Reconfiguring distribution routes to increase vehicle efficiency after inventory centralization

A design science study at a Swedish food wholesaler

Master Thesis for M.Sc. in Industrial Engineering and Management

Division of Engineering Logistics

Department of Mechanical Engineering Sciences

Faculty of Engineering, LTH Lund University

Authors: Sofia Larsson and Sofia Ottosson

Supervisor: Sandeep Jagtap, Division of Engineering Logistics, Lund University

Examiner: Joakim Kembro, Division of Engineering Logistics, Lund University

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This thesis was written in the spring of 2023 and concludes our Master of Science degree in Industrial Engineering and Management at the Faculty of Engineering, Lund University. This master's thesis is a design science study about how to reconfigure distribution routes to increase vehicle efficiency after centralizing inventory to one stocking point.

We would like to acknowledge our supervisor, Sandeep Jagtap, at Division of Engineering Logistics, Lund University for guiding us through this project and providing feedback on our thesis.

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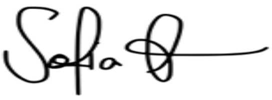

Sofia Larsson *Sofia Ottosson*

Lund, May 2024

ABSTRACT

Title	Reconfiguring distribution routes to increase vehicle efficiency after inventory centralization
Authors	Sofia Larsson, Sofia Ottosson
Supervisor	Sandeep Jagtap, Division of Engineering Logistics, Lund University
Background	Companies are increasingly realizing that efficient distribution can contribute to gaining a competitive advantage in the market. By efficiently routing vehicles, the optimal balance between customer service and costs can be achieved. Consequently, the vehicle routing problem is one of the most critical challenges logistics companies face today. However, previous research on vehicle routing in the context of inventory centralization and from a business perspective is scarce and therefore, this research aims to develop a solution for a company in this context.
Problem Description	The Company is in the process of centralizing its inventory into one central warehouse in the south of Sweden. In conjunction with centralizing the inventory, The Company aims to reconfigure its distribution routes to increase the truckload utilization of its in-house vehicles.
Purpose	The purpose of this thesis is to propose a reconfiguration of The Company's distribution routes to increase vehicle efficiency after centralizing inventory to one stocking point.
Research Questions	*RQ1: How is the current distribution setup at The Company designed? What are the key factors to consider when configuring routes at The Company?* *RQ2: How should future distribution routes be configured after centralizing inventory to maximize truckload utilization?* *RQ3: How does the proposed solution compare to the existing configuration?*
Methodology	This thesis followed a design science research methodology. Based on literature, an analytical framework (the artifact) was created. The analytical framework was demonstrated by applying it to a company in a single case study. Data was collected through secondary data collection, interviews, and observations and analyzed using the analytical framework.
Conclusion/ Findings	By applying the analytical framework to The Company, a future route configuration was proposed. When comparing the proposed solution to the current, it is estimated that the truckload utilization can be increased by 42%. Thus, the purpose of this thesis is achieved. Based on the solution, some next steps for implementing the new route configuration were identified.

Contribution: This thesis has been a complete elaboration between the two authors. Each author has been involved in every part of the process and contributed equally.

Keywords: truckload utilization, inventory centralization, transport planning, vehicle routing, distribution management

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DEFINITIONS

Truckload utilization	Truckload utilization refers to the efficiency with which the available space in a truck is used for transporting goods. It is a measure of how well a truck's capacity is utilized relative to its maximum capacity.
Vehicle efficiency	Vehicle efficiency refers to maximizing the amount of goods moved on the vehicles and minimize vehicle mileage

ABBREVIATIONS

B2B	Business-To-Business
B2C	Business-To-Consumer
CVRP	Capacitated Vehicle Routing Problem
FMCG	Fast Moving Consumer Goods
KPI	Key Performance Indicator
MCV	Multiple Compartment Vehicles
PVRP	Periodic Vehicle Routing Problem
RQ	Research Question
SCOR	Supply Chain Operation Reference
SCV	Single Compartment Vehicles
VJE	Vehicle Journey Efficiency
VRP	Vehicle Routing Problem
VRPTW	Vehicle Routing Problem with Time Windows
VSE	Vehicle Shipping Efficiency
VWE	Vehicle Weighted Efficiency
3PL	Third Party Logistics

1 INTRODUCTION

The purpose of this chapter is to identify a practical problem and motivate the research potential for this problem. This chapter encompasses the thesis background, a company overview, the thesis purpose, and the research questions to be addressed. Subsequently, the focus and delimitations of the thesis will be presented. Finally, the disposition of this thesis will be provided.

1.1 Background

Distribution refers to moving a product from the supplier to the customer and plays an important role in a company's supply chain operations (Chopra & Meindl, 2007, p. 81; Kazmi & Ahmed, 2022). It impacts both supply chain costs and the customer experience, and, therefore, can be seen as a key driver of a company's profitability influencing revenue and costs (Chopra, 2003). The significance of distribution is further exemplified by its impact on supply chain costs related to inventory, transportation, facilities & handling, and information, which are four of the six drivers for supply chain performance identified by Chopra & Meindl (2007, pp. 56-58).

In recent years, there has been a notable shift in attitudes towards distribution and logistics. The perception of distribution has changed from being an operational necessity that merely increases expenses for companies selling products, to being recognized as an activity that can provide a positive contribution to the value of a product (Kent & Flint, 1997; Rushton et al., 2014, p. 27). As distribution operations play a crucial role in ensuring that products reach the customer in the desired condition and location, companies have increasingly realized that efficient distribution can contribute to gaining a competitive advantage in the market (Kazmi & Ahmed, 2022; Rushton et al., 2014, p. 27). In addition to enhancing customer service levels (Manzini et al., 2013), an effective distribution network can present opportunities for improving financial performance (Rushton et al., 2014, p. 22). Due to companies acknowledging the significant importance of logistics to their overall business, there is now a growing need for effective planning and control of logistics activities, with distribution emerging as a crucial element (Gotzamani et al., 2010).

A crucial factor in establishing efficient distribution is achieving the optimal balance between customer service and costs (Hung Lau, 2012; Rushton et al., 2014, p. 481). Consequently, the primary objective in transportation is to optimize the use of assets while providing customers with an acceptable level of service (Chopra & Meindl, 2007, p. 414; Rushton et al., 2014, pp. 480-481). The objective can be accomplished through effective routing of vehicles aimed at optimizing asset utilization and thereby minimizing costs (Rushton et al., 2014, p. 474). The significance of vehicle routing in supply chain operations is highlighted by Konstantakopoulos et al. (2020), who state that vehicle routing largely determines distribution costs and customer satisfaction, making the Vehicle Routing Problem (VRP) one of the most critical challenges logistics companies face today.

Solving vehicle routing problems is generally complicated. Many aspects need consideration, and there are a large number of algorithms that can be used to address the problem (Konstantakopoulos et al., 2020; Rushton et al., 2014, p. 482). Extensive research exists on vehicle routing in various contexts (Konstantakopoulos et al., 2020). However, one field that has not received much research is vehicle routing in the context of a company transitioning from a decentralized to a centralized supply chain network. Additionally, most research papers approach vehicle routing from a strict mathematical optimization perspective rather than a business perspective. Therefore, this research aims to develop a solution for a company in the context of inventory centralization and enhance understanding of how routes can be configured from a business perspective to maximize asset utilization.

1.2 The Company

The case company studied in this thesis, from here referred to as 'The Company' for anonymity, is a Swedish wholesaler of food, delivering to business customers across the country. The Company is part of a large group consisting of companies in the same industry, thus facilitating access to suppliers and production from the other companies within the group.

In addition to their products, The Company offers services such as assisting and supporting their customers in business by providing recipes and practical advice that can boost customers' sales. The Company also aids customers in developing strategies and various marketing materials. Furthermore, The Company houses an innovation center dedicated to developing new products, recipes, and production solutions. Customers can consult the innovation center for enquiries related to the production process, recipe development, and packaging.

Distribution and logistics play a pivotal role in The Company's value proposition. They aim to ensure safe deliveries and customized packaging, striving to deliver "the right product at the right time".

1.3 Problem Description

The Company is in the process of making a major change to its supply chain network by centralizing its inventory into one central warehouse in the south of Sweden. This change will alter the conditions under which the distribution operates, necessitating a new route configuration. Additionally, The Company is experiencing low utilization of its in-house distribution vehicles. Therefore, in conjunction with centralizing the inventory, The Company aims to reconfigure its distribution routes to increase the truckload utilization of its in-house vehicles.

1.4 Purpose and Research Questions

The purpose of this thesis is to propose a reconfiguration of The Company's distribution routes to increase vehicle efficiency after centralizing inventory to one stocking point.

By analyzing the Company's current distribution setup, this thesis aims to identify key factors to consider in the route configuration at The Company and subsequently propose a solution that enhances vehicle efficiency. The proposed solution will take into account the new supply chain setup at The Company. This thesis will address the following research questions:

RQ1: How is the current distribution setup at The Company designed? What are the key factors to consider when configuring routes at The Company?

The first research question aims to map the current distribution at The Company, providing an overview critical for proposing a satisfactory solution. Specifically, The Company's business, network design, customers, products, distribution process, and distribution performance will be described. The second part of the research question aims to identify factors important in the configuration of distribution routes.

RQ2: How should future distribution routes be configured after centralizing inventory to maximize truckload utilization?

The second research question considers how to configure the routing of deliveries to customers within the context of the new supply chain setup, featuring a centralized warehouse instead of multiple decentralized warehouses. Routes will be configured primarily to maximize truckload utilization and secondarily to minimize travel distance.

RQ3: How does the proposed solution compare to the existing configuration?

The third and final research question will compare the performance of the current distribution configuration with the proposed configuration in terms of truckload utilization, travel distance, volume delivered, customers served, and outsourced volumes. This question will also include a qualitative comparison of the impact of the proposed configuration on The Company's business. This comparison will ensure that the proposed solution surpasses the current configuration and is therefore satisfactory. Finally, several recommendations regarding implementation of the new route configuration will be provided to The Company.

Based on the purpose and research questions above, a foundation for an analytical framework is constructed, as presented in Figure 1.1. The analytical framework illustrates how the three research questions will contribute to achieving the thesis' purpose.

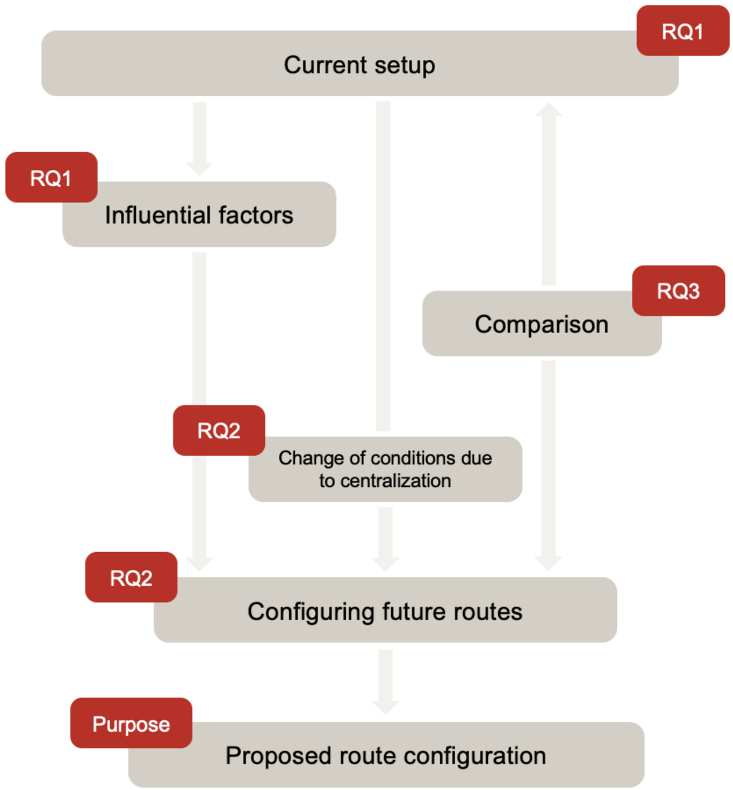


Figure 1.1: The foundation of the analytical framework based on the research questions and purpose

1.5 Focus and Delimitations

The objective of this thesis is to reconfigure the distribution routes from a wholesaler to their customers located in Sweden. This entails considering only downstream distribution, from the warehouse to the customer, see Figure 1.2. Hence, return orders from customers will be excluded from the analysis. The Company is a Swedish food wholesaler; thus, this study will be limited to distribution of food in a Business-to-Business (B2B) environment. The Company employs a combination of insourced and outsourced distribution, but this thesis will focus solely on configuring in-house distribution to maximize the utilization of The Company's own vehicles. However, the mapping of the current state, relating to the first research question, will include both in-house and outsourced distribution.

Data gathering will involve secondary data collection, observations, and interviews at The Company. Transactional data collected from The Company will be limited to 2023 to account for variability, assuming to represent a typical year.

This study will concentrate on how a medium-sized food wholesaler can enhance the utilization of their assets in distribution when transitioning from a decentralized to a centralized supply chain network. The findings of this study will be most relevant for similarly sized companies in the same or related industries facing a similar change in their supply chain network.

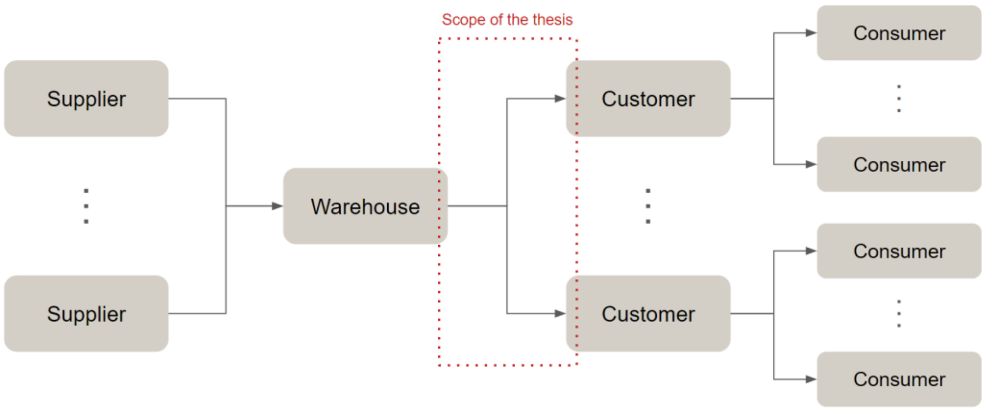


Figure 1.2: The scope of the thesis

1.6 Disposition

The following list outlines the structure of this thesis.

1. Introduction	This chapter covers the background of this thesis, an introduction to The Company, the problem description, purpose, and research questions. Finally, the focus and delimitations will be presented.
2. Methodology	This chapter covers the research strategy, research process and methods used for data collection. Finally, the strategy for data analysis is presented, and the research quality is discussed.
3. Frame of Reference	This chapter presents the theoretical foundation required to fulfill the purpose of this thesis. The frame of reference is divided into eight parts: distribution, outsourcing, food wholesale distribution, customer service, vehicle routing, distribution performance measurement, transport costs, and inventory centralization. Based on the frame of reference, an analytical framework is created and presented.
4. Empirical Findings	This chapter presents data about the current situation at The Company, gathered through interviews, observations, and secondary data collection. The chapter begins with an overview of The Company's business, followed by a description of the existing distribution network, demand and product characteristics, distribution process, and the performance of the current distribution network. Finally, a summary of the empirical findings is provided.
5. Analysis	This chapter contains three parts. The first part identifies factors to consider when route planning at The Company. The second part covers configuring the future routes and presenting the final route configuration. The third part consists of a quantitative and qualitative comparison between the current route configuration and the proposed solution. Finally, several recommendations on next steps will be provided.

6. Conclusion

This chapter contains three parts. The first part aims to answer all research questions. The second part discusses the theoretical and practical contribution of this thesis. The third part discusses limitations and suggests areas for future research.

2 METHODOLOGY

The aim of this chapter is to present the methodology used to fulfill the purpose of this thesis. The first part describes the research design, which includes selecting a research strategy and constructing the research process. This is followed by a description of the methods used for information collection, which is divided into literature review and empirical data collection. Afterwards, the methods for data analysis are presented and, finally, the research quality is discussed. The outline of this chapter is presented in Figure 2.1.

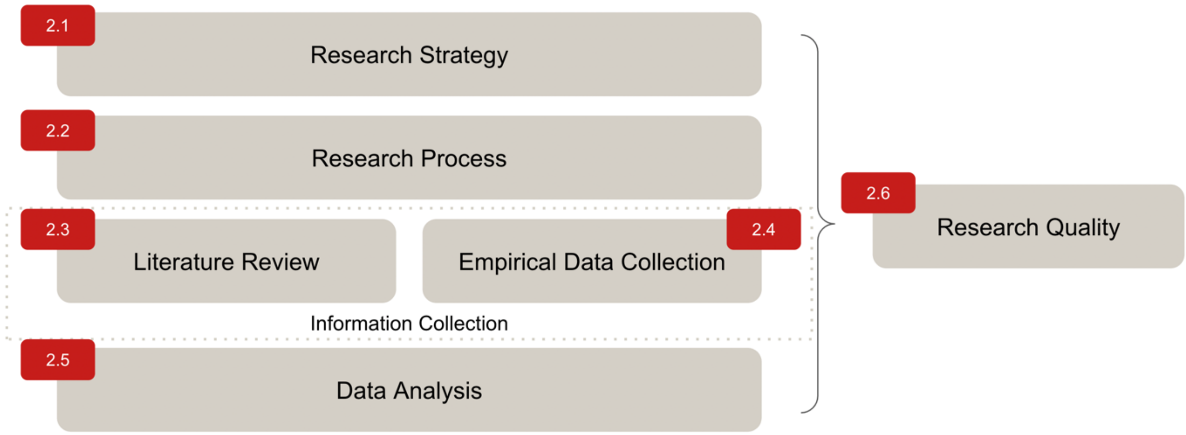


Figure 2.1: Outline of the methodology chapter

2.1 Research Strategy

The selection of research strategy is determined by the purpose of the thesis and the nature of the research questions. Lukka (2003) presents a matrix that can be used to choose a suitable research strategy. The matrix considers two different factors: whether the research is theoretical or empirical, and whether it is descriptive or normative. This thesis is considered empirical, as it requires data gathering through interviews, observations, and secondary data. Consequently, this study is placed on the right side of the matrix, as shown in Figure 2.2. Regarding whether the study is normative or descriptive, the first research question can be considered descriptive, since its purpose is to provide a detailed description of the current distribution. The second and third research questions aim to provide recommendations on how to reconfigure the distribution, and hence, they can be considered normative. According to the placement in the matrix presented by Lukka (2003), either design science or case study would be suitable research strategies.

In order to select one of the two methodologies, the primary differences between them need to be investigated. The main difference between a design science study and a case study lies in their respective purposes (Lukka, 2003). Case studies typically focus on describing and gaining a comprehensive understanding of empirical phenomena, while design science has a more problem-solving orientation, where the goal is to develop a satisfactory solution to a practical problem (Dresch et al., 2015a). Given that this thesis, particularly the second research question, seeks to address a practical issue within The Company, design science research emerges as an appropriate methodology.

Lukka (2003) describes the design science research strategy as "a procedure for producing innovative constructions", also called artifacts, intended to solve real-world problems and to contribute to both theory and practice. For research to be considered design science, the research must produce an artifact created to address a business problem (Peffers et al., 2007; Holmström et al., 2009). Further, the artifact has to be evaluated in terms of its utility, quality, and efficacy, and communicated appropriately (Peffers et al., 2007). The artifact could be for instance models, diagrams, plans, algorithms, or organization structures (Lukka, 2003). In this thesis, the artifact corresponds to the analytical framework for proposing a new route configuration. It is important that the artifact has practical relevance and is satisfactory to the problem under study, rather than being the optimal solution (Dresch et al., 2015a).

Another characteristic of design science research is that the research is linked to prior theoretical knowledge (Lukka, 2003). The development of the artifact should be a search process that draws from existing theories and knowledge to come up with a solution to the defined problem (Peffers et al., 2007). The empirical findings should then be reflected back to theory to contribute to the advancement of knowledge (Lukka, 2003). Even though the addressed problem is unique and specific, the solution has to be generalized to a specific class of problems (Dresch et al., 2015a). This emphasizes the need for a robust frame of reference.

While it is often challenging to align academic research interests with managerial practice interests (Holmström et al., 2009), design science research offers the advantage of narrowing the gap between practical implementation and research through knowledge interchange between practitioners and academics (Lukka, 2003; Dresch et al., 2015a). In line with this, Holmström et al. (2009) argues that the main strength of the design science approach is its focus on improving practice. However, the close collaboration between practitioners and academics can also bring risks, such as collusion of interests between the target organization and the researcher and the risk for not enough commitment from the organization (Lukka, 2003).

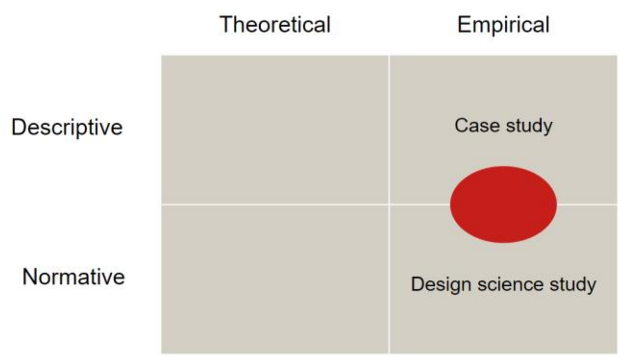


Figure 2.2: The placement of this study in Lukka's (2003) matrix

2.2 Research Process

This section will be divided into two parts. First, the research process will be constructed with the help of previous literature and subsequently, the application of the research process will be presented.

2.2.1 Construction of the Research Process

In order to construct a suitable research process for this study, inspiration was taken from two different design science processes presented by Peffers et al. (2007) and Dresch et al. (2015b, p. 81). Peffers et al. (2007) present a design science research process which comprises six steps, including: (1) problem identification and motivation, (2) definition of the objectives for a solution, (3) design and development, (4) demonstration, (5) evaluation and (6) communication. The authors emphasize that a researcher may not necessarily proceed the six steps in sequential order. Instead, a process iteration is likely to occur, typically between steps (2) and (6), see Figure 2.3. The first step in the model presented by Peffers et al. (2007) is about defining the problem and justifying the value of a solution, i.e., providing motivation for why research is conducted (Peffers et al., 2007). The second step involves defining the objectives of the solution based on the problem formulation. The objectives can be both qualitative and quantitative and should focus on illustrating how the new solution will surpass existing ones. The next step is to transition from the objectives into a design and create the artifact. This step involves determining the desired functionality of the artifact and applying theory to formulate the solution (Peffers et al., 2007). Stage (4) demonstration is about demonstrating the use of the artifact to solve the problem, in terms of, for instance, experimentation, simulation or a case study. The fifth step, evaluation, concerns observing and measuring how the artifact supports a solution to the defined problem, for instance by comparing the objectives with the observed results of the demonstration. In order to do this, quantifiable measures of system performance are needed (Peffers et al., 2007). At the end of this stage, there is possibility to iterate back to stage (3) if needed to improve the metrics further by modifying the design of the artifact. The final step is about communicating the results and their importance to relevant audiences, such as researchers and professionals (Peffers et al., 2007).

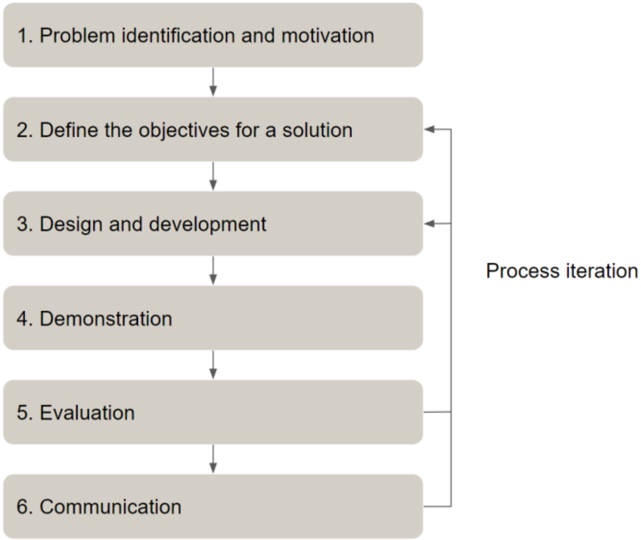


Figure 2.3: The design science process by Peffers et al. (2007)

The research process presented by Peffers et al. (2007) is satisfactory as it defines the fundamental processes of design science in a comprehensible manner. However, it may lack the perspective of generalizing the knowledge gained, which is needed to make a theoretical contribution. Dresch et al. (2015b, p. 81) presents a research process for *reflective design*, which has the purpose of solving problems, not only in a particular context, but to find generic solutions that can be applied in various contexts, see Figure 2.4. This model starts with defining a business phenomenon and finding gaps in literature regarding this type of business problem. After that, a problem-solving cycle starts, which includes understanding and defining the problem, analysis, and diagnosis of the problem, designing the solution, implementing the solution, and evaluating the solution. Eventually, the evaluation may lead to new problems being recognized, and the problem cycle can start again. The problem-solving cycle is then followed by academic reflection, where the researcher reflects on the problem and the proposed solution in an aggregated form to generalize the knowledge gained. General requirements, design propositions, should be formulated for a given class of problems.

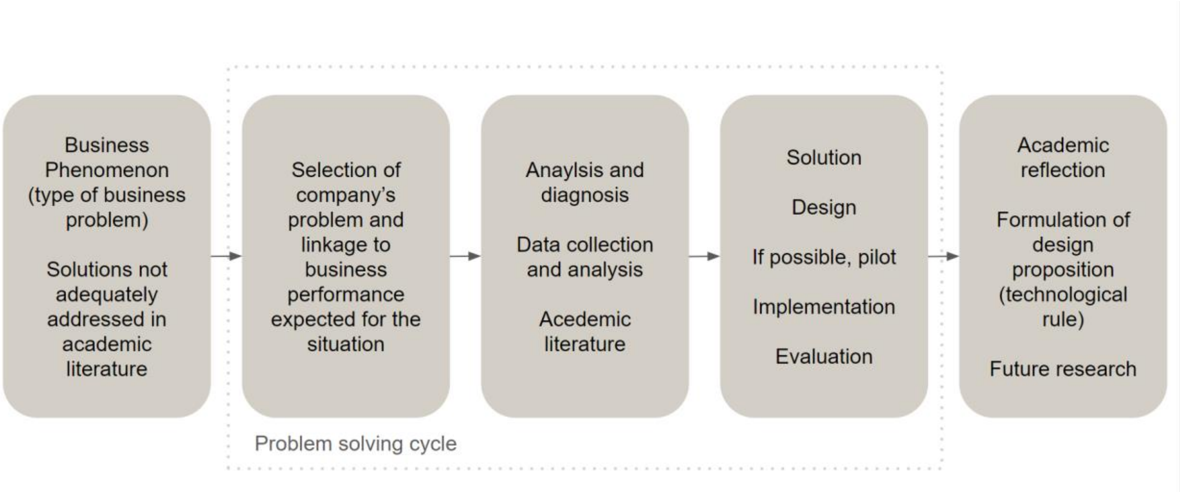


Figure 2.4: Reflective design research process (Dresch et al., 2015b, p.81)

By combining the two approaches, a research process can be constructed which is tailored to this study. The process consists of six steps, which are (1) problem identification and motivation, (2) framing the problem, (3) designing, (4) demonstrating, (5) evaluating, (6) theorizing, and (7) communicating, see Figure 2.5.

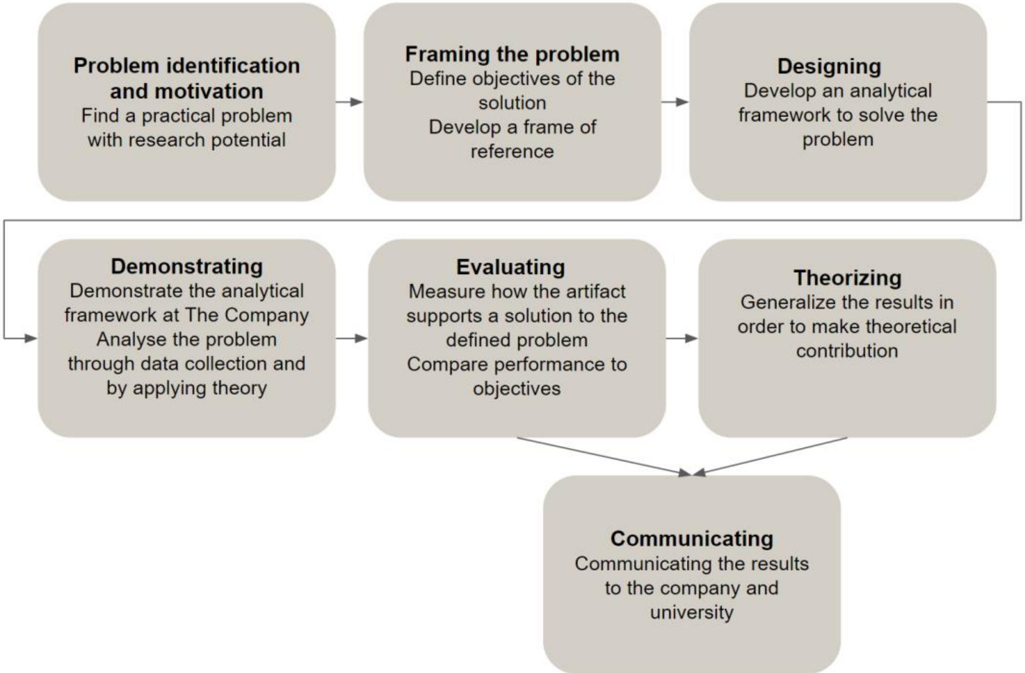


Figure 2.5: The research process used for this thesis

2.2.2 Application of Research Design Process

The first step in the research design process used for this thesis is problem identification and motivation. This step is about finding a practical problem at a company, which also has research potential. The problem identified at The Company is that routes need to be reconfigured because of a centralization of inventory. Additionally, The Company is experiencing low truckload utilization and, therefore, they want to solve this problem in connection with reconfiguring the routes. The research gap lies in how routes can be configured in the context of a company facing a transition from a decentralized supply chain setup to a centralized supply chain setup.

When the problem is identified and motivated, the next step is framing the problem. This is done by identifying the objectives of the solution. In this case, the objective is to develop an artifact which can be used for proposing a new route configuration. Utilizing the analytical framework should enable the configuration of new routes at The Company, which are satisfactory in the context of an inventory centralization and aim to increase truckload utilization. Another vital step in framing the problem is to understand previous research about distribution, route planning and centralization, to develop a frame of reference. The frame of reference serves as the foundation for designing the analytical framework, which is the artifact.

After framing the problem, the following step is to design the artifact, which involves developing an analytical framework. The analytical framework is based on the theoretical foundation established in the previous step during framing of the problem. In combination with the frame of reference, the purpose and research questions also act as a basis for the analytical framework. By applying the analytical framework, the research questions should be answered, and the purpose should be fulfilled. The analytical framework is then used as guidance for data collection and analysis. In this thesis, the analytical framework will result in a proposed solution for a future route configuration after inventory centralization with the objective of maximizing truckload utilization. The analytical framework is presented in the last section of the frame of reference (section 3.9).

To demonstrate the artifact, the analytical framework is applied to a real company case at The Company. There are several ways of demonstrating the artifact, including case study, field study, and simulation (Hevner et al., 2004). Case study research can be used for theory testing complicated issues in the operational management field (Voss et al., 2002). The paper continues by highlighting three advantages with case studies. The first advantage is that the phenomenon is studied in its natural environment, which generates meaningful and relevant theory. The second advantage is that this method provides a fuller understanding of what, how, and why. The third and last advantage is that the method can be used for exploratory research where the phenomenon is relatively unknown. The challenges related to case study research include that it is time-consuming and difficult to generalize the results. When conducting a case study, the number of cases must be chosen. Voss et al. (2002) emphasizes that with fewer cases, there is an opportunity for deeper analysis. However, single case studies may be more difficult to generalize.

For this study, a single case study has been selected as the preferred method of demonstrating the artifact. It provides the possibility of applying the analytical framework to a real situation, which increases the meaningfulness and relevance of the research. By applying the artifact to a case, it gives the opportunity to understand more fully how the framework works in practice. Since the result of applying the framework is unknown, case study is a suitable method of exploratory research. The framework is applied to a single case so the depth of analysis can be greater and due to time constraints.

After demonstrating the analytical framework, the performance is evaluated by assessing to what extent the artifact fulfills its purpose and achieves the defined objectives, which is to configure routes after inventory centralization in a way that maximizes truckload utilization. Additionally, the applicability of the analytical framework is evaluated by discussing its results, i.e., the proposed route configuration, with the company supervisor. After validating the analytical framework, the findings are generalized. In this step, the analytical framework's usability for other companies and researchers is discussed.

The last step is about communicating the knowledge acquired to stakeholders, both the knowledge gained from the theorizing step and the practical knowledge gained from applying the analytical framework in a real setting. Communicating the knowledge to the research field includes writing and publishing the report and giving a presentation to the supervisor. The practical results, in the form of a proposed solution to The Company, derived from applying the analytical framework to the problem The Company experiences, will be communicated to company stakeholders both in the form of a report and a presentation.

2.3 Literature Review

According to Rowley & Slack (2004), the objective of a literature review is to summarize the state of knowledge in a particular subject area. The literature review is important for supporting the research questions identified, for building a theoretical foundation of relevant concepts and terminology, and for analyzing and interpreting results later in the study (Rowley & Slack, 2004). Design science research combines both theoretical and practical perspectives as described by e.g., Lukka (2003) and to understand the theoretical perspective, a literature review is needed. Dresch et al. (2015b, pp. 80-81) also highlight the importance of a solid theoretical base both when finding a gap in academic literature, i.e., the need for research, and for generalizing the results to make a theoretical contribution. This also supports the need for a comprehensive literature review.

In this thesis, the main purposes of the literature review have been based on the aspects identified by Rowley & Slack (2004): (1) supporting the research questions identified, (2) building a theoretical foundation, and (3) analyzing and interpreting results. To achieve these three purposes, a five-step process will be used as proposed by Leite et al. (2019) consisting of (1) defining the main topic, (2) searching the literature, (3) analyzing the results, (4) writing, and (5) reflecting on the writing. The purposes and process of this thesis' literature review are summarized below in Figure 2.6.

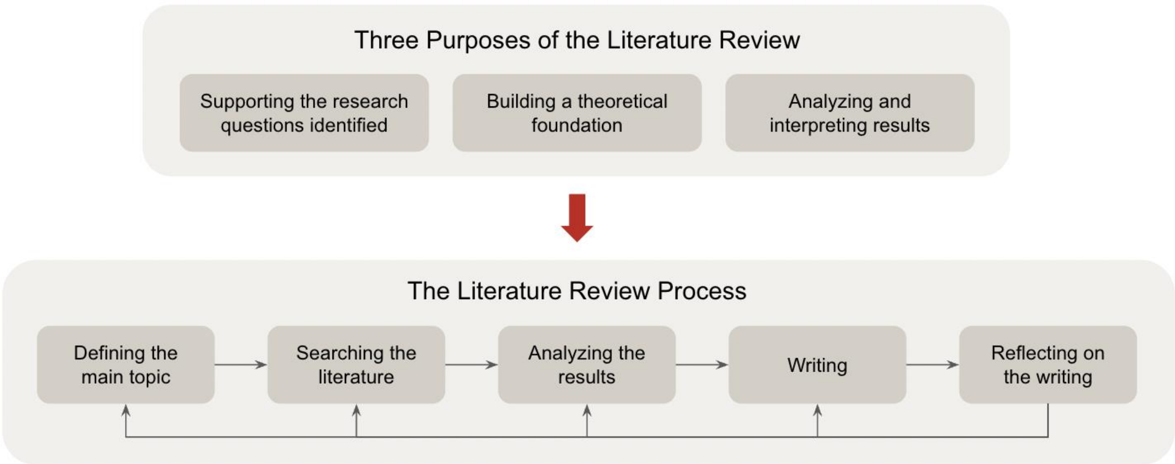


Figure 2.6: The purpose of the literature review in this thesis developed from Rowley & Slack (2004) and the literature review process of this thesis based on Leite et al. (2019)

The first step, defining the main topic, entails reflecting on the scope of the literature review, determining sections and subsections, as well as identifying keywords (Leite et al., 2019). In this thesis, the scope of the literature was distribution, inventory centralization, and vehicle routing. The scope was used as a basis for outlining sections and subsections of the literature review. Some of the keywords identified were *distribution network*, *distribution planning*, *route planning*, *route optimization*, *distribution performance measurement* and *centralization*.

The next step encompasses searching for literature and selecting which literature to be included in the literature review (Leite et al., 2019). In this thesis, the database *Web of Science* was primarily used since this database includes a large variety of articles from reputable journals and employs a user-friendly and effective search function. Articles with a higher number of citations and newer publication dates were prioritized. However, the relevance of the articles to the thesis was considered the highest priority. At this stage, reading the abstract and scanning the rest of the article was sufficient to comprehend whether the article could be relevant or not and this was done to manage time efficiently.

The third step is to analyze the results of the literature search including thoroughly reading articles and taking notes (Leite et al., 2019). In this thesis, the relevant literature was reviewed in more detail and relevant parts were noted to gain a more comprehensive understanding of the topic.

The fourth and fifth step of the literature review are to write and to reflect on the writing respectively. In this research, the writing step also included citing and referencing correctly using the Harvard referencing system as well as editing the written text. The last step entails analyzing the literature review to identify parts where unclarities, repetitions etc. exist. In this thesis, this was considered an important step to create a coherent literature review that fulfills the purposes established. The literature review was revisited throughout the thesis for changes and adjustments, and hence, can be seen as a non-linear and iterative process, in line with Leite et al. (2019).

2.4 Empirical Data Collection

Empirical data can be collected in various ways, in various settings, and from various sources (Forza, 2002). Examples are interviews, observations, and secondary data collection (Saunders et al., 2009, p. 11). Olhager (2022) highlights several aspects to consider when choosing which method(s) to use: accessibility of the data, limitation of resources in terms of time and money, time horizon of the study (historical or current events), and characteristics of the results in terms of a deep or broad understanding of the research topic. Denscombe (2010, pp. 153-154) emphasizes five aspects to consider when choosing which data collection method(s) to use. The first aspect is the research strategy; although some methods may be more suitable with some strategies, there is not a definitive match between method and strategy. The second aspect to consider is the strengths and weaknesses of each method, which leads to the third aspect, usefulness, i.e., how useful the data collection method is in this particular study. The fourth aspect to consider is whether to combine multiple methods. Using multiple methods can aid triangulation, which is the last aspect to consider.

In this research, a combination of interviews, observations, and secondary data collection was used. Design science research aims to produce an artifact and to be able to demonstrate the artifact, these three data collection methods were deemed necessary based on aspects presented by Olhager (2022) and Denscombe (2010, pp. 153-154). Interviews and observations were conducted to understand The Company's business qualitatively while secondary data collection was needed to understand the business from a quantitative point of view and to determine the future routes. All three methods were required in order to propose a satisfactory solution to The Company. Using multiple data sources also supports data triangulation, which increases the rigor of the study (Näslund et al., 2010).

2.5 Data Analysis

Denscombe (2010, p. 235) writes that the purpose of data analysis is to better understand a phenomenon and the aim is to describe, explain, or interpret what it means. The first part of this study relating to the first research question aims to describe the distribution at The Company. This is in line with Denscombe (2010, p. 235), who writes that description is often used as a starting point in research. A description can include the components of the phenomenon, when it occurs, who is involved, the frequency, and duration.

Data analysis consists of five stages: data preparation, initial exploration of the data, analysis of the data, presentation and display of the data, and validation of the data (Denscombe, 2010, p. 240). In this thesis, both quantitative and qualitative data, in terms of secondary data as well as interviews and observations respectively, was analyzed. The process for data analysis for both the quantitative and qualitative data is based on the stages of data analysis proposed by Denscombe (2010, p. 240). The process for analyzing quantitative data in this study consisted of (1) coding and categorizing the data, (2) searching for some obvious trends in an initial exploration of the data, (3) performing further analysis linked to the research questions, (4) visualizing the analysis in figures, and (5) validating the analysis by examining the internal consistency. Similarly for the analysis of qualitative data, the process involves (1) cataloging the interviews and observations, then (2) searching for common themes and/or issues, (3) categorizing these, (4) composing written interpretations of the analysis, and (5) validating the analysis through triangulation. The process for data analysis in this thesis is presented below in Table 2.4.

Table 2.4: Stages of the data analysis process for quantitative and qualitative data relevant for this thesis (Denscombe, 2010, p. 240)

	Quantitative data	***Qualitative data***
1 Data preparation	Coding and categorizing the data	Cataloging the interviews and observations
2 Initial exploration of the data	Looking for obvious trends	Looking for themes or issues
3 Analysis of the data	Further analysis Link to research questions	Categorize themes and issues
4 Presentation and display of the data	Figures	Written interpretation of findings
5 Validation of the data	Internal consistency	Data and method triangulation

Figure 2.7 visualizes how data will be analyzed in relation to the foundational analytical framework presented previously in section 1.4 to answer all three research questions and fulfill

the purpose of this thesis. To understand the current setup at The Company, secondary data, interviews, and observations will be analyzed. Further, the influential factors to consider when configuring routes will be determined based on the frame of reference. In the application of the analytical framework, data collected to understand the current setup will be used to determine which factors are relevant for route configuration specifically at The Company. This will contribute to answering the first research question. To answer the second research question, both literature and interviews will first be analyzed to understand how the conditions will change due to centralization. Secondly, literature and current distribution setup will be analyzed to determine the future routes. The performance of the current and proposed configuration will be compared and analyzed and, thereafter, a route configuration can be presented, achieving the purpose of the study. The foundational analytical framework will be developed further in section 3.9.

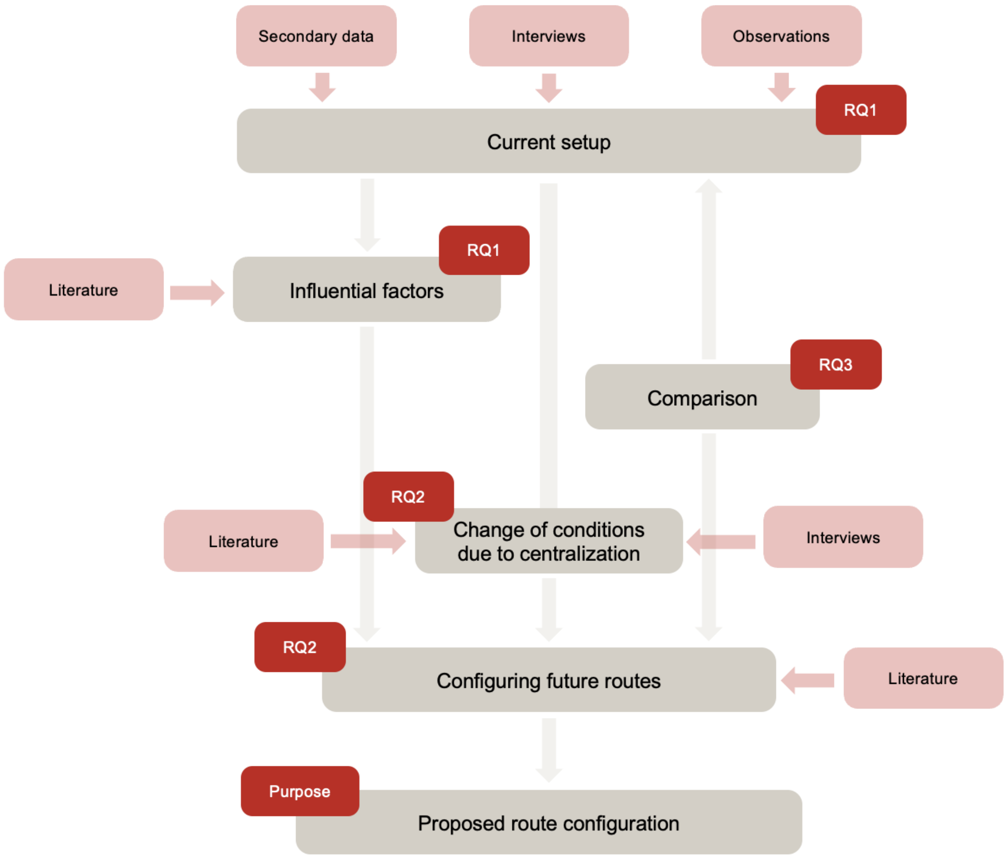


Figure 2.7: How data will be analyzed in relation to the foundational analytical framework

2.5.1 Interviews

Saunders et al. (2009) describe the differences between structured, semi-structured, and unstructured interviews and when each type of interview can be used. Structured interviews are based on a set of pre-written questions and for each question, the interviewee's answer is recorded. In semi-structured interviews, there is a list of themes to be covered during the interview, but the exact interview questions can vary depending on the direction of the interviewee's answers. Lastly, unstructured interviews only have a general topic the interviewer would like to explore, and the interviewee is encouraged to speak more freely.

Which type of interview to use relates to the research strategy and the purpose of the interview (Saunders et al., 2009).

In this thesis, a mix of semi-structured and unstructured interviews have been used. The overall purpose of conducting interviews in this study was to understand more qualitatively the ways of working at The Company regarding distribution from different levels and positions in The Company. Three semi-structured interviews were conducted to understand how The Company works with different areas related to distribution, including distribution strategy, distribution network design, outsourcing, route planning, and performance measurement. A semi-structured interview method was chosen for this purpose since it provides structure in the interview while giving the interviewer and interviewee room to deep dive into particularly interesting topics. One example that confirmed the advantages of using a semi-structured interview was during the interview with the Supply & Demand Manager. When asking about challenges related to distribution at The Company, the manager discussed also broader challenges within the wholesale industry. This led to several follow-up questions, which provided us with deep insights into issues such as how the pandemic has affected the industry.

Two unstructured interviews were conducted to understand how The Company works with distribution from two perspectives - both from a warehouse perspective and an operational perspective. The unstructured interview type was chosen to give the interviewees more room to speak freely and, in that way, better understand the operations at The Company. The interviews conducted are summarized in Table 2.1.

Table 2.1: A summary of interviews conducted

Interviewee	***Purpose***	***Type of interview***	***Duration***
Supply & Demand Manager	Understanding The Company’s business and the role of distribution at The Company	Semi-structured	1h 20min
Warehouse Director	Understanding how the distribution workflow looks like	Unstructured	1h 20min
Truck Driver	Understanding how the goods are delivered to customers	Unstructured	2h
Warehouse & Distribution Manager (southern Sweden)	Understanding how transport routes are planned	Semi-structured	1h
Warehouse & Transport Manager (central Sweden)	Understanding how transport routes are planned and how trailers are utilized	Semi-structured	30 min

2.5.2 Observations

Observations can be divided into two types: participant and structured observations (Denscombe, 2010, pp. 206, 213-214). Participant observations entails that the researcher participates in the organization being studied. Advantages of participant observations are that they can provide insights of the complexities that exist in practice as well as seeing the point of view of the people working in the organization. On the contrary, structured observations are systematic and have a pre-determined structure. The advantage of this type of observation is that they are more rigorous and reliable.

For this thesis, participant observations were the preferred type. By using participant observation, better understanding can be achieved regarding the daily routines and procedures in the distribution of goods from the warehouse to the customer. This was considered useful in understanding what the constraints of the problem are. Observations from the warehouse and during delivery by truck were made and summarized below in Table 2.2.

Table 2.2: A summary of observations conducted

Observation	***Attendees***	***Objective***
Warehouse visit	Warehouse Director	Overview of warehouse workflows and their impact on the distribution operations
Follow along distribution route	Truck driver	Insight into the daily distribution operations including loading and unloading of goods as well as customer interactions

2.5.3 Secondary Data

Secondary data refers to data that has been collected for another purpose than for this research (Saunders et al., 2009, p. 256). Saunders et al. (2009, p. 268-272) writes how one advantage of secondary data is that data collection requires less resources compared to primary data collection and, hence, more time can be spent analyzing and interpreting the data. However, two disadvantages presented are that the data may be collected for another purpose and that accessing secondary data can be challenging. Secondary data can be qualitative or quantitative as well as raw or compiled data.

In this thesis, the secondary data collected consists of quantitative, raw internal company data. The data was predominantly extracted from The Company's ERP system, Microsoft Dynamics 365, through data requests submitted to our supervisor and exported to Excel files to facilitate data analysis. In Table 2.3, the secondary data collected is detailed, categorized into two types: master data and transactional data.

Table 2.3: Secondary data collected from The Company

Types of data	***Data description***
Master data	Article data including: ● Number ● Name ● Product category Customer data including:

Types of data	*Data description*
	• Number • Name • Segment • Address (incl. zip code) • Order deadline • Load solution code Node data including: • Location • Type of node - internal or external warehouse Fleet data including: • Type of vehicle • Maximum weight • Capacity (number of EUR pallets) • Temperature control equipment Truck driver schedule • Number of employees • Working hours
Transactional data	Shipment data: • Customer • Warehouse • Route • Shipment drop off date • Number of pallets • Pallet type • Packed gross weight • Type of transport - internal or external

2.6 Research Quality

To achieve research quality, it is essential to establish a clearly defined strategy. The quality of research results is primarily dependent on validity and reliability (Näslund et al., 2010), where validity refers to if the evidence is valid, and reliability refers to if the evidence is correct. Typically, there are four criteria to evaluate the quality of a research: construct validity, internal validity, external validity, and reliability (Gibbert et al., 2008). The following paragraphs will describe each criterion and outline the strategies implemented for ensuring research quality as summarized in Table 2.5.

2.6.1 Internal Validity

Internal validity refers to the relationship between variables and results and relates to the data analysis phase. The focus is on the researcher's ability to support the findings with strong arguments (Gibbert et al., 2008). There are in general three ways to enhance internal validity.

The first one is to formulate a clear research framework, which should outline the relationship between different factors, making it clear that one factor is causing a particular outcome (Gibbert et al., 2008). The second way is to compare empirically observed patterns with predicted ones or patterns found in previous studies. Third, theory triangulation can be used to verify the findings of the research (Näslund et al., 2010; Gibbert et al., 2008). Dresch et al. (2015b, p. 97) discusses research validity in terms of a design science study and defines validity as a collection of methods employed to ensure the safe assertion of research findings. They argue that the validity of design science research must be established from the evaluation of artifacts, where the research should demonstrate that the artifact can effectively be utilized to solve real problems and that they achieve the desired objectives.

By adopting the measures proposed by Näslund et al. (2010), Gibbert et al. (2008) and Dresch et al. (2015b, p. 97), some strategies for this study were established. To ensure internal validity in this study, a research framework was derived from literature, which explains the relationships between variables and outcomes. To enhance the literature review and facilitate the interpretation of findings, theory triangulation was implemented, which involved drawing from various bodies of literature. Finally, the internal validity was enhanced by demonstrating the artifact through a case study, and by evaluating how well it achieves the defined objectives, i.e., increasing the truckload utilization.

2.6.2 Construct Validity

The construct validity of a procedure is related to the data collection phase and refers to the extent a procedure results in a valid observation of reality (Gibbert et al., 2008). To enhance construct validity, it is important that the researcher studies the phenomenon by using different data collection strategies and different data sources. This is to triangulate in order to adopt different perspectives (Gibbert et al., 2008). To ensure construct validity in this research, different information sources have been used during the data gathering phase, such as interviews with various stakeholders in the organization, observations, and secondary data collection. Additionally, multiple sources were used when conducting the literature review. The construct validity was further ensured through the verification of empirical findings with the company supervisor.

2.6.3 External Validity

External validity is about generalizing the knowledge derived from the research. This means that theories must demonstrate their ability to explain phenomena not only within the context where they are studied, but also in different settings (Gibbert et al., 2008). To ensure external validity, The Company has been described in detail, to enable similarly sized companies in the same industry or related industries to leverage the findings of this research. Additionally, external validity was ensured by combining theory and empirical findings to draw conclusions and to make a theoretical contribution. To facilitate this, a robust frame of reference was essential.

2.6.4 Reliability

Reliability implies that the research contains minimal errors, which allows subsequent researchers to replicate the study using the same procedures and obtain consistent results

(Gibbert et al., 2008). Essential components for ensuring reliability are transparency and replication, which can be achieved through documentation of research procedures, including notes, documents, and narratives, organized to facilitate replication of the study. Näslund et al. (2010) proposes several ways to improve the reliability of a research, emphasizing the importance of reducing biases and maintaining objectivity. Involving more than one researcher in interpreting study inputs and outputs, along with engaging key individuals from the case organization for collaborative data interpretation, are two approaches mentioned that can improve the analysis and research outcomes.

The strategies proposed by Näslund et al. (2010) and Gibbert et al. (2008) were implemented in this study in order to enhance reliability. To ensure transparency and facilitate replication, comprehensive documentation of interview guides, interview notes, and observations was carried out. Moreover, detailed descriptions of the research process were provided to enable replication of the study while maintaining transparency. To minimize biases and maintain objectivity, both researchers attended every interview, in order to prevent misinterpretation of interviewee responses. Additionally, the research was conducted in close collaboration with a company supervisor which strengthens the reliability of the research outcomes.

Table 2.5: Strategies implemented for ensuring research quality

Criterion	***Implemented strategies***
Internal validity	• Deriving a research framework from literature • Theory triangulation • Demonstrating artifact through case study
Construct validity	• Using different sources of information during both data collection and literature review • Verifying empirical findings with company supervisor
External validity	• Describing The Company in detail • Combining theory and empirical findings
Reliability	• Carrying out comprehensive documentation of interview guides • Providing a detailed description of the research process • Interviews are conducted by both researchers • Conducting the research in close collaboration with the company supervisor

3 FRAME OF REFERENCE

This chapter presents the theoretical foundation needed for understanding the role of distribution in a business and what factors impact the distribution setup. First, distribution from a strategic, tactical, and operational perspective is described. The second section encompasses outsourcing of distribution along with its advantages and disadvantages. Next, food wholesale distribution is reviewed to understand the circumstances for this type of distribution, relating to the first research question. Customer service is covered as it is closely linked to the process of distribution. A section about vehicle routing is included to be able to answer the second research question. Performance and costing are described to understand what impacts the performance and costs of distribution, which is needed for the third research question. Finally, before presenting the analytical framework, inventory centralization is reviewed to understand how centralization impacts distribution operations. The outline is presented below in Figure 3.1.

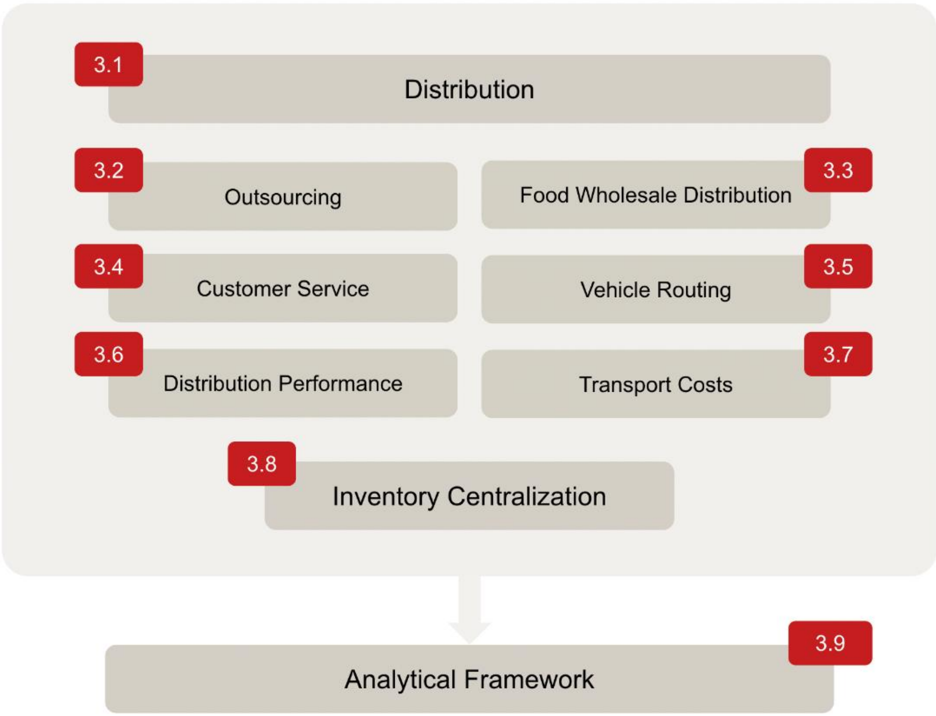


Figure 3.1: Outline of the frame of reference chapter

3.1 Distribution

According to Xia et al. (2009), a distribution network refers to a set of distributed customers, a set of facilities such as manufacturing sites, distribution centers, and retailers that serve customer demands. In this research, a distribution network is defined as a set of warehouse facilities and a set of customers, i.e., retailers. Depending on how a distribution network is designed, different supply chain objectives, such as high responsiveness or low cost, can be achieved. Consequently, the design is highly dependent on the supply chain strategy, and hence, the overall corporate strategy of a company. Song & Sun (2016) emphasize that the alignment of the logistics strategy with the business objectives is key for success. This is also highlighted by Xia et al. (2009) who argue that understanding the overall supply chain management strategy is evident for a design or redesign problem, since how a company positions its products and which market segments they target will directly impact the network design.

According to Akkerman et al. (2010) and Manzini et al. (2013), distribution management can be divided into three distinct planning levels: strategic, tactical, and operational. The strategic level involves long-term decisions related to the physical structure of a new distribution network or the redesign of an existing network (Akkerman et al. 2010). It includes, for instance, determining the number and sizes of warehouses and cross-docking points. The tactical level deals with mid-term distribution planning decisions such as aggregate product flows and delivery frequencies. Finally, the operational level is the short-term transportation planning, for instance loading and routing of vehicles. The following paragraphs will provide a more in-depth description of each level.

3.1.1 Distribution Network Design

The objective of distribution network design or redesign is to configure the distribution network's structure by specifying the number of echelons and, for each echelon, the type, size, quantity, and location(s) (Mangiaracina et al., 2015). It involves finding the best configuration of facilities in order to achieve the objectives of a company (Allesina et al., 2009). Designing a distribution network includes two main phases, where the first one is about visualizing the structure of the supply chain network in terms of its nodes, while the second phase specifies the supply chain network further in terms of deciding each node's location, capability, capacity, and demand allocation (Chopra & Meindl, 2007, p. 81).

Ballou (1981) has identified three decision areas that should be considered when designing a logistics system: facility location, inventory policy, and transport selection/routing. Facility location involves determining the number, location and size of the facilities and assigning market demand to them. This will affect the routes products are transported, and in turn the total distribution costs. Inventory policy pertains to the approach of inventory control, which means determining whether push or pull strategies should be used. Transport selection and routing include, for instance, which customers should be served out of which stocking points, which vehicle types should be assigned to which customers and which modes of transport to use (Ballou, 1981). The allocation of customer demand to stocking points significantly influences the utilization of transportation equipment. Consequently, decisions related to transport selection, scheduling, and routing has a considerable impact on logistics cost (Ballou, 1981).

There are many factors affecting the design of a distribution network. According to Mangiaracina et al. (2015) and Song & Sun (2016), product characteristics, service requirements, demand features, and supply characteristics constitute the four most important. Product characteristics, which refers to aspects such as quality, product variety and life cycle, have been shown to positively affect strategic supply chain network design. This is emphasized also by Fisher (1997), who argues that it is evident that a company matches the type of product with the type of supply chain to ensure competitive advantage. Supply characteristics are a crucial factor when designing a distribution network, as the number and location of suppliers will affect the location of nodes and the production cycles (Song & Sun, 2016). Additionally, service requirements have a major impact on the design. Chopra (2003) suggested certain customer service variables that notably impact both logistics costs and customer satisfaction, including cycle time, item fill rate, and accuracy in order fulfillment. Lastly, demand characteristics, in terms of demand level and predictability of demand, can strongly affect the network structure, particularly when it comes to deciding between a centralized and decentralized setup (Chopra, 2003).

When designing a distribution network, a firm must consider several trade-offs. One of them is the trade-off between responsiveness and transportation cost (Chopra & Meindl, 2007, p. 435). If a firm aims to have high responsiveness by shipping a customer order within a day, the outbound shipments will be small, which results in a high transportation cost. If the firm instead decreases its responsiveness and aggregates orders before shipping them, the firm can take advantage of economies of scale because of larger shipments. There is also a trade-off between transportation and inventory costs. This decision considers choice of transportation mode and the level of inventory aggregation (Chopra & Meindl, 2007, p. 428). The relation between inventory and transportation costs will be described further in chapter 3.8 about inventory centralization.

3.1.2 Distribution Network Planning

Distribution network planning concerns decisions related to fulfilling demand on an aggregated level when the distribution network is given (Akkerman et al., 2010). As the structure of the distribution network is already defined, the goal is to optimize the flows of goods, information, and money through the network, without changing its structure in terms of number and location of nodes (Allesina et al., 2009). Compared to distribution network design, distribution network planning necessitates a more detailed modeling of both production and distribution processes, incorporating the time aspect in modeling efforts. In relation to food distribution, Akkerman et al. (2010) highlights two main research fields regarding distribution network planning: aggregate flow planning and determination of delivery frequencies.

Aggregate flow planning is related to production quantities in different plants and the shipment quantities from these plants to retailers, sometimes through distribution centers. Additionally, it encompasses the reverse flow of products in terms of returns from customers. The aggregate flow planning problems are often modeled by mixed integer linear programming models. Akkerman et al. (2010) presents an overview of models for aggregate flow planning, and the general framework uses continuous decision variables to determine product flows within the distribution network for each time period, while considering the inventory levels at different locations. The objective function is usually to minimize costs, but several models also take customer-related aspects into account, such as service levels or flexibility. The models presented by Akkerman et al. (2010) incorporate a variety of constraints in the cost function. Some take vehicle requirements into account and address the extent to which distribution should be conducted using full truckload (FTL) or less than truckload (LTL). Other aspects that are considered in relation to food distribution is the products' perishability and temperature requirements during distribution.

Delivery frequency refers to a predetermined schedule of deliveries to customers (Akkerman et al., 2010). It concerns decisions on a tactical level regarding how often and when a customer will receive a delivery. Zanoni & Zavanella (2007) introduce a generic Mixed-Integer Linear Programming (MILP) model to determine delivery frequencies and the corresponding number of vehicles in the context of transporting goods from a single origin to a single destination. The primary emphasis of the model is on minimizing transportation and inventory costs, while taking shelf life of distinct product classes into account in determining the time intervals between deliveries. Other models are using methods such as local search and simulation to evaluate different scenarios of delivery frequencies (Akkerman et al., 2010).

3.1.3 Transportation Planning

Transportation plays a pivotal role as it corresponds to up to two-thirds of the overall logistics cost and has a major impact on customer service (Akkerman et al., 2010). Transportation planning involves the short-term planning of distribution operations and primarily focuses on planning deliveries to various customers. Common decisions at this decision level involve specifying delivery routes, determining the precise times, the vehicles used, and the sequence in which customers will receive their products. Planning at this short-term level takes place in a dynamically changing environment, and hence, requires frequent reassessment of decisions made earlier (Akkerman et al., 2010). For instance, delivery routes should be frequently recalculated based on changing demand (Manzini et al., 2013). The majority of methodologies used for transportation planning is based on the Vehicle Routing Problem (VRP) (Akkerman et al., 2010). Fisher (1995) defines the Vehicle Routing Problem as the task of efficiently routing a fleet of vehicles, meaning determining which customers should be delivered by each vehicle, and the sequence in which customers should be served. This is done with the objective of minimizing costs while adhering to various constraints, such as vehicle capacity and delivery time limitations. The vehicle routing problem will be further described in section 3.5 about Vehicle Routing.

3.2 Outsourcing of Distribution

Hsiao et al. (2010) define logistics outsourcing as “a process that involves the use of external logistics companies to perform activities that have traditionally been performed within an organization, where the shipper and logistics company enter into an agreement for delivering services at specific costs over some identifiable time horizon”. The authors categorize logistics processes into four levels: basic activities, value-added activities, planning and control, and distribution network design. The first level, which encompasses basic activities like transportation and warehousing, is more commonly outsourced compared to the other levels.

The decision to outsource logistics is strategic and requires a holistic approach (Gotzamani et al., 2010). Gotzamani et al. (2010) argue that the main reason for companies to outsource logistics to a third-party logistics (3PL) provider is to get access to the provider’s expertise and experience, which can be difficult to acquire or be expensive to have in-house. Many industries are undergoing a transition from prioritizing cost to emphasizing quality, as a result of customers increasingly seeking high-quality products and services rather than focusing on low prices. Consequently, quality has become one of the primary factors influencing decisions regarding outsourcing logistics services and selecting service providers (Gotzamani et al., 2010). In contrast, Szuster (2010) argues that outsourcing of basic logistics functions, such as transport, is based on operational and cost-based reasons. He also found that, within the food industry, companies that prioritize quality or flexibility tend to prefer retaining activities in-house as they do not trust service providers if they have adequate knowledge of handling specific goods. Hsiao et al. (2010) investigated outsourcing of logistics in the food industry and found that the decision to outsource logistics is related to three aspects: asset specificity, core closeness and supply chain complexity. They propose that as the firm's current investment in logistics assets decreases, the probability of outsourcing the activity decreases. Additionally, the farther the activity is from the core business, the more likely it is to be outsourced. Further, as supply chain complexity increases, the likelihood of outsourcing an activity also increases.

Outsourcing has evolved into a crucial strategic element in the development of supply chains (Azzi et al., 2013). 3PL relationships can present opportunities for competitive advantage for both parties, due to the ability to achieve economies of scale, focusing on core competencies and accessing know-how. Additionally, outsourcing logistics is beneficial in regard to reducing supply chain complexity. Szuster (2010) highlights that the main benefits of outsourcing transports are reduced costs, reduced administration, and improved customer service, while Nemoto & Tezuka (2002) mention economies of scale, saving on capital investments and reducing financial risks through risk sharing as the primary benefits.

There are also several drawbacks and risks related to outsourcing of logistics. First, establishing a reliable and cost-effective partnership between the firm and the 3PL provider is a complex task (Nemoto & Tezuka, 2002). Second, outsourcing logistics requires searching and coordination efforts, as well as information sharing between the parties. Similarly, Azzi et al. (2013) emphasize that the main drawbacks of logistics outsourcing are contract and negotiation costs, increased costs in relationship management, possible loss of internal competencies, employee resistance and unrealistic expectations about the job to be performed. All benefits and drawbacks mentioned are compiled in Table 3.1.

Table 3.1: Advantages and disadvantages of outsourcing of logistics (Azzi et al., 2013; Nemoto & Tezuka, 2002; Szuster, 2010)

Advantages	***Disadvantages***
● Ability to achieve economies of scale ● Focus on core competences ● Accessing know-how ● Reduced supply chain complexity ● Reduced cost ● Improved customer service ● Reduced financial risks	● Requires coordination efforts ● Requires information sharing between parties ● Contract and negotiation costs ● Increased relationship management costs ● Possible loss of internal competencies ● Employee resistance ● Unrealistic expectations

3.3 Food Wholesale Distribution

This section covers the characteristics of wholesale, special requirements for food distribution, and transport regulation to comply with. The first part about wholesale helps to provide an understanding of the wholesale industry in general as well as the conditions for wholesale distribution. Food distribution is included to give a foundation for which special requirements need to be considered and, finally, transport regulations are covered to understand how to achieve compliance with regulations related to transport. These can act as constraints for transport planning.

3.3.1 Wholesale

Wholesale is concerned with the sale of goods in large quantities to retailers or other kinds of professional businesses (Oxford Institute of Retail Management, 2014). The main activities of wholesalers are procurement and distribution of goods, which can include raw materials, finished products, or other products. In relation to the final consumer, the wholesaler is rather invisible as their main role has been traditionally to act as an intermediary between the manufacturer and retailer. However, changes in the supply chain environment have caused wholesalers to re-evaluate their role in the supply chain. This means moving from strictly being an intermediary to extending their service offerings to also include category management, logistics, and financial services (Oxford Institute of Retail Management, 2014).

The changing role of wholesale is supported by a report released by Deloitte (2016), which identified six factors that are disrupting wholesale distribution, see Figure 3.2. The first one is in regard to accelerating digitalization, where wholesalers have the possibility to not only create value by leveraging their physical assets but also by leveraging digital assets. Wholesalers can make more informed decisions regarding inventory stock as well as how to target different customer segments. Another factor is expanding competition, meaning new competitors are leveraging new business models. A third disruption is the emerging industries that create new customer demand to capture. Fourthly, product innovations are also causing wholesaler value chains to be reshaped. New products have the capacity to change the set of suppliers involved, create new go-to-market channels as well as alter characteristics of the revenue stream. A fifth factor is disintermediation of supply chains, which is not new, but continues to affect wholesalers. With more and more retailers buying directly from manufacturers, the role of wholesalers is ambiguous. One last disrupting factor is the consumerization of B2B sales. Businesses tend to expect experiences associated with Business-to-Consumer (B2C) sales, like transparent pricing and tailored user experiences, to a greater extent. Wholesalers who cannot adapt to these expectations risk missing potential revenue growth (Deloitte, 2016).

Figure 3.2: Six disrupting factors in wholesale distribution (Deloitte, 2016)

Similar to a retail supply chain, the distribution process within a wholesale supply chain is often complex and expensive due to a wide product range and a large number of customer segments, each with distinct requirements and characteristics (Hung Lau, 2012). Distribution is a key driver of the overall profitability of a wholesaler (Hung Lau, 2012; Chopra & Meindl, 2007, p. 81), and can impact up to 35% of the revenue. According to D'Arcy et al. (2012), half of the final sale price can be attributed to the costs associated with distribution. These costs primarily encompass labor and other input expenses, with wholesaler profit margins comprising less than 10% of the final sale price. Consequently, wholesalers often prioritize achieving cost-effectiveness in their distribution operations, and many retailers rely on strategies such as order consolidation and optimizing routing and scheduling to reduce distribution costs (Hung Lau, 2012).

3.3.2 Food Distribution

There are several aspects that distinguish food distribution from distribution of non-food goods. Akkerman et al. (2010) mentions the importance of quality and safety. The quality of food products is not constant, i.e., it varies along the supply chain. This is related to one of the key characteristics of food: perishability. Poor food quality can lead to poor food safety, which can have considerable financial consequences. Another aspect mentioned is traceability and transparency, meaning that food products are traced during production, processing, and distribution. Bortolini et al. (2015) also raise perishability and traceability as special requirements of food distribution. Behdani et al. (2019) discuss the significance of keeping the cold chain in food supply chains, including distribution. To keep the cold chain and preserve food quality, food distribution is categorized into three temperature control zones: frozen, chilled, and ambient (Akkerman et al., 2010).

To prevent poor food quality and safety, the legislation regarding food storage and transport is rather rigorous. The Swedish Association for Frozen and Refrigerated Foods (2016) compiled all the relevant legislation into national industry guidelines for frozen and refrigerated foods. The Swedish food legislation is in turn based on regulations and directives from the European

Parliament and the Council of Europe and applies to the entire food supply chain. The individual actors in the supply chain are responsible for ensuring food safety, which requires self-monitoring in all stages from food production to retailers and restaurants. In regard to distribution, regulations for loading, transporting, and unloading food products are relevant. When loading cargo, it is important to consider if there is a need for pre-cooling the cargo space and preventing freezing of refrigerated foods. Another aspect to consider is that the air can circulate properly, so that the entire cargo space has the correct temperature. During transport, the air temperature needs to be within the legislated limits and the specific requirement for that product. This needs to be substantiated by, for example, documented analyses and assessments. During unloading of food products, more temperature control measurements are completed both immediately when unloading is initiated and in the cargo space or on the receiver's dock (Swedish Association for Frozen and Refrigerated Foods, 2016).

Vehicles used for food distribution can either be Single Compartment Vehicles (SCVs) or Multiple Compartment Vehicles (MCVs) (Ostermeier et al., 2020). The loading area of MCVs can be divided into different compartments and the temperature for each compartment can be individually adjusted. In the context of food distribution, these types of vehicles can transport products with different temperature requirements in the same truck. This facilitates more flexibility regarding which orders are included on a route as well as the sequencing of the route. This is in contrast to SCV, where only products with the same temperature requirements can be transported in the same vehicle. The number of stops, the number of necessary vehicles and the travel distance may be reduced significantly when using MCVs in comparison with SCVs (Ostermeier et al., 2020). This is also demonstrated in a study by Frank et al. (2021) where the number of orders delivered could be increased, the number of stops decreased, capacity utilization increased, and costs decreased when using MCVs instead of SCVs.

3.3.3 Transport Regulations

One aspect to consider in distribution of goods is the transport regulations that the truck driver needs to comply with. Within the European Union (EU), there is a common set of regulations that covers all those active in commercial traffic. For instance, there are several EU rules that truck drivers must adhere to concerning driving times and rest periods (Transportstyrelsen, n.d). First, drivers are not allowed to work for more than 6 consecutive hours without taking a break. After a driving period of 4.5 hours, the driver must either take a minimum of 45 minutes of uninterrupted break, or divide the break into two parts, with one break lasting 15 minutes and the other lasting 30 minutes (Your Europe, n.d). The daily driving time may not exceed 9 hours, but it can be extended to 10 hours twice per calendar week. The maximum driving time per week is 56 hours, and during two consecutive weeks, driving time may be a maximum of 90 hours (Transportstyrelsen, n.d). Rest periods encompass both daily rest and weekly rest. Truck drivers are required to have a daily rest period of at least 11 consecutive hours per day and a weekly rest of at least 45 continuous hours after 6 days of driving. All rules mentioned are compiled in Table 3.2. The Swedish Transport Agency is the Swedish state administrative authority responsible for conducting regular checks to ensure that all truck drivers comply with these regulations (Transportstyrelsen, n.d).

There are also regulations regarding how fast a certain truck is allowed to drive and what roads the truck can enter. A heavy truck, which is a truck with a weight exceeding 3.5 tons, is not allowed to drive faster than 90 km/hour on a highway and 80 km/hour on other roads. Regulations regarding truck access vary between cities, with a common restriction preventing heavy trucks from entering the city center between 22:00 and 06:00. This applies in, for instance, Stockholm and Malmö (Malmö stad, 2023; Stockholms stad, 2024). Additionally, it is important to consider weight limits on roads. The public road network is categorized into different load-bearing capacity classes, which determines where heavy vehicles are permitted to travel (Malmö stad, 2023).

Table 3.2: Regulations on driving times (Transportstyrelsen, n.d; Your Europe, n.d)

Aspect	***Time constraint***
Maximum working time without break	6 hours
Maximum driving time without break	4.5 hours
Maximum daily driving time	9 hours
Maximum weekly driving time	56 hours
Maximum driving time during two consecutive weeks	90 hours
Minimum daily rest period	11 hours
Minimum weekly rest period	45 consecutive hours after 6 days of driving

3.4 Customer Service

Distribution management is about achieving the optimal balance between customer service and costs (Rushton et al., 2014, p. 32). Therefore, this section will review logistics customer service and the rising customer expectations related to distribution.

3.4.1 Logistics Customer Service

Logistics customer service activities are about ensuring that "the product is delivered to the right place, at the time the customer wants it, and in an undamaged condition" (Theodoras et al., 2005). This means that customer service is closely linked to the process of distribution (Rushton et al., 2014, p. 50). Since distribution management is about achieving the optimal balance between customer service and costs, it is vital for any company engaged in distribution to have a clear definition of customer service and to have specific and recognized customer service measures (Rushton et al., 2014, p. 32). Rushton et al. (2014, p. 32) state that there are many different elements of customer service, and that their importance will vary depending on the product, company, and the targeted market. The authors divide logistics customer service elements into three categories: pre-transaction, transaction, and post-transaction, where the transactional elements are those related to physical distribution. Those elements are, for instance, order cycle time, delivery alternatives, delivery time, delivery reliability and inventory availability. The logistics customer service elements can also be classified by four multifunctional dimensions, which are time, dependability, communications, and flexibility. Time concerns order fulfillment cycle time, dependability is about guaranteeing fixed delivery times of accurate orders, communications is the ease of order taking, and flexibility concerns the ability to respond to changing customer needs (Rushton et al., 2014, pp. 35-36).

3.4.2 Customer Expectations

In a period marked by global competition, managing the customer interface is key to supply chain success (Rexhausen et al., 2012). The importance of customer service as a critical success factor has grown significantly, as companies recognize that meeting customer needs is vital for gaining a competitive advantage (Rushton et al., 2014, p. 50). This is driven by several factors, such as rising customer expectations, markets being more service-sensitive, and increased competition. Additionally, the brand loyalty has decreased and instead, immediate product availability is prioritized, especially in the fast-moving consumer goods (FMCG) industry. Cepeda-Carrión et al. (2023) writes about customer experience dimensions in business-to-business (B2B) delivery services and emphasizes that the role of logistics has changed drastically in the last few years. Due to the COVID-19 pandemic, consumer habits have shifted, which places greater emphasis on companies to enhance customer experience and satisfaction. For a firm to stay competitive, it is essential to constantly adapt the supply chain to changing customer expectations (Chopra & Meindl, 2007, p. 18). Additionally, it is important to understand customer requirements and that they will most likely differ between the market segments a business serves (Rushton et al., 2014, p. 32).

Lal & Narayanswamy (2022) state that there is a continuously evolving market and demand for convenient customer experience across many industries. Customers expect faster and more efficient deliveries, including order tracking, safety, and security of their goods. This applies also in B2B contexts, where the growth of online sales and increased order volumes puts pressure on wholesalers to provide efficient delivery in terms of speed, price, service, and quality. Lal & Narayanswamy (2022) argue that the last-mile delivery, which includes the activities from the distribution center to the final receive point of a supply chain, is the most important step in a logistics process in regard to customer experience. This is because there are several elements involved in the last mile delivery process which affect the customer experience, for instance, speed, timeliness, accuracy, and precision of deliveries.

In addition to the factors outlined by Lal & Narayanswamy (2022), customer experience in a B2B environment is influenced by industrial customer touchpoints, which refer to those moments when the customer interacts with the supplier. Those touch points involve cognitive, behavioral, emotional, and social aspects and are key to achieve experiences that lead to repurchase and recommendation. According to Cepeda-Carrión et al. (2023), the customer experience in a B2B environment is complicated, since there are several actors involved in different points of contract. To provide excellent touchpoints, suppliers must offer a flexible service with customer-centric staff. In a distribution context, Bode et al. (2011) researched how delivery persons in terms of truck drivers affect customers purchase behavior in industrial customer-supplier relationships. They found that there is a positive effect of face-to-face interactions between delivery personnel (i.e., truck drivers) and employees from customer firms on sales. This emphasizes the significance of touchpoints in logistics. Additionally, the authors discovered that the impact of personal contact quality on sales diminishes as the size of the customer firm increases (Bode et al., 2011). Another finding is that when the touchpoints are more frequent, the quality of personal contact becomes less important for the customer's purchase behavior.

3.5 Vehicle Routing

Distribution costs are dependent on which routes are chosen, as described more in detail below in section 3.7. In order to reduce these costs as well as enable faster deliveries, route planning and optimization can be leveraged (Liu et al., 2023b). This section covers what policy to select when route planning. The VRP is also described in this section, as it is one of the most central topics related to vehicle routing.

3.5.1 Routing Policy

There are two main types of routing policies: fixed and dynamic routing. According to Zhai et al. (2011), fixed routing entails that the same route is used for the same set of retailers, in comparison to dynamic routing, where the route is allowed to be changed, even as the vehicle is traveling a pre-planned route. Rushton et al. (2014, pp. 483-484) describe fixed route planning as vehicle routing and scheduling in the medium- and long-term time perspectives. It is particularly applicable if there are consistent deliveries of similar products and quantities to regular customers. The main characteristics of this type of routing policy is that there is a steady demand for products at the same locations, which enables a fixed route planning for a certain time period (Rushton et al., 2014, pp. 483-484). Fisher (1995) also writes that fixed routing is applicable when customer demand is relatively stable, so the same routes can be used repetitively. In the case of fixed routes, average demand data is used as a basis for planning. This route policy requires less time replanning compared to dynamic routing and creates stability in the route schedule, for example, the same driver delivers to the same customer, which can be preferable (Fisher, 1995).

Variable route schedules (i.e., dynamic routing) can be preferred if the demand cannot be estimated and/or if the delivery locations vary (Rushton et al., 2014, pp. 483-484). This type of routing is more complex to plan, but can also facilitate more flexibility, i.e., the scheduler can make changes to the routes if needed. Fisher (1995) describes variable routing as developing routes only for the next planning horizon. For example, for a daily variable routing system, the route schedule for the coming day is constructed.

In addition to choosing either a fixed or dynamic policy, there is also the possibility of combining fixed and variable routing, i.e., some routes are fixed, and some are variable. Liu et al. (2023a) presented an example of this in their study about how to design a service network. The fixed routes were determined in advance while the variable routes were determined the same day. The authors found that in their case implementing four fixed routes and two variable routes resulted in a reduction of operational costs by 6.37%.

3.5.2 Vehicle Routing Problem

The first version of the Vehicle Routing Problem (VRP) was introduced by Dantzig & Ramser (1959) as the "Truck Dispatching Problem" and modeled how a number of trucks could supply a number of service stations from a central terminal while minimizing the distance traveled, illustrated in Figure 3.3. Clarke & Wright (1964) further developed the Dantzig's & Ramser's Truck Dispatching Problem into a general linear optimization problem common in logistics known as the VRP. This model entails optimizing the routing of a fleet of vehicles with varying capacities from a central depot to a large number of delivery points. The objective function of the VRP can be to minimize the total transportation cost, the transportation distance, the number of vehicles required, the running time of empty vehicles, or the penalty value from not being able to serve customers in a timely manner (Zhang et al., 2022).

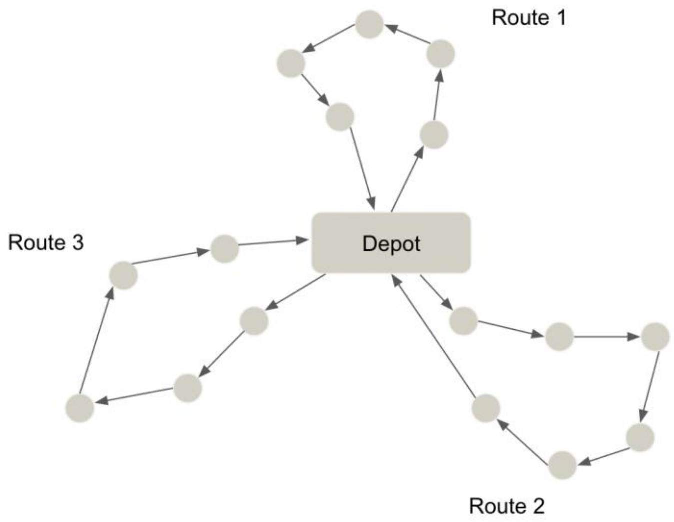


Figure 3.3: Illustration of the Truck Dispatching Problem

The VRP has been extended since the first model by Dantzig & Ramser (1959) into a number of different variants, compiled in Table 3.3. Braekers et al. (2016) concluded that there is an increasing volume of articles published concerning the variants of the VRP. These variants include more real-world aspects of the VRP, with the aim of applying the results of the optimization more easily in practice. In a literature review conducted by Konstantakopoulos et al. (2020), it was found that two of the most common variants published in research articles are the Capacitated Vehicle Routing Problem (CVRP) and the Vehicle Routing Problem with Time Windows (VRPTW). In the CVRP, the fleet of vehicles all have the same capacity, in contrast to heterogeneous fleet VRP, in which the vehicles have variable capacities and are associated with various variable and fixed costs. Most companies do not have a homogenous vehicle fleet, but instead use different types of vehicles for long-haul and last-mile deliveries respectively. The other common variant, VRPTW, includes customers' requests for when goods are to be delivered. This can be in the form of a hard time window, where delivery time is seen as a constraint, or a soft time window, where delivery outside the time window is penalized with a cost (Konstantakopoulos et al., 2020). Yet another variant of the VRP is the Periodic Vehicle Routing Problem (PVRP), which is based on a planning horizon and each customer specifies a service frequency and a number of allowable visit days. The PVRP is particularly common in the setting of grocery distribution (Cordeau et al., 1997).

Table 3.3: Variants of the VRP (Dantzig & Ramser,1959; Konstantakopoulos et al., 2020; Cordeau et al., 1997)

Variants of the VRP	***Description***
VRP	Optimizing the routing of a fleet of vehicles with varying capacities from a central depot to a large number of delivery points
CVRP	The fleet of vehicles all have the same capacity
VRPTW	Includes customers' requests for when goods are to be delivered.
PVRP	Based on a planning horizon and each customer specifies a service frequency and a number of allowable visit days

To route vehicles, Fisher (1995) states that the following data is required: number of vehicles and their capacities, customer order information (the size of the delivery to each customer) and geographic data (travel cost and time between any two points). Additionally, if configuring period routing, which means developing a set of daily routes for some period so that each customer receive delivery at a predetermined frequency, the desired delivery frequency for each customer needs to be determined. Geographic data is the most difficult to obtain, as companies seldom maintain travel costs and distances. One way of obtaining geographical information is to assign coordinates to each customer and assume that the distance between them is the Euclidean distance between the coordinate pairs. The cost is then assumed to be proportional to distance. In order to compensate for deviations from a straight-line route between customers, the distances are often adjusted by a factor. Cooper (1983) proposed the value 1.2 in the 1980s for approximating road distances for UK roads when using coordinates. This factor, called "the wiggle factor", has since then been widely accepted (Domínguez-Caamaño et al., 2016) and used by several authors (Rushton et al., 2014, p. 486; McKinnon & Ge, 2007).

Fisher (1995) mentions a number of factors that need to be considered in real vehicle routing problems, which are not included in the basic VRP model. One of them is that there can be additional capacity constraints to the vehicle, for instance both weight and volume restrictions. Additionally, some vehicles are divided into different storage sections, depending on what product should be transported, which complicates capacity constraints further. Another factor to consider is that the total time duration of a route may be constrained, and that the number of vehicles used in a fleet is usually variable rather than constant. Customer requirements also appear as one factor complicating the Vehicle Routing Problem (Fisher, 1995; Konstantakopoulos et al. 2020). There can be requirements regarding time-windows when the customer wishes to receive its delivery and other constraints that require some customers to be the first or last stop on a route. The number of aspects influencing vehicle routing creates a complex problem where multiple requirements and constraints need to be taken into account simultaneously (Konstantakopoulos et al. 2020).

The VRP is a NP-hard combinatorial optimization problem, which implies substantial complexity in finding an optimal solution. VRPs can only be solved to optimality in a small number of cases, and so to solve VRPs in a feasible amount of time, different kinds of heuristics have been developed (Arnold & Sörensen, 2019). Griffis et al. (2012) mention three approaches to solving supply chain problems: optimization, simulation, and heuristics. Since finding an optimal solution can be difficult with large and complex problems, simulation can be a preferred choice in some contexts, especially to model variability. However, finding optimality is often impractical and time-consuming and knowing if the achieved solution is optimal is not assured. Heuristics are a set of steps in a specific sequence that can be used to solve combinatorial optimization problems, like VRPs. Although heuristics can find feasible solutions, there are limitations. For example, it is possible for heuristics to terminate at a local optimum, ignoring solutions in a different part of the solution space. Despite this, the solutions are often near optimal and are much less costly to find. A fourth newer approach to solving these kinds of problems is metaheuristics, which aim to bridge the gap between optimization and heuristics. This approach is particularly well-adopted to solve supply chain problems due to the nature of these problems in terms of size and complexity (Griffis et al., 2012).

According to Manzini et al. (2013) and Fisher (1995), a researcher should consider using heuristics rather than optimization models for large instances, to overcome computational difficulties in VRP. The authors propose a two-stage heuristic procedure for operational distribution planning (Manzini et al., 2013). The first stage is cluster analysis and grouping, where the demand points, i.e., the customers, should be grouped in clusters depending on the distance between them. The demand points with short distance to each other can be grouped into one cluster, and a vehicle is then assigned to the cluster. The second step is routing, where the visits to customers are sequenced within a cluster. The optimal sequence is the one which minimizes the travel distance.

Ronen & Goodhart (2008) conducted a study of tactical delivery planning for a major US retailer using PVRP. The retailer has stores all over the US which are served by several regional distribution centers. The retailer utilizes a fixed multi-stop delivery route schedule that is replanned several times per year prior to peak seasons. Their solution approach consisted of three steps. The first step was to cluster geographically adjacent stores with the same delivery characteristics, such as delivery frequency per week, required delivery days, and delivery equipment requirements. The next step was to assign the clusters created in the former stage to delivery days that both balances the workload at the distribution center and satisfies transportation capacity constraints, aiming to minimize both transportation and warehouse labor costs. The last step was then to create the truck routes for each day of the week separately.

This approach is known as the "cluster first, route second" approach, which is in line with what Manzini et al. (2013) recommends.

3.6 Distribution Performance Measurement

There are three main characteristics that make supply chain performance measurement challenging (Kueng, 2000). The first is that performance is not absolute, meaning that the performance of different processes are difficult to compare. Second is that performance is multidimensional and cannot only be assessed by one measure. The third characteristic is that performance measures are not independent, but usually have some type of relation between each other. Cost, time, and quality as well as the relationship between them are usually aspects to consider when evaluating the performance of the supply chain.

Regarding supply chain performance measurement, Vidalakis & Sommerville (2013) raise cost efficiency and customer responsiveness as two primary measures. Concerning cost efficiency of transport operations, the authors identify volume of vehicle movements and travel distance as key measures. Additionally, they mention three measures for loading efficiency (Vidalakis & Sommerville, 2013), which are detailed further in section 3.6.1 below. García-Arca et al. (2018) identified 12 key performance measures (KPIs) related to road transport in the literature review part of their article. Included in this selection of KPIs were transport cost, vehicle utilization, and transport distance.

3.6.1 Loading Efficiency

Vidalakis & Sommerville (2013) write about loading efficiency in terms of vehicle shipping efficiency (VSE), vehicle journey efficiency (VJE), and vehicle weighted efficiency (VWE). VSE concerns the initial loading condition of the vehicle without considering how the vehicle loading efficiency changes over the course of the delivery. In comparison with VSE, VJE considers how the loading efficiency varies during the journey between delivery locations. Similar to VJE, VWE takes into account the loading efficiency between two delivery locations, but also weighing the loading efficiency based on the length of the journey (Vidalakis & Sommerville, 2013). Santén (2017) highlights how increasing the load factor, which is defined as the ratio of the actual load to the maximum load, is crucial for efficient transport operations.

McKinnon (2010) specifies five ways of measuring transport efficiency through the load factor. The first is the level of empty running, which means the proportion of the distance that the truck travels with an empty load. The second measure is the weight-based loading factor and concerns the ratio between the actual weight of the goods and the maximum weight the truck can load. The ton-km loading factor is the third measure and entails the ratio of the actual ton-km moved to the maximum ton-kms. This measure takes into consideration that the load varies over the course of delivery. The fourth measure described is the volumetric loading factor, which is the proportion of the loading space filled with goods in terms of volume. The fifth measure is the deck-area coverage, and this is the proportion of the floor area in the loading space that is filled with goods. If the stackability of goods is limited, this measure can be preferred.

Santén (2017) describes five ways to increase the load factor are warehousing, order & delivery, packaging, loading, and consolidation. Reducing the number of warehouses, i.e., centralization, restructures the flow of goods into a main flow, which can enlarge and stabilize transportation flow. Order and delivery concern choices related to delivery frequency and order size. Encouraging customers to stick to an established ordering and delivery timetable increases the load factor by matching loads with vehicle capacity efficiently. Packaging entails redesigning the dimensions and shape of the packaging, packing more efficiently, and choosing an appropriate packaging system. Loading concerns actions related to load units and handling. This can be, for example, harmonizing unit loads, standardizing load carriers, and increasing stacking height. Consolidation refers to several different actions including consolidating internal flows, which has the potential to increase the load factor (Santén, 2017). Consolidation is also highlighted by Vidalakis & Sommerville (2013), as consolidating shipments can increase both the distance and weight per shipment and, hence, reduces the number of vehicle movements while also increasing loading efficiency.

3.6.2 Travel Distance

Vidalakis & Sommerville (2013) as well as García-Arca et al. (2018) mention travel distance as an important KPI for measuring the performance of transport operations. Rushton et al. (2014, p. 130) describe how the cost of delivery is strongly dependent on the travel distance regardless of whether a company is using their own vehicles or a third-party carrier. The authors continue with dividing delivery distance into two parts: drop distance and stem distance. The stem distance is the distance to and from a delivery zone and the drop distance occurs once the delivery zone has been reached.

Rushton et al. (2014, pp. 486-487) describes three methods of measuring the distance traveled in a distribution operation. The first is the true distance method, which entails that the actual distances are physically measured on a road map. This is typically time-consuming and not to be recommended for large applications. The second method is the coordinate method. In this method, the straight-line distances between depot and customer delivery points are measured and multiplied by a factor to estimate the road distance (common factor to be used is 1.2). The third method is the digitized road network, which most computer scheduling systems now use. This method can distinguish between different road types (e.g., highways) and different types of land use (e.g., city center, town center) and is relatively accurate in estimating travel distances.

Performance measures related to distribution mentioned in this section are summarized in Table 3.4.

Table 3.4: Summary of distribution performance measurement

KPI	***Mentioned by***
Loading efficiency	Vidalakis & Sommerville (2013) García-Arca et al. (2018) McKinnon (2010) Santén (2017)
Travel distance	Vidalakis & Sommerville (2013) García-Arca et al. (2018) Rushton et al. (2014, pp. 486-487)
Volume of vehicle movements	Vidalakis & Sommerville (2013)
Transport cost	García-Arca et al. (2018)

3.7 Transport Costs

The distribution costs account for a large part of the selling price of the final product (Konstantakopoulos et al., 2020). In order to effectively manage and maintain control over transportation resources, it is essential to have a well-designed costing system (Rushton et al. 2014, pp. 456-457). By weekly monitoring mileage and fuel expenses of each vehicle, discrepancies can be identified, and corrective measures can be implemented to increase cost efficiency.

3.7.1 Categorization of Transport Costs

Transport costs can be broken down into three main types: fixed costs, variable costs, and overhead costs (Rushton et al., 2014, p. 460). Fixed costs refer to expenses that remain constant regardless of the mileage operated, irrespective of the route or the number of customers served (Konstantakopoulos et al., 2020). The most common vehicle fixed costs are depreciation, tax and licenses, vehicle insurance, driver's basic wages and interest on capital. Variable costs, on the other hand, refers to those costs that are directly related to the distance traveled by the vehicle (Rushton et al., 2014, p. 464; Konstantakopoulos et al., 2020). This means that the variable costs are affected by the length and the duration of a route (Konstantakopoulos et al., 2020). The key vehicle running costs are fuel, oil and lubricants, tires, repairs and maintenance, drivers' overtime, bonus, and subsistence. Among these, fuel expenses generally represent the largest portion. The reasons are, mainly, that commercial vehicles typically have a high fuel consumption and that there is a constant rise in energy costs. This implies that the fuel usage has to be regularly monitored (Rushton et al., 2014, pp. 464-465).

The fixed and variable costs can be considered direct costs that are directly related to an individual vehicle (Rushton et al., 2014, pp. 466-467). Vehicle overhead costs are, in contrast, considered indirect expenses as they are not directly tied to an individual vehicle but rather distributed across the entire fleet. These costs encompass both fleet overheads and business overheads. Fleet overheads refer to the expenses associated with all auxiliary equipment and labor essential for the efficient operation of a vehicle fleet, while business overheads relate to transport department and company administrative overheads, such as company cars and expenses, rent and training. The categorization of transport costs is summarized in Table 3.4.

Table 3.5: Categorization of transport costs (Rushton et al., 2014, p. 460; Konstantakopoulos et al., 2020).

Category	***Example***
Fixed costs	• Depreciation • Tax and license • Vehicle insurance • Drivers' basic wages
Variable costs	• Fuel • Oil and lubricants • Repairs and maintenance • Driver's overtime
Overhead costs	• Fleet overheads • Business overheads

3.7.2 Vehicle Utilization

To calculate the total transport operation cost, vehicle expenses must be allocated based on each vehicle's activity (Rushton et al., 2014, p. 467). This means that the initial step in total transport operation costing is to estimate vehicle utilization. Rushton et al. (2014, p. 467) states that there are two areas of utilization that need to be determined: for days worked in the year and distance driven per year. Days worked can serve as the foundation for covering vehicle standing costs, while distance traveled can be employed to evaluate vehicle running costs (Rushton et al., 2014, p. 467). The fixed, variable, and overhead costs can then be expressed on either a daily basis or an average mileage basis. This cost breakdown enables a detailed assessment of the costs of different elements within the delivery operation (Rushton et al., 2014, p. 468).

Another type of vehicle utilization which can be used to allocate fixed costs related to vehicle expenses is truckload utilization. By improving truckload utilization several benefits related to costs can be attained (Wong et al., 2018). When a firm can fully utilize the spaces in trucks, they can lower operation costs and increase revenue, as a result of the lower number of trucks needed to serve the customers. According to Horvitz (1960), measuring equipment utilization in terms of the amount of products moved on the vehicle is one of the most effective means of finding potential for profit.

3.8 Inventory Centralization

Drawing on the terminology employed by Wanke & Saliby (2009), this study defines inventory centralization as "physical consolidation of stocks at a limited number of locations (often a single facility) from which all demand is satisfied". Corts et al. (2019) highlights both advantages and disadvantages with centralization, from a food manufacturing point of view. While centralizing the inventory decreases costs related to inventory and warehousing, it decreases customer proximity and thereby increases transportation costs. This is supported also by Chopra & Mendl (2007, p. 345) who emphasizes that moving from several distribution centers to only one will decrease facility cost but increase transportation costs.

A centralized setup necessitates less safety stock to serve a set of markets compared to a decentralized setup, as the demand variance in each source is counterbalanced. This is a phenomenon called “the risk pooling effect” (Corts et al., 2019; Schmitt et al., 2015). The risk pooling effect implies that when supply is deterministic and demand is stochastic, centralization is preferable as it leads to a reduction in expected costs. On the contrary, a decentralized setup is beneficial when demand is deterministic, and supply may be disrupted. In this case, a decentralized setup can reduce cost variances though “the risk diversification effect”, which occurs when inventory is stocked at a decentralized set of locations. This enables the mitigation of the impact of each disruption, which leads to a decrease in cost variance (Schmitt et al., 2015).

Apart from that centralization ties up less capital, it also reduces the number of warehousing employees, learning costs and fixed warehousing costs (Corts et al., 2019). Additionally, the control and management of material flows are facilitated with a centralized configuration, which in turn decreases inventory costs. The benefits from centralization are highest for high-value, low-demand items with unpredictable demand (Chopra & Meindl, 2007, p. 87). Centralized inventory is also beneficial if inventory and facility costs correspond to a large fraction of a supply chain’s total cost (Chopra & Meindl, 2007, p. 431).

According to Chopra & Mendl (2007, p. 345), there are two primary drawbacks of consolidating all inventory to one location, both stemming from the increased average distance between the inventory and the customer. The first one is that transportation costs increase. However, a case study at Atlas Copco Industrial Techniques indicates that centralizing the inventory can have the opposite effect (Abrahamsson & Brege, 1997). By delivering all products from one central distribution center directly to customers all over Europe, full truck loads could be used from the distribution center to a local breakpoint. The larger volumes increased the economies of scale and the total distribution costs decreased from 13% to 4% of the sales.

The second drawback mentioned by Chopra & Meindl (2007, p. 345) is that the response time to customer order will increase. However, Corts et al. (2019) argue, in contrast to Chopra & Meindl (2007, p. 345), that centralization does not necessarily result in increased delivery times, despite the increased distance to the customer. This is because centralized inventory can ensure a complete assortment and a seamless flow of deliveries. They reason that by consolidating demand into fewer stock points, it opens up the potential to acquire advanced and specialized equipment, thereby enhancing the efficiency of warehouse operations, which results in increased flexibility and agility in distribution (Corts et al., 2019).

One factor to take into consideration when deciding whether to centralize or decentralize inventories is the level of planning required (Corts et al., 2019). A centralized system requires strategic planning and alignment through the chain. Higher levels of controlling capabilities are necessary, compared to a decentralized configuration, which instead requires local controlling capabilities (Corts et al., 2019). This is in line with Shamsuzzoha et al. (2020) who states that with longer distances, organizing a centralized logistic system can require more planning and integration between the supply chain members, compared to a decentralized setup.

3.9 Analytical Framework

Based on the frame of reference, the analytical framework presented in chapter 1.4 can be expanded. The final objective of the analytical framework is to propose a route configuration, and its usability will be demonstrated by applying it to The Company. Hence, the analytical framework will be used as a guideline when collecting data about The Company and when conducting analyses.

The first part of the analytical framework is related to addressing RQ1, where the purpose is to map the current state. Understanding the current distribution process and the business is deemed to be critical to be able to propose a satisfactory route configuration later. When mapping the current state, literature suggests that mainly six parts are of interest: (1) the company, (2) the distribution network design, (3) the distribution process, (4) products, (5) customers and (6) distribution performance, see Figure 3.4. Mapping the company includes understanding its overall strategy, value proposition, customer segments and product assortment. As stated by Xia et al. (2009) and Song & Sun (2016), understanding the overall strategy is evident for a design or a redesign problem. Additionally, to be able to align the logistics strategy with the business objectives, there is a need to understand how a company positions its products and which market segments they target, as it will directly impact the network design.

The second aspect, distribution network design, includes visualizing the structure of the supply chain in terms of its nodes and each nodes' location. The location of facilities is an important part to map as it will affect the routes products are transported, and in turn the total distribution costs (Ballou, 1981).

The third factor to consider when mapping the current state is the distribution process, which encompasses decisions related to transport selection and routing. These decisions are among the three key areas highlighted by Ballou (1981) that should be taken into account when designing a logistics system. The current distribution process needs to be mapped in terms of delivery routes, delivery frequencies, shipment quantities, and the capacity of the fleet of vehicles. Additionally, whether the distribution is performed in-house or is outsourced needs to be understood. Mapping the distribution process also involves understanding what methodologies are currently used for route planning and with what objective the routes are planned.

The fourth aspect to consider when mapping the current state is customers, which includes understanding demand characteristics and customer expectations that need to be fulfilled. Demand characteristics strongly affect the choice of routing policy (Fisher, 1995; Rushton et al., 2014, pp. 483-484), and understanding customer expectations is key to supply chain success (Rexhausen et al., 2012). The fifth aspect, products, is evident to thoroughly understand as certain characteristics of perishables impose special requirements on distribution (Bortolini et al., 2015). Finally, the performance of the current distribution network needs to be analyzed in terms of several KPIs. Since a redesign problem is about finding the best configuration that achieves the objectives of a company (Allesina et al., 2009), it is essential to monitor KPIs to ensure that the reconfiguration aligns with the company's goals and surpasses the existing configuration.

The second part of RQ1 aims to review previous literature on vehicle routing and identify factors to consider when configuring transport routes. The factors identified will then be applied to The Company when configuring the new routes in RQ2. The literature highlights that vehicle routing problems are complex, and that there exists a variety of models considering different aspects (Konstantakopoulos et al., 2020). Three fundamental aspects to take into account are highlighted by Fisher (1995): customer order sizes and frequencies, geographical data of customers and vehicle capacities. Other factors to consider, mentioned by both Fisher (1995) and (Konstantakopoulos et al., 2020), are customer requirements and expectations. For instance, there can be a time window defined by the customer during which the goods need to be delivered. In route planning, there are also several transport regulations to comply with, which sets restrictions on when a route can be driven and can limit the total time duration of a route (Transportstyrelsen, n.d). Additionally, related to food distribution, food regulations such as keeping the cold chain needs to be complied with and taken into account during route configuration (Behdani et al., 2019). Finally, product characteristics have been shown to affect distribution network design (Mangiaracina et al., 2015; Song & Sun, 2016), making it a fundamental aspect to consider in route configuration. All identified influential factors are shown in Figure 3.4.

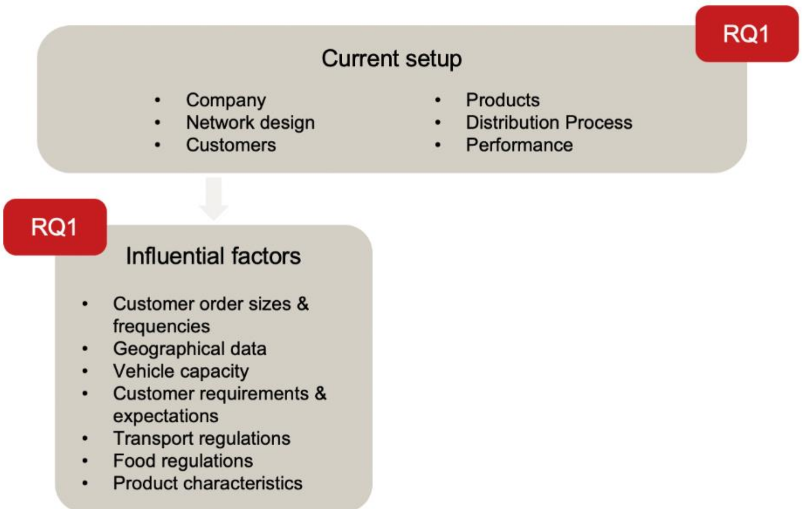


Figure 3.4: Part of the analytical framework relating to the first research question

Before configuring the new routes, i.e., addressing RQ2, changes in conditions due to centralization need to be identified. Literature on centralization highlights longer distances to customers as the main drawback, resulting in higher transportation costs and longer response times (Chopra & Meindl, 2007, p. 345). Additionally, centralization alters the structure of the distribution network, which in turn affects the conditions for route configuration.

Using the current setup, the influential factors and change of conditions as the input, the future routes can be configured, see Figure 3.5. The process of configuring the routes is designed with inspiration taken from literature on vehicle routing and consists of three parts, which are: (1) define objectives, (2) select routing policy and (3) decide upon an approach to use. The first step is about defining the objective of the vehicle routing problem. It could, for instance, be to minimize the total transportation cost, the transportation distance or the number of vehicles required or the running time of empty vehicles (Zhang et al., 2022). The second step concerns deciding upon either a fixed or dynamic routing policy, based on demand characteristics. The third step involves deciding upon the approach for solving the vehicle routing problem. Griffis et al. (2012) mentions, for example, three approaches to choose from: optimization, simulation, or heuristics.

The third research question involves comparing the performance of the current distribution system with the proposed solution. The purpose of the comparison is to ensure that the proposed solution will surpass the current configuration and, hence, be satisfactory. This comparison is conducted based on several Key Performance Indicators (KPIs), including truckload utilization, travel distance, volume delivered, customers served, and outsourced volumes, see Figure 3.6. The selection of Key Performance Indicators (KPIs) for the analytical framework was influenced by the papers written by Vidalakis & Sommerville (2013), García-Arca et al. (2018) and Rushton et al. (2014, pp. 486-487).

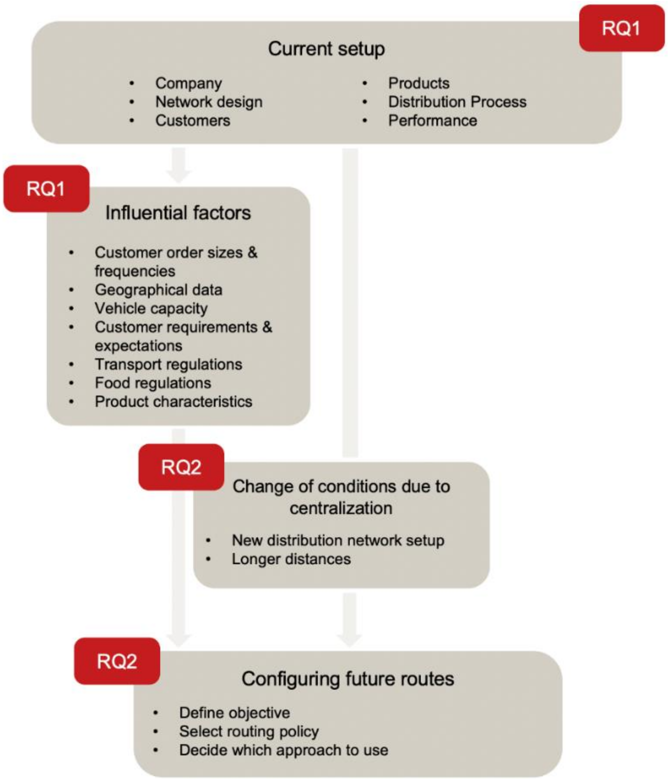


Figure 3.5: Part of the analytical framework relating to the first and second research questions

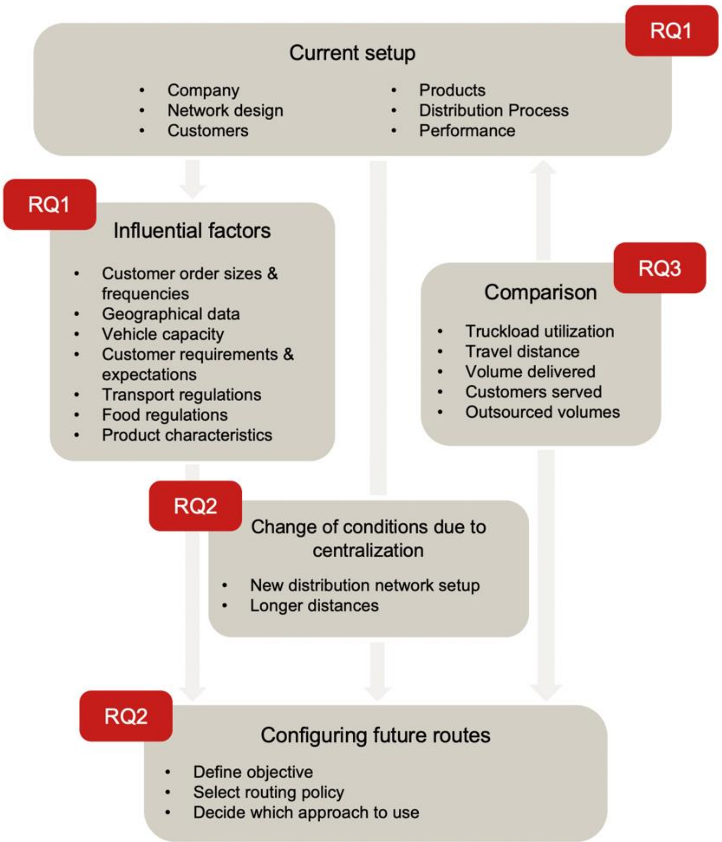


Figure 3.6: Part of the analytical framework relating to the first, second, and third research questions

By combining Figures 3.4, 3.5, and 3.6, the complete analytical framework can be constructed, as illustrated in Figure 3.7. The final output of this analytical framework is a proposed route configuration. This configuration will be presented through a route table, detailing all routes: the customers assigned to each route, the route schedule, type of delivery, type of vehicle, and duration per route.

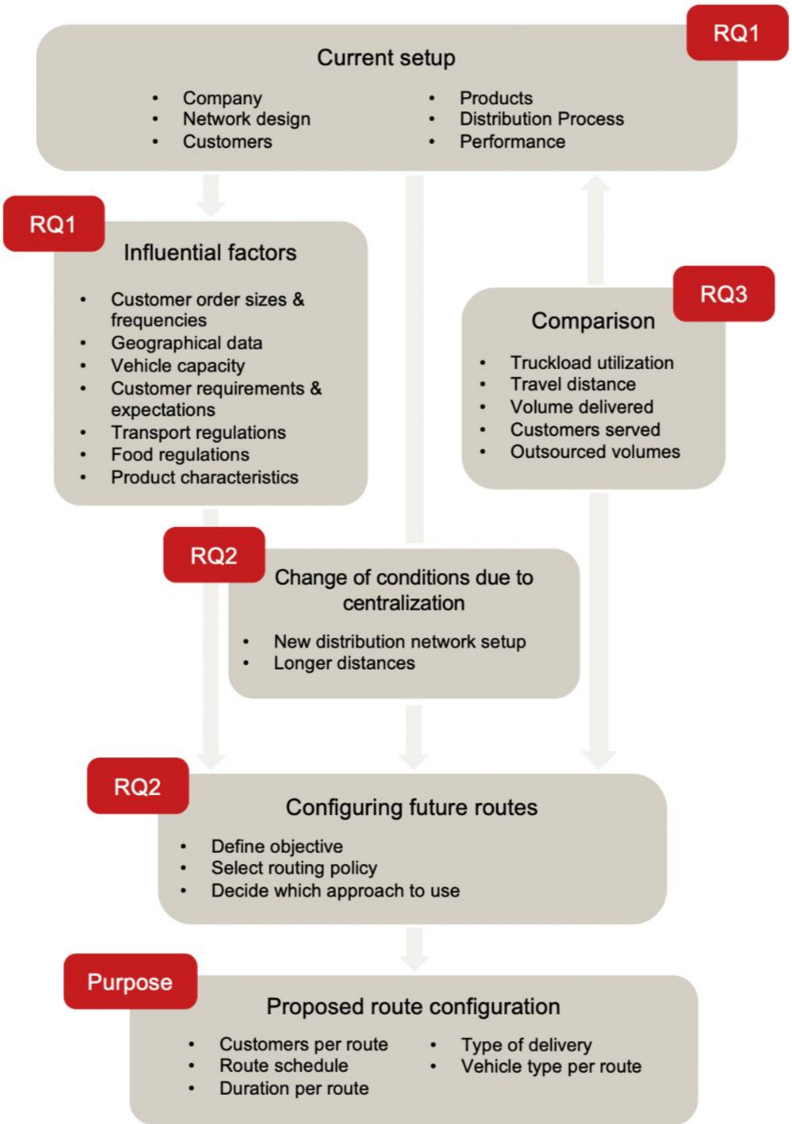


Figure 3.7: Final analytical framework

4 EMPIRICAL FINDINGS

This chapter aims to present quantitative and qualitative data about The Company, gathered through interviews, observations, and secondary data collection. The objective is to understand the current situation at The Company, including its business and distribution operations, to address the first research question. The description of the current situation forms a foundation for configuring future distribution routes and the data gathered will be used later in this thesis when addressing the second and third research question. The chapter begins with an overview of The Company's business, followed by a description of the existing distribution network, demand and product characteristics, distribution process, and the performance of the current distribution network. Finally, a summary of the empirical findings will be provided. The outline of this chapter is presented in Figure 4.1.

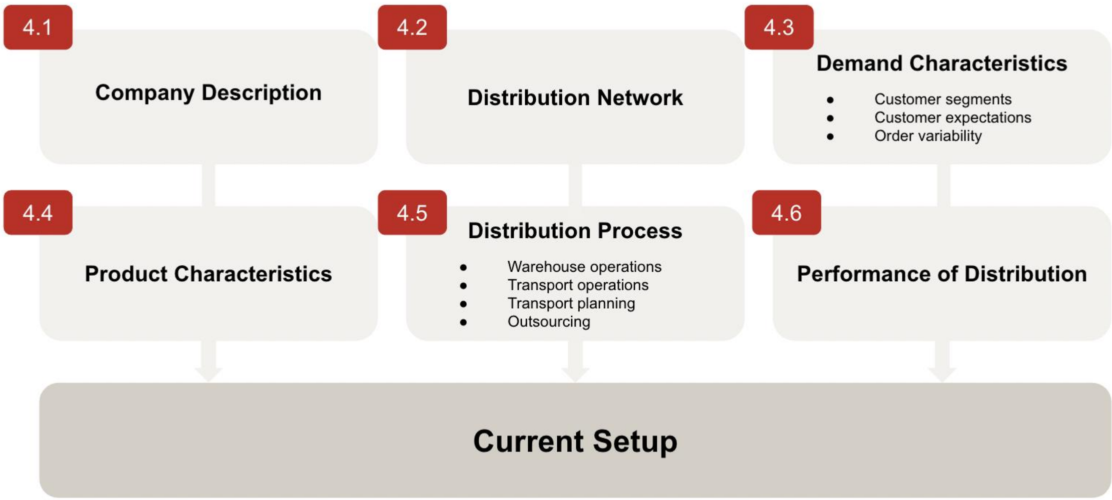


Figure 4.1: Outline of the empirical findings chapter

4.1 Company Description

According to the Supply and Demand Manager[1], the mission of The Company is to create value for their customers, so they can, in turn, develop and grow their business. This entails both increasing sales volumes and developing the product assortment. To achieve this, the Supply and Demand Manager highlights that The Company contributes in two ways: from an operational and a business development point of view. The operational perspective entails that The Company handles some of the complexity in the supply chain, meaning that they procure large quantities of the products and repackages them into mixed pallets. The business development side concerns being an innovative player in the Swedish food industry by creating new recipes and marketing material. The Company offers their customers e-commerce solutions, driving digitalization in the industry. All these efforts aim to create long-term, sustainable value for their customers. The Company is neither a cost leader nor carries the most premium products but can provide a holistic solution for their customers.

[1] Supply & Demand Manager, The Company. Interview. 2024-02-26.

The Company does not have a specific supply chain strategy formulated, as expressed by the Supply and Demand Manager[2]. The Company needs to be able to manage complexity for the customer, and, hence, the supply chain has to be designed to facilitate this, i.e., it should be both flexible and agile. Cost efficiency has not been a priority, but the Supply and Demand Manager explains that they have experienced that the market has become more price sensitive. Therefore, The Company needs to consider costs to a greater extent going forward.

The Supply and Demand Manager[3] divides their customers into two main segments: segment A and segment B. Segment A consists of smaller customers, who sell their products to consumers. On the other hand, segment B consist of large industry customers, delivering to grocery stores, restaurants, and hotels. The two main segments are split further into subsegments; in this thesis, these are referred to as customer groups. The customers' expectations differ depending on the segment since the businesses of these segments have completely different conditions. The customers are dispersed all over Sweden but are more concentrated around the metropolitan areas and around where The Company has warehouses.

The product assortment at The Company is divided into six product groups. Further, in the sales order data, the products are segmented into 20 different product categories.

4.2 Distribution Network

The current distribution network consists of four warehouses, where two are located in the south of Sweden, one in central Sweden and one in northern Sweden. Two of the warehouses are owned internally, while the other two are outsourced. According to the Warehouse Director,[4] the majority of all purchase orders are delivered to the warehouse in southern Sweden before there is an internal flow of goods to the other warehouses. The reason for this is that most suppliers are located in Europe or south of Sweden. Customers all over Sweden are served from these four warehouses, and one of the warehouses is dedicated to one single customer. Both of The Company's own warehouses have a combination of inhouse and outsourced distribution. Going forward, all data collected will concern the two internal warehouses.

The Company is planning to make a major change to their distribution network and will centralize its inventory into one central warehouse in the south of Sweden, see Figures 4.2 and 4.3. According to the Supply and Demand Manager,[5] there are several reasons for this decision. Among other things, The Company wants to reduce facility and personnel costs and optimize inventory levels better. Additionally, it is believed that the logistics flows will be streamlined with the new setup. When all inventory is consolidated in one location, the risk of stockouts can be minimized, thus preventing the possibility of having an item stored in the wrong warehouse. However, there are also several risks associated with centralizing the inventory. The interviewee mentioned that the total distribution costs will increase as a result of the

[2] Supply & Demand Manager, The Company. Interview. 2024-02-26.
[3] Supply & Demand Manager, The Company. Interview. 2024-02-26.
[4] Warehouse Director, The Company. Observation. 2024-02-20.
[5] Supply & Demand Manager, The Company. Interview. 2024-02-26.

centralization, due to increased average distance to customers. Nevertheless, costs related to the internal distribution between warehouses will be eliminated.

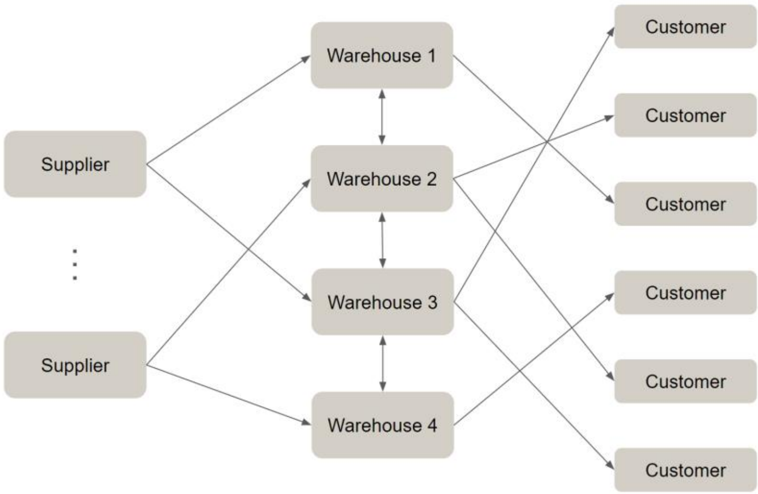


Figure 4.2: The Company's supply chain before centralization

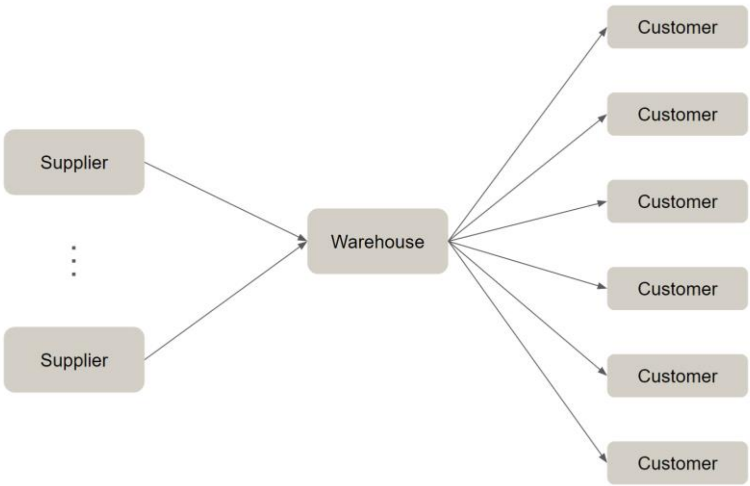
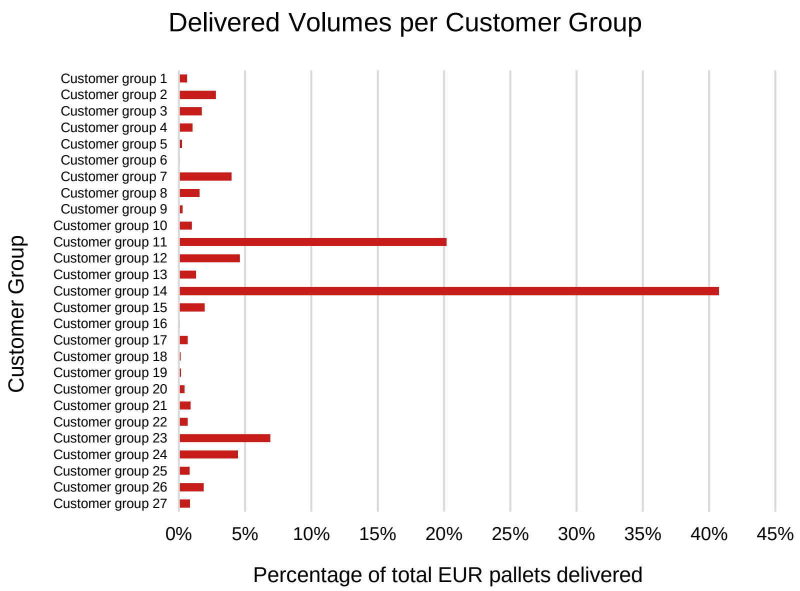


Figure 4.3: The Company's supply chain after centralization

4.3 Demand Characteristics

4.3.1 Customer Segments

As mentioned in section 4.1 above, The Company's customers are split into various segments. In 2023, the delivered volume per customer segment was substantially larger for segment A in relation to segment B as seen in Figure 4.5. The customer groups with the largest percentage of delivered pallets were customer group 11 and 14 with around 35% and 23% respectively, see Figure 4.4.



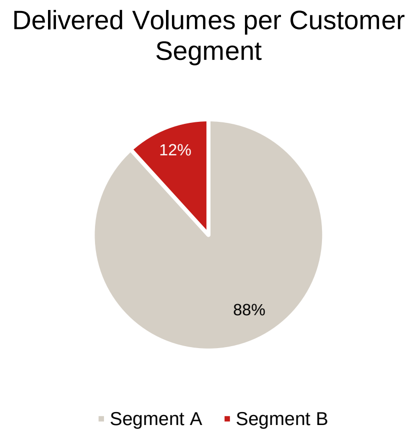


Figure 4.4: Percentage of delivered volume per customer group in 2023

Figure 4.5: Percentage of delivered volume per customer segment in 2023

The geographical spread of The Company's customers can be visualized in Table 4.1 by the percentage of pallets delivered, number of deliveries, and number of customers for each route area. The location of each route area is presented in Figure 4.6. The largest volume was delivered to route area 1, which corresponds to the Stockholm region, followed by route area 7 and 2, i.e., central Sweden and Scania respectively. Similar to the delivered volume, the largest percentage of deliveries was distributed to route area 1. In contrast to the delivered volume, route area 2 had the second largest percentage of deliveries followed by route area 7. Regarding the number of customers, most customers belong to route area 1, followed by route area 2.

Table 4.1: Geographical spread of The Company's customers

Route area	***Percentage of EUR pallets delivered***	***Percentage of deliveries***	***Percentage of customers***
1	25.33%	24.27%	18.85%
2	14.03%	14.30%	16.94%
3	7.08%	8.56%	9.37%
4	9.29%	8.87%	11.03%
5	9.97%	10.98%	11.33%
6	9.78%	9.73%	9.87%
7	14.44%	14.23%	13.33%
8	6.37%	5.62%	5.81%
9	3.70%	3.43%	3.46%

Figure 4.6: The location of route areas

4.3.2 Customer Expectations

The customers' expectations regarding distribution vary among the customer segments. According to the Supply & Demand Manager at The Company[6], the major differences are between the two customer segments. Customers in segment A tend to have limited opening hours and, in some cases, are only operating during the nights and early mornings. These customers are closed during one or two days in the week, which limits which days customers can receive their deliveries[7]. Another characteristic that distinguishes segment A from segment B is that they may not have sufficient space for storing safety stock, which makes timely deliveries critical for their business.

The conditions for delivering goods to customer segments differ greatly. Customers in segment B are typically located outside the city center while customers in segment A are located in proximity to the city center. In the city center, streets are smaller and moving goods from the truck inside to the customer can be more difficult, demanding more adaptability from the driver[8]. Segment B may have better physical conditions for delivery, but cooperation between the truck driver and the customer is also vital. A close relationship can facilitate faster unloading of the goods since customers tend to answer the door faster and are more inclined to be helpful[9]. Another aspect to consider is the importance of a personal relationship with the customers in segment A and B respectively. As observed during the distribution route to customers in segment A[10], it was evident that many of the customers appreciate having a personal relationship with the truck driver delivering their goods. In customer segment B, the number of employees is higher, and it is possible that this personal relationship is more difficult to be attained.

The Company's customers also have different requirements regarding how they want to receive deliveries. To accommodate customer's wishes, The Company has different load solution codes (A, B, C, D, E), which detail how the customer wants their goods delivered, see Table 4.2.

Customers' expectations regarding distribution vary also between geographical regions[11], as expressed by the Warehouse & Distribution Manager. In large metropolitan areas like Stockholm, customers expect more flexibility as well as more precise delivery windows.

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6 Supply & Demand Manager, The Company. Interview. 2024-02-26.
7 Truck Driver, The Company. Interview. 2024-02-28.
8 Truck Driver, The Company. Observation. 2024-02-28.
9 Truck Driver, The Company. Interview. 2024-02-28.
10 Truck Driver, The Company. Observation. 2024-02-28.
11 Supply & Demand Manager, The Company. Interview. 2024-02-26.

Table 4.2: Load Solution Codes with explanations

Load Solution Codes	
A	Pallet unloading
B	Carry-in without stairs
C	Carry-in with stairs >5
D	Carry-in without stairs and picked onto shelves
E	Carry-in with stairs >5 and picked onto shelves

4.3.3 Order Variability

The number of orders delivered per week during 2023 is overall stable over the course of the year, as displayed in Figure 4.7. Some small variation of orders per week in total can be detected, but when considering average per customer, the variation is much less prominent. When looking at the number of delivery orders over a week in Figure 4.8, it is evident that a larger number of orders are delivered in the middle of the week and in the beginning and end of the week, the number of delivery orders are fewer. Delivery orders per customer peaks on Tuesday while delivery orders in total reaches a plateau during Tuesday, Wednesday, and Thursday.

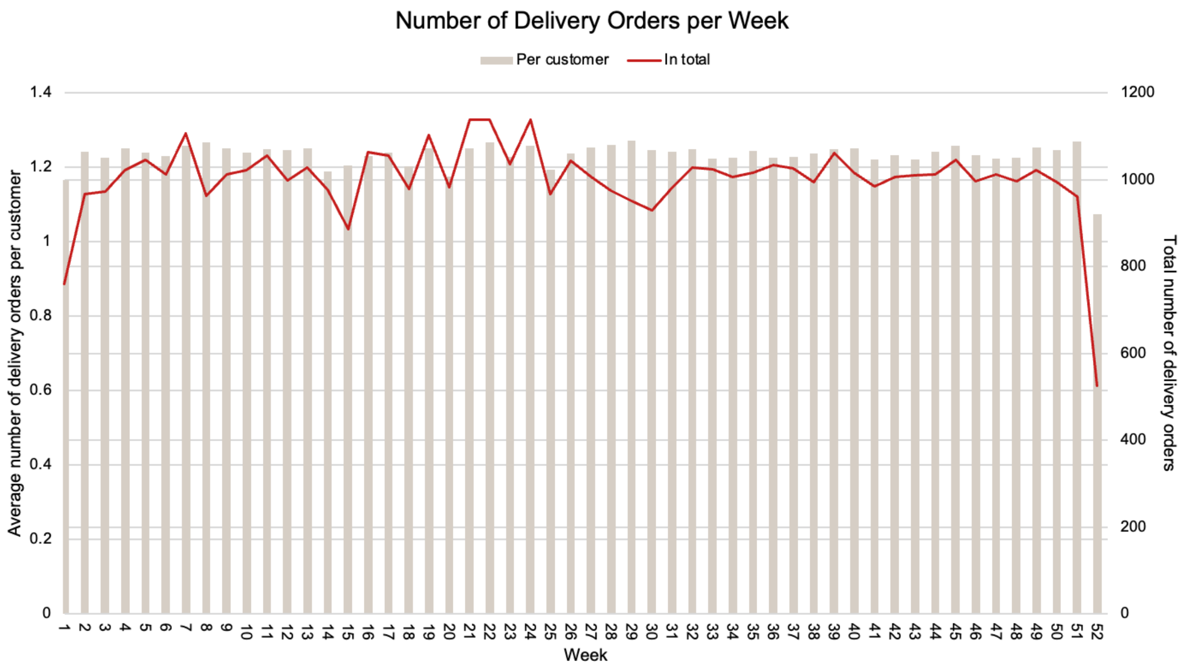

Figure 4.7: Weekly number of delivery orders in total and per customer in 2023

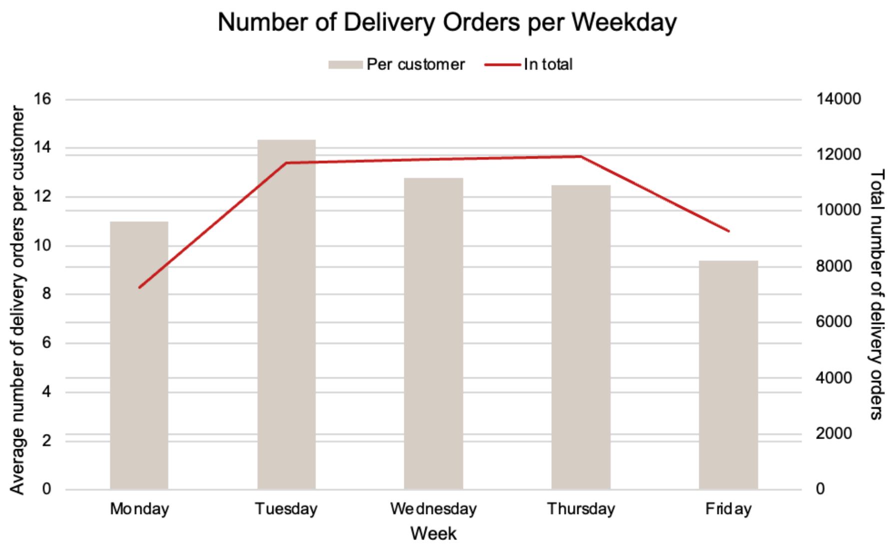

Figure 4.8: Average number of delivery orders per customer and weekday and total number of sales orders per weekday in 2023

The number of pallets delivered per week over the year per customer and in total is shown in Figure 4.9. In similarity to the number of deliveries per week, there is less variation when considering the number of pallets delivered per customer compared to in total. The number of pallets delivered over the course of a week peaks in the middle of the week as can be seen in Figure 4.10. The number of pallets per customer and in total peaks on Wednesday and, thereafter, starts to decline.

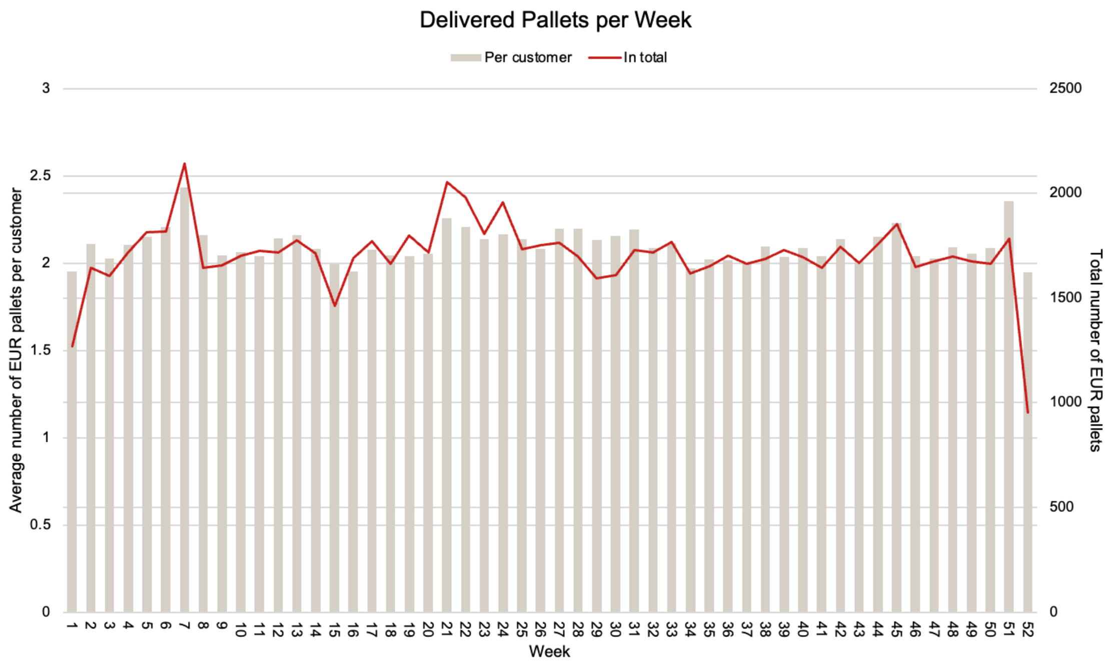

Figure 4.9: Weekly delivered volume in total and per customer in 2023 (EUR pallets)

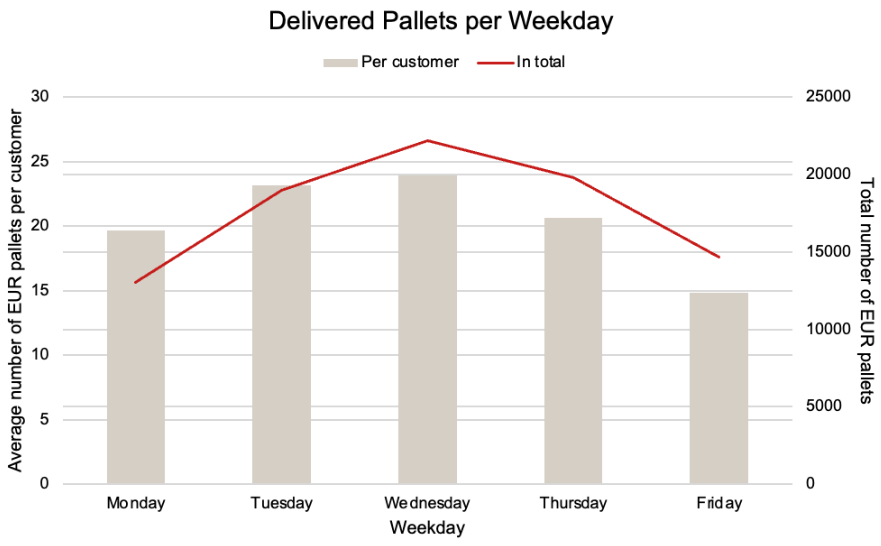

Figure 4.10: Average number of pallets delivered per customer and weekday and total number of pallets delivered per weekday in 2023

4.4 Product Characteristics

The Company is offering a wide product assortment, divided into six different categories. Currently, there are 2634 active products in The Company's assortment, which are further divided into 20 subcategories. The category "SERV", which corresponds to non-food, includes the largest number of articles.

There are several product characteristics to consider that make the distribution complex, including temperature requirements, shelf life and fragility[12]. The products have different temperature requirements and can be categorized as either cooled, dry or frozen. The majority of the products are dry, see Table 4.3.

Table 4.3: Temperature requirements

Temperature requirements	***Percentage of total number of items***
Cooled	12.6%
Dry	79.8%
Frozen	7.6%

Certain products provided by The Company cannot be stacked due to their fragility[13]. This aspect must be considered during the picking and distribution processes to prevent damages. Additionally, when distributing food, it is crucial to recognize that certain products should not

[12] Truck Driver, The Company. Interview. 2024-02-28.
[13] Truck Driver, The Company. Interview. 2024-02-28.

be loaded onto a truck alongside items with other characteristics to avoid the risk of contamination.

4.5 Distribution Process

This section describes The Company's distribution process in terms of warehouse operations, transport operations, transport planning and outsourcing of distribution. Warehouse operations concern the interaction between warehousing and distribution, transport operations concern how goods are transported from the warehouse to the customers and the fleet capacity. Transport planning details how routes are planned at The Company, and outsourcing describes how The Company outsources transport along with its advantages and disadvantages.

4.5.1 Warehouse Operations

As expressed by the Warehouse Director[14], there is a significant interaction between warehousing and distribution. The picking operations in the warehouse are prioritized based on the distribution order. Depending on what time the pallets need to be ready to be loaded onto the truck, the customer orders are released to be picked. Most pallets picked are mixed, meaning several stock keeping units (SKUs) are combined on the same pallet. Different kinds of pallets, such as EUR pallets, plastic pallets, and roll cages, are all used during picking depending on what the customer has specified. In total, The Company has 27 different pallet types, which have different dimensions. Important to note is that some of the pallet types are packages. They are considered to not occupy any area in the vehicle as they will be stacked on other pallets. Once picked, the pallets are placed in the outbound area, ready to be loaded onto a truck.

4.5.2 Transport Operations

Each morning, the truck driver receives a driving list including the customers, belonging to a particular route, that need to be served that day[15]. The delivery sequence is pre-determined in collaboration with the truck driver since it is he/she who possesses the best knowledge regarding what sequence works best for the customers while also minimizing the travel time[16]. This sequencing is dependent on any customer-specific requirements regarding the preferred time for order delivery. For instance, some customers wish to receive their deliveries early in the morning before the employees leave for the day and in those cases, these customers need to be handled first. Some customers do not open their business until later during the day, and hence, they have to be placed later in the order. Thus, it is important that the truck driver knows its customers and their specific needs. Consequently, a decision has been made to allocate specific routes and customers to each driver, in order to ensure consistency on a weekly basis. This approach enables drivers to develop familiarity with their assigned routes and customers, which facilitates a more efficient and personalized service.

[14] Warehouse Director, The Company. Interview. 2024-02-20.
[15] Truck Driver, The Company. Interview. 2024-02-28.
[16] Warehouse & Distribution Manager, The Company. Interview. 2024-03-11.

When the driver arrives at the outbound area, he/she collects the delivery notes for the route from the office and begins to load the truck with the pallets to be delivered during the route[17]. The driver loads the pallets according to which order they will be delivered to the customer to ease the unloading at the customer. Depending on the temperature requirements of the pallets, the loading space of the truck can be split into cool and frozen areas. The pallets are stacked on top of each when necessary, and when the driver deems it possible without damaging the goods. Once the truck is loaded, the driver begins the delivery route. For routes with longer driving distances, the driver sometimes pre-loads the truck the day before in order to save time. In other cases, when customers are located near a warehouse, it is possible for the truck driver to reload the truck during the day.

There are several ways of unloading and delivering the goods when the truck is at the customer site[18]. Some customers request the deliveries to be carried inside and placed onto designated storage shelves while other customers request that the pallets are unloaded from the truck into the customers' inbound. At some customers, there is limited space to transport the pallets from the truck and to place them inside at the customer, which increases the level of difficulty of the delivery. The truck driver also collects load carriers in connection with delivery. The aim is to collect the same number of load carriers as delivered, but since the number can vary between deliveries, the number of load carriers collected is not the same as delivered.

The truck fleet at The Company amounts to 5 trucks at the warehouse in southern Sweden and 8 trucks as well as 3 trailers at the warehouse in central Sweden. All trucks can load 18 pallets with a maximum weight of 13 tons and the trailers can load 27 pallets with a maximum weight of 24 tons. All trucks and trailers can facilitate both cool and frozen temperature requirements. It is possible to utilize trucks for double decking, allowing pallets to be loaded onto the truck on two levels. This increases the truck's capacity to 36 pallets. However, double decking is not commonly used because it complicates the unloading process and requires more time to unload the goods. Not all trucks and trailers are out distributing to customers Monday to Friday, there may be days where a truck and a trailer is not used.

Trailers are used for two purposes[19]. One of the three trailers is used for long-haul distribution of goods to metropolitan cities, and then the last-mile delivery to customers is outsourced. The two other trailers are used for two-day trips to customers that cannot be reached on a one-day trip or when the volumes exceed the capacity of a truck. On those trips, the goods are transferred from the trailer to the truck during the route. There are four routes which are two-day trips with trailers, and all of them depart from the warehouse in central Sweden. Those routes are: O01 Thursday and Friday, O08 Thursday, O03 Monday, Tuesday, and Wednesday, and O77 Wednesday and Thursday. The Warehouse & Transport Manager[20] at the warehouse in central Sweden believes that the trailers are essential for their distribution. They are needed for two-day trips and for pickups of large volumes at suppliers.

[17] Truck Driver, The Company. Observation. 2024-02-28.
[18] Truck Driver, The Company. Observation. 2024-02-28.
[19] Warehouse & Transport Manager, The Company. Interview. 2024-04-08.
[20] Warehouse & Transport Manager, The Company. Interview. 2024-04-08.

At the warehouse in southern Sweden, there are four full-time employees and at the warehouse in central Sweden, there are eight full-time employees. The employees work between 9.5 and 12 hours per day excluding breaks. Table 4.4 presents a summary of capacity at each warehouse. The Company has the possibility to utilize flexible manpower in case of sickness or planned absence. The Company has experienced difficulty finding truck drivers that are able to meet their expectations in terms of timeliness and customer service[21].

Table 4.4: Summary of capacity at each warehouse

	Warehouse Southern Sweden	***Warehouse Central Sweden***	***Total***
# of trucks	5	8	13
# of trailers	0	3	3
# of FTE	4	8	12

4.5.3 Transport Planning

The transport routes are fixed and are only replanned when new customers are added or removed, otherwise one to two times a year[22][23]. The objectives when planning the routes are to minimize travel distance and maximize truckload utilization. No software is used for optimizing the routes in terms of truckload utilization or travel distance. Instead, the planning is done manually and is based on historical routes. Some deliveries are moved around between routes on a daily basis to ensure there is enough space for the deliveries as well as to increase utilization[24]. As The Company grows, more customers are added to the routes. New customers are added to the route that best fits in terms of geographical area and expected order volume[25]. Another consideration when adding new customers to a route is to ensure that there is sufficient time to serve all customers. How much time is required for delivery at each customer depends on the volume, conditions for unloading, unloading specifications (carry-in or just dropping the pallet off), and the season. In instances where the volume for a single route surpasses truck capacity or where the number of customers is deemed to be unmanageable, a route may be divided into two. There are also instances when customers are removed from a route. For example, in cases when it is noted that the customer has started to order significantly less volumes, adjustments to the route schedule are made. When a customer has not ordered in several months, the customer is removed from the route unless the customer is marked as seasonal[26].

[21] Truck Driver, The Company. Interview. 2024-02-28.
[22] Warehouse & Distribution Manager, The Company. Interview. 2024-03-11.
[23] Supply & Demand Manager, The Company. Interview. 2024-02-26.
[24] Warehouse & Distribution Manager, The Company. Interview. 2024-03-11.
[25] Warehouse & Distribution Manager, The Company. Interview. 2024-03-11.
[26] Warehouse & Distribution Manager, The Company. Interview. 2024-03-11.

According to the Warehouse & Transport Manager[27] at the warehouse in central Sweden, there are several challenges related to route planning. One of them is the difficulty to estimate how many customers that can be served within a day. The reason for this is that the time required for unloading the truck at customers differs greatly between customers.

According to the Supply and Demand Manager[28], internal transport is booked the day before the truck is departing, where an approximate number of pallets is established depending on the volume of customer orders. However, the final volume in terms of number of pallets cannot be determined until every item is picked and loaded on the truck. The reason for this is that mixed pallets are common, making it challenging to determine the volume in advance. External transport is booked by sending a file to the transport provider with details regarding the shipment, such as weight, number of pallets and temperature requirements.

In total, there are 91 routes, of which 43 are driven by trucks owned by The Company and 48 are outsourced to transport providers, see Table 4.5. During 2023, 1996 different customers have been served from these routes, where 982 belong to internal routes and 1400 belong to external routes. Important to note is that the sum of those numbers exceeds the total customer served, meaning that some customers have been served by both internal and external carriers during the year. From the data, it is evident that one customer can belong to several routes. When studying the internal routes, it can be observed that certain customers have belonged to six different routes during 2023. Table 4.6 illustrates the five most frequently driven routes internally and the number of customers that have been assigned to the route, number of times it has been driven and the number of pallets delivered by the route during a year.

Table 4.5: Number of routes and customers handled internally and externally

Carrier	***Number of routes***	***Number of customers served***
External	48	1400
Internal	43	982
Total	91	2382*

* Some customers have been served by both external and internal routes. In total, 1996 customers have been served during 2023.

[27] Warehouse & Transport Manager, The Company. Interview. 2024-04-08.
[28] Supply & Demand Manager, The Company. Interview. 2024-02-26.

Table 4.6: Overview of the top 5 most frequently internally driven routes

Top 5 most frequently driven routes	***Number of customers assigned to the route***	***Number of times driven during 2023***	***Number of pallets delivered by the route during 2023***
L01	144	251	3457.25
O04	76	239	3082
O01	77	236	3522.5
L03	100	235	3026.75
L02	119	202	3636.75

4.5.4 Outsourcing

The Company has decided to keep some of the distribution in-house and outsource the rest. According to the Supply and Demand Manager,[29] The Company currently outsources approximately 60% of its distribution in terms of volumes delivered to customers. This is supported by the data collected, which indicates that 55.98% of the total volume delivered to customers during 2023 was handled by an external carrier, see Table 4.7. The Company currently employs around eight different transport providers. The interviewee explained that the transport is procured by geographic area. It is most common that internally owned trucks are used for distribution in proximity to the warehouses in southern Sweden and central Sweden, while distribution to areas in the north are more often outsourced. This is indicated also by the data, where it can be observed that cities in the north with zip codes starting with 8 and 9 have only a few internal routes, see Table 4.8 and Figure 4.11. Additionally, metropolitan cities, which correspond to those zip codes starting with 1 and 4, also have less internally driven routes.

The Supply and Demand Manager[30] mentioned both advantages and disadvantages with keeping distribution in house. He emphasized that the primary advantages are control, maintaining market knowledge and establishing a well-known presence in the market. The truck driver[31] also mentioned that some customers value that their goods are delivered by The Company itself and appreciate the continuity of the same truck driver delivering the goods every time. However, there are also numerous challenges associated with owning trucks, which are related mainly to cost efficiency, as ownership of trucks entails significant fixed costs[32]. Additionally, the Warehouse Director[33] explained the challenge with filling up the internally owned trucks. The volumes transported to customers are often too small to fill an entire truck,

[29] Supply & Demand Manager, The Company. Interview. 2024-02-26.
[30] Supply & Demand Manager, The Company. Interview. 2024-02-26.
[31] Truck Driver, The Company. Interview. 2024-02-28.
[32] Supply & Demand Manager, The Company. Interview. 2024-02-26.
[33] Warehouse Director, The Company. Interview. 2024-02-20.

resulting in low truckload utilization. When outsourcing distribution, this issue can be overcome as deliveries can be jointly loaded, thereby increasing truckload utilization.

Table 4.7: Percentage of number of pallets delivered with internal and external distribution in 2023

Carrier	***Percentage of pallets delivered***
External	55.98%
Internal	44.02%

Table 4.8: Number of routes driven internally and externally per route area ID

Route area ID	***Internal routes***	***External routes***
1	5	22
2	11	6
3	8	15
4	2	13
5	12	18
6	25	13
7	31	19
8	4	12
9	1	9

Figure 4.11: The location of route areas

4.6 Performance of Current Distribution

The Supply and Demand Manager at The Company[34] mentioned that the performance of distribution is measured with several KPIs, such as cost per kilograms, cost per stops at customers, and travel distances. Travel distance is mainly measured for internal transport, as it is difficult to estimate distances for outsourced distribution. Another measure used is truckload utilization, which is currently only measured in terms of weight. However, the Supply and Demand Manager believes that it would be more appropriate to measure utilization in terms of volume. The reason for this is that the weight of the goods seldom reaches the maximum allowed weight before the loading space of the truck is filled. By analyzing the data received, an estimation of the truckload utilization in terms of volume was made. The measure was determined only for the internal routes. Since transport providers often carry The Company's products alongside those of other companies, estimating truckload utilization for outsourced routes is deemed irrelevant.

The average truckload utilization of each route was calculated by dividing the total volume delivered by each route by the total number of times that specific route was driven, to achieve an average volume per route. Subsequently, the truckload utilization was calculated by dividing by the truck's pallet storage capacity, i.e., 18 pallets. For some of the routes departing from the warehousing in central Sweden, trailers are used and for those, the capacity is 45 pallets. To estimate the average utilization of each route, it was assumed that pallets cannot be stacked

[34] Supply & Demand Manager, The Company. Interview. 2024-02-26.

inside the truck. It is worth noting that the utilization is calculated from the moment the truck departs from the warehouse and, hence, does not account for the decrease in utilization as goods are delivered to customers.

The travel distance for each internal route was determined by first identifying all customers who have ever been assigned to each route. Calculating the mileage between all these customers would not accurately represent the travel distance per route, as the composition of customers on a route has varied throughout the year. As previously mentioned, some customers have been assigned to as many as six different routes within a year. To obtain an average travel distance per route, we divided the number of times a customer has been assigned to a route by the total number of times the route has been driven. We then summed up this ratio for all customers on each route and divided it by the total number of customers who have ever been assigned to that route. This calculation results in a percentage, which we then multiply by the actual travel distance between all customers for each route. To estimate travel distances, the sequence in which customers within a route should be served is determined. This is achieved by first identifying the customer closest to the warehouse and then sorting the remaining customers based on their distance to the initial customer in the route. To calculate Euclidean distances, we used coordinates in terms of longitude and latitude for each customer and both warehouse locations. The total Euclidean distance between all stops on a route was then multiplied by 1.2 to approximate the driving distance, in line with literature (Cooper, 1983; Rushton et al., 2014, p. 486; McKinnon & Ge, 2007). To facilitate the calculations, a function was written in MATLAB, see Appendix F.

Table 4.9 presents the five most frequently driven routes along with their average truckload utilization and travel distance. For details regarding the truckload utilization and travel distance for each internal route, see Appendix D. The truckload utilization varies significantly, with an average utilization rate of 66%. Table 4.10 displays the routes with the lowest utilization. The route called 300I has, according to the table, been driven 51 times but only delivered 4 pallets. This route delivers a special pallet type, called cold packages, which are considered to not occupy any space in the truck. The utilization of 0% is misleading, and therefore, this route is excluded when determining the average truckload utilization. Regarding the travel distance, it was calculated to be 19780 kilometers in total for all routes.

Table 4.9: Top 5 most frequently driven routes and their average truckload utilization and travel distance during 2023

Route	***Number of pallets delivered***	***Number of times driven***	***Average pallets per route***	***Average truckload utilization***	***Average travel distance (km)***
L01	3457.25	251	13.77	77%	1075
O04	3082	239	12.90	72%	176
O01	3522.5	236	14.80	56%	384
L03	3026.75	235	12.83	71%	103
L02	3636.75	202	15.48	86%	105

Table 4.10: Top 5 routes with lowest average truckload utilization during 2023

Route	***Number of pallets delivered***	***Number of times driven***	***Average pallets per route***	***Average truckload utilization***	***Average travel distance (km)***
300I	4	51	0.08	0%	2491
S04	7	8	0.88	5%	0.007
ÄR LEV	49.5	36	1.13	6%	663
L EXTRA	37.75	10	3.78	21%	21
O77	566.3	51	11.10	25%	304

4.7 Summary of Empirical Data

The Company's business is summarized in Figure 4.12. The mission is to create value for their customers, so their customers can continue to develop and grow their business in turn. To achieve their mission, The Company aims to create value both in operations and business development by managing some of the complexities in the supply chain for their customers and helping their customers with business development. The supply chain and, more specifically, the distribution function at The Company needs to be able to serve their customers and, historically, this has entailed flexibility and agility. However, the Supply and Demand Manager[35] expressed that there should be a stronger focus on cost efficiency moving forward in order to align with the customers' increasing price sensitivity. In addition, The Company will centralize their warehouses into a single warehouse, which changes the conditions for distribution.

[35] Supply & Demand Manager, The Company. Interview. 2024-02-26.

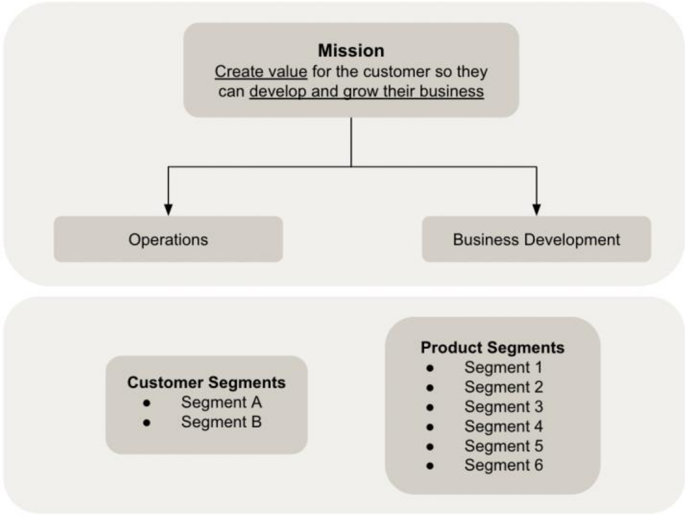

Figure 4.12: Summary of The Company's business including mission, customer segments, and product segments

The differences between customer segments can be categorized into personal relationship, delivery accuracy, geographical differences, and ease of delivery. Segment A value having a more personal relationship with the driver delivering their goods compared to segment B. Delivery accuracy is more important for segment A and, particularly, for the smaller customers in this segment. They are unable to keep large stocks and rely, therefore, on that their order is delivered on time in complete. The hours they are able to receive deliveries may also be more limited compared to segment B. Deliveries to customers in segment A can occur more smoothly in some respects. For example, one driver expressed that they are faster to answer the door or phone and are overall more helpful. However, the location of these customers can make the delivery more difficult since there is usually less space, more people in movement in the area, and the streets are more uneven (for example, cobblestone). Differences between geographical segments also exist.

The order variability over the year and week looks relatively similar when considering the number of orders compared to volume. It is relatively constant over the course of the year when considering per customer and week but has some more peaks and surges when considering the total. When examining variability over the course of a week, the average number of deliveries and delivered volume per customer and in total peaks in the middle of week.

Another important aspect to consider for the distribution are the characteristics of the products. There are different temperature requirements - dry, cool, and frozen - and these must be complied with during distribution. Other considerations that impact the distribution are shelf life, contamination, and fragility. Some products are fragile, which makes it difficult to stack pallets on top of each other.

The current distribution is based on fixed routes and replanning of the routes is seldom performed unless new customers are added or removed. Most routes are either driven internally or externally, with the exception of some routes in the Lomma area. About 44% of the pallets are distributed internally and 56% are distributed with external partners.

Regarding the performance of the distribution network, it can be concluded that truckload utilization varies to a great extent between the internal routes, with an average utilization of 66%. The total travel distance for all internal routes was calculated to be 19780 km.

5 ANALYSIS

This chapter aims to address the three research questions by applying the analytical framework to the empirical findings. The first part focuses on identifying the influential factors affecting route configuration at The Company, followed by the configuration of new routes. Lastly, a comparison between the performance of the current distribution network and the proposed solution will be conducted, encompassing both quantitative and qualitative analyses and recommendations on next steps. The outline for this chapter is demonstrated below in Figure 5.1.

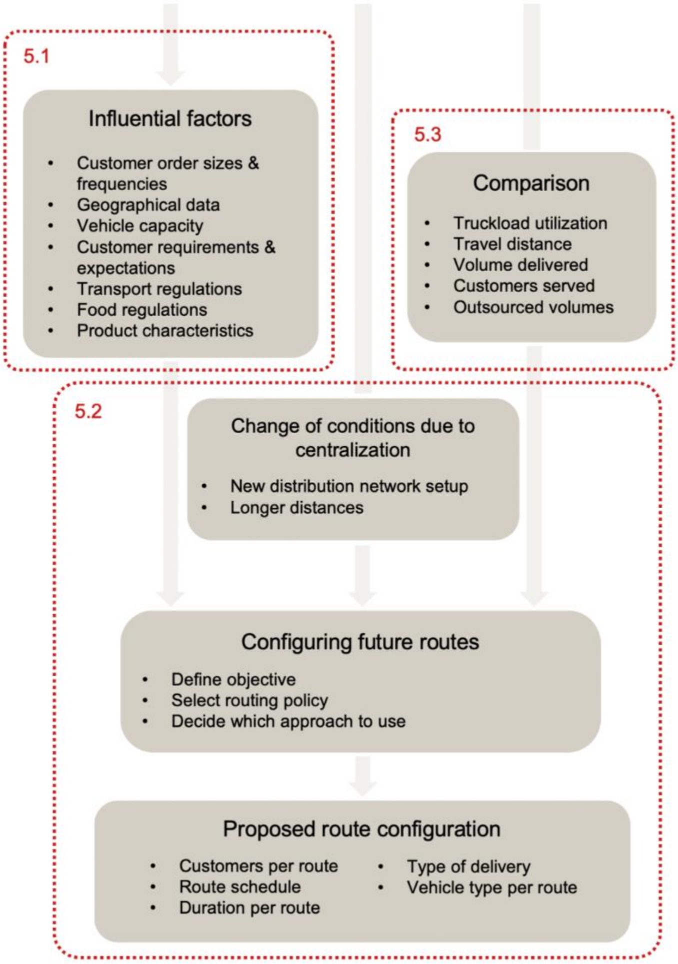

Figure 5.1: Outline of the analysis chapter

5.1 Analysis of Current Configuration

In order to configure the future routes effectively, addressing RQ1 is essential. In the previous chapter, *4 Empirical Findings*, the current situation was mapped using aspects identified in literature as a starting point. The next step in addressing RQ1 is to apply the influential factors identified in literature to the Company to understand what The Company needs to consider in the route configuration. Hence, the purpose with this section is to generate the input necessary to address RQ2. In the following paragraphs, each influential factor will be applied to The Company.

5.1.1 Customer Order Sizes and Frequencies

Customer order sizes are essential to determine for configuring the routes and allocating resources properly (Fisher, 1995). As presented in empirical findings, the customer demand is relatively stable. This suggests a fixed routing policy and, consequently, an average demand can be used in route planning.

For each customer, the average demand per delivery was calculated using demand data from the empirical findings by first determining the total volume delivered during 2023. The demand was standardized to EUR pallets to facilitate truckload utilization calculations, as it is known that a truck can store 18 EUR pallets and a trailer can store 27 EUR pallets. The standardization was made by dividing the area of each pallet type with the area of an EUR pallet. An average demand per delivery per customer was determined by dividing the total number of pallets delivered during 2023 by the total number of deliveries during the same time period. For those customers who order more seldom than once a week, a weekly demand was determined by dividing the total number of pallets delivered by the number of weeks of a year. The result of the calculations indicates that 0 to 1 pallet are most commonly ordered, see Figure 5.2.

Figure 5.2: Customer order sizes

In addition to customer order sizes, the delivery frequency per customer was determined in line with what Fisher (1995) suggests. This was done by dividing the total number of deliveries during a year by 52 weeks. The results indicate that the delivery frequency varies from 5 times a week to once a year, see Figure 5.3. From the figure, it can be seen that most customers receive deliveries more seldom than once a month.

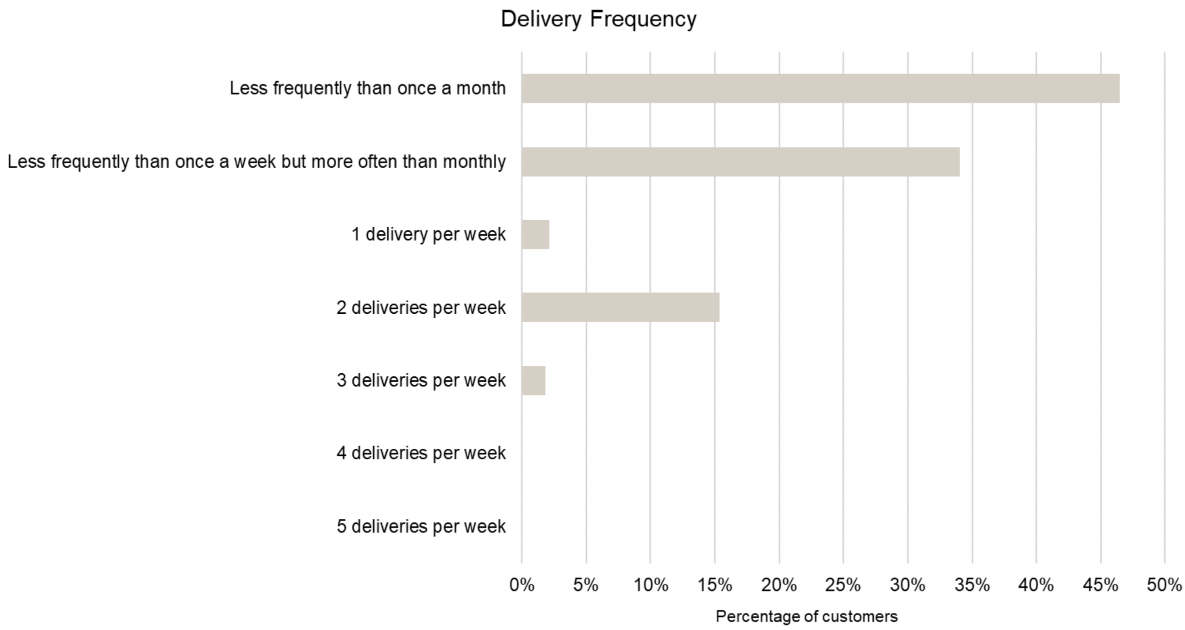

Figure 5.3: Delivery frequency

5.1.2 Geographical Data

As identified by Fisher (1995), geographical data is necessary for configuring the future distribution routes. Geographical data in this context consists of the delivery address for each customer, and to represent this information, zip code has been selected. The zip code consists of five integers, which facilitates easier data analysis compared to a complete delivery address while still retaining some precision of the delivery location. From the zip code, the route area ID and the route subarea ID could be constructed based on the first number as well as the first and second numbers of the zip code respectively. For example, for a customer with the zip code 24430, the route area ID is 2 and the route subarea ID is 24. The route area ID and route subarea ID are used for segmenting customers into different groups based on geographical location.

In addition to segmenting customers based on location, geographical data is used for calculating distances. For this, longitudinal and latitudinal coordinates are used to calculate the distance between two locations from a bird's eye view. This distance is multiplied by a factor 1.2 to estimate the actual driving distance (Cooper, 1983; Rushton et al., 2014, p. 486; McKinnon & Ge, 2007). The distance is used for comparing the current route configuration with the proposed as well as validating the proposed solution.

5.1.3 Vehicle Capacity

Next, the vehicle capacity was considered to be an important factor in vehicle routing (Fisher, 1995). Vehicle capacity also plays a critical role in defining vehicle routing problems as can be noted in the literature review by Konstantakopoulos et al. (2020). The Company has a homogenous fleet of vehicles, meaning that all the trucks have the same capacity (Konstantakopoulos et al., 2020). As described previously in section 4.5.2, the fleet consists of 5 vehicles in southern Sweden and 8 vehicles in central Sweden. However, the number of vehicles in use depends on the number of drivers on the work schedule that day. The number of trucks available for deliveries each day when combining trucks both from the warehouse in southern Sweden and central Sweden is presented in Table 5.1. Although all the vehicles have homogenous capacity, there is some degree of variable capacity by utilizing trailers. There are 3 available trailers in central Sweden and by attaching a trailer to the truck, the capacity increases from 18 EUR pallets to 45 EUR pallets. Furthermore, the capacity of a truck can be increased by utilizing double decking, which increases the capacity of a truck from 18 EUR pallets to 36 EUR pallets.

Table 5.1: Number of trucks in use each day of the week

	Monday	***Tuesday***	***Wednesday***	***Thursday***	***Friday***
Number of trucks in use	7	11	11	10	9

5.1.4 Customer Requirements & Expectations

As described in empirical findings, The Company's customers have several expectations and requirements on deliveries, for instance preferred delivery time windows. Although this aspect is recognized as a crucial factor in route configuration (Rushton et al., 2014, p. 50; Fisher, 1995; Konstantakopoulos et al. 2020), it is deemed unfeasible to incorporate into the distribution route planning at The Company. This is primarily due to the absence of formal agreements regarding customer expectations and requirements. Instead, the emphasis lies on the truck drivers' familiarity with their customers and their individual preferences. Since there is insufficient data on each customer's preferences, it cannot be included during the planning stage. Instead, the routes have to be fine-tuned manually after planning, based on the truck driver's knowledge about the specific customer requirements, such as their preferred delivery time window. However, the exception is the customers' requirements about how they want to receive their goods, which is described by the load solution code. This aspect will be considered when configuring the future routes, since formal agreements exist regarding this.

5.1.5 Transport Regulations

Transport regulations limit the working hours and driving time for truck drivers (Transportstyrelsen, n.d), thereby restricting the time available per route and the number of customers that can be served. Based on data collected in the empirical findings, 8 customers were served per route driven on average during 2023. However, as seen in Figure 5.4, it varies to a great extent, from 1 customer up to 25 customers. The number of customers that can be served is dependent on several factors, such as geographic location, order sizes and whether the route is driven on a single day or a two-day trip. For instance, more customers can be served if driving in proximity to a warehouse, compared to driving farther away. Additionally, with larger volumes ordered, less customers can be served as the truck will be filled faster. For instance, for routes O07 and O08, an average of 2.4 customers are served due to large order sizes.

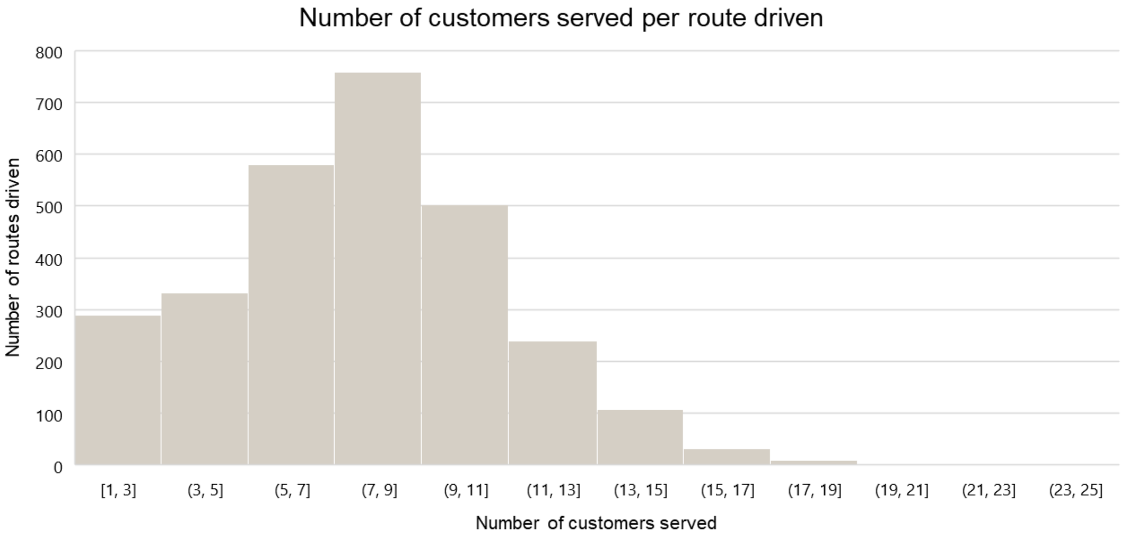

Figure 5.4: Number of customers served per route driven

Currently, The Company estimates the number of customers that can be served during a route based on experience and knowledge about unloading times at various customer locations. The time it takes to serve a customer depends on many aspects. For instance, it depends on where the truck can park in relation to the receiving area. Additionally, it depends on a customer's requirements regarding whether they want the goods to be carried in or not. As mentioned in empirical findings, The Company has different load solution codes (A, B, C, D, E) which describe the customer's wishes regarding delivery. 93% of all customers are assigned the solution code A, which corresponds to the fastest unloading method: unloading a pallet at the customers receiving area. Based on observations from following a truck driver along a distribution route, the time it takes to unload the goods per load solution code has been estimated, see Table 5.2.

Table 5.2: Estimated time for unloading per load solution code

Load Solution Codes		Estimated time
A	Pallet unloading	15 min regardless of number of pallets
B	Carry-in without stairs	20 min/pallet
C	Carry-in with stairs >5	20 min/pallet
D	Carry-in without stairs and picked onto shelves	25 min/pallet
E	Carry-in with stairs >5 and picked onto shelves	25 min/pallet

In addition to the unloading time at customers, the time it takes to load the truck at the warehouse needs to be estimated to be able to determine the total time it takes to manage a route. Based on observations from following a truck driver along a distribution route, it was observed that loading a truck with 18 pallets takes approximately 30 minutes. As a result, we assume a loading time of 1.67 minutes per pallet.

In route planning, it is essential to ensure that the truck driver can effectively serve and reach all customers included in the route within the working hours. Estimating the total time per route, including time for loading the truck at the warehouse, driving time, and time for unloading at the customer, is used in this thesis to make sure that transport regulations are complied with, as well as ensuring that the proposed route configuration is feasible.

5.1.6 Food Regulations

As highlighted in literature, compliance with food regulations, such as keeping the cold chain, is necessary when distributing food (Swedish Association for Frozen and Refrigerated Foods, 2016). All of The Company's trucks and trailers are MCV (Multi Compartment Vehicles) which means that the loading area can be divided into compartments with different temperature zones (Ostermeier et al., 2020). Hence, all vehicles can transport products with various temperature requirements in the same truck. It is possible to move the partition between chilled and frozen and this facilitates flexibility regarding which orders are included on a route, and, as a result, this factor will not influence the route planning. However, it is important that the truck driver monitors temperatures during the route to ensure the quality of the goods (Behdani et al., 2019).

5.1.7 Product Characteristics

Product characteristics have an impact on distribution network setup (Mangiaracina et al., 2015; Song & Sun, 2016), making it a factor to consider in route planning. Based on interviews with multiple company representatives, it is evident that the characteristics of perishable goods entail substantial requirements and constraints in distribution. For instance, the product's fragility determines the maximum capacity of The Company's trucks and trailers. As several products cannot be stacked in the truck, the route planning at The Company is currently based on utilizing the floor area to a maximum, rather than the volume of the truck. Therefore, in this thesis, it is assumed that a truck or trailer is full when the floor area is fully utilized. However, if stacking is necessary and feasible, the truck driver utilizes it to also maximize the truck's vertical space.

5.2 Proposing a New Route Configuration

This section will address RQ2, i.e., the proposed solution for a future route configuration. First, the necessary steps for configuring routes identified in the analytical framework will be analyzed and second, the final route configuration will be presented.

5.2.1 Changes in Conditions

The inventory centralization entails a new distribution network for The Company and hence, new conditions under which the distribution operates (Chopra & Meindl, 2007, p. 345). For The Company, centralization allows for volume consolidation, offering opportunities to enhance truckload utilization (Santén, 2017). However, centralizing inventory to the south of Sweden will lead to increased distances to customers. This increased distance raises the risk that The Company may not reach as many customers within a single or two-day trip as before.

Consequently, The Company may find that it no longer requires all of its trucks and as a result, The Company might have to outsource deliveries to a larger percentage of customers compared to with a decentralized setup.

Another concern associated with centralization is the uncertainty of capacity. In this thesis, we assume that all capacity, including trucks, trailers, and truck drivers, located at the warehouses in central and southern Sweden, will be relocated to the new warehouse site. However, there is a possibility that this assumption may not hold true due to various factors such as staffing issues or delays in the relocation process.

5.2.2 Objective

In accordance with the analytical framework, the first step in route planning is to define an objective (Zhang et al., 2022). Based on interviews with company representatives involved in route planning, the primary goal when planning the routes should be to maximize truckload utilization, and the secondary objective should be to minimize travel distance. It was decided that a truckload utilization of 100% should be aimed for. When determining the maximum capacity of vehicles, we assume that pallets cannot be stacked in the truck. However, based on interviews, it appears that stacking pallets is still common practice at The Company. Therefore, it is deemed reasonable to aim for a high truckload utilization, as some pallets are likely to be stacked regardless, in both trucks and trailers. Due to this, it is also acceptable if the utilization exceeds 100%.

5.2.3 Routing Policy

The second step in configuring the future routes is to select a routing policy (Fisher, 1995; Zhai et al., 2011). After discussions with company representatives, it became evident that The Company wants to keep its fixed routing policy even for the future warehouse setup. Additionally, after analyzing the demand data, it was clear that a fixed routing policy is suitable due to the stable demand. When the demand is stable, a fixed routing policy is preferred since the planning process is less time-consuming (Rushton et al. 2014, pp. 483-484; Fisher, 1995). The choice of a fixed routing policy means that the same routes are driven every week. However, not all customers assigned to each route receive deliveries every week; this depends on how frequently they place orders.

5.2.4 Approach

As a third step, the approach was decided on with inspiration from Griffis et al. (2012). The Company believes that they do not require any software or optimization model for route configuration. Given the complexity of distribution, with multiple factors to consider, pursuing an optimal solution that maximizes truckload utilization and minimizes travel distance may not be feasible. Instead, the emphasis should be on achieving a satisfactory solution for The Company. This approach aligns with Manzini et al. (2013) and Fisher (1995), who suggests that for large instances, heuristics rather than optimization should be considered, in order to address the computational challenges related to solving a VRP problem. The approach chosen for configuring the routes, which will be further described in next section, is inspired by the two-stage heuristic procedure presented by several authors.

5.2.5 Configuring Future Routes

Based on the motivations outlined in section 5.1, the influential factors presented in Table 5.3 are identified as viable considerations when configuring the new routes.

Table 5.3: Factors to consider when planning routes at The Company

Factor to consider	***Details***
Customer order sizes and frequencies	● Average number of pallets per delivery per customer ● Number of deliveries per week per customer
Geographical data of customers and warehouse site	● Coordinates ● Zip codes
Vehicle capacity	● # of trucks, # of trailers, # of truck drivers ● Weight restrictions ● Volume restrictions ● Truck driver schedule
Customer requirements and expectations	• Load solution code (how goods are delivered to the customer)
Transport regulations	● Maximum driving time
Product Characteristics	● Stackability

The overall approach used for configuring the routes is the two-stage heuristic approach of *1. Clustering* and *2. Routing* presented by for instance Manzini et al. (2013). In the clustering stage, the customers are segmented on zip codes and in the routing stage, each customer is assigned to a route in a way that achieves the desired truckload utilization. The proposed solution has the main objective of achieving high truckload utilization to make sure that The Company utilizes its assets in the most efficient way. The secondary objective is to minimize travel distance, achieved by grouping customers into clusters based on the distances between them.

Some assumptions are made to be able to reach a proposed solution. First, in line with the current outsourcing strategy, we assume that internal trucks prioritize serving customers close to the warehouse, while deliveries to customers beyond their reach are outsourced. Additionally, we assume that trailers are used for transporting large volumes to terminals in metropolitan cities, and from there split into outsourced last-mile deliveries. The other option considered was to utilize trailers to reach customers further away. However, this option was discarded as it may be difficult to deliver to customers with a trailer due to accessibility issues. Moreover, in order to achieve a high truckload utilization when utilizing a truck and a trailer, an unreasonable large number of customers need to be assigned to the route, due to the relatively low order sizes per customer. To ensure high truckload utilization while still assigning a reasonable number of customers to each route, it was decided that customers located further away will be served exclusively by trucks. Double decking in trucks is decided to only be used for terminal-deliveries, as double decking requires more time to unload the goods. All assumptions made for reaching the final solution are compiled in Table 5.5.

During 2023, The Company served a total of 1996 number of customers, both with internal and external vehicles. For configuring the future routes, not all customers are considered. First, all customers that place an order less frequently than once a month are excluded, as those who buy more infrequently were deemed unnecessary to assign to the fixed routes. Additionally, all customers on Gotland are excluded, as it is an island not connected to the mainland by roads, and hence, it is deemed time consuming and not economically justifiable to operate internal trucks in that area. The customers are then clustered into four groups, see Table 5.4. The first group consists of customers closer to the central warehouse and includes customers belonging to zip codes beginning with 20 to 31 & 34 to 37 (see Figure 5.5 for corresponding areas). The second and third groups consist of the metropolitan cities, where double-deck trucks and trailers are used to transport large volumes to terminals. The fourth group are customers farther away from the central warehouse and consist of customers belonging to zip codes beginning with 38 to 98. In total, 1054 customers are considered; however, not all of them may be feasible to include in the final route configuration due to capacity constraints.

Within each group, customers are segmented based on different route area IDs and route subarea IDs, as described in Section 5.1.2 Geographical Data. For Group 1, segmentation is done using the route subarea ID, while for Groups 2, 3, and 4, the route area ID is utilized. The rationale behind this approach is that customers closer to the warehouse, i.e., Group 1, are serviced with one-day trips. Therefore, customers with smaller location differences can be grouped together on the same route. In contrast, customers farther from the warehouse are grouped into larger route areas, as these routes are typically completed over two days. This allows customers located further apart to be included in the same route.

Table 5.4: Geographical segmentation of customers

	Group 1	***Group 2***	***Group 3***	***Group 4***
Segment name	Southern Sweden	Gothenburg	Stockholm	Central and Northern Sweden
Zip codes*	20 to 31 & 34 to 37	40 to 42	10 to 19	38 to 98
Type of delivery	Customer	Terminal	Terminal	Customer
Number of customers considered	216	25	233	580
Vehicle	Truck - single deck	Truck - double deck + trailer	Truck - double deck + trailer Trailer - double deck	Truck - single deck
Average speed of vehicle	60 km/h	80km/h	80km/h	70km/h
Maximum capacity of vehicle	18 pallets	63 pallets	63 pallets 36 pallets	18 pallets
Segmentation	First two numbers of zip code (route subarea ID)	First number of zip code (route area ID)	First number of zip code (route area ID)	First number of zip code (route area ID)

* See Figure 5.5 for an illustration of zip codes

After completing the segmentation stage, the next step is routing. In order to facilitate the routing stage, a script and several functions in MATLAB were developed, see Appendix F. The code is divided into four parts, where each part handles each customer group. Based on a customer's average weekly demand (in EUR pallets) and the fleet's capacity, customers are assigned to routes until the desired level of utilization for each route is reached. The code ensures that vehicle weight restrictions are not exceeded and that all customers on each route are located in the same region. For customers requiring more than one delivery per week, they are added to routes with available space and the same route area ID. All four customer groups are handled in a similar way, but with different maximum capacities depending on the type of vehicles used for each group.

Travel distances for each route are estimated using longitude and latitude coordinates for both the warehouse location and each customer. Rushton et al. (2014, pp. 486-487) mentions three methods for measuring travel distance. As The Company does not measure the actual distances between stops, the true distance method was not feasible. The digitized road network method was not viable either since The Company does not use this type of system. Consequently, the coordinate method was chosen to be the most appropriate method to use. This method uses Euclidean distances, which represent a bird's-eye view. Therefore, all distances are multiplied by a constant to approximate road distance. The constant chosen is 1.2, in line with literature (Cooper, 1983; Rushton et al., 2014, p. 486; McKinnon & Ge, 2007). To estimate travel distances, the sequence in which customers within a route should be served is determined. This is achieved by first identifying the customer closest to the warehouse and then sorting the remaining customers based on their distance to the initial customer in the route. It is important to note that the sequence of customers within a route might change in reality due to several customer requirements. Important to note is that the coordinate method is an approximation but was considered sufficient for this thesis. Using actual distances would be significantly more time-consuming. Since minimizing travel distances is not the primary objective of the proposed solution, using actual distances could not be justified.

Travel distances are used in order to determine the total time required to drive a particular route. The travel time is determined by dividing the distance of each route with an average driving speed. The average driving speed is considered to be different depending on the customer groups, see Table 5.4. By combining the unloading time per customer, which is dependent on the load solution code and the number of pallets delivered, with the travel time and loading time of the truck, a total time per route can be determined. As the truck drivers are assumed to work for 10 hours per day four days a week, a route that takes less than 10 hours is considered to be a one-day trip, while a route between 10 and 20 hours is considered to be a two-day trip. Routes that exceed 20 hours of total time cannot be managed internally and must therefore be outsourced. Additionally, routes that cannot be accommodated in the weekly schedule due to either a shortage of truck drivers or insufficient vehicles also need to be outsourced.

One important consideration is that all customers assigned to each route will not be included on the route every week. This is because we consider customers placing orders once a month or more frequently. In order to determine an average travel distance and unloading time per route, we summed up the number of deliveries per week of all customers on each route to achieve an average number of deliveries per route. This number was then divided by the total number of customers assigned to each route, and finally, the percentage was multiplied by the travel time, travel distance, and unloading time for each route.

Table 5.5: Summary of assumptions made for configuring the future routes with motivations

Assumption	***Motivation***
Only the customers that order at least once a month are considered	As every route will be driven at least once a week, those who buy more infrequently were deemed unnecessary to assign to the fixed routes
For customers receiving deliveries less frequently than once a week, the average	To achieve a weekly demand rather than demand per delivery

Assumption	*Motivation*
demand is determined by dividing the total demand by 52 weeks	
Trailers are used for terminal-deliveries but not for customer-deliveries	Trailers are prioritized to transport large volumes to terminals in metropolitan cities as trailers cannot always be used to unload at customers, and to ensure high truckload utilization
The truckload utilization is considered to be 100% if a truck is loaded with 18 pallets (36 for terminal-deliveries which utilizes double decking) or a trailer is loaded with 27 pallets, or if the weight restriction is achieved	Stacking of pallets is not included at the planning stage due to the uncertainty of the product's fragility
Reloading of trucks during a route is possible for routes in proximity to the warehouse	Based on interview responses
Double decking is used for terminal deliveries but not for customer deliveries	Double decking makes the unloading process more difficult and time-consuming and hence, it is avoided for customer deliveries
In the new warehouse location, there will be 13 trucks, 3 trailers and 12 truck drivers	All capacity is assumed to be relocated from the two current warehouse locations to the new warehouse site
Internal trucks are prioritized to serve the customers in proximity to the warehouse. The customer that cannot be served by internal trucks are outsourced	In line with the current outsourcing strategy
The fixed routing policy will remain	In accordance with The Company's wishes and due to the stable demand
It is possible to change the customers' delivery day	To enable a new route configuration
If a route takes less than 10 hours, it is considered to be a one-day trip, if it takes between 10-20 hours, it is considered to be a two-day trip	A result of the truck driver schedule
The Company can drive either one- or two-day trips	In line with the current configuration
Truck drivers work for 10 hours per day, 4 days a week	Most common working structure in the warehouse in southern Sweden. Makes up a full-time employment

* See Figure 5.5 for an illustration of zip codes

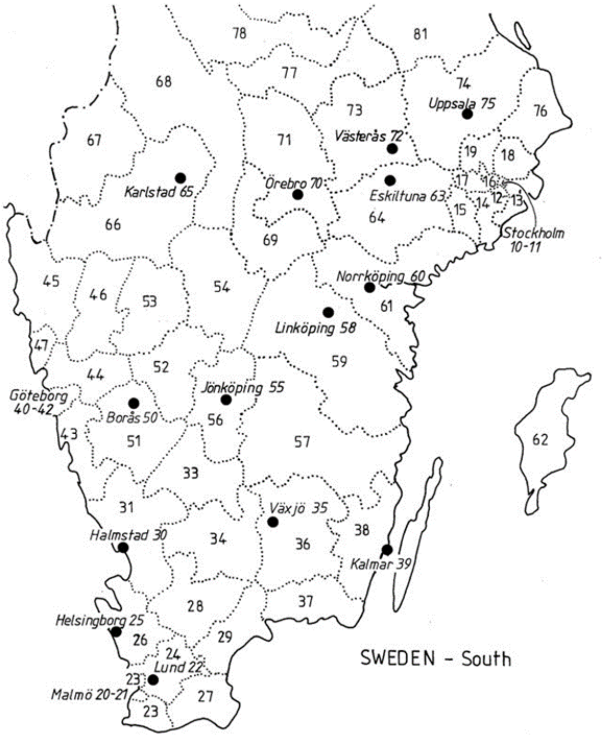

Figure 5.5: Zip codes in southern and central Sweden

5.2.6 Final Configuration

The last part of the new route configuration includes presenting the final configuration as well as validating the configuration. The new configuration is the result of all the aspects detailed in the previous sections 5.2.1 to 5.2.5 and, hence, considers the objective, the routing policy, the approach, and the assumptions of the new configuration. The result of this is presented below in Table 5.6. The new route configuration covers customers up until route area 57, which is around Oskarshamn area. The routes are summarized by route type in Table 5.7. Noteworthy is that not all customers requesting two deliveries per week will receive their second deliveries by internal distribution. This is a consequence of focusing on maximizing utilization and ensuring travel distances are within reasonable limits. These deliveries will have to be outsourced. When studying Table 5.6 it can be noted that route 16 has lower utilization than the rest of the routes. The reason for this is the grouping of customers and how the script in MATLAB is developed. As the script considers one customer group at a time, it means that the last customers of group 1 are added to route 16, and although the truck is not fully utilized, customers belonging to group 2 cannot be added. This can be considered a limitation of the script.

Table 5.6: The new route configuration for The Company

Route	*Type of route*	*Type of delivery*	*Vehicle type*	*Route area*	*Average volume (pallets)*	*Number of customers assigned*	*Average utilization*
1	One-day	Customer	Truck	21	17.52	14	97%
2	One-day	Customer	Truck	21	18.29	13	102%

Route	***Type of route***	***Type of delivery***	***Vehicle type***	***Route area***	***Average volume (pallets)***	***Number of customers assigned***	***Average utilization***
3	One-day	Customer	Truck	21,22	18.99	14	106%
4	One-day	Customer	Truck	22,23	18.22	14	101%
5	One-day	Customer	Truck	23	15.83	7	88%
6	One-day	Customer	Truck	23,24	15.96	13	89%
7	One-day	Customer	Truck	24,25	15.98	9	89%
8	One-day	Customer	Truck	25,26	15.62	11	87%
9	One-day	Customer	Truck	26	17.93	16	100%
10	One-day	Customer	Truck	26,27	15.78	24	88%
11	One-day	Customer	Truck	27-29	17.07	16	95%
12	One-day	Customer	Truck	29	17.31	17	96%
13	One-day	Customer	Truck	29,30	15.72	11	87%
14	Two-day	Customer	Truck	30,31,34-35	18.12	19	101%
15	One-day	Customer	Truck	35-37	15.96	22	89%
16	One-day	Customer	Truck	37	8.30	6	46%
17	One-day	Terminal	Double deck truck + trailer	41-42	53.03	27	84%
18	Two-day	Terminal	Double deck truck + trailer	11-19	61.79	24	98%
19	Two-day	Terminal	Double deck truck + trailer	11-19	61.86	25	98%
20	Two-day	Terminal	Double deck truck + trailer	11-19	61.86	42	98%
21	Two-day	Terminal	Double deck truck + trailer	11-19	61.81	39	98%
22	Two-day	Terminal	Double deck truck + trailer	11-19	61.98	97	98%
23	Two-day	Terminal	Double deck truck + trailer	11-19	61.43	41	98%
24	Two-day	Terminal	Double deck truck	33,38-39	33.84	15	94%
25	Two-day	Customer	Truck	33,38-39	17.00	19	94%
26	Two-day	Customer	Truck	33,38-39	17.26	19	96%
27	Two-day	Customer	Truck	39,43	16.78	14	93%
28	One-day	Customer	Truck	43,44	17.38	13	97%

Route	Type of route	Type of delivery	Vehicle type	Route area	Average volume (pallets)	Number of customers assigned	Average utilization
29	One-day	Customer	Truck	43,44	17.04	16	95%
30	One-day	Customer	Truck	44,45,47	16.06	13	89%
31	Two-day	Customer	Truck	44,45	16.91	13	94%
32	Two-day	Customer	Truck	44-47	16.75	16	93%
33	Two-day	Customer	Truck	47,50-52	16.76	16	93%
34	Two-day	Customer	Truck	50-53	17.13	15	95%
35	Two-day	Customer	Truck	50,53,54, 57	17.32	15	96%

Table 5.7: Summary of the new route configuration for The Company

Type of route	Number of routes	Total number of pallets	Number of customers assigned
One-day	19	348	262
Two-day	16	559	371
Total	35	907	626

In the current setup, it is possible for the truck driver to return to the warehouse to reload pallets for a second route on the same day. This occurs for deliveries to customers located in proximity of the warehouse. In the new configuration, reloading of the vehicles will occur for the routes delivering to customers in proximity of the new warehouse, meaning routes 1 to 6. When determining which routes to reload, the total time, including loading time, unloading time at the customer and travel time, is considered to ensure that it does exceed the working hours of the drivers (10 hours) and one hour is added so there is enough time for reloading the pallets onto the truck at the warehouse. It is ensured that the same customer is not included on both routes on the same day, but rather is spread out over the week. Considering all of this, it was determined that routes 1 and 4, routes 2 and 3 as well as routes 5 and 6 would be delivered by the same truck on the same day, i.e., reloading would be required.

After the routes were determined, the routes could be positioned in the schedule. The schedule is based on the available capacity in terms of truck drivers, trucks, and trailers, which corresponds to 12 employees, 13 trucks and 3 trailers. All employees work four shifts per week and the number of shifts per week are distributed over the week according to the general pattern of demand. This means that fewer shifts are placed in the beginning and at the end of the week while more shifts are scheduled in the middle of the week. Customers requesting two deliveries per week will have their deliveries spread out over the week, so they do not receive two deliveries on consecutive days or even the same day. The exception is, however, deliveries going to terminals in Stockholm and Gothenburg (routes 17 to 24). Since these are delivered to terminals and from there are split into last-mile deliveries, consideration for customers requesting two or more deliveries per week is not taken. The schedule in Table 5.8 shows which employee will drive what route number on which day and highlighted in beige if both truck and trailer is used. If there are two numbers in the same box, it means that reloading occurs, i.e., the truck driver will drive back to the warehouse to reload the truck between the two routes.

Table 5.8: Route numbers placed in the work schedule; trailers highlighted in beige

<table>
<tr><th></th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>Employee 1</td><td>17</td><td colspan="2">24</td><td rowspan="2"></td><td>8</td></tr>
<tr><td>Employee 2</td><td colspan="2">23</td><td>28</td><td>5, 6</td></tr>
<tr><td>Employee 3</td><td colspan="2">22</td><td>2, 3</td><td>9</td><td></td></tr>
<tr><td>Employee 4</td><td>1, 4</td><td>7</td><td colspan="2">19</td><td></td></tr>
<tr><td>Employee 5</td><td>13</td><td>10</td><td colspan="2">18</td><td></td></tr>
<tr><td>Employee 6</td><td>11</td><td colspan="2">21</td><td>16</td><td></td></tr>
<tr><td>Employee 7</td><td></td><td>12</td><td>30</td><td colspan="2">20</td></tr>
<tr><td>Employee 8</td><td>29</td><td>15</td><td colspan="2">25</td><td></td></tr>
<tr><td>Employee 9</td><td></td><td colspan="2">26</td><td colspan="2">34</td></tr>
<tr><td>Employee 10</td><td></td><td colspan="2">31</td><td colspan="2">27</td></tr>
<tr><td>Employee 11</td><td></td><td colspan="2">35</td><td colspan="2">33</td></tr>
<tr><td>Employee 12</td><td></td><td colspan="2">32</td><td colspan="2">14</td></tr>
<tr><td>Number of trucks in use</td><td>7</td><td>12</td><td>12</td><td>10</td><td>7</td></tr>
</table>

5.2.7 Validating the Solution

To assess the validity of the solution, the number of customers, the travel distance, travel time, loading time, unloading time and total time for each route were estimated. These numbers can be found in their entirety in Appendix E but are summarized for each route type below in Table 5.9. In the table, it can be noted that the average total time for each route type is well below the allowed limit. For the route type *One-day*, the limit is 10 hours and for the route type *Two-day*, the limit is 20 hours (since these are two-day trips). The validation reveals that the routes are reasonable to manage, given the truck driver's schedules and transport regulations.

Table 5.9: Average travel time, unloading time and total time per route type for factor 1.2

Type of route	***Number of routes***	***Average travel time (h)***	***Average loading time (h)***	***Average unloading time (h)***	***Average total time (h)***
One-day	19	3.74	0.49	2.54	6.77
Two-day	16	12.93	0.93	2.49	16.34

As previously described, the approximation of travel time is based on a multiplication of 1.2. To test the sensitivity of this factor, the travel time was estimated also using factors 1.1 and 1.3, see Tables 5.10 and 5.11. The most noteworthy impact of using different multiplication factors is how many routes are determined to be one-day routes and how many routes are two-day routes. Using the factor 1.1 results in more one-day routes compared to when using factor 1.2, which is expected since the estimated travel time decreases when using a lower multiplication factor. In contrast, using the factor 1.3, the number of one-day routes decreases compared to when using the factor 1.2. One observation is that the difference between factor 1.2 and 1.1 in terms of number of one-day and two-day routes is larger compared the difference between 1.2 and 1.3. Additionally, to see that the multiplication factor 1.2 was not entirely inaccurate, some distances were selected as samples and cross-referenced against the distance shown in Google Maps.

Table 5.10: Average travel time, unloading time and total time per route type for factor 1.1

Type of route	***Number of routes***	***Average travel time (h)***	***Average loading time (h)***	***Average unloading time (h)***	***Average total time (h)***
One-day	22	4.02	0.49	2.60	7.11
Two-day	13	11.64	1.04	2.38	15.06

Table 5.11: Average travel time, unloading time and total time per route type for factor 1.3

Type of route	***Number of routes***	***Average travel time (h)***	***Average loading time (h)***	***Average unloading time (h)***	***Average total time (h)***
One-day	18	5.26	0.49	2.53	6.68
Two-day	17	16.18	0.90	2.50	16.21

In addition to estimating the total time for each route, the validity of the solution was assessed by testing the route configuration against historical data. Since the routes are configured based on average customer demands, it is crucial to ensure that the solution achieves the desired truckload utilization when using real demand data. The test was conducted using delivery data from seven weeks spread throughout the year of 2023: weeks 2, 10, 15, 20, 30, 40 and 50. Truckload utilization was calculated for each route for all seven weeks. If a route achieved a truckload utilization between 70% to 130%, the route passed the test. The lower limit was set at 70% because the objective of this thesis was to, at least, achieve a higher truckload utilization than the current configuration, which averages 66%. The upper limit of 130% was determined based on observations on how often pallets are stacked in a truck. The result of the test is displayed in Table 5.12. On average, the success rate for the route configuration during the seven weeks is 81%, which is considered to be satisfactory. Both the average utilization per route during the seven weeks and the average utilization of all routes per week were measured to be 98%.

Table 5.12: Percentage of routes passing the validity test per week in 2023

Week	***Percentage of routes passing the test***
2	81.1%
10	86.5%
15	78.4%
20	81.1%
30	75.7%
40	75.7%
50	86.5%

5.3 Comparison of Current and Future Configuration

The purpose of this section is to compare the current and the future configuration both quantitatively and qualitatively, to understand what the proposed solution will entail for The Company and its business. Additionally, this section helps to ensure that the proposed solution is satisfactory and surpasses the existing configuration in terms of high truckload utilization, which was the primary objective when configuring the routes. Finally, recommendations on next steps are provided to The Company.

5.3.1 Quantitative Comparison

In order to compare the performance of the current configuration with the future configuration, the five following KPIs were chosen: average truckload utilization, travel distance per customer served, volumes delivered, customers served, and outsourced volumes, see Table 5.12. These KPIs were selected based on what literature suggests, for instance García-Arca et al. (2018), and what The Company deems important to measure.

When comparing the average truckload utilization, it can be seen that with the new solution, it reaches a rate of 93%, indicating an increase of 42%. The new configuration was planned with the primary objective of filling up the trucks as much as possible, and the results indicate that the objective has been fulfilled. The average utilization exceeds 100% for some routes, which is considered acceptable since the routes are planned without accounting for stacking in the vehicles, even though stacking is a common practice at The Company.

The total travel distance per customer served will increase by 60% with the proposed solution, which is an expected result as centralizing the warehouse to the south of Sweden will increase the average distance to customers (Chopra & Mendl, 2007, p. 345). The number of customers served, i.e., the number of customers assigned to routes, will decrease by 36% as a result of increasing distances and hence, fewer customers that can be reached. However, it can be seen that larger volumes are delivered with the new solution, which is a result of the higher truckload utilization of vehicles. The larger volumes driven internally also mean that a lower percentage in terms of volumes will be outsourced, namely 53% instead of 56%.

Table 5.12: Comparison of KPIs for the current and proposed configuration

	Current configuration	***Proposed configuration***	***Difference (%)***
Average truckload utilization (%)	66%	93%	+42%
Travel distance per customer served (km)	20.14	32.15	+60%
Volumes delivered (# of pallets during a year)	39049	47144	+21%
Customers served (#)	982	626	-36%
Outsourced volumes (%)	56%	53%	-5%

5.3.2 Qualitative Comparison

Implementing the proposed route configuration has certain implications for The Company and its business. First, the new configuration suggests that customers may need to adjust their delivery day based on the new schedule outlined in Table 5.8. Currently, customers receive deliveries consistently on the same day each week. The fixed routing policy will remain with the proposed solution, but the new route configuration was planned without taking individual customer delivery preferences into account. Since interviews with company representatives revealed that some customers may not be flexible in changing their delivery day, this factor could potentially hinder the implementation process. Therefore, to successfully implement the new solution, The Company needs to engage in change management and maintain clear communication with customers well in advance of any changes to their delivery dates.

Another consequence of not considering customer requirements for delivery days and time windows could be that the truck driver may need to adjust the proposed order in which customers are served on a route. This adjustment would be based on the driver’s knowledge of each customer’s specific time window requirements.

The proportion of customers handled internally and externally will change with the new solution. As a result of centralization and longer distances to customers, several customers who are currently handled internally will have to be handled by an external carrier instead as they cannot be reached by internal trucks during a one or two-day trip. It is important that The

Company communicates this change clearly well in advance to the customers that will be affected. Another aspect which is important to note is that, in the proposed route configuration, we only assign customers who place an order at least once a month to routes and as a result, those customers ordering less frequently than once a month need to be handled separately or be outsourced. Noteworthy is also that not all customers requesting two deliveries per week will receive their second deliveries by internal distribution. This is a consequence of focusing on maximizing utilization and ensuring travel distances are within reasonable limits. As a result, customers requesting more than one delivery per week may receive one delivery from an internal truck and the other from an external truck.

The strategy for how trailers is used will change with the new configuration. Currently, trailers are used both for terminal and customer deliveries, but with the new configuration, trailers will be used exclusively for terminal deliveries. This shift in strategy for trailer usage is driven by two main reasons: to avoid potential challenges associated with delivering to customers using trailers, and to be able to maximize truckload utilization while maintaining a manageable number of customers per route.

When comparing the existing schedule for the truck drivers with the schedule outlined in Table 5.8, there are some differences. In the current schedule, the truck drivers work either three or four days per week, and between 9.5 hours to 12 hours per shift, excluding lunch breaks. In the proposed solution, all truck drivers will work four days a week and 10 hours per shift. All employees are driving at least one two-day trip per week, which may differ from their previous schedule. One potential risk when centralizing the inventory is that The Company might need to hire new truck drivers in case those employed in central Sweden are not willing to move to the south of Sweden. This may become a challenge for The Company due to the lack of truck drivers, and hence, it can hinder the implementation of the proposed solution.

5.3.3 Recommendations on Next Steps

In order to implement the proposed route configuration, we recommend the following next steps to The Company:

(1) Validate the proposed solution

The proposed solution must be more thoroughly validated by The Company before implementation, involving truck drivers, transport planners and the Supply and Demand Manager. This ensures the solution is not only strategically viable but also practical in implementation. During validation, The Company should confirm that the number of customers per route is reasonable, and that the configuration meets special customer requirements not addressed in this thesis. Once the route configuration is validated, the implementation process can begin.

(2) Communicate the changes to stakeholders

Effective communication with stakeholders is crucial when introducing changes to the distribution routes. The customers need to be informed well in advance of any changes in terms of delivery dates and changes in whether they will receive their deliveries from internal or external trucks. This proactive approach will help maintain trust and satisfaction among customers. Additionally, truck drivers must be informed about the new schedule and their assigned routes. Training on the new routes, procedures, and any changes in responsibilities needs to be provided to all employees. If truck drivers currently located in central Sweden are unwilling to relocate to the south, The Company may need to recruit new drivers. Alternatively, external truck drivers could be employed to operate the internal trucks.

(3) Outsource new geographical areas

As highlighted in the comparison, The Company needs to outsource more customers with the new configuration, given the longer distances to customers. Since The Company can only manage customers up to route area 57 internally, areas north of route area 57 need to be outsourced. The Company has two options: they can either utilize one of their existing partners and expand into new geographical areas or seek out new partners.

(4) Monitoring

It is important that The Company monitors the implementation closely to identify any issues or challenges that may arise and also address them properly. Additionally, the performance of the new route configuration needs to be monitored using KPIs like truckload utilization, travel distance, and customer service level. This ongoing assessment ensures that the implemented solution aligns with The Company’s business objectives.

(5) Conduct periodic reviews

Periodic reviews of the route configuration need to be conducted to identify opportunities for further improvement. Routes need to be replanned and adjusted based on changes in customer demand or changing conditions, to maintain high truckload utilization and meet customer expectations. The script in MATLAB can be utilized to efficiently recalculate the routes when demand changes or when there is a need to add or exclude customers from specific routes.

6 CONCLUSION

This chapter aims to conclude this master's thesis by discussing three parts. The first part describes how the purpose of this thesis has been achieved, along with answering each of the three research questions. The second part discusses how this thesis contributes to theory and practice and, finally, limitations and future research are presented.

6.1 Fulfilling the Purpose

The purpose of this thesis was to propose a reconfiguration of The Company's distribution routes to increase vehicle efficiency after centralizing inventory to one stocking point. This research seeks to contribute to both literature and practice by developing a solution for a company in the context of inventory centralization, and enhancing the understanding of how routes can be configured to maximize the use of vehicles. To fulfill the purpose of this thesis, a design science approach was used. An artifact in terms of an analytical framework was created by combining the purpose, research questions and the frame of reference. The analytical framework served as a guideline for data collection and analysis. Through interviews, observations and secondary data, the current state at The Company was mapped and factors to consider when planning the routes at The Company were identified. With the influential factors and changes of conditions due to centralization as input, the new routes were configured with the primary objective of maximizing truckload utilization. After comparing the current setup with the proposed solution both quantitatively and qualitatively, several recommendations could be provided to The Company.

In order to fulfill the purpose of this thesis, the following research questions have been addressed:

RQ1: How is the current distribution setup at The Company designed? What are the key factors to consider when configuring routes at The Company?

The first part of this research question was addressed within the empirical findings chapter. The distribution setup at The Company was mapped with the help of five interviews, two observations and secondary data. The mapping consists of detailed descriptions of The Company's business, the existing distribution network, demand and product characteristics, distribution process, and the performance of the current distribution network. The second part of the research question was addressed in the analysis chapter, where the influential factors identified in the analytical framework were applied to The Company. Then, a selection of these was made based on what was deemed relevant for The Company. The following influential factors were identified as viable considerations when configuring the new routes: customer order sizes and frequencies, geographical data, vehicle capacity, customer requirements & expectations, transport regulations and product characteristics. This research question serves as a foundation for the subsequent two research questions, as its results will be used as input to address RQ2.

RQ2: How should future distribution routes be configured after centralizing inventory to maximize truckload utilization?

The second research question was addressed in the analysis and resulted in a proposed route configuration for The Company in the context of the new supply chain setup. This question was approached by first analyzing the changes in conditions due to centralization, and subsequently, following the necessary steps for route configuration outlined in the analytical framework. The objective was defined as maximizing truckload utilization, a fixed routing policy was chosen, and a two-stage approach was used to configure the routes. In the first stage, clustering, the customers were segmented into groups based on zip codes and coordinates and in the second stage, routing, a script in MATLAB was written to assign all customers to routes in a way that maximizes truckload utilization. A route schedule was created based on available manpower and the pattern of demand. The solution was validated by determining the total travel time, loading time, and unloading time per route to ensure that all routes are possible to manage during either a one or two-day trip. Additionally, the solution was validated by testing the route configuration against historical delivery data. The routes achieved a truckload utilization within an acceptable range in 80% of the test cases. The final configuration resulted in a route table with 35 routes in total, where 18 are one-day trips driven by truck, 8 are routes assigned to terminal deliveries and driven by both a double deck truck and trailer, and 9 are two-day trips driven by truck. Totally, 626 customers are assigned to the routes.

RQ3: How does the proposed solution compare to the existing configuration?

This research question compared the performance of the current distribution configuration with the new configuration in terms of truckload utilization, travel distance, volume delivered, customers served, and outsourced volumes. It was seen that the truckload utilization increases by 42%, and hence, the main objective with the proposed solution has been achieved. The travel distance per customer served increases by 60% which is an expected result of centralization. Larger volumes are delivered internally with the new solution, which is a result of the higher 49customers. The qualitative comparison reveals that implementing the proposed route configuration has certain implications for The Company and its business. Some customers will need to adjust the weekday of their deliveries. Several customers currently serviced internally will be served by an external carrier. Customers requesting more than one delivery per week might receive one of them by an internal truck and the other by an external truck. The strategy for how trailers is utilized will shift, they will be used for terminal deliveries exclusively. There will be changes to the truck drivers' schedules. Finally, The Company needs to be aware of the risk of potentially needing to hire new truck drivers. This is because the assumption that all truck drivers from the warehouses in southern and central Sweden will be relocated to the new warehouse site may not hold true.

The comparison resulted in the following recommendations on next steps for The Company: (1) validate the solution, (2) communicate the changes to stakeholders, (3) outsource new geographical areas, (4) monitoring (5) conduct periodic reviews.

6.2 Contribution

This thesis contributes within three main theoretical areas: (1) approaching route configuration from a business perspective as opposed to strict mathematical optimization (2) developing knowledge on the interaction between centralization and route configuration, and (3) providing a way of reconfiguration routes through the analytical framework developed. As highlighted by Akkerman et al. (2010), previous literature focused on vehicle routing through mathematical optimization, but this approach is documented to have several drawbacks, for instance requiring significant computational power (Fisher, 1995; Griffis et al., 2012; Manzini et al., 2013) and difficulty incorporating aspects important for the company's business (Fisher, 1995). This thesis contributes to this theoretical area by focusing on aligning route configuration with The Company's overall business objectives and supply chain setup. Secondly, this thesis highlights how centralization changes the conditions for distribution and compares the performance of the current and proposed distribution configuration. This emphasizes the impact of inventory centralization on distribution and route configuration, which was identified as an area of research potential. Lastly, the analytical framework developed in this thesis provides a guideline for approaching a reconfiguration of distribution routes with the aim of increasing vehicle efficiency. Thus, it can contribute with helping future researchers analyze this topic.

This thesis also has practical contributions for The Company. The thesis proposes a new route table, which details which customers are served by which route and on which day as well as the type of delivery (customer or terminal), the duration (one- or two-day deliveries), and the vehicle type (truck or truck & trailer). After The Company has transitioned to a centralized supply chain setup, the route table provides a solution which after some minor adjustments is ready to implement. As written in the introduction chapter, distribution is more commonly viewed as a competitive advantage. This is also the case for The Company as described by the Supply and Demand Manager, and therefore, it is important for their future distribution to operate as efficiently as possible. The proposed route configuration gives The Company a solution that can contribute towards achieving a distribution setup that increases the truckload utilization, and, hence, increasing the cost efficiency of the distribution operations, while also ensuring that the customers are served in a timely and precise manner.

The findings of this thesis can be generalized through applying the analytical framework to other companies facing a similar change in their supply chain network and aiming to improve the distribution operations. The approach detailed in the framework is appropriate for small to medium-sized organizations delivering perishable goods, who seek to align their route configuration with their business objectives. The framework can further be generalized for companies facing transitions outside of centralization to include changes of different kinds that alter the conditions for distribution.

6.3 Limitations and Future Research

One of the main limitations of this study is in the demonstration step of the design research process. In this study, the artifact (the analytical framework) was only demonstrated through a single case study. To gain a better understanding of how the analytical framework performs in a practical setting, it would have been ideal to implement the proposed solution in real life, but implementation is time-consuming and could not be completed during the time period for this master's thesis. Another way of demonstrating the artifact would be to apply the framework on multiple cases. For this thesis, this was assessed to be unrealistic from a time perspective. The validity of the proposed solution could also further be increased by hosting a workshop with a focus group. Also in this case, this was not done due to time constraints. Instead, further validation by The Company is suggested as a next step. Another way to increase the validity would be to include more weeks in the validity test.

There are some limitations related to the assumptions made when configuring the routes at The Company and if these assumptions are incorrect, it would impact the quality of the proposed solution. One assumption that impacts the solution substantially is the estimated unloading time for each type of load solution code since these impacts how many customers can be served under the course of the route. This is used when estimating the total time of each route, which is used in the validation of the routes. Another assumption is the vehicle capacity including number of trucks and trailers as well as number of truck drivers. It is assumed that the capacity at the new central warehouse is the combined capacity of the warehouse in southern Sweden and central Sweden. Furthermore, it is assumed that the travel distance can be estimated using the Euclidean distance multiplied by a factor. This is used for calculating the expected travel time, which in turn is used for validating routes.

In the proposed solution, not all aspects that affect the route configuration are considered. Delivery time windows for each customer and access to roads are, for example, not taken into account since this data was not available. Further, returns and pickups at suppliers were not considered as part of the distribution routes and hence descoped from the thesis. Including all of these aspects would take into account more aspects that are relevant for route planning and, hence, contribute to a better solution, but it would also entail adding complexity.

This thesis also has limitations related to data collection and analysis. During data analysis of secondary data, some data quality issues were detected including discrepancies and missing fields. Also, regarding the number used for expected volumes per customers and number of deliveries, averages only based on the year 2023 were used. It could be that 2023 was an abnormal year and not representative of a normal year for The Company. Since the centralization is not yet implemented and it will take several years to do so, it would have been suitable to consider how the volumes and number of deliveries are expected to grow over the coming years. Another limitation is that the observations were made at the warehouse in southern Sweden, and we did not have the possibility to visit the warehouse in central Sweden. If this would be done, it would have provided a better overview of the distribution as a whole at The Company. However, from interviews, it was indicated that the processes at the two warehouses were relatively similar in nature.

The Company can further improve the route planning by optimizing the sequence in which customers are served within a route. Another suggestion for The Company is to investigate more in detail the cost structure for internal compared to external distribution. This would give a better understanding of the differences between internal and external distribution and could be used when evaluating tradeoffs between the two types.

In the future, it would be interesting to consider the truckload utilization under the course of the delivery instead of only looking at the truckload utilization right after the goods are loaded into the truck. This could capture the vehicle efficiency in a more holistic way. Another interesting study would be to compare configuring routes from the beginning to using the existing routes as a foundation and making changes to them to see what performance can be achieved. Making changes to existing routes could entail less changes for the customers, which could ease implementation.

REFERENCES

Abrahamsson, M. & Brege, S. (1997). Structural Changes in the Supply Chain. *The International Journal of Logistics Management*. 8(1), pp. 35-44. https://doi.org/10.1108/09574099710805574

Akkerman, R., Farahani, P. & Grunow, M. (2010). Quality, safety and sustainability in food distribution: a review of quantitative operations management approaches and challenges. OR Spectrum, 32(4), pp.863–904. https://doi.org/10.1007/s00291-010-0223-2

Allesina, S., Azzi, A., Battini, D. & Regattieri, A. (2009). Performance measurement in supply chains: new network analysis and entropic indexes. *International Journal of Production Research*. 48(8), pp.2297–2321.https://doi.org/10.1080/00207540802647327.

Arnold, F. & Sörensen, K. (2019). What makes a VRP solution good? The generation of problem-specific knowledge for heuristics. *Computers & Operations Research*, 106, pp.280–288. https://doi.org/10.1016/j.cor.2018.02.007

Azzi, A., Persona, A., Sgarbossa, F. & Bonin, M. (2013). Drug inventory management and distribution: outsourcing logistics to third-party providers. *Strategic Outsourcing: An International Journal*. 6(1), pp. 48-64. https://doi.org/10.1108/17538291311316063

Ballou, R.H. (1981). Reformulating a Logistics Strategy: A Concern for the Past, Present and Future. *International Journal of Physical Distribution & Materials Management*. 11(8), pp. 71-83. https://doi.org/10.1108/eb014522

Behdani, B., Fan, Y. & Bloemhof, J.M. (2019). Cool chain and temperature-controlled transport: An overview of concepts, challenges, and technologies. Accorsi, R. & Manzini, R. (red.). *Sustainable Food Supply Chains: Planning, Design, and Control through Interdisciplinary Methodologies*. Academic Press. pp.167-183 https://doi.org/10.1016/C2016-0-05053-2

Bode, C., Lindemann, E. & Wagner, S.M. (2011). Driving Trucks and Driving Sales? The Impact of Delivery Personnel on Customer Purchase Behavior. *Journal of Business Logistics*. 32(1), pp.99–114. https://doi.org/10.1111/j.2158-1592.2011.01009.x.

Bortolini, M., Faccio, M., Ferrari, E., Gamberi, M. & Pilati, F. (2015). Fresh food sustainable distribution: cost, delivery time and carbon footprint three-objective optimization. *Journal of Food Engineering*. 174, pp. 56-67. https://doi.org/10.1016/j.jfoodeng.2015.11.014

Braekers, K., Ramaekers, K. & Van Nieuwenhuyse, I. (2016). The vehicle routing problem: State of the art classification and review. *Computers & Industrial Engineering.* 99, pp.300–313. https://doi.org/10.1016/j.cie.2015.12.007

Cepeda-Carrión, I., Alarcon-Rubio, D., Correa-Rodriguez, C. & Cepeda-Carrion, G. (2023). Managing customer experience dimensions in B2B express delivery services for better customer satisfaction: a PLS-SEM illustration. *International Journal of Physical Distribution & Logistics Management*. 53(7/8), pp. 886-912. https://doi.org/10.1108/IJPDLM-04-2022-0127

Chopra, S. (2003). Designing the distribution network in a supply chain. *Transportation Research Part E: Logistics and Transportation Review*. 38(2), pp. 123-140. https://doi.org/10.1016/S1366-5545(02)00044-3

Chopra, S. & Meindl, P. (2007), Supply Chain Management. Strategy, Planning & Operation, Springer, Prentice Hall, Upper Saddle River, NJ.

Clarke, G. & Wright, J. W. (1964). Scheduling of Vehicles from a Central Depot to a Number of Delivery Points. *Operations Research*. 12(4):568-581. https://doi.org/10.1287/opre.12.4.568

Cooper, J.C. (1983). The Use of Straight Line Distances in Solutions to the Vehicle Scheduling Problem. *Journal of the Operational Research Society*. 34(5), pp.419–424. https://doi.org/10.1057/jors.1983.94

Cordeau, J.-F., Gendreau, M. & Laporte, G. (1997). A tabu search heuristic for periodic and multi-depot vehicle routing problems. *Networks*. 30(2), pp.105–119. https://doi.org/10.1002/(sici)1097-0037(199709)30:2%3C105::aid-net5%3E3.0.co;2-g

Corts, N.F., Herbert-Hansen, Z.N.L., Larsen, S.B. & Khalid, W. (2019). The degree of inventory centralization for food manufacturers. *Production Engineering.* 13(1), pp.21–32. https://doi.org/10.1007/s11740-018-00872-1

D'Arcy, P., Norman, D., & Shan, S. (2012). Costs and margins in the retail supply chain. *Reserve Bank of Australia Bulletin*. June Quarterly, pp.13-22. https://www.rba.gov.au/publications/bulletin/2012/jun/pdf/bu-0612-2.pdf?source=content_type%3Areact%7Cfirst_level_url%3Aarticle%7Csection%3Amain_content%7Cbutton%3Abody_link (Accessed 2024-02-15)

Dantzig, G. B. & Ramser, J. H. (1959). The Truck Dispatching Problem. *Management Science*. 6(1):80-91. https://doi.org/10.1287/mnsc.6.1.80

Deloitte (2016). *Wholesale distribution disrupted.* https://www2.deloitte.com/us/en/pages/consumer-business/articles/wholesale-distribution-trends-disruption.html (Accessed 2024-02-15)

Denscombe, M. (2010). *The good research guide: for small-scale social research projects*. 4th ed. Maidenhead, England: Mcgraw-Hill/Open University Press.

Domínguez-Caamaño, P., Benavides, J. A. C., & Prado, J. C. P. (2016). An improved methodology to determine the wiggle factor: An application for Spanish road transport. *Brazilian Journal of Operations & Production Management*. 13(1), 52-56.

Dresch, A., Lacerda, D. P., & Cauchick Miguel, P. A. (2015a). A Distinctive Analysis of Case Study, Action Research and Design Science Research. *Review of Business Management*. 17(56), 1116–1133. https://doi.org/10.7819/rbgn.v17i56.2069

Dresch, A., Lacerda, D.P. and Antunes Jr, J.A.V. (2015b). Design Science Research - A Method for Science and Technology Advancement. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-07374-3

Fisher, M. (1995). Chapter 1 Vehicle routing. [online] ScienceDirect. https://www.sciencedirect.com/science/article/pii/S0927050705801057.

Fisher, L. M. (1997). What Is the Right Supply Chain for Your Product? *Harvard Business Review*. 75(2), pp. 105-116.

Forza, C. (2002). Survey research in operations management: a process-based perspective. *International Journal of Operations & Production Management*. 22(2), pp. 152-194. https://doi.org/10.1108/01443570210414310

Frank, M., Ostermeier, M., Holzapfel, A., Hübner, A. & Kuhn, H. (2021). Optimizing routing and delivery patterns with multi-compartment vehicles. *European Journal of Operational Research*. 293(2), pp.495–510. https://doi.org/10.1016/j.ejor.2020.12.033

García-Arca, J., Prado-Prado, J.C. and Fernández-González, A.J. (2018). Integrating KPIs for improving efficiency in road transport. *International Journal of Physical Distribution & Logistics Management*. 48(9), pp.931–951. https://doi.org/10.1108/ijpdlm-05-2017-0199.

Gibbert, M., Ruigrok, W. & Wicki, B. (2008). What passes as a rigorous case study? *Strategic Management Journal.* 29(13), pp.1465–1474. https://doi.org/10.1002/smj.722.

Gotzamani, K., Longinidis, P. and Vouzas, F. (2010). The logistics services outsourcing dilemma: quality management and financial performance perspectives. *Supply Chain Management.*15(6), pp. 438-453. https://doi.org/10.1108/13598541011080428

Griffis, S.E., Bell, J.E. & Closs, D.J. (2012). Metaheuristics in Logistics and Supply Chain Management. J*ournal of Business Logistics*. 33(2), pp.90–106. https://doi.org/10.1111/j.0000-0000.2012.01042

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*. 28(1), pp. 75–105. http://doi.org/10.2307/25148625

Hsiao, H.I., van der Vorst, J.G.A.J., Kemp, R.G.M. & Omta, S.W.F.(O). (2010). Developing a decision-making framework for levels of logistics outsourcing in food supply chain networks. *International Journal of Physical Distribution & Logistics Management*. 40(5), pp. 395-414. https://doi.org/10.1108/09600031011052840

Holmström J., Ketokivi M. & Hameri A.P. (2009). Bridging practice and theory: A design science approach. *Decision Sciences*. 40(1), pp. 65-87. https://doi.org/10.1111/j.1540-5915.2008.00221.x

Horvitz, O. (1960). Controlling truck costs. Journal of Accountancy (pre-1986), 109(000003), 51.

Hung Lau, K. (2012). Demand management in downstream wholesale and retail distribution: a case study. *Supply Chain Management.* 17(6), pp. 638-654. https://doi.org/10.1108/13598541211269247

Kazmi, S.W. & Ahmed, W. (2022). Understanding dynamic distribution capabilities to enhance supply chain performance: a dynamic capability view. *Benchmarking: An International Journal*. 29(9), pp. 2822-2841. https://doi.org/10.1108/BIJ-03-2021-0135

Kent, J., J.L. & Flint, D.J. (1997). Perspectives on the evolution of logistics thought. *Journal of Business Logistics.* 18(2), pp. 15–29. https://search-ebscohost-com.ludwig.lub.lu.se/login.aspx?direct=true&AuthType=ip,uid&db=bth&AN=1443454&site=eds-live&scope=site (Accessed: 2 April 2024).

Konstantakopoulos, G.D., Gayialis, S.P. & Kechagias, E.P. (2020). Vehicle routing problem and related algorithms for logistics distribution: a literature review and classification. *Operational Research*. 22, pp.2033-2062. https://doi.org/10.1007/s12351-020-00600-7

Kueng, P. (2000). Process performance measurement system: A tool to support process-based organizations. *Total Quality Management*. 11(1), pp.67–85. https://doi.org/10.1080/0954412007035.

Lal, P. & Narayanswamy, S. (2022) Challenges in Last Mile Delivery – Case of FMCG Industry. *International Journal of Advanced Research and Review.* 7(5), 50–67.

Leite, D.F.B., Padilha, M.A.S. & Cecatti, J.G. (2019). Approaching Literature Review for Academic purposes: the Literature Review Checklist. *Clinics*. 74(74). https://doi.org/10.6061/clinics/2019/e1403

Liu, C., Lin, S., Zuo-Jun Max Shen & Zhang, J. (2023a). Stochastic service network design: The value of fixed routes. *Transportation Research Part E: Logistics and Transportation Review.* 174, pp. 103118–103118. https://doi.org/10.1016/j.tre.2023.103118

Liu, D., Hu, X. & Jiang, Q. (2023b). Design and optimization of logistics distribution route based on improved ant colony algorithm. *Optik*. 273. Article 170405. https://doi.org/10.1016/j.ijleo.2022.170405

Lukka, K., (2003). Case Study Research in Logistics (Ch. The Constructive Research Approach). Turku School of Economics and Business Administrations, pp.83-101.

Manzini, R., Accorsi, R. & Bortolini, M. (2013). Operational planning models for distribution networks. *International Journal of Production Research*. 52(1), pp.89–116. https://doi.org/10.1080/00207543.2013.828168.

Mangiaracina, R., Song, G. & Perego, A. (2015). Distribution network design: a literature review and a research agenda. *International Journal of Physical Distribution & Logistics Management.* 45(5), pp. 506-531. https://doi.org/10.1108/IJPDLM-02-2014-0035

Malmö stad. (2023). *Tunga, långa och breda transporter.* https://malmo.se/For-foretag-och-verksamheter/Miljo--och-halsoskydd/Tunga-langa-och-breda-transporter.html (Accessed 2024-03-08)

McKinnon, A. (2010). European freight transport statistics: limitations, misinterpretations and aspirations. *ACEA 15th SAG Meeting, Brussels*. https://www.acea.auto/files/SAG_15_European_Freight_Transport_Statistics.pdf (Accessed 2024-03-25)

McKinnon, A.C. and Ge, Y. (2006). The potential for reducing empty running by trucks: a retrospective analysis. *International Journal of Physical Distribution & Logistics Management.* 36(5), pp. 391-410. https://doi.org/10.1108/09600030610676268

Nemoto, T. & Tezuka, K. (2002). Advantage of Third Party Logistics in Supply Chain Management. Graduate School of Commerce and Management, Hitotsubashi University.

Näslund, D., Kale, R. & Paulraj, A. (2010). ACTION RESEARCH IN SUPPLY CHAIN MANAGEMENT-A FRAMEWORK FOR RELEVANT AND RIGOROUS RESEARCH. *Journal of Business Logistics*. 31(2), pp.331–355. https://doi.org/10.1002/j.2158-1592.2010.tb00155.x.

Olhager, J. (2022). Exjobb – Introkurs 2022 – Del 3 Infosökning, rapportskrivning [internal publication]. Lund: Lund University.

Ostermeier, M., Henke, T., Hübner, A. & Wäscher, G. (2020). Multi-Compartment Vehicle Routing Problems: State-of-the-art, Modeling Framework and Future Directions. *European Journal of Operational Research*. 292(3), pp.799-817. https://doi.org/10.1016/j.ejor.2020.11.009.

Oxford Institute of Retail Management (2014). *Retail & Wholesale: Key sectors for the European economy.* SAID Business School.

Peffers, K., Tuunanen, T., Rothenberger, M.A. & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*. 24(3), pp.45–77. https://doi.org/10.2753/mis0742-1222240302

Rexhausen, D., Pibernik, R. & Kaiser, G. (2012). Customer-facing supply chain practices - The impact of demand and distribution management on supply chain success. *Journal of Operations Management*. 30(4), pp.269–281.https://doi.org/10.1016/j.jom.2012.02.001

Ronen, D. & Goodhart, C.A. (2008). Tactical store delivery planning. *Journal of the Operational Research Society*. 59(8), pp.1047–1054. https://doi.org/10.1057/palgrave.jors.2602449

Rowley, J. & Slack, F. (2004). Conducting a literature review. *Management Research News*. 27(6), pp. 31-39. https://doi.org/10.1108/01409170410784185

Rushton, A., Croucher, P. & Baker, P. (2014). The Handbook of Logistics and Distribution Management. 5th ed. London, United Kingdom: Kogan Page.

Santén, V. (2017). Towards more efficient logistics: increasing load factor in a shipper's road transport. *The International Journal of Logistics Management*. 28(2), pp. 228-250. https://doi-org.ludwig.lub.lu.se/10.1108/IJLM-04-2015-0071

Saunders, M., Lewis, P. & Thornhill, A. (2009). Research Methods for Business Students. 5th ed. Pearson Education Limited.

Schmitt, A.J., Sun, S.A., Snyder, L. & Shen, M. (2015). Centralization versus decentralization: Risk pooling, risk diversification, and supply chain disruptions. *Omega*. 52, pp. 201-212. https://doi.org/10.1016/j.omega.2014.06.002

Shamsuzzoha, A., Ndzibah, E. & Kettunen, K. (2020). Data-driven sustainable supply chain through centralized logistics network: Case study in a Finnish pharmaceutical distributor company. *Current Research in Environmental Sustainability*. 2, Article 100013. https://doi.org/10.1016/j.crsust.2020.100013.

Song, G. & Sun, L. (2016). Evaluation of factors affecting strategic supply chain network design. *International Journal of Logistics Research and Applications.* 20(5), pp.405–425. https://doi.org/10.1080/13675567.2016.1267125

Stockholms stad. (2024). *Ansök om tillstånd för tunga, långa och breda fordon.* https://tillstand.stockholm/tillstand-regler-och-tillsyn/transporter/ansok-om-tillstand-for-tunga-langa-och-breda-fordon/ (Accessed 2023-03-08).

Swedish Association for Frozen and Refrigerated Foods. (2016). *Correct temperature during storage and transport: national guidelines for frozen and refrigerated foods*. https://www.svenskdagligvaruhandel.se/wp-content/uploads/Branschriktlinjer-2018-English-final-1.pdf (Accessed 2024-02-15)

Szuster, M. (2010). Outsourcing of transport service – perspective of manufacturers. *Total Logistics Management*. No.3, pp. 87-98.

Theodoras, D., Laios, L. and Moschuris, S. (2005). Improving customer service performance within a food supplier-retailers context. *International Journal of Retail & Distribution Management*. 35(5), pp. 353-370. https://doi.org/10.1108/09590550510596731

Transportstyrelsen. (n.d.). *Regler om kör- och vilotider - Transportstyrelsen*. [online] https://www.transportstyrelsen.se/sv/vagtrafik/yrkestrafik/kor-och-vilotider/regler-om-kor--och-vilotider/ (Accessed 2024-03-02).

Vidalakis, C. & Sommerville, J. (2013). Transportation responsiveness and efficiency within the building supply chain. *Building Research & Information.* 41(4), pp.469–481. https://doi.org/10.1080/09613218.2012.715824.

Voss, C., Tsikriktsis, N. & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*. 22(2), pp.195–219. https://doi.org/10.1108/01443570210414329

Wanke, P.F. & Saliby, E. (2009). Consolidation effects: Whether and how inventories should be pooled. *Transportation Research Part E: Logistics and Transportation Review.* 45(5), pp.678–692. https://doi.org/10.1016/j.tre.2009.01.006

Wong, E.Y.C., Tai, A.H. & Zhou, E. (2018). Optimising truckload operations in third-party logistics: A carbon footprint perspective in volatile supply chain. *Transportation Research Part D: Transport and Environment*. 63, pp.649–661. https://doi.org/10.1016/j.trd.2018.06.009.

Xia, L.X.X., Lim, R. & Yu, W.F. (2009). Re-designing a distribution network in a supply chain: - A case study. 2009 7th IEEE International Conference on Industrial Informatics. https://doi.org/10.1109/indin.2009.5195893

Your Europe. (n.d.). *Road transportation workers: weekly working time & rest.* [online] https://europa.eu/youreurope/business/human-resources/transport-sector-workers/road-transportation-workers/index_en.htm (Accessed 2024-02-28).

Zanoni, S. & Zavanella, L. (2007). Single-vendor single-buyer with integrated transport-inventory system: Models and heuristics in the case of perishable goods. *Computers & Industrial Engineering.* 52(1), pp.107–123.https://doi.org/10.1016/j.cie.2006.10.005.

Zhai, X., Ward, J.E. & Schwarz, L.B. (2011). Coordinating a one-warehouse N-retailer distribution system under retailer-reporting. *International Journal of Production Economics*. 134(1), pp.204–211. https://doi.org/10.1016/j.ijpe.2011.06.017

Zhang, H., Ge, H., Yang, J. & Tong, Y. (2022). Review of Vehicle Routing Problems: Models, Classification and Solving Algorithms. *Archives of Computational Methods in Engineering*. 29, pp. 195-221. https://doi.org/10.1007/s11831-021-09574-x.

APPENDIX

Appendix A: Interview Guide - Supply Chain

Interviewee: Supply and Demand Manager
Date: 2024-02-26

Introduction

- We are Sofia & Sofia, and we are in our final year studying Industrial Engineering and Management at LTH. We are writing our thesis at The Company about how the distribution can be configured to meet customer expectations and minimize costs. The purpose of this interview is to gain an understanding of how the current distribution at The Company operates.
- Could you please tell us briefly about yourself and your role and responsibilities at The Company?

Overall strategy

- What is The Company's overall corporate strategy?
    - - Vision/mission?
- What is The Company's value proposition?
- What market segments do you target?
- What is The Company's supply chain strategy?
- How is the overall strategy aligned with the supply chain/distribution strategy?

Distribution strategy

- Do you think distribution is important for The Company's business?
- In regard to distribution, what is valued by The Company's customer?
- What challenges related to distribution have you/your team experienced?

Distribution network design

- Can you tell us about the major change that will be made to The Company's distribution network setup?
    - What is the main reason behind the change?
- How do you think the change will impact the distribution?
    - What advantages can the change bring?
    - What challenges/risks can the change bring?

Outsourcing

- To what extent is the distribution outsourced today?
- How many transport providers are you using? Which ones?
- How do you decide what is outsourced and what is insourced?
- What are the main advantages and disadvantages for The Company of outsourcing and insourcing distribution respectively?
- Do you outsource any other logistics activities outside of distribution? (E.g., warehousing)

Routes

- How are the routes determined? Are you using some route optimization model?

- How often do you replan routes? Is it done manually, or do you have a system or software for it?
- Are all routes static or do you have dynamic routes also?
- How much flexibility is required in terms of capacity and routes?

Transport

- How are the products transported?
- How are the pallets/cages returned?
- Do you measure the truckload utilization? If so, how do you measure it?
- What is the truck utilization rate? Do you transport less than truckloads or full truckloads?
- Does the planning of deliveries differ between long, medium, and short term?
- Does the product's shelf life impact the transport planning?
- How flexible are customers regarding which days they receive their deliveries on?

Processes and procedures

- How is transport booked? Both insourced and outsourced transport
- What IT systems are involved in the distribution from The Company to the customers?
- What is the procedure for returns and claims?
- Do you make a distinction between long-haul and short-haul/last-mile?
- Are there any procedures for quality assurance during distribution?

Performance measurement

- What KPIs do you use to measure the performance of the distribution network?
- Do you think that the new distribution network setup will impact the performance of the distribution?

Ending

- Is there anything else you deem important for this context?
- Thank you for taking your time to answer our questions!

Appendix B: Interview Guide - Transport & Distribution

Interviewee: Warehouse & Distribution Manager at the warehouse in southern Sweden
Date: 2024-03-11

Introduction

- We are Sofia & Sofia, and we are in our final year studying Industrial Engineering at LTH. We are writing our thesis at The Company about how the distribution can be configured in a more efficient way in order to increase the truckload utilization of in-house vehicles. The purpose of this interview is to gain an understanding of how routes are planned currently at The Company.
- Could you tell us more about yourself, your role, and your responsibilities at The Company?

Routes

- How are the routes planned?
  - Is there a particular objective when planning the routes? For example, minimizing travel distance or maximizing utilization
  - What are the routes based on? For example number of pallets, a customer usually orders, number of orders per customer during the week etc.
  - How do you incorporate reloading of the trucks into the route planning?
  - How do you estimate how many customers can be served in one day?
  - Do you prioritize deliveries to some customers to be outsourced and to some customers to be in-house?
  - Do you differentiate between long-term and short-term planning?
- How do you decide which customers to be included in a specific route?
  - How do you manage when new customers are added?
  - How do you manage when customers are removed from the customer base?
- How is the delivery order decided?
- How flexible are customers regarding what day and time they receive their deliveries?
- How often are the routes replanned? Is it done manually, or do you use any kind of tool?
- How much flexibility is required in terms of capacity?
- How do you manage exceptions? For example, if a customer places an urgent order

Transport

- How is the performance of the distribution measured?
  - Do you measure the truckload utilization? If so, how is that measured?
  - Do you measure fleet utilization?
- What kinds of products constitute the largest volumes delivered?
- How is transport booked internally and externally?
- Do you have any flexible manpower?
- Do the ways of working differ between the warehouse in southern Sweden and central Sweden?
- What challenges do you experience in regard to transport and distribution?
  - Are there any differences between internal and external distribution?

Ending

- Is there anything else you deem important for this context?

- Thank you for taking your time to answer our questions!

Appendix C: Interview Guide - Warehouse & Transport

Interviewee: Warehouse & Transport Manager at the warehouse in central Sweden
Date: 2024-04-08

Introduction

- We are Sofia & Sofia, and we are in our final year studying Industrial Engineering at LTH. We are writing our thesis at The Company about how the distribution can be configured in a more efficient way in order to increase the truckload utilization of in-house vehicles. The purpose of this interview is to gain an understanding of how routes are planned currently at The Company.
- Could you tell us more about yourself, your role, and your responsibilities at The Company?

Distribution & Route Planning

- How are the routes planned?
- Is it common to reload the trucks during a route?
- Is it common to stack pallets in the truck?
- To what extent are you using trailers?
    - Are the trailers connected to specific routes?
    - When are the trailers used?
        - For longer distances?
        - For larger volumes?
    - Do you believe the trailers are essential for The Company's distribution?
- To what extent do you drive two-day trips?
    - Is it some particular routes that are driven for two days?
    - Are those routes driven with both truck and trailer?
- Do you measure the truckload utilization? If so, how is that measured?
    - Have you experienced difficulties in filling up the trucks?
    - Is it a priority to maximize truckload utilization?
- Do you measure travel distance per route? If so, how?
    - Is it a priority to minimize travel distance?
- What challenges have you experienced related to transport and distribution?
- Does The Company have both internal and external trucks departing from the warehouse in central Sweden?

Ending

- Is there anything else you deem important for this context?
- Thank you for taking your time to answer our questions!

Appendix D: Truckload Utilization and Travel Distance per Internal Route for the Current Configuration

Route	*Truckload utilization (%)*	*Travel distance (km)*
300I	0%	2491
L EXTRA	21%	21
L01	77%	1075
L02	86%	104
L03	71%	103
L04	79%	118
L05	72%	152
L06	80%	118
L07	51%	108
L08	64%	324
MAXI	98%	199
MAXI2	104%	6921
O01	56%	384
O02	107%	253
O03	35%	251
O04	72%	177
O05	74%	175
O06	97%	104
O07	44%	61
O08	28%	255
O09	93%	149
O11	73%	467
O12	87%	310

O13	62%	346
O14	64%	191
O15	63%	246
O16	100%	140
O17	42%	242
O18	54%	283
O19	39%	333
O21	59%	542
O22	86%	380
O23	68%	429
O24	61%	216
O25	58%	149
O26	128%	55
O27	29%	137
O28	44%	231
O29	107%	337
O45	94%	237
O77	25%	304
S04	5%	0
ÄR LEV	6%	663
Average/total	66%	19780

Appendix E: Travel Distance, Travel Time, and Unloading Time for Each Route

Route number	*Type of route*	*Type of delivery*	*Average number of customers*	*Unloading time*	*Loading time*	*Travel distance*	*Travel time*	*Total time*
1	One-day	Customer	9.52	2.38	0.47	22.80	0.38	3.23
2	One-day	Customer	8.31	2.29	0.49	21.43	0.36	3.13
3	One-day	Customer	11.54	3.24	0.51	38.93	0.65	4.40
4	One-day	Customer	10.75	2.92	0.49	36.27	0.60	4.01
5	One-day	Customer	6.00	1.50	0.42	28.74	0.48	2.40
6	One-day	Customer	9.71	2.76	0.43	105.20	1.75	4.94
7	One-day	Customer	7.48	2.04	0.43	135.46	2.26	4.72
8	One-day	Customer	8.87	2.31	0.42	142.07	2.37	5.09
9	One-day	Customer	13.04	3.19	0.48	205.49	3.42	7.09
10	One-day	Customer	13.27	3.91	0.42	402.29	6.70	11.03
11	One-day	Customer	12.21	3.04	0.46	359.31	5.99	9.49
12	One-day	Customer	12.42	3.11	0.46	219.33	3.66	7.22
13	One-day	Customer	7.13	1.96	0.42	239.69	3.99	6.38
14	Two-day	Customer	14.29	3.92	0.48	475.29	7.92	12.32
15	One-day	Customer	13.38	3.44	0.43	338.15	5.64	9.50
16	One-day	Customer	4.50	1.13	0.22	323.76	5.40	6.74
17	One-day	Terminal	21.17	1.57	1.41	591.02	7.39	10.37
18	Two-day	Terminal	24.00	2.00	1.65	1274.29	15.93	19.58
19	Two-day	Terminal	25.00	2.00	1.65	1274.29	15.93	19.58
20	Two-day	Terminal	42.00	2.00	1.65	1274.29	15.93	19.58
21	Two-day	Terminal	37.58	1.93	1.65	1274.29	15.93	19.50
22	Two-day	Terminal	51.40	1.06	1.65	1274.29	15.93	18.64
23	Two-day	Terminal	24.37	1.19	1.64	1274.29	15.93	18.76
24	Two-day	Terminal	15.00	1.50	0.90	1274.29	15.93	18.33
25	Two-day	Customer	15.46	3.79	0.45	753.02	10.76	15.00
26	Two-day	Customer	13.21	3.22	0.46	623.47	8.91	12.59
27	Two-day	Customer	10.54	2.65	0.45	737.81	10.54	13.64
28	One-day	Customer	9.19	2.30	0.46	418.04	5.97	8.73
29	One-day	Customer	10.08	2.43	0.45	372.34	5.32	8.21
30	One-day	Customer	10.42	2.79	0.43	609.00	8.70	11.92
31	Two-day	Customer	8.44	2.09	0.45	697.47	9.96	12.51
32	Two-day	Customer	10.65	3.35	0.45	822.02	11.74	15.54
33	Two-day	Customer	11.85	3.35	0.45	949.51	13.56	17.36
34	Two-day	Customer	10.63	2.86	0.46	649.29	9.28	12.59
35	Two-day	Customer	11.48	2.86	0.46	886.17	12.66	15.98

Appendix F: MATLAB Code

```
%% short distance deliveries

clc
clearvars
load('variables_one.mat')

max_util = 16;
max_weight = 13;
customers = customers_og;
i = 1;

% monday
[customers,routes_mon,cities_mon,utilization_mon,routeareaid_mon,count_mon,weight_mon,i] = ...
    oneday(customers,cities,i,max_util,7,max_weight);

% tuesday
[customers,routes_tue,cities_tue,utilization_tue,routeareaid_tue,count_tue,weight_tue,i] = ...
    oneday(customers,cities,i,max_util,11,max_weight);

% wednesday
[customers,routes_wed,cities_wed,utilization_wed,routeareaid_wed,count_wed,weight_wed,i] = ...
    oneday(customers,cities,i,max_util,11,max_weight);

% thursday
[customers,routes_thu,cities_thu,utilization_thu,routeareaid_thu,count_thu,weight_thu,i] = ...
    oneday(customers,cities,i,max_util,10,max_weight);

% friday
[customers,routes_fri,cities_fri,utilization_fri,routeareaid_fri,count_fri,weight_fri,i] = ...
    oneday(customers,cities,i,max_util,9,max_weight);

final_i = i;

% second deliveries
max_second = 19.5;

[customers,routes_mon,cities_mon,utilization_mon,count_mon,weight_mon] = ...
    seconddeliveries(customers,cities,cities_mon,routes_mon,utilization_mon,...
    routeareaid_mon,count_mon,weight_mon,final_i,max_second,max_weight);


[customers,routes_tue,cities_tue,utilization_tue,count_tue,weight_tue] = ...
    seconddeliveries(customers,cities,cities_tue,routes_tue,utilization_tue,...
    routeareaid_tue,count_tue,weight_tue,final_i,max_second,max_weight);


[customers,routes_wed,cities_wed,utilization_wed,count_wed,weight_wed] = ...
    seconddeliveries(customers,cities,cities_wed,routes_wed,utilization_wed,...
    routeareaid_wed,count_wed,weight_wed,final_i,max_second,max_weight);


[customers,routes_thu,cities_thu,utilization_thu,count_thu,weight_thu] = ...
    seconddeliveries(customers,cities,cities_thu,routes_thu,utilization_thu,...
    routeareaid_thu,count_thu,weight_thu,final_i,max_second,max_weight);


[customers,routes_fri,cities_fri,utilization_fri,count_fri,weight_fri] = ...
    seconddeliveries(customers,cities,cities_fri,routes_fri,utilization_fri,...
    routeareaid_fri,count_fri,weight_fri,final_i,max_second,max_weight);

no_trucks = sum(count_mon~=0)+sum(count_tue~=0)
util = (sum(utilization_mon)+sum(utilization_tue))/(no_trucks*18)
not_served = sum(customers(:,2))
customers_served = final_i

%% gothenburg
clc
clearvars
load('variables_gbg.mat')

customers = customers_og;
max_util = 63;
max_weight = 37;
i = 1;

[customers,routes_mon,cities_mon,utilization_mon,routeareaid_mon,count_mon,weight_mon,i] = ...
    oneday(customers,cities,i,max_util,1,max_weight);
```

```
final_i = i;
max_second = 63;

[customers,routes_mon,cities_mon,utilization_mon,count_mon,weight_mon] = ...
    seconddeliveries(customers,cities,cities_mon,routes_mon,utilization_mon,...
    routeareaid_mon,count_mon,weight_mon,final_i,max_second,max_weight);

no_trucks = sum(count_mon~=0)
util = (sum(customers(customers(:,2)==1,3))+utilization_mon)/(no_trucks*63)
not_served = sum(customers(:,2))
customers_served = final_i

%% stockholm
clc
clearvars
load('variables_sthlm.mat')

customers = customers_og;
max_util = 55;
max_weight = 37;
i = 1;

[customers,routes_mon,cities_mon,utilization_mon,routeareaid_mon,count_mon,weight_mon,i] = ...
    oneday(customers,cities,i,max_util,2,max_weight);

[customers,routes_tue,cities_tue,utilization_tue,routeareaid_tue,count_tue,weight_tue,i] = ...
    oneday(customers,cities,i,max_util,1,max_weight);

[customers,routes_wed,cities_wed,utilization_wed,routeareaid_wed,count_wed,weight_wed,i] = ...
    oneday(customers,cities,i,max_util,2,max_weight);

[customers,routes_thu,cities_thu,utilization_thu,routeareaid_thu,count_thu,weight_thu,i] = ...
    oneday(customers,cities,i,max_util,1,max_weight);

[customers,routes_fri,cities_fri,utilization_fri,routeareaid_fri,count_fri,weight_fri,i] = ...
    oneday(customers,cities,1,30,1,13);

final_i = 233;
max_second = 62;

[customers,routes_mon,cities_mon,utilization_mon,count_mon,weight_mon] = ...
    seconddeliveries(customers,cities,cities_mon,routes_mon,utilization_mon,...
    routeareaid_mon,count_mon,weight_mon,final_i,max_second,max_weight);

[customers,routes_tue,cities_tue,utilization_tue,count_tue,weight_tue] = ...
    seconddeliveries(customers,cities,cities_tue,routes_tue,utilization_tue,...
    routeareaid_tue,count_tue,weight_tue,final_i,max_second,max_weight);

[customers,routes_wed,cities_wed,utilization_wed,count_wed,weight_wed] = ...
    seconddeliveries(customers,cities,cities_wed,routes_wed,utilization_wed,...
    routeareaid_wed,count_wed,weight_wed,final_i,max_second,max_weight);

[customers,routes_thu,cities_thu,utilization_thu,count_thu,weight_thu] = ...
    seconddeliveries(customers,cities,cities_thu,routes_thu,utilization_thu,...
    routeareaid_thu,count_thu,weight_thu,final_i,max_second,max_weight);

[customers,routes_fri,cities_fri,utilization_fri,count_fri,weight_fri] = ...
    seconddeliveries(customers,cities,cities_fri,routes_fri,utilization_fri,...
    routeareaid_fri,count_fri,weight_fri,final_i,36,13);

no_trucks_trailers = sum(count_mon~=0)+sum(count_tue~=0)+sum(count_wed~=0)+sum(count_thu~=0)
no_trucks = sum((count_fri~=0))
util = (sum(utilization_mon)+sum(utilization_tue)+sum(utilization_wed)+sum(utilization_thu)+...
sum(utilization_fri))/(no_trucks_trailers*63+no_trucks*36)
not_served = sum(customers(:,2))
customers_served = final_i


%% long distance deliveries
clc
clearvars
load('variables_two.mat')

customers = customers_og;
max_util = 14.5;
max_weight = 13;
i = 1;

[customers,routes_mon_two,cities_mon_two,utilization_mon_two,routeareaid_mon_two,...
```

```
    count_mon_two,weight_mon_two,i] = twodays(customers,cities,i,max_util,20,max_weight);

[customers,routes_tue_two,cities_tue_two,utilization_tue_two,routeareaid_tue_two,...
    count_tue_two,weight_tue_two,i] = twodays(customers,cities,i,max_util,20,max_weight);

final_i = i;
max_second = 17.5;

[customers,routes_mon_two,cities_mon_two,utilization_mon_two,count_mon_two,weight_mon_two] = ...
    seconddeliveries(customers,cities,cities_mon_two,routes_mon_two,utilization_mon_two,...
    routeareaid_mon_two,count_mon_two,weight_mon_two,final_i,max_second,max_weight);

[customers,routes_tue_two,cities_tue_two,utilization_tue_two,count_tue_two,weight_tue_two] = ...
    seconddeliveries(customers,cities,cities_tue_two,routes_tue_two,utilization_tue_two,...
    routeareaid_tue_two,count_tue_two,weight_tue_two,final_i,max_second,max_weight);

no_trucks = sum(count_mon_two~=0)+sum(count_tue_two~=0)
util = (sum(utilization_mon_two)+sum(utilization_tue_two))/(no_trucks*18)
not_served = sum(customers(:,2))
customers_served = final_i


%% distance proposed
clc
clearvars
load('variables_distance.mat')

origin = [55.6402 13.2093];
d = distance(customers,origin)

d_shortdistance = d(1:16);
d_gbgsthlm = d(17:24);
d_longdistance = d(25:44);

time_shortdistance = d_oneday./60
time_gbgsthlm = d_gbgsthlm./80
time_longdistance = d_twodays./70

%% distance current lomma
clc
clearvars
load('variables_distance_lomma.mat')

origin = [55.6747 13.0801];
d = distance(customers,origin)


%% distance current Ã¶rebro
clc
clearvars
load('variables_distance_Ã¶rebro.mat')


origin = [59.2669 15.1965];
d = distance(customers,origin)


function [customers,routes_day,cities_day,utilization_day,routeareaid_day,...
    count_day,weight_day,final_i] = oneday(customers,cities,i,max_util,...
    no_trucks,max_weight)
    %INPUT
    % customers : numeric matrix - customer account, number of
    % deliveries, no of pallets per delivery, routesubareaid
    % cities : string array of city names
    % i : position of customer to start at
    % max_util : maximum utilization in EUR pallets
    % no_trucks : number of trucks available that day
    % max_weight : maximum weight capacity of each truck

    %OUTPUT
    % routes_day : customer accounts to deliver to
    % cities_day : city names of customer accounts to deliver to
    % utilization_day : utilization in EUR pallets for each truck
    % routeareaid_day : route area id for each truck
    % count_day : how many customers to deliver for each truck
    % weight_day : weight of each truck
    % final_i : position of last customer served

    routes_day = zeros(40,no_trucks);
    cities_day = string(zeros(40,no_trucks));
    utilization_day = zeros(1,no_trucks);
```

```
    routeareaid_day = zeros(1,no_trucks);
    count_day = zeros(1,no_trucks);
    weight_day = zeros(1,no_trucks);

    % loop through customers
    truck = 1;
    j = 1; % row in routes_day
    while i<size(customers,1)
        if truck > no_trucks % if all trucks on that day are filled
            break;
        end
        if customers(i,2) > 0 && ~any(routes_day(:,truck)==customers(i,1),1)
        % check if no deliveries is greater than 0 and the customer does not
        % already on the route
            if utilization_day(truck) + customers(i,3) > max_util || ...
                    weight_day(truck) + customers(i,5)/1000 > max_weight
                    % check if one of the next five customers can be added
                    temp_j = j;
                    for k=(i+1):(i+5)
                        if k <= size(customers,1) && customers(k,2) > 0 && ...
                                ~any(routes_day(:,truck) == customers(k,1),1)
                            if customers(k,4)==routeareaid_day(truck) && ...
                                    utilization_day(truck) + customers(k,3) <= max_util ...
                                    && weight_day(truck) + customers(k,5)/1000 <= max_weight
                                routes_day(j,truck) = customers(k,1);
                                count_day(truck) = count_day(truck) + 1;
                                weight_day(truck) = weight_day(truck) + ...
                                    customers(k,5)/1000;
                                cities_day(j,truck) = cities(k);
                                utilization_day(truck) = utilization_day(truck)...
                                    + customers(k,3);
                                customers(k,2) = customers(k,2)-1;
                                routeareaid_day(truck) = customers(k,4);
                                j = j + 1;
                                break;
                            end
                        end
                    end
                    if j==temp_j
                        truck = truck + 1; % next truck
                        j = 1;
                    end
            else
                routes_day(j,truck) = customers(i,1);
                count_day(truck) = count_day(truck) + 1;
                weight_day(truck) = weight_day(truck) + ...
                    customers(i,5)/1000;
                cities_day(j,truck) = cities(i);
                utilization_day(truck) = utilization_day(truck) + customers(i,3);
                customers(i,2) = customers(i,2)-1;
                routeareaid_day(truck) = customers(i,4);
                i = i + 1;
                j = j + 1;
            end
        else
            i = i + 1;
        end
    end
    final_i = i;
end


function [customers,routes_day,cities_day,utilization_day,routeareaid_day,count_day,weight_day,...
    final_i] = twodays(customers,cities,i,max_util,no_trucks,max_weight)
    %INPUT
    % customers : numeric matrix - customer account, number of
    % deliveries, no of pallets per delivery, routesubareaid
    % cities : string array of city names
    % i : position of customer to start at
    % max_util : maximum utilization in EUR pallets
    % no_trucks : number of trucks and trailers available
    % max_weight : maximum weight capacity

    %OUTPUT
    % routes_day : customer accounts to deliver to
    % cities_day : city names of customer accounts to deliver to
    % utilization_day : utilization in EUR pallets for each truck
    % routeareaid_day : route area id for each truck
    % count_day : how many customers to deliver for each truck
```

```matlab
    % weight_day : weight of each trucks
    % final_i : position of last customer served

    routes_day = zeros(20,no_trucks);
    cities_day = string(zeros(20,no_trucks));
    utilization_day = zeros(1,no_trucks);
    routeareaid_day = zeros(1,no_trucks);
    count_day = zeros(1,no_trucks);
    weight_day = zeros(1,no_trucks);

    % loop through customers
    truck = 1;
    j = 1; % row in routes_day
    while i<size(customers,1)
        if truck > no_trucks % if all trucks on that day are filled
            break;
        end
        if customers(i,2) > 0 && ~any(routes_day(:,truck)==customers(i,1),1)
        % check if no deliveries is greater than 0 and the customer does not
        % already on the route
            if utilization_day(truck) + customers(i,3) > max_util || ...
                     weight_day(truck) + customers(i,5)/1000 > max_weight
                    % check if one of the next five customers can be added
                    temp_j = j;
                    for k=(i+1):(i+5)
                        if k <= size(customers,1) && customers(k,2) > 0 &&
~any(routes_day(:,truck)==customers(k,1),1)
                            if customers(k,4)==routeareaid_day(truck) && utilization_day(truck) +
customers(k,3) <= max_util ...
                                    && weight_day(truck) + customers(k,5)/1000 <= max_weight
                                routes_day(j,truck) = customers(k,1);
                                count_day(truck) = count_day(truck) + 1;
                                weight_day(truck) = weight_day(truck) + ...
                                    customers(k,5)/1000;
                                cities_day(j,truck) = cities(k);
                                utilization_day(truck) = utilization_day(truck) + customers(k,3);
                                customers(k,2) = customers(k,2)-1;
                                routeareaid_day(truck) = customers(k,4);
                                j = j + 1;
                                break;
                            end
                        end
                    end
                    if j==temp_j
                        truck = truck + 1; % next truck
                        j = 1;
                    end
            else
                routes_day(j,truck) = customers(i,1);
                count_day(truck) = count_day(truck) + 1;
                weight_day(truck) = weight_day(truck) + customers(i,5)/1000;
                cities_day(j,truck) = cities(i);
                utilization_day(truck) = utilization_day(truck) + customers(i,3);
                customers(i,2) = customers(i,2)-1;
                routeareaid_day(truck) = customers(i,4);
                i = i + 1;
                j = j + 1;
            end
        else
            i = i + 1;
        end
    end
    final_i = i;
end


function [customers_new,routes_new,cities_new,utilization_new,count_new,weight_new] = ...
    seconddeliveries(customers,cities,cities_day,routes_day,utilization_day,...
    routeareaid_day,count_day,weight_day,final_i,max_util,max_weight)
    %INPUT
    % customers : numeric matrix - [customer account, number of
    % deliveries, no of pallets per delivery, routeareaid]
    % cities : string array of city names
    % cities_day : city names of customer accounts to deliver to for each
    % truck
    % routes_day : customer accounts to deliver to
    % utilization_day : utilization in EUR pallets for each truck
    % routesareaid_day : route area id for each truck
    % count_day : how many customers to deliver for each truck
```

```
    % weight_day : weight of each truck
    % final_i : position of last customer served
    % max_util : maximum utilization in EUR pallets
    % max_weight : maximum weight capacity of each truck

    %OUTPUT
    % customers_new : updated customer matrix - [customer account, number of
    % deliveries, no of pallets per delivery, routeareaid]
    % routes_new : updated customer accounts to deliver to
    % cities_new : updated city names of customer accounts to deliver to for each
    % truck
    % utilization_new : updated utilization in EUR pallets for each truck
    % count_new : updated how many customers to deliver for each truck
    % weight_new : updated weight of each truck

    i = 1;
    while i < final_i
        if customers(i,2)>0
            for k=1:size(routeareaid_day,2)
                if routeareaid_day(k)==customers(i,4) && utilization_day(k)+customers(i,3)...
                        <=max_util && weight_day(k)+customers(i,5)/1000<=max_weight
                    % check the route area id, utilization constraint &
                    % weight constraint
                    % check if customer already exists
                    if ~any(routes_day(:,k)==customers(i,1),1)
                        routes_day(count_day(k)+1,k) = customers(i,1);
                        count_day(k) = count_day(k) + 1;
                        weight_day(k) = weight_day(k) + customers(i,5)/1000;
                        cities_day(count_day(k),k) = cities(i);
                        utilization_day(k) = utilization_day(k) + customers(i,3);
                        customers(i,2) = customers(i,2)-1;
                        break;
                    end
                end
            end
        end
        i = i + 1;
    end
    customers_new = customers;
    routes_new = routes_day;
    cities_new = cities_day;
    utilization_new = utilization_day;
    count_new = count_day;
    weight_new = weight_day;
end


function d = distance(customers,origin)
%INPUT
% customers : numeric matrix with customer account, route id, latitude,
% longitude and delivery type (one- or two-day)
% origin : latitude and longitude of origin (i.e. the central warehouse)

%OUTPUT
% d : travel distance per route (array)

no_routes = customers(size(customers,1),2);
d = zeros(no_routes,1);
origin(1) = origin(1)*111.7;
origin(2) = origin(2)*68.9;
customers(:,3) = 111.7.*customers(:,3);
customers(:,4) = 68.9.*customers(:,4);

routeid = 1;
while routeid <= no_routes
    temp = customers(customers(:,2)==routeid,:);
    if size(temp,1)>0
        n = size(temp,1);
        dist = sqrt((origin(1)-temp(:,3)).^2+(origin(2)-temp(:,4)).^2);
        dist_wh = [temp dist];
        m = min(dist_wh(:,5));
        pos = 1;
        for i=1:n
            if dist_wh(i,5)==m
               pos = i;
               break;
            end
        end
        dist = sqrt((temp(pos,3)-temp(:,3)).^2+(temp(pos,4)-temp(:,4)).^2);
```

```
        dist_min = [dist_wh dist];
        dist_min = sortrows(dist_min,6)
        temp = dist_min;

        % from warehouse
        dist = sqrt((origin(1)-temp(1,3))^2+(origin(2)-temp(1,4))^2);
        d(routeid) = dist;
        % to warehouse
        dist = sqrt((origin(1)-temp(n,3))^2+(origin(2)-temp(n,4))^2);
        d(routeid) = dist + d(routeid);
        for k=2:n
            dist = sqrt((temp(k,3)-temp(k-1,3))^2+(temp(k,4)-temp(k-1,4))^2);
            d(routeid) = dist+d(routeid);
        end
    end
    routeid = routeid+1;
end

d = 1.2.*d;

end
```