially utilizing 50% more of the available space in the pallets (using all three shelves instead of only two).

5.3.2 Laxå Special Vehicles

A major issue especially noticeable with regard to the Laxå Special Vehicles (LSV) flow is the lack of information sharing and communication. Emergency orders are frequent and sudden, leaving the pickers with inexplicable workload peaks. Reducing the occurrence of these orders could save the repackaging team precious time that could be used to create value through other activities. Since June 2021, the production planners have a document where all deviations are collected. However, as explained in subsection *5.1.3 Picking errors*, the quality of the data is poor, and thus its purpose is vague. Additionally, the dissemination of information is considered inadequate. The root cause of the problem is believed to be the insufficient level of standardization.

Even though the existing LSV data is not of the highest quality, some insights can be attained regarding who caused the emergency orders. In Figure 5.6 it can be seen that the distribution of responsibility between LSV and Scania is quite even. When LSV is the responsible party, causes can e.g. be that they simply had forgotten to order the item in question or that they had incorrect inventory levels in their system. When Scania caused the emergency order the underlying reasons were e.g. picking errors or poor quality of items.

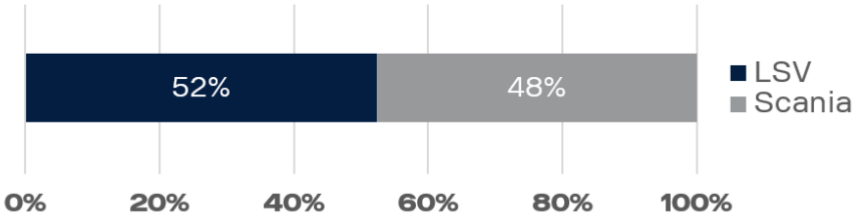


Figure 5.6: Illustration of who caused the need for emergency orders (Data period: 2021-06-21 to 2022-03-07).

There is no roadmap for how to attain well-functioning routines. What matters is that the work is initiated. From there, the procedures can be refined until a satisfactory situation is reached. For Scania, the first step towards standardizing how LSV orders are managed is to sit down with the customer and agree on a procedure for how deviations should be reported. A possible solution is to utilize EQ, an already established system for tracking and reporting deviations. However, we believe that the practicalities of this are more appropriately settled between Scania and LSV, hence the details will not be discussed further. Once a routine has been established, the data will automatically become more useful since the legitimacy and consistency are enhanced. This can play a vital role when determining whether LSV or Scania should carry the costs stemming from emergency orders. Furthermore, reliable data can facilitate decision-making and drive development.

After obtaining consistent, accurate data, the next step is to ensure that the data is communicated effectively to all relevant parties. This is currently not the case, with both the pickers and the group manager working with the LSV flow explaining that they feel excluded and uninformed. By improving information sharing across the organization, several benefits can be realized. First of all, the pickers will be given the opportunity to understand how their work relates to the outcome. When employees understand the process on a deeper level, the likelihood of them making decisions that are in the best interest of the entire process increases. It can also spark motivation and job satisfaction among the pickers since a more involved employee generally sees more meaning in his/her work. Secondly, it has the potential of providing the functional manager with valuable insights. When this person is given the chance to monitor and comprehend the situation at hand, continuous improvement initiatives ought to require less effort and yield more significant results.

Regardless of how well-functioning the communication between pickers, group managers, production planners, and material planners is, some issues cannot be tackled. This relates to both the return flow and the unique situation where half-full/empty pallets are brought to the platforms. To get to the bottom of this, the dialogue must extend across company boundaries. Both problems are consequences of the current agreement between Scania's and LSV's material/production planners and we believe that a discussion needs to be held concerning the order pattern. What complicates the matter further is that the two issues are competing. On one hand, if LSV were to order more full pallets, the problem with non-full pallets to platforms would decrease, but the return flow would increase. On the other hand, if LSV were to order exactly what they need, thus reducing the return flow, the other issue would become more noticeable. In addition, Scania's material planners can sometimes be reluctant to accept bigger shipping quantities to LSV due to the risk of internal material shortage.

The key to attaining a solution that can deliver sustained performance is *balance.* Balancing the cumbersomeness of dealing with return flows with the risk of sending incomplete pallets to the platforms. One potential solution could be to renegotiate the terms for how LSV can return unused articles. Perhaps it is possible for them to keep redundant material in stock until they need it, potentially also reducing the number of orders. Considering that this is between Scania and a partner with their own agenda and requirements, it is difficult for us to propose a solution that accommodates all needs. What we do want to emphasize is that, once again, standardization should be beneficial for the process. Full pallets should not be ordered haphazardly, and with a well-established routine and rationale, this can be avoided.

A somewhat related problem is how items from different purchase orders cannot be shipped together. The issue can be approached from two separate angles: either by addressing the root cause or by taking actions to limit the occurrence of the problem. Essentially, the reason why this is even a problem is due to the lack of system support. With a more developed system that can manage several POs within one pallet, the problem would vanish into thin air. While this sounds like a quick fix, it should be noted that IT solutions are often costly and entail complicated implementations. The second approach is based on cooperation and communication with LSV. By simply reducing the number of POs, the problem would not be as palpable. Assuming that LSV has forecasts and production schedules in place for (at least) a few days ahead, it ought to be possible to consolidate orders. To exemplify: instead of ordering 5 of a specific SKU every day, they could order 10 of said SKU every other day, or 20 every fourth day. Not only does this approach keep the initial problem at bay, but it also benefits the picking process as a whole. Larger order batches imply that the pickers have to pick the items less frequently, thus saving time with regard to traveling and searching. Consequently, the greater the extent to which this is applied, the greater the savings.

5.3.3 Spare parts

Managing and picking spare parts is undeniably challenging due to the fundamental urgency associated with these activities. Initially, one might wonder why a company like Scania, which is built on lean and efficient principles undertakes such demanding responsibilities associated with a responsive supply chain strategy. On second thought, however, it is perfectly understandable given the added value it provides the customer. The importance of maintaining and offering value-adding services should not be underestimated with regard to attracting and retaining customers. Hence, the Spare parts flow can be considered a necessary evil.

The challenge of picking and packing items on short notice is inherent to the process and can thus not be overcome. However, other aspects can be improved to attain a more efficient process. Interviewees emphasized the picking of heavy, bulky items as especially time-consuming. In its most extreme form, such items (e.g. doors) can require four employees cooperating to lift the article without any form of lifting equipment. For some items, lifting equipment is available, albeit occupied during days by ordinary production workers. Moreover, the existing equipment is installed to accommodate the needs in relation to the main production and consequently, it is not always possible to conduct lifting to other locations, e.g. to the forklift aisles. This implies that there are two potential solutions: (1) invest in additional lifting equipment, or (2) pick large items during nights when the equipment is unoccupied.

Investing in new, stationary lifting equipment has obvious drawbacks such as the need for investment and the fact that the equipment will be unused most of the time. However, to attain a higher degree of utilization, mobile alternatives can be ‘mounted’ onto forklifts. Such equipment (e.g. Schmalz’s JumboFlex Picker) could be modified to allow for a combination of lifting with vacuum tubes and straps, thus enabling the picking of diverse items.

Picking large spare parts during nighttime is unfeasible with the current organizational setup, but not impossible per se. If we envisage a future where the night pickers are conducting picks for all internal customers, it would make sense to allocate the heavy items to them. Naturally, the use of lifting equipment mitigates the risk of physical harm and injuries but it also affects the cost. Night personnel is indeed more costly, although not twice as expensive as day personnel. This implies that every item requiring more than one employee to pick during the days is advantageously picked during the nights if one employee can conduct the pick single-handedly with the use of lifting equipment.

Requests for spare doors are further mentioned as particularly inconvenient due to the activities taking place prior to the actual picking. When one of the chassis factories places an order for a new door, a complete cab is produced at MB, whereafter the door(s) is removed and the remainder of the cab is scrapped. Next, the door(s) is primed and coated, before it enters MC where the final assembly takes place. This, especially the scrapping of the cab, seems like an immense waste of resources, not at all harmonizing with today's environmental awareness. How the doors/cabs are manufactured is outside the scope of this thesis, but we believe that the situation is too bizarre not to mention.

Lastly, the issue with having to pack items from different purchase orders in separate pallets is as relevant for the Spare parts flow as for the LSV flow. However, the solution is more straightforward. Asking the customers within this flow to consolidate orders is unrealistic since demand is more sudden and deliveries have to be made more urgent. Consequently, this calls for the implementation of more developed systems to surmount the challenge and realize efficiencies.

5.3.4 "Partner X"

The mere characteristics of "Partner X" orders inevitably lead to a challenging situation for Scania. Items requested range from standard articles to military ones, the orders are occasional, and the shipped volumes are limited. As concluded in the literature review, standardization is known to have a positive impact on process performance. However, attaining a standardized process is not easy, and the results must be worth the effort. For a process so scarcely used as the "Partner X" picking process, it makes sense to not invest heavily in development. While it is a reasonable business decision to not throw money into a negligible process, the consequence is that the process performance is lagging. With that as a starting point, one must ask: does it make sense to keep a process with uncertain benefits for the company?

The core question must be whether the value of the partnership outweighs the cost and cumbersomeness of maintaining an infrequent, substandard process. Exactly how the contract between the two parties is designed is unknown to the authors of this paper, why the following discussion is of a hypothetical nature. If the answer is yes – the relationship has value – Scania ought to actively work with process development. A logical start to this is to address the challenges conveyed by the interviewees. First of all, as mentioned several times throughout the report, there is a need for establishing a more developed digital landscape. The primary purpose of doing so is to eliminate the task of transforming the article list into a formal picklist, but it could also entail advantageous side effects. For instance, this could facilitate the picking process taking place at LVL, reduce the picking time, and even reduce the shipping costs. If the system had information on article characteristics and volume, it could potentially inform the picker which pallet is most appropriately used for a certain picklist. Furthermore, if this is conveyed early on in the process before the picking starts, all pallets intended for the "Partner X" items could be kept together so that the picker does not have to spend as much time trying to locate an appropriate pallet. This implies a cost reduction in a double sense – quicker picking implies less labor while improved volume utilization of pallets implies cheaper transportation.

In the process development work that should be conducted if the partnership is considered valuable to Scania, the picking responsibility should be investigated. It makes sense, as it is done today, to merge the picking with the picking activities related to another internal customer.

However, it should be evaluated whether the night shift (that is also conducting picking for the TC flow) should keep this responsibility, or if it should be conducted by the pickers at the repack conveyor (who pick items for the LSV and Spare parts flows). A compelling reason to change from the night shift to the repackaging team is the similar characteristics of the “Partner X” and LSV flows – Scania provides components (and not complete cabs) to another company that produces cabs that are non-competing with Scania's. By utilizing the AS/RS to extract pallets and the repack conveyor to pick items (similar to the LSV flow), travel distance would drastically decrease, thus implying a lower cost. Moreover, since “Partner X” is a low volume flow and its development is not highly prioritized, it can capitalize on the positive future developments of the LSV flow if it is part of the same process. However, the possibility of implementing this is dependent on the solution of LSV-specific issues to avoid congestion on the repack conveyor and unreasonable workload for the repackaging team.

On the other hand, if the answer is no – the relationship is rather a disturbance than a valuable source of revenue – Scania ought to reconsider the foundational design of the contract. In that case, it could be adequate to strive for a situation more akin to Scania’s normal business, i.e. where complete cabs are shipped. Due to the significant modifications required by “Partner X”, this might not be feasible. However, a step in the right direction could be to reach an agreement where “Partner X” orders contain more sub-assemblies rather than individual SKUs, thus utilizing Scania's expertise more appropriately.

6 RECOMMENDATIONS

Based on the analysis, this chapter includes our recommendations regarding how Scania can improve their external picking and how implementations can be conducted – thus answering RQd. The recommended actions are divided into three categories: Order-Picking Process, Organizational Structure, and Flow-Specific. For each recommendation the implications are discussed before the recommendation itself is stated and the implementation is addressed.

6.1 Order-Picking Process

IT system

The substandard digital system support for the material flows to internal customers should be developed in order to (1) support the sorting of picklists, (2) enable the merging of picklists that will be co-packed by pickers, (3) remove the need to use Microsoft Excel to create the picklists for "Partner X", and (4) enable the possibility of merging POs for especially the LSV material flow. Moreover, if assistive devices will be introduced, the IT systems need to support that as well.

Recommendation 1: Develop the IT systems to better support the four material flows.

To realize these features the MCLD team should prepare requirement specifications and discuss with the IT department how this can be conducted, and thereafter place an order to said department.

Assistive devices

The external picking processes would have great use of assistive devices, especially wearable technologies due to the benefit of still having both hands available. It would (1) help to reduce picking errors, (2) increase the amount of data gathered, (3) reduce the issues occurring due to short notice changes in the production schedule, and (4) enable a future change of where along the value chain items are considered consumed.

Recommendation 2: Commence utilization of assistive technologies in the external picking process.

The implementation requiring the least investments would be the use of pick-by-voice and/or pick-to-light since those technologies are already in use at MC. Therefore, the short-term recommendation is to investigate the possibility of utilizing those for the external picking process. In the long run, the implementation of smart gloves and glasses should be investigated properly, and the possibility of learning from other parts of Scania should be utilized.

Placement of SKUs

The process of picking items intended for TC would benefit by reconsidering SKU locations at MC to mitigate the risk of mispicks. The obvious benefit of this is that the mispick rate will be reduced, not only for the external picking process but in theory also for the picking of items to the main production line. Moreover, by ensuring this, the need for pickers to keep track of items with similar appearances or article numbers is reduced, which in turn allows for a more efficient picking process.

Recommendation 3: When assigning SKUs to locations, items that either have similar appearances and/or article numbers should not be placed close to each other. Items that are currently stored in inappropriate locations should be moved. However, if there is a reason for the items to be close to each other, proper distinctions should be made.

The responsibility of SKU locations lies on MCLD's logistics engineers, why the responsibility of properly placing newly introduced items is their responsibility. The items found to be frequently mispicked in the analysis conducted for this thesis should be moved, of which the responsibility also lies on the logistics engineers. Lastly, if in the future, it surfaces that other items are frequently mispicked, an investigation should be made by the group manager in order to see what the cause may be, and appropriate actions should be taken. However, if items need to be stored close to each other to satisfy the need of the main production, pronounced labeling should be implemented. If the location is in a flow rack, labels are needed on both the restocking and picking sides, since external picking is commonly conducted from the restocking side. As an extra precaution, the items can be stored as far apart as possible within the rack.

Standardized picking process

The lack of standardization is impeding process performance. Developing routines for how the night pickers should conduct their picking (in terms of where to pick from and where to place the items) should lead to fewer errors and in the long run increase efficiency. Furthermore, it would facilitate the assembly process at TC due to easier localization of items in the pallets.

Recommendation 4: Develop a standardized picking process for the night pickers.

To agree on a procedure, the night manager should, with input from the pickers, establish a rationale for when to pick from lines and when to pick from platforms. A folder with pictures of where to put the picked items, similar to the one used by the day pickers, should be developed and used. A step-wise implementation ought to be the most effective since it allows the pickers to learn and accept the new routines.

Standardized error reports

In order for data to be useful, it must be consistent and legitimate. Thus, standardized procedures for how to collect data and report deviations should be established. The chosen method is beneficially implemented across all four flows to ensure uniformity and enable benchmarking.

Recommendation 5: Standardize data collection of errors and enhance data consistency.

The group managers for each flow should meet and agree on a solution that works for everyone, possibly EQ. In the system, picking errors should be divided into three categories; ‘mispicked’, ‘wrong quantity’, and ‘not picked’. After the procedure has been determined, they must communicate it to the recipients of the picked items and ensure that they too understand the importance of keeping records. Only when the internal customers persistently bring attention to the problems can the performance be continuously improved.

Performance measurements

Currently, the quality metric 'picking errors' is the only KPI measured pertaining to the external picking. Further, the use of this metric to drive functional improvements is limited. To increase the process maturity and allow managers to understand the performance of their respective flows more comprehensively, KPIs should be utilized to a greater extent.

Recommendation 6: Implement cost, efficiency, and quality metrics to track performance and set ambitious targets. Compare the KPIs to benchmarks and customer needs.

The cost metrics should preferably be derived from customer requirements. Considering that the functional managers possess the most knowledge of the respective customer needs, the task of developing proper metrics is appropriately allocated to them. Once the metrics have been established, it is up to the managers to take advantage of the insights gained.

6.2 Organizational Structure

Process owner

In the analysis, it was found that the external picking process lacks an official process owner. To improve the process maturity and realize synergies between the flows, a person with the authority to redesign the process should be appointed. The process owner should document the process, ensure compliance with the process design, and articulate a vision for the process' future state.

Recommendation 7: Appoint a formal process owner with clear responsibilities and the authority to initiate improvement efforts.

The implementation of this recommendation is difficult since it requires some organizational restructuring. Currently, the functions MCLFL, MCLFV, and MCAEL are involved in the picking of mixed pallets. MCLFL and MCLFV are part of the larger group MCL (logistics) whereas MCAEL belongs to the group MCA (assembly). Considering that the act of picking items is a logistics activity, we suggest that the pickers from MCAEL are formally relocated to MCLFL. This does not imply that their tasks are any different – the purpose is simply to reduce the number of functions involved and to unite the pickers. What it does imply is that the setup changes from day picking (MCAEL) and night picking (MCAEL + MCLFL) to day + night picking (MCLFL). This group could have two co-managers (one for the day and one for the night) which means that the responsibilities are maintained. Lastly, these two and the group manager from MCLFV would report to the newly appointed process owner, e.g. the manager for MCLF. To realize this change, one would have to address the question on a rather high level in the organization since it concerns two separate branches of the organizational structure (MCA and MCL).

Zone-oriented picking strategy

As concluded in the literature review, picking is time-consuming and thus costly. In most picking operations, traveling is the main driver of cost. Consequently, actions should be taken to reduce traveling. This can be done by abandoning the customer-oriented division of responsibilities to pursue a more explicit zone-oriented picking strategy. Implementing this would also enable the pickers to become experts on the picking in their respective zones.

Recommendation 8: Assign the responsibility of picks based on the location of picks rather than based on who the internal customer is.

The practical implications of adopting this approach are that the lines for which function conducts picks for which customer is blurred. To exemplify, let's revisit the current solution for LSV-picks. The repackaging team conducts most of these picks from the repack conveyor. When that is not possible, they travel across the facility to pick items from lines/platforms. With the new approach, all picks from lines/platforms would be conducted by the day or night pickers regardless of the customer, thus allowing the repackaging team to be more stationary. Similarly, picks to for example "Partner X" could (to some extent) be reassigned to the repackaging team since these order characteristics are closely related to the LSV orders. The feasibility of this implementation is dependent on some of the earlier recommendations (Recommendations 6 and 7). Extensive data on picking times etc. must be available to allocate resources appropriately and a process owner must be appointed to supervise the implementation.

6.3 Flow-Specific

6.3.1 Technical Center

Forward area – Paternoster

Moving the break area into a construction barrack would free up valuable space in proximity to the production lines at LVL. A space-efficient solution would be to introduce a paternoster at this location. Storing IP items in a paternoster would induce several benefits and the investment of a single paternoster has a theoretical payback time of less than 2 years. The paternoster would probably not utilize all freed-up space, allowing that space to be used for other purposes as well. Even if one would decide that a paternoster is not of interest, the move of the break area should still be considered due to the benefits of attaining more available space.

Recommendation 9: Move the break area at LVL and store IP items in paternoster at TC.

The comprehensive explanation of how we suggest the responsibilities of this solution to be distributed is explained in subsection *5.3.1 Technical Center*. However, the responsibility for conducting the actual implementation of this change would fall on MCLD in order to disseminate RFQs (request for quotations) to potential suppliers of paternosters and construction barracks.

Lowest shelf redesign

With today's solution of avoiding the placement of items on the lowest shelf in the pallets, up to one-third of the pallet might not be utilized. Placing rails on the lowest shelf (similar to a drawer) would remove the need for employees to crawl on the floor to reach items on said shelf, and allow them to only conduct vertical lifts instead of angled lifts.

Recommendation 10: Modify the pallets to enable higher utilization and better ergonomics.

Firstly, an actual design of this solution would need to be developed (e.g. by the logistics engineers – part of the MCLD team). The physical implementation of this modification would not require the production to come to a halt since not all pallets are used each day. Therefore, with proper planning, a few pallets at a time can be modified and the project can be continuously ongoing during a predetermined time period. The modification work can be conducted by an already existing business partner that handles pallet maintenance.

6.3.2 Laxå Special Vehicles

Communication

Many of the problems related to the LSV flow stems from inadequate communication. Time and effort should be devoted to improving upon this aspect. By having a better dialogue, material planning can be improved and consequently, issues related to the return flow should decrease. Furthermore, picking accuracy could be improved if relevant data is shared.

Recommendation 11: Maintain frequent contact with representatives from LSV and cooperate to solve functional problems. Make sure that the information reaches all relevant parties within both organizations.

By incorporating LSV’s production schedule and forecasts with Scania’s material planning, the likelihood of being able to meet LSV’s demand is increased – consequently reducing the need for emergency orders. The main dialogue should be held between material/production planners from Scania and LSV. After the meetings, it is up to the participants to ensure sufficient dissemination of information within their respective organizations. Employees at LSV need to know how to report deviations while the pickers at Scania need to be informed when they have made a mistake.

6.3.3 Spare parts

Picking heavy items

Heavy lifting is an ergonomic peril that should be avoided if possible. Furthermore, the heavy lifting with regard to spare parts is often conducted by several employees, making the task burdensome and labor-intensive. Concurrently, the lifting equipment used by the personnel from the main production line remains untouched during nighttime.

Recommendation 12: Investigate if some of the heavy picks could be conducted at night with the use of pre-existing lifting equipment and/or if a mobile lifting device is a feasible solution.

Since the existing equipment is not very difficult to learn, the night pickers could, in theory, take over the responsibility of these picks immediately. However, some prerequisites are needed. First of all, members of the MCLD team have to conduct an analysis concerning which of the heavy picks could utilize lifting equipment during the night. Secondly, the recommendation does not conform with the current organizational setup where MCLFV, who only works daytime, is responsible for the Spare parts flow. Hence, the implementation of this is dependent on the implementation of the zone-oriented picking strategy (Recommendation 8). If the picking instead should be conducted during daytime, or the existing equipment is deemed insufficient, an investigation regarding mobile lifting devices should be conducted.

6.3.4 "Partner X"

Partnership agreement

The collaboration that Scania has with "Partner X" is quite different from the other material flows investigated in this study – it is the only flow where components are shipped to a business partner unrelated to Scania and the Traton Group. Questions by various employees have been raised regarding whether the partnership makes sense, and if the benefits are worth the effects it might have on other operations.

Recommendation 13: Investigate whether the value of the partnership outweighs its costs and perceived cumbersomeness.

The partnership with "Partner X" is still in relatively early stages, which is why this evaluation is hard to conduct at this point. However, once the collaboration is up and running, the customer responsible at Scania together with individuals from the organizations involved in this material flow should conduct a comprehensive investigation of how it affects other operations in Oskarshamn. Moreover, depending on if recommendation 6 (Performance measurements) is implemented and more data becomes available, an analysis of the actual profitability of this material flow can be conducted.

7 CONCLUSION

In this final chapter, the thesis is concluded. Firstly, the purpose fulfillment is addressed and answers to the sub-questions are summarized. Following is a discussion regarding the generalization and credibility of the results. Next, we highlight the limitations of the study and propose future areas of research, both in general and for Scania Oskarshamn. Finally, a short section with concluding remarks is provided, thus bringing this thesis to its end.

7.1 Purpose Fulfillment

The purpose, quoted from section *1.3 Purpose of the Study* reads as follows:

> *"The purpose of this master thesis is to propose improvements for the process of external picking at Scania's production unit in Oskarshamn and to provide suggestions on how such changes can be implemented."*

To fulfill the purpose, the research question "*How can Scania's process of external picking be improved?*", presented in section *1.4 Research Questions,* was developed together with four supporting sub-questions. The various chapters provide answers to the sub-questions, which in turn act as building blocks to answer the actual RQ. This methodical process has enabled well-grounded suggestions of improvement together with how they can be implemented – thus the purpose of this thesis has been fulfilled. The structure of how the sub-questions have been answered is explained in the remainder of this section.

> ***RQa: What do the material flow and processes related to external picking currently look like?***

This first sub-question, RQa, is answered in chapter *4 Empirical Study*. Firstly, the context of the external picking process is explained, including; who the customers are, what the operations in Oskarshamn look like on a general basis, and how the organization is structured. Secondly, the investigation into the identified material flows is presented. Here, each flow is mapped in three ways; (1) the material flow, (2) the organizational responsibilities, and (3) the picking process. By this, a comprehensive explanation of the material flows and the processes is provided.

It was found that the material flows can be categorized as follows; (1) TC, (2) Laxå Special Vehicles, (3) Spare parts, and (4) "Partner X". The responsibility of picking mixed pallets is divided between three different organizations, based on material flow; MCAEL and MCLFL pick the mixed pallets for the TC and "Partner X" flows, while MCLFV picks the items for the Laxå Special Vehicles and Spare parts flows. Moreover, on a general basis, the external picking process can be described as significantly different from the processes conducted for the material intended for the main production line. The external picking process is not a core process for Scania, which is why the pickers have to yield and wait in case they risk interfering with any process related to the main production.

> ***RQb: What are the problems and drawbacks of the current solution?***

The second sub-question, RQb, is answered both in chapter *4 Empirical Study* and *5 Analysis*. When the four flows are presented in section *4.2 Material Flows and Processes to Internal*

Customers, the challenges for each of them are presented based on what was brought up and explained by the interviewees. Moreover, in the analysis, this sub-question has been investigated by (1) comparing the current solution with literature, (2) analyzing data, and (3) applying a theoretical model to attain insights regarding where the need for improvement is greatest.

The main problems with the current solution are that standardized working routines are not established, that the level of digitalization and data collection is deficient, and that multiple separate organizations are involved in the picking process. In addition, assistive devices are not yet utilized for the external picking, as opposed to the picking for the main production lines. Furthermore, flow-specific challenges such as limitations in space and inadequate communication have been identified.

RQc: Which changes can be done to improve the current logistical setup?

Throughout chapter *5 Analysis*, the problems highlighted by RQb were investigated. By addressing each challenge and developing potential solutions, RQc was answered. It was found that a considerable number of ideas could be implemented to ultimately improve the logistical setup. Some of the most significant changes discussed were the possibility of developing standardized routines, the introduction of more developed IT solutions in combination with the implementation of assistive technologies, and the need for organizational restructuring. Moreover, actions for removing bottlenecks and reducing the frequency of picking errors were discussed.

RQd: What changes should be done and how can they be implemented?

The fourth, and final, sub-question is answered in chapter *6 Recommendations*. The possibilities investigated in chapter *5 Analysis* that were considered most advantageous for Scania were cherry-picked and modified to actual recommendations. The recommendations follow a generic structure; (1) it is explained what the recommendation would entail, (2) the recommendation is stated, and (3) it is explained how it should be implemented.

In total, 13 recommendations were developed and divided into three main areas depending on whether they were related to the general order-picking process, the organizational structure, or a specific flow. The recommendations within the order-picking category concern IT and technology, standardization of the process, and the implementation of performance measurements. When it comes to the organizational structure, the recommendations are to appoint a formal process owner and to pursue a zone-oriented picking strategy. Lastly, the flow-specific recommendations range from installing a paternoster to reevaluating the entire relationship with an external partner.

7.2 Generalization of Results

The results can be generalized from three distinctive perspectives: (1) internally at Scania, (2) externally for other actors, and (3) for academia. For Scania, the results of this thesis reveal the importance of not neglecting non-core processes. This goes beyond the scope of external picking and applies to virtually all business areas. Furthermore, the findings regarding standardization and communication are highly relevant for all processes. Keeping this in mind, Scania can work with process development at other production units and potentially recognize previously undiscovered opportunities for improved performance. Secondly, for the external actors, this thesis can be of interest when looking at improving non-core processes in general, but especially when looking to improve a low volume picking process that is run in parallel with more prioritized picking processes. However, challenges and the corresponding recommendations might vary as some challenges are specific to Scania's operational setup and organizational structure. Lastly, with regards to the generalization towards academia it is quite low considering that it is a single case study – just because this is the situation at one automotive company does not mean it is statistically true from an academic overarching perspective. However, it can act as an interesting example for university courses or as part of literature reviews in future studies.

7.3 Credibility of Results

To attain credibility in this study, the theory included in section *2.5 Credibility of Study* concerning validity, reliability, and objectivity has been utilized.

The concept of validity relates to measuring what you intend to measure. Since the phenomenon of external picking was not comprehensively understood by a single employee at Scania, the right questions had to be asked to the right persons. This was ensured by having an open-minded approach to all interviews. If an interviewee could not answer a question with utmost certainty, contact was established with another employee more involved in the operations related to that particular question to guarantee that all collected data was valid. In addition, the triangulation principle was continuously sought. The interviews were complemented with observations of the processes and when possible, quantitative data was gathered to further enhance the validity. Consequently, the influence of fundamental biases on the results should be negligible.

To attain reliability in the study, i.e. that the result will be consistent over time and that the results can be reproduced, various precautionary measures have been taken. For example, control questions have been asked during interviews to ensure that the data gathered is of good quality. Moreover, the same questions have been asked in interviews with different individuals to ensure that we get consistent answers which thus improves the likelihood of attaining a correct understanding.

With regards to objectivity, there has been great focus on keeping an open mind and considering alternative competing explanations to data. For example, individuals actively participating in a process do, to varying degrees, provide their own subjective opinions on (1) how well a process works, (2) what challenges there are, and (3) what the underlying reasons for said challenges might be. For this reason, interviews with several individuals with insights into the same flow have been conducted to attain an objective understanding.

7.4 Future Research

7.4.1 Scania

Throughout the work with this thesis, several interesting areas for future research within Scania have been encountered. The reason why these were not investigated is either that they were impossible to scrutinize due to limitations in data availability or that they simply were out of scope.

If the data were to improve in the future, more quantitative analyses would appropriately be conducted to strengthen the findings from this thesis and provide new insights. This relates both to quality, cost, and time. One aspect we consider particularly interesting is that of resource allocation. To be able to determine how many pickers should work in each team and assess the need for different capabilities, one would have to know how much time is spent picking for each order/line/platform. By analyzing this, it would also be possible to conclude whether the night shift could be transformed into a secondary day shift instead.

The only actor involved in all four flows is the logistics center managed by the organization OLO. Their role in the external picking process was excluded in this study due to time constraints. We believe that a thorough analysis of the activities and systems in place there is a highly relevant area of future research (perhaps in the form of a master's thesis). Such an investigation would push the boundaries of this thesis, extend our findings, and ultimately result in a more holistic understanding of the external picking.

Lastly, we have to mention the absurd situation where a complete cab body is built and painted in MB just to send a spare door to one of the chassis factories. Since only the door is needed, the remainder of the body is scrapped. While this is clearly out of the scope of this thesis, it is the most peculiar solution we encountered. It ought to be a better, more sustainable solution out there. An investigation of this, examining the avoidable scrap and environmental impact stemming from the manufacturing process would be very interesting. It should also be interesting for Scania, as this could not only cut costs but also help them in their pursuit of environmental sustainability.

7.4.2 Academic research

Future research with an academic perspective that would be interesting to see, is e.g. a multiple case study that investigates how similar processes are conducted at other manufacturing companies in order to develop best practices. However, setups similar to the one investigated in this study are probably highly individualized and customized to the specific factory and warehouse solutions, which is why general best practices might be difficult to develop.

During the literature review, it was also noted that the academic literature does not seem to have investigated the phenomenon of parallel material flows to a great extent. In the case of this study, parallel material flow refers to the setup where Scania Oskarshamn (more specifically MC) primarily ships finalized truck cabs, but shipments of individual SKUs or sub-assemblies are also made. Thus, since we perceived a lack of such literature, it would be interesting to see if future research within logistics, supply chain, and operations would dig deeper into this area.

7.5 Concluding Remarks

The authors of this master thesis found the subject of material flows and picking processes highly interesting and relevant to our graduate studies. It has been challenging at times considering that there is no single individual or organization with a holistic understanding of all the material flows and processes investigated. For that reason, it has allowed us as researchers to talk to individuals from various parts of Scania in Oskarshamn. Thanks to all the interviews and observations made, it has also allowed for great individual developments. We hope the readers of this thesis have found it insightful and interesting.

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APPENDIX

Appendix A – Interviewees

INTERVIEWEE	ROLE	ORG.	FOCUS OF THE INTERVIEW(S)	FLOW
Maria Fyhr	Logistics Developer	MCLD	About one meeting per week during this semester to ask general questions about Scania Oskarshamn.	• All flows
Åsa Bergström	Material handler	MCLFV	**1st interview:** To understand the general process of picking to LSV and Chassis/Spare part. **2nd interview:** To get deeper understanding and confirm initial mapping of flow and process.	• LSV • Spare parts
Lars Gustafsson	Logistics developer	MCLD	To understand the relationship between Scania and "Partner X".	• "Partner X"
Anneli Nilsson	Project manager logistics development	MCLD	**1st interview:** To understand what differentiates LVL to ordinary production, and to understand the general material flow from MC to TC. **2nd interview:** To confirm initial mapping and get deeper understanding of challenges.	• TC
Sylvia Erlandsson	Group manager (LVL)	MCAEL	**1st interview:** To understand the workload distribution (w.r.t. picking) between organizations. **2nd interview:** Confirm initial mapping, understand process of day picking, and discuss KPIs.	• TC • "Partner X"
"Partner X" picker	Material handler/picker	MCAEL	To understand the picking process at TC for material heading to "Partner X".	• "Partner X"
Johan Winnsäter	Production planner	MCLP	To understand the production planning and how orders are generated.	• LSV • "Partner X" • Spare parts
Marilyn Holmberg	Material handler	MCAEL	To understand how the picklists for "Partner X" are generated and to get a better understanding of the material flow between MC and TC.	• TC • "Partner X"
Maria Brånstrand	Group manager (factory feeding night)	MCLFL	**1st interview:** To understand the night picking process at MC for material heading to TC and "Partner X". **2nd interview:** To confirm initial mapping, clarify processes, and discuss KPIs.	• TC • "Partner X"
Emma Johansson	Group manager (workshop technicians)	MCLFV	**1st interview:** To understand the relationship and material flows to LSV and Chassis/Spare parts. **2nd interview:** To confirm initial mapping, get deeper understanding of challenges, and discuss KPIs.	• LSV • Spare parts
Sinnika Lindgren	Workshop technician	MPCA	To understand the situation at the Arena.	• TC

Appendix B – Problematic SKU locations

Item 2 629 994 is commonly picked instead of 2 824 094. A potential reason for this is the identical last two digits and the items being stored right next to each other.

Item 2 655 769 is commonly picked instead of 2 655 768. A potential reason for this is that all digits are identical except the last one and the items being stored in the same rack. Moreover, the only difference between these items is that one is intended for right-hand drive and the other for left-hand drive – meaning the only visual difference is that they are mirrored.

Appendix C – Maturity of the external picking process assessed

		P-1	P-2	P-3	P-4
Design	Purpose	The process has not been designed on an end-to-end basis. Functional managers use the legacy design primarily as a context for functional performance improvement.	The process has been redesigned from end to end in order to optimize its performance.	The process has been designed to fit with other enterprise processes and with the enterprise's IT systems in order to optimize the enterprise's performance.	The process has been designed to fit with customer and supplier processes in order to optimize interenterprise performance.
	Context	The process's inputs, outputs, suppliers, and customers have been identified.	The needs of the process's customers are known and agreed upon.	The process owner and the owners of the other processes with which the process interfaces have established mutual performance expectations.	The process owner and the owners of customer and supplier processes with which the process interfaces have established mutual performance expectations.
	Documentation	The documentation of the process is primarily functional, but it identifies the interconnections among the organizations involved in executing the process.	There is end-to-end documentation of the process design.	The process documentation describes the process's interfaces with, and expectations of, other processes and links the process to the enterprise's system and data architecture.	An electronic representation of the process design supports its performance and management and allows analysis of environmental changes and process reconfigurations.
Performers	Knowledge	Performers can name the process they execute and identify the key metrics of its performance.	Performers can describe the process's overall flow; how their work affects customers, other employees in the process, and the process's performance; and the required and actual performance levels.	Performers are familiar both with fundamental business concepts and with the drivers of enterprise performance and can describe how their work affects other processes and the enterprise's performance.	Performers are familiar with the enterprise's industry and its trends and can describe how their work affects interenterprise performance.
	Skills	Performers are skilled in problem solving and process improvement techniques.	Performers are skilled in teamwork and self-management.	Performers are skilled at business decision making.	Performers are skilled at change management and change implementation.
	Behavior	Performers have some allegiance to the process, but owe primary allegiance to their function.	Performers try to follow the process design, perform it correctly, and work in ways that will enable other people who execute the process to do their work effectively.	Performers strive to ensure that the process delivers the results needed to achieve the enterprise's goals.	Performers look for signs that the process should change, and they propose improvements to the process.
Owner	Identity	The process owner is an individual or a group informally charged with improving the process's performance.	Enterprise leadership has created an official process owner role and has filled the position with a senior manager who has clout and credibility.	The process comes first for the owner in terms of time allocation, mind share, and personal goals.	The process owner is a member of the enterprise's seniormost decision-making body.
	Activities	The process owner identifies and documents the process, communicates it to all the performers, and sponsors small-scale change projects.	The process owner articulates the process's performance goals and a vision of its future; sponsors redesign and improvement efforts; plans their implementation; and ensures compliance with the process design.	The process owner works with other process owners to integrate processes to achieve the enterprise's goals.	The process owner develops a rolling strategic plan for the process, participates in enterprise-level strategic planning, and collaborates with his or her counterparts working for customers and suppliers to sponsor interenterprise process-redesign initiatives.
	Authority	The process owner lobbies for the process but can only encourage functional managers to make changes.	The process owner can convene a process redesign team and implement the new design and has some control over the technology budget for the process.	The process owner controls the IT systems that support the process and any projects that change the process and has some influence over personnel assignments and evaluations as well as the process's budget.	The process owner controls the process's budget and exerts strong influence over personnel assignments and evaluations.
Infrastructure	Information Systems	Fragmented legacy IT systems support the process.	An IT system constructed from functional components supports the process.	An integrated IT system, designed with the process in mind and adhering to enterprise standards, supports the process.	An IT system with a modular architecture that adheres to industry standards for interenterprise communication supports the process.
	Human Resource Systems	Functional managers reward the attainment of functional excellence and the resolution of functional problems in a process context.	The process's design drives role definitions, job descriptions, and competency profiles. Job training is based on process documentation.	Hiring, development, reward, and recognition systems emphasize the process's needs and results and balance them against the enterprise's needs.	Hiring, development, reward, and recognition systems reinforce the importance of intra- and interenterprise collaboration, personal learning, and organizational change.
Metrics	Definition	The process has some basic cost and quality metrics.	The process has end-to-end process metrics derived from customer requirements.	The process's metrics as well as cross-process metrics have been derived from the enterprise's strategic goals.	The process's metrics have been derived from interenterprise goals.
	Uses	Managers use the process's metrics to track its performance, identify root causes of faulty performance, and drive functional improvements.	Managers use the process's metrics to compare its performance to benchmarks, best-in-class performance, and customer needs and to set performance targets.	Managers present the metrics to process performers for awareness and motivation. They use dashboards based on the metrics for day-to-day management of the process.	Managers regularly review and refresh the process's metrics and targets and use them in strategic planning.