CHALMERS
UNIVERSITY OF TECHNOLOGY

A Fan of Green Transport

Consolidation Route Optimization for Inbound Logistics at FläktGroup Sweden AB

Master's thesis in Supply Chain Management

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Cover: Routes consolidating freight to the manufacturing site in Jönköping for FläktGroup Sweden AB.

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Abstract

Consolidation of freight transport is an effective way of reducing environmental impact and optimizing logistics flows. This master's thesis aimed to locate and analyze potential consolidation solutions for external road freight of goods within inbound logistics at the manufacturer FläktGroup Sweden AB. The goal was to find optimized freight transport routes that reduce the company's environmental impact of road transport, while still maintaining the effectiveness and economics of the manufacturing. To enable this, a mapping of the current inbound logistics external freight flow was necessary. This was supported by a sufficient theoretical exploration of parameters influencing inbound logistics and its surrounding operations.

The thesis used a hybrid data collection approach, combining quantitative and qualitative methods to gather primary and secondary data. Several analytical tools such as the Kraljic matrix, Fisher's model, EOQ calculations, and the SWOT analysis, were used to identify improvement potentials in the current freight flow and suggest shipment consolidating routes. The environmental impact of the proposed routes was evaluated using the NTMCalc Basic 4.0 calculator.

The master's thesis resulted in a map of the current collection points of incoming goods and a segmentation of vendors that had the potential to be included in initial shipment consolidation solutions. It suggested an efficient supply chain design to enable transport optimization tactics within inbound logistics and proposed several routes for future implementation, which combined a majority of the segmented vendors in routes with close characteristics to a milk-run delivery system. A following recommendation was made for FläktGroup to in the future consider an order consolidation policy internally within inbound logistics.

In conclusion, the thesis successfully located and analyzed potential consolidation solutions for external road freight of goods within inbound logistics at FläktGroup Sweden AB. The findings provide a framework for optimizing freight transport routes while reducing environmental impact, which could potentially be applied to other manufacturing firms with similar supply chains.

Keywords: Consolidation, Transport Optimization, Efficiency, Inbound Logistics, Road Freight Transport, Environmental Impact, Route Suggestions, Manufacturing Sector

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Anna Skötte & Filip Vallin, Gothenburg, June 2023

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List of Abbreviations

3PL	Third-Party Logistics
AF	Area Forwarding
EOQ	Economic Order Quantity
FG	FläktGroup Sweden AB
FTL	Full Truck Load
HCV	High-Capacity Vehicles
JIT	Just-In-Time
JKP	Jönköping
LTL	Less than Truck Load
LCA	Life Cycle Assessment
MR	Milk-Run
MM	Mixed Mode
MTO	Make To Order
MTS	Make To Stock
OTD	On Time Delivery
P2P	Point-To-Point
SCL	Shipment Consolidation

1. Introduction

Today, practically any type of production is dependent on thousands of deliveries to be performed daily, providing freight necessary to keep industrial factories running and contribute to countries economy and society (Trafikanalys, 2022). Road freight transport is a vital component for most countries, including Sweden. However, transport operations also have a significant impact on the environment, with national road freight alone responsible for 10% of Sweden's total greenhouse gas emissions (Naturvårdsverket, 2022). Furthermore, trucks in Sweden currently are less than 55 % utilized, and 18 % of them run empty (Eurostat, 2021, 2022*a*,*b*), meaning that a significant amount of emissions from road transport are wasted instead of being utilized for actual freight.

One of the most attractive ways of reducing the environmental impact of road transportation is by increasing the utilization of available capacity (McKinnon and Edwards, 2010). Increasing the utilization could lead to significant reductions both in greenhouse gas emissions and logistics costs. An approach to achieve this is to implement shipment consolidation (Buffa, 1986), a concept combining smaller shipments to increase the overall truck utilization.

Consolidating shipments is an option the Swedish manufacturing company FläktGroup Sweden AB (hereafter FläktGroup) wants to analyze for their inbound logistic. The manufacturer provides a good case for understanding how transport solutions might affect a producing company's environmental impact. Specifically, how freight optimization via shipment consolidation can influence environmental and financial costs within the inbound logistic processes.

Shipment consolidation is affected by a variety of different external and internal constraints (Baller et al., 2022). These constraints vary depending on surrounding circumstances, products, and other company specific characteristics. This master's thesis aims to look into such constraints, and investigate the ability to increase the manufacturer's overall effectiveness and lower the environmental impact while balancing with consideration to the company's financial sustainability.

1.1 Background

FläktGroup is a well-established Indoor Air Quality and Critical Ventilation manufacturing company (FläktGroup, 2023). Today, FläktGroup operates globally with a presence in 65 countries and has 13 manufacturing plants located in Europe, Asia, and the US. One of FläktGroups main production sites is located in Jönköping Sweden. There, the company produces air handling units, chilled beams, heat exchangers, and control systems, characterized by high customization options and a wide range of products.

The parts and components necessary for manufacturing to be successful can seldom be sourced from internal operations only. An extensive number of external suppliers is needed in one way or another for the manufacturer to produce products as effectively and qualitatively as possible. For the handling and transfer of such parts and materials, logistics management processes must be in place. The design of these processes creates value for the production and the firm, but they can also generate waste and unnecessary costs if not fully optimized. From a sustainability perspective, these can be economic, environmental, and social costs.

Due to the significant number of different suppliers and components being delivered, FläktGroup's COO has expressed a need to understand the potential of consolidating a portion of their inbound deliveries. Implementing consolidated transport within the company's inbound logistics could lead to a reduction in transportation costs and carbon emissions, as well as give the company increased control over component prices and more visibility into its logistics processes. This reduction in costs would not only be a strategic choice but would also reflect the company's commitment to reducing its environmental impact.

1.2 Purpose

The purpose of the master's thesis is to identify freight transport flows within the geographical boundary of Sweden that can be consolidated to increase efficiency and reduce the environmental impact of inbound logistics. The consolidation should not limit the effectiveness of the manufacturing operations or increase logistics costs. On the contrary, it should aim for establishing a basis where solutions for economic reductions can be developed as a consequence of the optimized inbound logistics operations. The thesis aims to identify external and internal factors surrounding logistics that affect the feasibility of consolidated transport. Following this, the purpose is to provide suggestions on how consolidated routes can be designed considering the current freight transport flows and the factors affecting or constraining consolidation solutions. Finally, the master's thesis seeks to evaluate the current delivery system's environmental impact and compare it to the developed suggestions for optimized freight transport routes.

1.2.1 Research Questions

Every company is unique and its operations dependent on a wide range of internal and external factors. To be able to find and implement changes in any operational flow, one must know the present first. Research question one (RQ1) focus on mapping the current external freight within FläktGroup's inbound logistics operations, a mapping that can be used to identify FläktGroup's freight transport flows of incoming goods to their manufacturing site to Jönköping. Specifically, the question seeks to identify how some of the flows are organized from FläktGroup's Swedish suppliers to their production site.

RQ1 ***How do the present inbound logistic solution look like for FläktGroup in Jönköping?***

Following, the mapping of the inbound logistic flows enables an overview of where opportunities for consolidation lie. Research question two (RQ2) formulate what is necessary to know before starting to fulfill the aim of finding improvements and consolidation potential in FläktGroup's incoming delivery system. To be able to utilize freight mapping for this purpose, an understanding of what factors might constrain a successful implementation of consolidated transport, and what might strengthen it, should be developed. This should be done from the perspective of costs and effectiveness in manufacturing and inbound logistics.

RQ2 ***Where in the inbound logistics are there opportunities for improvement through consolidation, without affecting the manufacturing plants effectiveness and logistics cost?***

To be able to understand the potential impact consolidated transport solutions might have for FläktGroup's inbound logistics, optimized route suggestions can be developed and calculated, enabling a concrete way to compare the current system to a future one in line with the aim of the thesis. Therefore, research question three (RQ3) is added as a final purpose. The question thus also includes the seeking of calculated effects on the company's change in environmental impact, were they to implement the suggested consolidation suggestions.

RQ3 ***How can the current inbound logistics be improved with a suggestion of consolidation via route planning, and what environmental effect does it have?***

Together, the three research questions shape the master's thesis and enables a systematical structure of its research. The aim is thus to find and analyze the answers methodically and in the chronological order as they are listed.

1.3 Scope & Limitations

Since the studied production site receives a large volume of diverse articles regularly, it is necessary to narrow the scope of this thesis to create value within the time limitation. Therefore, this thesis will not comprehensively cover all components and geographical areas of FläktGroup's suppliers. Additionally, the mapping of the freight transport will be limited to road freight only, as it is the only freight method used nationally in the company today. Any future solutions will also be limited within road freight transport.

The geographical scope when mapping the inbound logistics operations is limited to Sweden, with a limitation on investigating and analyzing deliveries of products and components from suppliers located in Sweden. By focusing on one country's regulatory demands, such as maximum weight and length of road freight allowed, the thesis can simply identify parameters and constraints affecting consolidation possibilities.

The data included in this thesis will be limited to data provided by FläktGroup regarding inbound deliveries within a specific time frame. Specifically, the quantitative data collection will be limited to data from the previous year (2022) and any sensitive information will be respected and not included in the thesis report.

Regarding the assessment and calculations on the operations' environmental impact, the thesis will only investigate the greenhouse gas emissions from the incoming road freight transportation. Furthermore, while the sustainability of FläktGroup's inbound logistics will be evaluated and mapped with a focus on environmental and economic sustainability, social sustainability will not be included in the scope of this thesis. All three pillars of sustainability cannot be fully regarded all at once, which is why a decision to focus on two of them is necessary.

Due to time constraints and lack of resources, potential suggestions of consolidation via route planning will not be done with advanced route planning algorithms.

1.4 Outline

The master's thesis is divided into seven chapters. Chapter 1 *Introduction* provides the purpose, objective and scope of the master's thesis. It also provides background information of the studied company. Chapter 2, *Frame of Reference*, presents the findings from established literature and theory related to the purpose of the master's thesis.

Chapter 3, *Methodology*, explains the approach used for the master's thesis. The methodology describes how the thesis was structured, what activities were performed, and what tools were used. It introduces the developed research model, with detailed steps outlined for the collection and handling of the research's data. Following the model, the qualitative and quantitative data findings are presented in Chapter 4, *Empirical Findings*. Here, the findings are illustrated with support from an established visualisation tool, and summarized in tables.

Chapter 5, *Analysis*, focuses on analyzing the data collected from the empirical findings. The chapter presents a conclusive deduction of where the inbound shipment could be optimized and how so. The consolidation opportunities are then mapped and calculated, and a study of their potential environmental impact follows thereof.

Chapter 6, *Discussion*, highlights some discussion points to enable reflections on the contributions of the master's thesis and the execution of the work. The chapter covers reflections on the interpretations of the empirical findings, connections between the analysis and already existing theory from the frame of reference, and possible areas of improvement. The chapter also covers how changes in the methodology and execution of the research and analysis would have affected the outcome of the master's thesis.

Chapter 7, *Conclusions and Recommendations*, presents the conclusions and recommendations of the master's thesis. The chapter provides answers to the three research questions outlined in the introduction. It also covers a summary of the contributions the master's thesis has made to the company and researched area. Finally, some future recommendations are suggested, and enable an entry towards forthcoming research and improvement areas for the studied company.

2. Frame of Reference

Findings from established literature and theory related to the purpose of the master's thesis are presented below. The frame of reference embarks from a broader perspective of operations surrounding inbound logistics and freight consolidation, followed by a deeper review of the established theories regarding the key areas of the thesis.

2.1 Logistics management

For a production firm, logistics refers to the segment of the supply chain that handles activities, actors, and resources related to the transportation and storage of parts and materials (Zijm et al., 2019). Logistics can also be explained to bridge production, markets and suppliers, by adding value to the movement converting raw material into components or finished products (Kasilingam, 1998). Logistics can be divided into two parts, inbound and outbound processes, depending on where in the supply chain the activities take place (Zijm et al., 2019). As a result, logistics management involves various controlling activities, such as transport operations management, inventory and warehousing, designing the logistics network, supply and demand planning, and coordinating third-party logistics (3PL) service providers, to name a few (Zijm et al., 2019). Logistic operations also impact and depend on other operations within the supply chain, such as procurement and sourcing. Stadtler (2015) describes logistics as one of the functional units necessary to cooperate with each other to provide a competitive supply chain. Figure 2.1 illustrates the relationship and hierarchy levels of supply chain management, logistics management, and transportation. Managing logistics is thus part of managing a supply chain (Elmhurst University, 2020). Or as (Stadtler, 2015) explains, logistics is one of the building blocks creating integration and coordination within a supply chain, thus also enabling high customer service and supply chain management competitiveness.

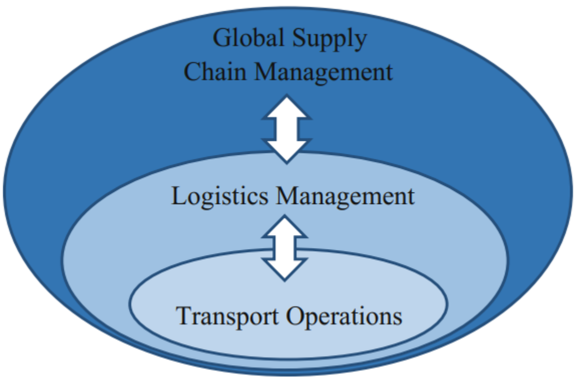

Figure 2.1: Hierarchy of transport, logistics, and supply chain management.
Note. Sourced from Zijm et al. (2019).

2.1.1 Supply Chain Management

Supply chain management can be defined as all activities needed for a value chain to convert raw materials into products and distribute these to customers (Zijm et al., 2019; Elmhurst University, 2020). An established model for supply chain management is the SCOR model (Poluha, 2007; Zijm et al., 2019), which can be viewed in Figure 2.2 below. In recent years, supply chain theory has developed to also include return flows from the end-user back to the upper-value chain, enabling circularity and sustainable supply chains (Zijm et al., 2019). The main focus of supply chain management is to plan and manage all operations that link different actors and resources throughout the value chain. Supply chain management is not limited to one company; instead, it links several individual companies to create an efficient supply chain that benefits everyone (Stadtler, 2015). This means that coordination and collaboration are important aspects of supply chain management, as highlighted by Lambert and Cooper (2000), who describes how individual firms' profitability is a result of competition between supply chains rather than between individual firms.

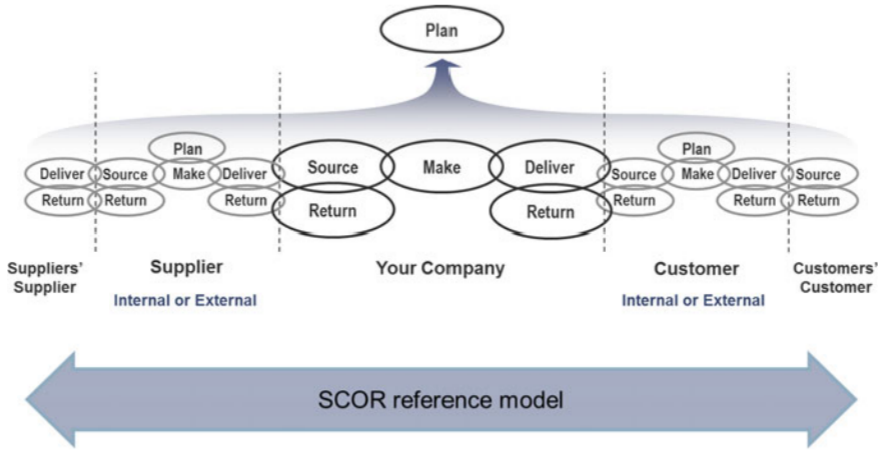

Figure 2.2: The SCOR-model.
Note. As described by Zijm et al. (2019) and Poluha (2007).

2.1.2 Transport Operations

Logistics and transport have been shown to be strongly interrelated with transport of materials being one of the major activities within logistics (Kasilingam, 1998; Tseng et al., 2005). Tseng et al.'s research looks further into the impact of transport operations on logistics and their relationship (Tseng et al., 2005). Their findings reveal that improving the efficiency of related transport operations is crucial for increasing the overall performance of a logistics system. This is because, among all activities within logistics, transportation accounts for some of the highest costs. To design a robust and successful logistics strategy, transportation must be integrated with the rest of the logistics processes.

2.1.3 Inbound Logistics

Inbound logistics is a critical process for manufacturing companies. It involves securing parts and components from suppliers and delivering them to the manufacturing site (Minner, 2019). Inbound logistics comprises a range of actors, activities, and resources that connect everything from order placement to the point of use. In general, inbound logistics can be classified into two types of material flows; external transportation to the factory and internal transportation and storage within the factory (Knoll et al., 2016).

For external transportation, transportation cost is a key performance indicator that needs to be closely monitored (Minner, 2019). The cost of transporting goods between two locations includes driver wages, fuel, and maintenance, and it remains relatively constant regardless of whether the vehicle is full or empty (Hall, 1987). Thus, to optimize cost per item, the more goods that can be transported in a single vehicle, the better. However, external transportation is also linked to other internal transportation performance indicators, such as handling cost, inventory cost, and service level agreements (Minner, 2019). These factors can influence the characteristics of external transportation. For instance, if an item requires frequent replenishment and is not stocked in large quantities, it may lead to more frequent less-than-truckload (LTL) deliveries. Conversely, if an item is kept in stock in larger quantities, it would result in less frequent deliveries, and full truckload (FTL) deliveries instead.

The EOQ formula is a common tool used to connect external and internal flows (Hall, 1987). Furthermore, it helps to calculate the ideal order quantity and the number of deliveries per year. The formula uses the annual demand for the product, the fixed cost of order placement (including shipping and handling), the cost of warehousing, and tied up inventory capital. By using the EOQ formula, companies can determine their optimal order frequency and level from an economic point of view.

2.1.4 Logistics Collaboration

Bergqvist and Monios (2016) highlights how changes in distribution strategy affect the supply chain collaboration balance, and create a need for reconfiguration of the supply chain. This applies to a narrower logistics perspective as well, changes such as new hub locations and implementation of consolidated freight require synchronization of affected actors in the logistics network (Simatupang and Sridharan, 2002; Bergqvist and Monios, 2016). Thus, an important aspect to keep in mind while discussing future route optimization and consolidation is how to enable well-functioning logistics collaborations and relationships. Furthermore, the ever-growing demand for efficiency, by reducing both time and cost, mixed with the growing flexibility requirements makes collaboration between actors in the supply chain vital (Bergqvist and Monios, 2016).

Logistics collaboration is often divided into two types, either vertical or horizontal (Ferrell et al., 2020). Vertical collaboration is explained to include actors upstream and downstream in the value chain. An example of a vertical collaboration is a manufacturer sharing responsibilities and activities with its distributors, carriers, and retailers, to achieve a common goal (Ferrell et al., 2020; Simatupang and Sridharan, 2002). Horizontal collaboration instead includes parallel actors at the same level of the value chain (Ferrell et al., 2020). Here several competing suppliers could work together sharing for instance information, carriers, and distributions centers (Simatupang and Sridharan, 2002). In literature, studies on horizontal collaboration often focus on freight consolidation, where collaboration between competitive actors can enable consolidated freight solutions and increased transport utilization (Ferrell et al., 2020; Vargas et al., 2018). The general goal of horizontal- and vertical collaboration is although argued similar for both, to make logistics more effective and to reduce operations cost. Studies show how logistics collaboration provides opportunities for cost reduction. For instance, Ferrell et al. (2020) provides a list of case studies that have done research in the areas of horizontal-, and vertical collaboration, as well as a combination of them both. Moreover, Gadde and Snehota (2000) discusses the effects vertical collaboration can have on economic costs and revenue, depending on the degree of relationship a buying firm has with its suppliers. However, the researchers also explain the complexity of understanding which relationship and collaboration affect which changes in costs. Furthermore, potential paradoxes of collaboration are arguably essential to highlight as well. On one hand, information sharing within a supply chain- or logistics network has efficiency benefits; raising utilization, enabling consolidation, and reducing costs (Ferrell et al., 2020). On the other hand, tighter relationships might also restrict a firm's ability to change, and increase a company's dependability on other specific partners (Gadde and Snehota, 2000).

One case example of horizontal collaboration is the one between Nestle and United Biscuit (Vargas et al., 2018), where the two competitors recognized they had empty trucks running in opposite directions. By collaborating, one actor's return flow became the other one's distribution flow. Their horizontal collaboration enables a better balance of transportation flow, whose imbalance otherwise is another reason for not fully utilized trucks (Vargas et al., 2018).

2.1.5 Manufacturing Sector

The manufacturing sector is widely affected by the economic state of the surrounding world (Jonsson et al., 2015). When the economy booms, people have more money to spend, driving the demand for products up and consequently manufacturing firm's production. Similarly, recession instead drives the demand down, hurting the production in manufacturing firms. The average profit margin for manufacturing firms in Sweden was just above 5% in 2018, when the economy was in a boom (Företagarna, 2018). However, since then the Covid-19 pandemic and geopolitical tensions have affected the economy, and it has been sent into recession (Swedish Ministry of Finance, 2022). The global situation has been explained to affect the manufacturing industry, both in lessened demand and longer lead times due to component shortages. Thus, leading to the profit margin for manufacturing companies dropping slightly.

Within the manufacturing environment, the industry often differentiates between having a make-to-order (MTO) manufacturing policy, and a make-to-stock (MTS) policy (Lenny Koh and Simpson, 2005; Günalay, 2011). Furthermore, a mixed-mode (MM) is explained as an environment combining the two policies in a sort of hybrid policy (Günalay, 2011). A firm in an MTO environment either produces or assembles products after customers place an order. In an MTS environment, products are instead produced to stock (Lenny Koh and Simpson, 2005). Historically, an MTS policy has been used to a large extent in the manufacturing sector to achieve economies of scale. But with an increasing demand uncertainty, it has become more common to use an MTO policy instead. This so a higher flexibility of demand response could be achieved (Günalay, 2011). With higher response flexibility, demand uncertainty has less impact on inventory costs. An otherwise MTS environment could lead to more inventory than planned to pile up with increased demand uncertainty, increasing the total cost of production (Günalay, 2011). So, by using an MTO policy, companies can plan for less inventory and storage, lowering logistics costs.

2.2 Inbound Flow Optimization

Optimization of inbound logistics flows is a complex process that could lead to large benefits both in cost and carbon emissions if executed correctly (Baller et al., 2022). In the past, most research regarding inbound optimization has focused on the economical benefits it initially can bring in terms of lowered transportation cost, and eventually also in terms of the total purchase cost per unit (Buffa, 1986). However, more recently the focus arguably lies as much on the environmental benefits, to reduce and optimize any overflow of inbound transport, and decrease fuel and energy usage (Merrick and Bookbinder, 2010; Oumer et al., 2015; Baller et al., 2022). The optimization is explained to require both coordination and consideration of a wide range of constraints of external factors such as delivery frequency, volume of delivery, and transportation mode (Baller et al., 2022). Internal factors such as goods entry, order quantities, and storage space are essential to contemplate as well. Companies often perform the optimization manually, either based on experience, or by the use of decision trees (Baller et al., 2022).

2.2.1 Shipment Consolidation Policies

Inbound Shipment consolidation (SCL) can be defined as an optimization of inbound flows. SCL combines two or more shipments or orders from the same geographical area to be transported in the same vessel. Thus, providing an environmental responsive logistics strategy (Ülkü, 2012).

Generally, researchers within inbound SCL divide the strategy into three overall policies (Buffa, 1986; Ülkü, 2012; Merrick and Bookbinder, 2010). One policy is for the buyer to increase order sizes from each suitable supplier or vendor to aggregate previous small orders and obtain a full truckload (Buffa, 1986). Another option is to keep order sizes but consolidate freight from several suppliers instead, where geographically close suppliers are decided to be jointly consolidated to achieve a substantial freight volume. A third policy is explained as a combination of SCL via both increased order sizes and freight (Buffa, 1986). In cases where solely an order size policy is implemented, cost savings can be achieved within shipping, in-transit holding, ordering, and purchase. When implementing consolidation with several products and suppliers, savings can be achieved also here in shipping and purchase costs. However, an increase in cost can arise due to increased handling- and ordering complexity, and increased transit time (Buffa, 1986).

Merrick and Bookbinder (2010) investigate and establish how shipment consolidation affects the logistic cost and pollution emissions by studying holding time, order arrival rate, kilometers traveled per vehicle, speed of travel, and value of CO2 emissions. Their developed simulation model illustrates how the length of holding time and size of order-arrival rates affect which policy they find best suited for shipment release and planning. For short holding times before order dispatch, the describe a so-called quantity policy for consolidating order sizes to be optimal, but for long holding times combined with low order arrival rates, a time policy relating to a max time before orders should be released was preferred instead. The model also provides a conflicting area for some cases, where it is not entirely certain which policy is the optimal one to use for the lowest emissions and cost possible. For high-order arrival rates combined with either medium long- or long holding times, Merrick and Bookbinder (2010) describe how additional aspects such as distance length, travel speed, and unit cost of emissions were decisive for concluding the most suitable consolidation strategy.

Oumer et al. (2015) conducted a study on a producing automotive company, presenting a case where some inbound shipments were difficult to consolidate due to the high variation of products, parts, and suppliers from different origins. An overall SCL strategy proved to reduce carbon emissions and fuel cost by reducing the total number of freight vehicles per month. Thus, the case gave examples of how at least a part of a company's inbound logistics with potential for consolidation could reduce logistics' overall economical and environmental costs.

Conclusively, Buffa (1986) describe how identifying SCL opportunities is merely a first step of the cost-saving process within a firm's inbound logistics. To achieve a further economical reduction, surrounding activities such as those within internal inventory and storage policies are explained to also affect and to be affected by SCL. As a following step therefore, inventory cost must be compared to transport cost to understand if any total logistic cost can be lowered with consolidated shipments. Furthermore, there can always be firm-specific parameters to take into consideration (Merrick and Bookbinder, 2010), making each flow optimization policy unique. Buffa (1986) emphasize how several decisions need to be made by the purchaser in question if they were to consider consolidating inbound deliveries. In particular, decisions regarding whether order size could be changed, which suppliers should be included in the consolidation, and in what regional areas consolidated freight could take place (Buffa, 1986). Additionally, no matter the characteristics of the specific inbound flow, the choices are recommended to be made in relation and consideration to each other.

2.2.2 Freight Consolidation Delivery Systems

The freight consolidation policy can be further divided into subcategories and definitions. Literature and studies in the area describe freight consolidation to be achieved in different ways but generally with similar outcomes (Buffa, 1986; Meyer and Amberg, 2018; Minner, 2019). Overall, what distinguishes direct deliveries from some kind of consolidated ones partly lies in the word direct. A direct delivery is transport from one source, or supplier, directly to the customer (Minner, 2019; Oumer et al., 2015). For instance, one manufacturing facility or warehouse. Meyer and Amberg (2018) defines this concept of direct delivery without any additional coordination as a point-to-point (P2P) transport. On the other end, when the delivery is coordinated between several collection points, the transport is in one or another way consolidated. Hosseini et al. (2014), categorizes different freight consolidation strategies into three established concepts. They explain how the consolidation is implemented either by using a cross-docking network, by establishing a milk-run system, or by having a so-called tailored network.

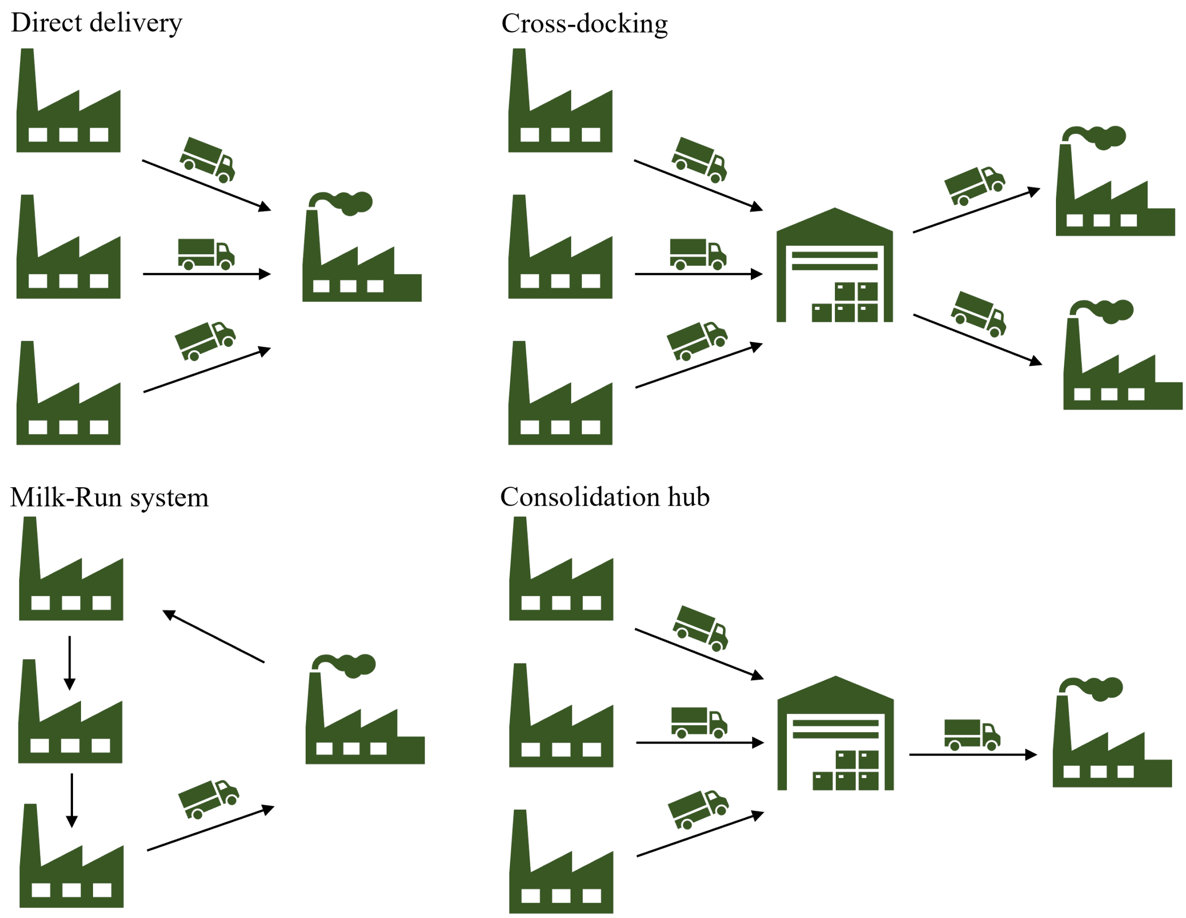

Figure 2.3: Various types of delivery systems.
Note. Inspired by Minner (2019).

For starters, a common concept of a freight consolidation is by using a consolidation point as Minner (2019) illustrate, in other words cross-docking as described by Hosseini et al. (2014). Suppliers with LTL deliveries instead delivers to a consolidation- or cross-docking point geographically closer to them. There, collected deliveries from several suppliers can be jointly delivered to the customer, thus increasing the total transport utilization (Minner, 2019; Buffa, 1986; Hosseini et al., 2014). Generally, the shipments from the suppliers to the hub are described to be made by smaller trucks, whereas the joint delivery is carried out with a larger truck. This type of consolidation is similar to an area forwarding (AF) service (Meyer and Amberg, 2018). In AF a manufacturer demand their orders to be delivered to a collection point belonging to a logistics service provider, who then is responsible for final delivery to the manufacturing site (Meyer and Amberg, 2018). The concept often suits JIT (Just-in-Time) and MTO manufacturing environments (Hosseini et al., 2014). It provides benefits including reduced inventory and products handling activities, improved customer service and speed of products flow, as well as decreased cost for the purchasers due to elimination of storage activities (Hosseini et al., 2014; Higginson and Bookbinder, 2005). A disadvantage with AF can be the complexity and coordination necessary to create an efficient cross-docking consolidation network (Higginson and Bookbinder, 2005). Furthermore, a cross-docking system requires the buyer to establish an accurate flow of information between the actors involved.

Another form of consolidated delivery is the use of a milk-run (MR) system. The MR system involves coordinating several geographically close pick-ups with low delivery volume or frequency. In comparison to cross-docking, an MR delivery system is made entirely without any individual supplier shipments (Minner, 2019). Instead, the collections are consolidated with a joint vehicle, in a pre-decided route going either from suppliers to a consolidation point, or directly to the delivery destination without involving a hub or the need to handle the goods in between (Minner, 2019; Hosseini et al., 2014). An MR system can be decided either to include several suppliers in the same route or be used as a systematic round trip between consolidation points or storage facilities (Minner, 2019). The typical milk-run system consists of a fixed schedule between the suppliers and the delivery site, where the route is either a closed round-trip from collection points to the site or an open tour where a carrier can collect return freight from external customers on the way back (Meyer and Amberg, 2018). The potential for cost saving lies with the reduced number of trips done with LTL vehicles, but also reduced inventory costs (Higginson and Bookbinder, 2005). Moreover, an MR often suits JIT manufacturing systems as well. Depending on the inbound delivery characteristics, the MR system's additional advantages can vary in form and strength. If many external actors and pick-up destinations are involved in the decided route, the MR might lead to a vehicle routing problem (Minner, 2019). The concept is thus explained to enable difficulties in coordination and loading operations in cases of multiple suppliers. Some of the mentioned types of delivery systems are visualized in Figure 2.3.

However, if not too multi-dimension and complex, the repeatability and systematic scheduling of freight vehicles, typical characteristics of a milk-run system, can in some cases produce certain advantages. Schöneberg et al. (2013) provides an example of how planned delivery schedules can facilitate efficient material requirement planning and strengthen supply chain collaboration while still enabling cost reduction due to increased effectiveness. Scheduled milk-run routes Meyer and Amberg (2018) can thus bring stability to delivery planning and transport cost efficiency. However, this is dependent on the reliability of the material requirements to act as expected for a planned period of time. Schöneberg et al. (2013) address how unplanned demand changes might upset delivery schedules and thus supplier cooperation as well.

The third strategy described by Hosseini et al. (2014) as a tailored network, is a concept suitable when there is a combination of FTL and LTL volumes ordered from suppliers of a buying firm. When the network does not exist only of direct deliveries or consolidated ones in any form, but combines them depending on order characteristics. This combination can in turn provide additional cost savings (Ülkü, 2012). Also Minner (2019) describe how the variety and complexity of supply networks seldom acquire solely one type of consolidation strategy, but rather a hybrid form where advantages from the different concepts can be combined, and the disadvantages reduced.

As the different types of delivery systems for freight consolidation now has been presented, one can reflect upon the differences in how the systems create consolidation activities, and to what degree. As described, a consolidation hub (Hosseini et al., 2014; Minner, 2019), an AF service (Meyer and Amberg, 2018), as well as a cross-docking system (Hosseini et al., 2014), all combine shipment at one point before final delivery to consolidate the freight towards the final customers or production facilities. Additionally, a cross-docking system might result in more than one truck per incoming shipment going out from the cross-docking point as well, as they are to be delivered to different end-customer (Hosseini et al., 2014). Nevertheless, neither of them is described as a system achieving a complete degree of consolidation. The deliveries to the cross-docking- or consolidation hubs are presented as often smaller and can arguably be compared to smaller direct deliveries to that point. Thus, the total number of vehicles used to ship a component from the initial-pick up address to the end customer is multiple, even once the freight is partly consolidated. Conversely, for an MR system, the delivery is explained to solely involve one vehicle for the entire delivery (Meyer and Amberg, 2018). One could therefore argue it achieved an even higher optimization rate, and therefore a complete degree of consolidation as well.

To address what suppliers and deliveries to consolidate, Minner (2019) initially recommends making a segmentation based on an ABC analysis, classifying the A-category as those to fulfill weight and volume requirements of direct deliveries, the B-category as those LTL to be consolidate in any form, and the C-category for small shipments to be grouped through third party carriers.

2.3 Road Freight Characteristics

In transportation, trucks are limited by either size or weight (McKinnon and Edwards, 2010). If an item takes up a lot of space but has relatively light weight, it may not fully utilize the weight capacity of the truck. Conversely, if an item is heavy but takes up less volume, the transport provider may be unable to use the extra space due to weight restrictions. In both cases the truck is full, just limited by different dimensions. To solve this problem, volumetric weight is used in transportation to estimate the amount of space being utilized in the truck (Wang et al., 2022).

Volumetric weight is calculated by multiplying the volume of the goods with a standard weight. There are three common ways to calculate volumetric weight in Sweden: by dimension (cubic meter), pallet (EU-pallet), or load meter (1 meter of the truck's length for non-stackable goods) (Delego, 2019; ColliCare, 2023). Each volume corresponds to a standard weight equivalent. A package taking up one cubic meter is equivalent to 280 kg of volumetric weight, while an EU pallet is equivalent to 780 kg of volumetric weight (Delego, 2019; ColliCare, 2023). One load meter of non-stackable goods is calculated by multiplying the length and width of the goods and dividing the product by 2.4 (the width of the truck). The result is then multiplied by 1950 kg to obtain the volumetric weight. If the actual weight of the goods is higher than the calculated weight, the actual weight is used as the volumetric weight.

In Sweden, the maximum length of a truck allowed on commercial roads is 25.25 meters (Vierth et al., 2008). The most common truck is explained to be a truck and trailer with a length of 24 meters, providing a total load volume of 7.2 load meters for the truck and 12 load meters for the trailer. A truck and trailer of this size could be loaded with 42 EU pallets or roughly 36 tons of volumetric weight (Delego, 2019). However, since many other EU countries have stricter limits on truck length, Delego (2019) explains that shorter trailers of 13.6 load meters are becoming more common in Sweden. A truck of this smaller size could thus be loaded with 33 EU pallets and have a maximum volumetric weight of roughly 24 tons.

2.3.1 Environmental Impact of Road Freight

Transportation is considered the greatest environmental impact of logistics systems (Ülkü, 2012). Transportation account for 20% of global CO2 emissions, and road freight is one of the major contributors in this sector (Albuquerque et al., 2020). The combustion process from trucks also produces other greenhouse gases such as NOx and CH4, which also contributes to the global warming effect (Quiros et al., 2017; Albuquerque et al., 2020). CO2 is although the major gas emitted from trucks and account for 60% of greenhouse gas emissions (Albuquerque et al., 2020). The other gasses are thus often quantified in terms of CO2-equivalent to make comparison easier. As demand for transportation remains high, it is essential to optimize the current system and develop future solutions in an effort to fight climate change.

According to McKinnon (2007), truck utilization is an important part in calculating the CO2 emissions from road freight transportation. A truck running full will have much lower emissions per transported unit of goods than a truck running empty. Therefore, it should be emphasized that the greatest benefits for emission reduction are achieved when trucks are fully utilized. The utilization of vehicle capacity when measuring environmental impact is often based on either weight or volume (McKinnon, 2007). What should be considered especially when comparing different emission result is that the measurements might vary depending on what method for utilization rate is used. For example, in a case where utilization is based on weight. A truck that carries a heavier load and is half-full based on volume might be considered better than a truck carrying a lighter load that fully utilizes the truck's volume. A common mistake researchers often make when using utilization in environmental analyses of road transportation is making assumptions about the utilization of capacity in the trucks (McKinnon, 2007). Wrongly estimating the actual utilization of capacity or comparing results with different utilization rates could lead to inaccurate results.

One solution for lowering the environmental impact of road transportation is to consider using high-capacity vehicles (HCVs). HCVs utilize an increment in the truck's maximum weight capacity, allowing them to carry more goods per truck and therefore reducing the environmental impact (McKinnon, 2005; Liimatainen et al., 2020). The benefits are mainly derived from the reduced transport distance in terms of fewer trucks being needed to transport the same amount of goods, thereby reducing greenhouse gas emissions per transported unit of goods. However, these large benefits are only present if the HCV's utilization rate is high enough. This raises the question of if using smaller trucks for transportation where the utilization limit is not reached, thereby increasing truck utilization, could be beneficial instead. In his article, Campbell (1995) examined the environmental impact of switching from larger trucks to smaller trucks in urban areas. While the study showed that utilization increased with a decrease in truck size, the environmental impact decreased only for the larger of the smaller trucks and increased for the smallest trucks (vans). This because more combustion engines were required to transport the same amount of goods. However, the study was limited to examining the environmental impact in urban areas, where the speed limits are generally lower and lots of starts and stops occur. There is uncertainty about whether this reduction in CO2 emissions applies when larger distances or constant speeds are used.

From his study, McKinnon (2005) presents that increasing weight limits for trucks shifts them being limited by size rather than weight as most goods transported have a lower density than what is needed to reach the weight limit. A solution to this is presented by McKinnon and Campbell (1997) where an opportunity to add a shelf in the middle of the trailer to fit and ”stack” more low-volume, non-stackable goods, thus increasing utilization and lowering emission from the truck. Another opportunity is presented in the case study by Muylaert and Stofferis (2014) where the two companies Procter & Gamble and Tupperware collaborated by shipping their heavy-, and respectively, light goods together, to increase the fill rate of the trucks. This resulted in a large decrease in CO2 emissions due to the truck utilization increasing.

From a sustainability perspective, traditional road transport can also be compared to options with potentially lower environmental impact, to understand what effects such transport mode could have on logistics carbon emissions and energy usage. For instance, intermodal transport is a concept aiming to take advantage of the strengths of each mode while simultaneously reducing the energy usage of freight (Altuntaş Vural et al., 2020). The characteristics of a product influence its suitability for intermodal transport, such as physical characteristics, value, order size, and lead time (Bergqvist and Monios, 2016). Moreover, intermodal transport requires significant collaboration among firms and stakeholders, which could increase the complexity of logistics operations (Bergqvist and Monios, 2016; Altuntaş Vural et al., 2020). Other options apart from traditional freight would be the usage of alternative fuels, e.g., using electric trucks for road transport is a concept currently being researched and discussed (Inkinen and Hämäläinen, 2020). Literature in the area provides different opinions regarding the sense of urgency for electrical transportation, due to the varied regulation for biofuels in the world and the emission reduction that often can be done by managing and optimizing traditional road transport (Inkinen and Hämäläinen, 2020). Furthermore, electrical vehicles are still expensive to buy, an aspect often needed to be considered as well.

3. Methodology

Below the approach for the master's thesis is presented. The chapter includes how the thesis was structured, what activities were performed, and what tools were used.

3.1 Research Design

The master's thesis was divided into five phases. The five phases consist of the following: the Planning & Scheduling phase, the Background & Frame of Reference phase, the As-Is Analysis & Empirical Findings phase, the Evaluation & Strategy Development phase, and finally the Discussion & Conclusion phase. As the master's thesis was conducted with a company, the continuous input from the company together with the initial topics and theory from the literature review in the Background & Scheduling phase served as a basis for the framework of research.

A research model was developed to illustrate the five phases of the master's thesis. The model supported the systematic combination from Dubois and Gadde (2002), and it is presented in Figure 3.1. There, an overview of the general work path from planning to final suggestion is illustrated and has been followed throughout the master's thesis.

Figure 3.1: The Research Model.
Note. The model is developed within this master's thesis and is illustrating an overview of the different stages of the thesis.

As presented in Figure 3.1, the Research model's path started with the Planning & Scheduling phase. It set the ground work for the entire work structure, and ensured that the work could be carried out withing the given time frame so that the research goal could be reached.

Following Background & Frame of Reference consisted of a literature review. At first a brief, more general literature review was conducted, which later was complemented with an extensive frame of reference. A gathering of background information on FläktGroup as a company and their expectations of the thesis was also a major part of this second phase. Additionally, the Research Questions was formulated here, as a result from the background- and literature review.

During the third phase, the As-Is Analysis & Empirical Findings, an initial focus lied on the analysis of FläktGroup's inbound logistics flow. Moreover, further and extensive data collection was conducted in the phase as well. Here, an additional and more detailed substructure within the Research model was composed for the processing of quantitative data, supporting the qualitative data gathering in the later phases of the master's thesis. This substructure was thus designed to help manage and organize the large amounts of raw data collected during the As-Is Analysis & Empirical Findings phase, and is further introduced in section *Data collection methods* below.

The Evaluation & Strategy Development phase could be further categorized into the analysis of the empirical findings from the past phase, using various analysis tools and models, followed by strategy- and route suggestions and calculations.

The fifth and final phase Discussion & Conclusion summarizes the work of the master's thesis, here an emphasis was laid on making sure all relevant perspectives are taken into consideration. The conclusion wrapped up the work and made sure the research question was answered in an as holistic and well-supported way possible.

As the master's thesis involved observing a company, a one-way process for the research design would have limited the depth, understanding, and potential advantages of conducting such a case study (Dubois and Gadde, 2002). Although the model is illustrated as a linear process, a note should be made that constant returns and reevaluations between the phases and stages was made. The research model's process took in this aspect inspiration from Dubois and Gadde (2002) and their described systematic combining approach. Such an approach enables a way of going back and forth between the different phases in a research process. Thus, the systematic combining approach for this thesis' research model accordingly broadened the understanding of both theory and empirical findings. As more observations were made, new theoretical knowledge was needed to support and fully understand the findings, and vice versa.

3.2 Literature Review

The frame of reference for the master's thesis was established through a comprehensive literature review. This allowed for a theoretical foundation for the topic and provided insight into previous research in the field. The primary sources of references were scientific articles, while books and statistical websites were used as complementary sources. The research databases of Chalmers Library and Google Scholar were utilized to gather relevant literature. In the literature review keywords and concepts related to each topic were searched for, including inbound logistics, optimization in logistics, consolidation in logistics, freight consolidation, logistics collaboration, and environmental impact of road transport. Emphasis was placed on including recently published articles to ensure that the research was up to date. As the work progressed, additional articles were reviewed to expand the frame of reference and deepen the understanding of core topics. Previously reviewed articles were also revisited and analyzed further as needed, as inspired by Dubois and Gadde (2002).

3.3 Data Collection Methods

The master's thesis collection of data had a combination of a quantitative- and qualitative approach. By gathering both types of data and linking them together, a more holistic perspective could be made of the findings, and an analysis richer in detail be achieved (Miles and Huberman, 1994). The initial quantitative data collection focused on the processing of retrieved raw data. This presented a partial result based only on numerical information on surrounding inbound logistics. The result served as a base for gathering in-depth qualitative data, where variously structured interviews and questionnaires were used as collection methods. Each partial result from both the quantitative and qualitative data collection were then combined to provide the final result and a summary of the empirical findings. A couple of further calculations were also added to complement the quantitative data, with consideration to information gathered from the qualitative one. The result from these include EOQ calculations, and weight calculations for some of the goods that are being delivered to FläktGroup.

The type of data to be collected can additionally be differentiated as either primary or secondary data. Primary data is the data gathered by the researchers for the purpose of the current research (Hox and Boeije, 2005). Moreover, it can be collected by various methods, depending on which are anticipated to suit the research best. For instance, typical primary data collection methods involve experiments, surveys, and various forms of interviews (Hox and Boeije, 2005). Further, secondary data is explained to be such already existing prior to the research. For instance, it could have been collected by previous researchers either for similar or completely other purposes. Secondary data can also be in the form of already existing internal reports and statistics, or external documents and reports publicly published. This master's thesis data was a combination of primary and secondary data, where the qualitative collection methods mainly gathered primary data, and the quantitative data collection is based on already established internal sales-, and transport statistics, thus secondary data.

3.3.1 Collection and Handling of Quantitative Data

In their article Galletta (2013), describes the importance of structured data collection. To facilitate this, a substructure to the research model for quantitative data processing was developed. The data processing consists of four different steps: the raw data collection, preparation of the data according to the thesis scope, the visualization of the data, and finally the filtration of the data. In Figure 3.2, the Quantitative Data Process can be viewed. The quantitative data process can be reused for other similar cases as well, thanks to the generic steps describing how to filter any raw data in the purpose of finding consolidation opportunities. This strengthens the replicability of the methodology and the master's thesis approach, enabling future research to use the process as well and reproduce the same findings from it.

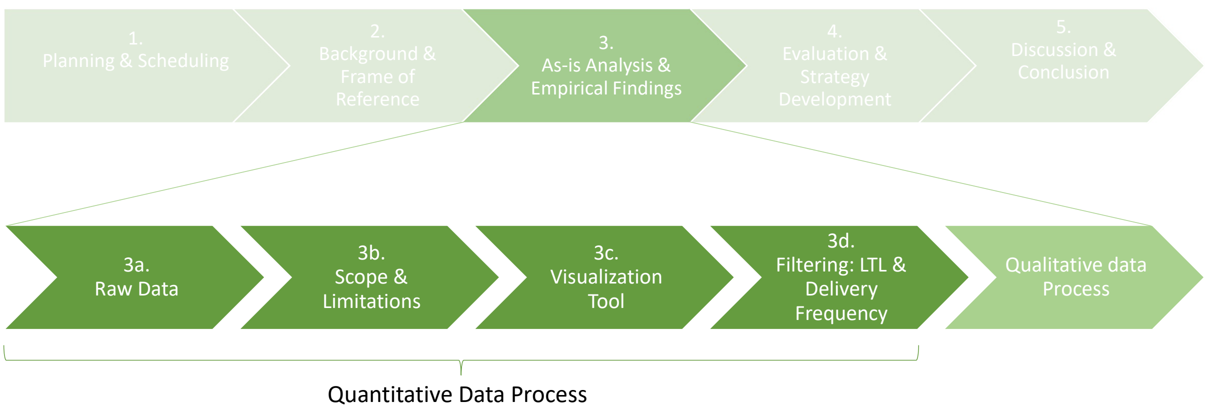

Figure 3.2: The steps of the Quantitative Data Process.

The Quantitative Data Process

3a. In the first step, raw data was collected and structured. Parameters such as pick-up- and delivery location, weight and size of orders, terms of delivery, supplier information, product type, cost of delivery, and the number of transports were collected from various raw data sources, combined, and structured.

3b. This step involves removing unnecessary data so that only data that is inside the scope of the master thesis is processed. All data rows containing outbound logistics or deliveries originating from outside Sweden were removed in this step.

3c. The third step, step 3c. involves visualizing the data. For this thesis, the Tableau (2021) data visualization tool was used. The tool offers a way to visualize location from address inputs on a map and makes the process of analyzing geographical locations easier than looking at the locations from a text file.

3d. The final step, step 3d. involved filtering the suppliers and pick-up locations incompatible for consolidation. In this case, the data is filtered according to truckload volume, where suppliers and pick-up locations delivering FTL were removed, as consolidation opportunities rather appear where low volume deliveries are present instead (Minner, 2019; Buffa, 1986). The requirements for defining a total freight's truckload depends on the truck's volumetric weight. To simplify the filtration process, the boundary between LTL and FTL was reasoned to be all freight with an average volumetric weight below half full, as the average utilization of trucks in Sweden is 55% (Eurostat, 2022*a*,*b*). Thus, all collections with orders less than half of the maximum volumetric weight were decided to be interpreted as LTL.

After completing step 3d., the partial result was formulated as a foundation for the qualitative data collection. By following the above described steps of the Quantitative Data Process, a first categorization was made, and a list providing all inbound deliveries with potential for further research on consolidation was established. Here, there is also room for further finer filtration if desired by any actor involved in the research, which gave an additional reason for the multi-dimensional approach of the data collection. Receiving qualitative inputs on the outcome from the quantitative processing resulted in that continuous iterations of step 3d. in the Qualitative Data Process could be performed.

3.3.2 Collection and Handling of Qualitative Data

The qualitative part of the data finding process included methods such as semi-structured interviews, group interviews, questionnaires, and weekly informal meetings with traits similar to focus groups. By combining several qualitative data collection methods, the validity of the findings is straightened. The major source of qualitative data was the semi-structured interviews, while the other methods served as complementary data gatherings, although equally important to form a complete view of the data to gather within the thesis scope and time limit. Furthermore, emphasis was placed on the importance of a systematic structure before, during, and after each data gathering occasion. Galletta (2013) highlight the importance of establishing a data analysis plan on how to organize the collected data. In this case, the literature review and quantitative data were the baseline for the qualitative data collection and continuously formed the path for the analysis as well. After collecting sufficient data, the established plan was systematically followed to identify patterns related to the research question, reflect on the findings, and connect them with the theoretical framework studied, drawing inspiration from Galletta's (2013) approach. References to all interviewees and their areas of responsibilities are presented in Table 3.1.

Semi-structured Interviews

Conducting semi-structured interviews is a commonly used method for qualitative research (Galletta, 2013). The method is explained to provide individual insights and reflections from each person being interviewed, whilst still keeping enough structure so it can be planned beforehand and ensure that the required information is obtained. One general questionnaire was developed as a foundation for each interview, but with alterations and added or removed questions depending on the role of each interviewee. The questions were sent out at least a couple of days before each interview, to enable the interviewee to reflect upon some potentially less straightforward questions or to investigate if she/he is missing some essential information. Moreover, while conducting the actual interview, guidelines on how to perform this as well as possible was followed, such as those who can be found in the work of Galletta (2013). There, the author explains how three phases of the interview should be performed, the opening segment, the middle, and the concluding segment of the semi-structured interview.

The two company representatives within the Purchasing and Strategic Sourcing department were decided early on to be included in semi-structured interviews. Additional representatives within Strategic Sourcing were also decided as suitable for interviews in order to map the inbound logistics and the strategy thereof. Within the department, there are different roles and responsibilities for each employee, connected to different commodity groups and supplier's. Therefore, who to interview depended on the findings from the quantitative data processing. The persons responsible for the products, components, and suppliers identified as valuable for further analysis for consolidation opportunities, would be the ones most relevant to conduct semi-structured interviews with.

Group Interview

Except for the relevant actors within Strategic Sourcing, other roles within the company have additional, often hands-on, knowledge of purchasing and inbound logistics operations. Those working with day-to-day order placement and coordinating inbound logistics would carry valuable information which could influence and complete an evaluation of transport optimization opportunities. In the company, these roles were within the so-called Vendor Planning department. Their knowledge regarding product- and freight characteristics from relevant suppliers, among others, were thus information searched for. Who to interview within Vendor Planning also depended on the findings from the quantitative data processing, and could not be completely decided beforehand. However, seeing as the questions to be asked to these were rather straightforward and did not need to be altered between each interviewee, a group interview was decided to be a sufficient data collection method. The group interview supported the semi-structured interviews and enabled a larger data collection within a shorter time. All relevant vendor planners were gathered, and each responded individually to questions asked about the suppliers and freight of their responsible commodity. The questions had been sent out to them at least two working days beforehand.

Weekly Meetings

Regarding the weekly meetings, they were designed as a form of regularly occurring focus groups, similar to those described by Carter and Henderson (2005). The meetings opened up more dialogue and interaction between the company stakeholders and the researchers, and strict questions were not planned beforehand or asked. Moreover, Carter and Henderson (2005) explain how in focus groups, the researchers still often take on a moderator role and provide the topics for the session. The weekly meetings often corresponded to those typical features, while still keeping a systematic structure to follow the organized set-up of the data handling work. They were always done together with the company stakeholders, who have been the closest contact within the company during the master's thesis work. These representatives have acted both as company supervisors and as sources of valuable qualitative information throughout the thesis. They have roles responsible for strategic sourcing and sustainability and are thus influenced by the purpose of the research. Moreover, their interests and request are partially affecting the outcome of the work.

Table 3.1: Reference to the Interviewees, their roles and the respectively interview collection methods.

Interviewee Reference	Designation of Interviewee	Interview Characteristics
I_1	Head of Purchasing, Strategic Sourcing	Presentation, semi-structured interview, meetings
I_2	Strategic Sourcing	Semi-structured interview, meetings, group interview
I_3	Strategic Sourcing	Semi-structured interview, follow up questionnaire
I_4	Strategic Sourcing	Semi-structured interview, follow up questionnaire
I_5	EHS-manager	Presentation, meetings
I_6	Vendor Planning	Group interview, follow up questionnaire
I_7	Vendor Planning	Group interview, follow up questionnaire
I_8	Vendor Planning	Group interview, follow up questionnaire
I_9	Vendor Planning	Group interview, follow up questionnaire
I_{10}	Key Account Manager (External 3PL)	Questionnaire

Questionnaire

Additionally, a questionnaire was sent out to an external actor, the current largest freight provider for FläktGroup in Sweden. It complemented the data findings from the internal sources and made sure a holistic picture was gathered during the quantitative data process. Gathering different views is essential when collecting data (Bell et al., 2016), motivating the search for the external perspective as well. Furthermore, the questionnaire was established also due to a recognized gap in the theoretical framework regarding practical knowledge from larger 3PL service providers and their strategies for daily operations, such as the freight services to and from their customer FläktGroup. Thus, the questionnaire and its findings from it was a supplementary source in the mapping of the inbound logistics and transport routing.

The primary data collection method additionally supported the various conducted interviews, were in some cases collected data from the interviews needed to be complemented. Then, follow-up questionnaires were developed with the purpose to clarify some previous answers.

3.4 Analysis

After collecting the quantitative and qualitative data, using company data and interviews, the findings were combined and summarized in order to perform an analysis. Systematically structuring all data that was collected were essential for initiating the analysis. The data were then processed using below described models and tools, followed by suggestions of potential routes for consolidation.

Since all activities and operations within a company's supply chain management is connected (Zijm et al., 2019; Stadtler, 2015), a tool was needed to determine what supply chain, and thus inbound logistics design the company should strive for from a holistic perspective. Therefore, the Fisher's model was chosen as an analytical tool, it is one of the mostly accepted models for analysing supply chain strategies for manufacturing companies (Selldin and Olhager, 2007). The Fisher's model focuses on evaluating overall supply chain based on finished products, thus outside the scope of the thesis and the choice of using the model could be questioned in terms of this thesis. However, as it enables a holistic guideline how to structure processes within a supply chain without disturbing the optimal design (Selldin and Olhager, 2007), it credits the usage of it in this thesis as well.

Transport optimization opportunities are reliant on complex constraints and factors within the inbound logistics network (Buffa, 1986; Baller et al., 2022). To achieve the economical and environmental benefits of inbound logistics without risking negative effects on a manufacturing flow, careful consideration of the current network could be made (Baller et al., 2022). Externally, supplier and their goods could be considered by creating a purchasing portfolio. A widely used model within purchasing is the Kraljic matrix (Pagell et al., 2010). Therefore in this thesis, a purchasing portfolio based on the Kraljic matrix was done during the analysis, as it gave an insight into the risk of the different components and suppliers, and enabled insight into what items could be easily consolidated without increasing any additional risks for the company. The purchasing portfolio analysis was entirely based on collected qualitative data that then was interpreted, which might pose a risk of confirmability for the analysis. However, as the purchasing portfolio was not the main basis for drawing conclusions, the combination of using several analytic tools strengthened the credibility of the master's thesis.

Finally, combining and connecting the empirical findings from the quantitative and qualitative data collection together with the analysis was required to enable identification of shipment consolidation opportunities. To enable this, a SWOT analysis was conducted as it is one of the most common tools used, especially in strategic analysis (Glaister and Falshaw, 1999).

3.4.1 Fisher's Model, Products and Supply Chain Design

The analysis was initiated by taking a larger perspective of the company and its supply chain. As Selldin and Olhager (2007) describe, manufacturing companies aiming towards increased performance should consider the supply chain design before striving to improve the processes within it (processes such as forecasting, information sharing, and logistics solutions). To be able to establish the optimal supply chain design, the company needs certain tools to match its products and demands to the fitting supply chain. One such tool developed is Fisher's model (Fisher, 1997), indicating that depending on demand- and market expectations, products can either be functional or innovative. The two product categories can from there be matched with either an efficient or a responsive supply chain (Fisher, 1997).

In further detail, investigating products by their life cycle length, product variety, demand predictability, lead time, and service, will according to Fisher's model establish if they are functional or innovative (Selldin and Olhager, 2007; Fisher, 1997). The basic requirements for either product characteristic are illustrated in Figure 3.3. A functional product accordingly has features such as long life cycles, low margins, steady demand patterns, and low product variety (Fisher, 1997). Thus, a supply chain design should strive for increased resource utilization and cost minimization, i.e., a physically efficient supply chain. On the other hand, a product is established as innovative if it, for instance, has a more unpredictable demand pattern, shorter life cycles, shorter lead time, and a very high product variety per category. Here, Selldin and Olhager (2007) explain how Fisher's model suggests striving for a market-responsive supply chain instead, to increase flexibility, capacity, and information processing. The matching of product and supply chain is demonstrated in Figure 3.5.

There exists developed adaptations on Fisher's model that were relevant to consider as well, those adjusting the model slightly depending on other characteristics of the firm. Because, as Selldin and Olhager (2007) concluded by testing Fisher's model on various firms, not all companies with categorized functional products necessarily have, or strive for, an efficient supply chain as recommended by Fisher. Although the majority of the companies with the Fisher-recommended product-supply chain match proved a higher performance in demand speed, demand durability, and cost, there was no significant difference in quality for the companies having a mismatched supply chain. Furthermore, manufacturing companies were also discussed as being more limited to change in their supply chain, seeing as they more often might experience limitations in resources needed to establish the absolute perfect supply chain. Therefore, an adaptation to Fisher's model enabled an establishment of a more adapted match in the case of a less standard result. For instance, the adaptation from Lee (2002) suggests four different supply chain designs instead of two, depending on demand- and supply uncertainty. For either functional- or innovative products in a stable process with low demand uncertainty, the matching supply chains recommended follows Fisher's model, i.e., efficient- respectively responsive. However, in cases of high supply uncertainty and an evolving process, Lee (2002) rather recommends a so-called risk-hedging supply chain for functional products and an agile supply chain for innovative ones.

The analysis recognized an adaption such as Lee's (2002) and took the author's findings into consideration along with the original Fisher model (Fisher, 1997) as well. By using the list of product characteristics illustrated in Figure 3.3 in combination with those from Lee (2002) in Figure 3.4, both a qualitative data collection strategy and further analysis process and a matching with Figure 3.5 and 3.6 could be developed. Thus, before the analysis, the interview questions were formulated and followed, providing qualitative data findings in the area. Here, the work of Selldin and Olhager (2007) was of great influence, their interpretation of Fisher's model and questionnaire to manufacturing companies supported the conduction of this master's related data collection. Just like Selldin and Olhager (2007), the stock-out rate was interpreted as a late delivery rate instead due to the company in question being a manufacturer. Moreover, the analysis of the answers then established whether FläktGroup possesses functional or innovative finished products and whether they have a high (evolving process) or low (stable process) demand uncertainty.

Functional versus innovative products: differences in demand

	Functional (Predictable demand)	Innovative (Unpredictable demand)
Aspects of demand		
Product life cycle	more than 2 years	3 months to 1 year
Contribution margin*	5% to 20%	20% to 60%
Product variety	low (10 to 20 variants per category)	high (often millions of variants per category)
Average margin of error in the forecast at the time production is committed	10%	40% to 100%
Average stockout rate	1% to 2%	10% to 40%
Average forced end-of-season markdown as percentage of full price	0%	10% to 25%
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

* The contribution margin equals price minus variable cost divided by price and is expressed as a percentage.

Figure 3.3: Characteristics of functional and innovative products.
Note. Sourced from Selldin and Olhager (2007).

Stable	Evolving
Less breakdowns	Vulnerable to breakdowns
Stable and higher yields	Variable and lower yields
Less quality problems	Potential quality problems
More supply sources	Limited supply sources
Reliable suppliers	Unreliable suppliers
Less process changes	More process changes
Less capacity constraint	Potential capacity constrained
Easier to changeover	Difficult to changeover
Flexible	Inflexible
Dependable lead time	Variable lead time

Figure 3.4: Supply demand uncertainty characteristics.
Note. Sourced from Lee (2002).

While this master's thesis aim was not to conduct a deep study in or suggestion of the best fitting overall supply chain strategy for FläktGroup, an emphasis to be made again is that it was argued important still to get an overview and general idea of an appropriate supply chain design for the company. This avoided a recommendation of an inbound logistics solution that would entirely misfit the product-supply chain match.

Which logistic solution could fit what supply chain design was based on the presented literature (Fisher, 1997; Selldin and Olhager, 2007; Lee, 2002). Cost efficiency for supply chains with functional products and low demand uncertainty (efficient supply chains), can for example be achieved by improvements in productivity, or by efficient logistics systems, e.g., applying direct deliveries to reduce steps in the distribution process, thus eliminating some costs (Lee, 2002). In an evolving process with functional products, pooling inventory and multiple sourcing might be a performance-increasing strategy instead (Lee, 2002). Furthermore, for innovative products with a stable process (low uncertainty), a postponement strategy and modular design might be highly applicable (Fisher, 1997; Lee, 2002). Whereas in a high demand uncertainty (evolving process), Lee (2002) additionally emphasized the importance of fast information sharing within the supply chain, seeing as the challenges with this combination are particularly tough.

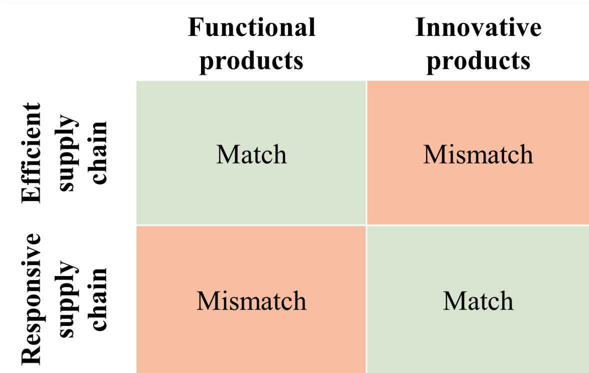

Figure 3.5: Fisher's supply chain matching for the product categories.
Note. Adapted from Fisher (1997).

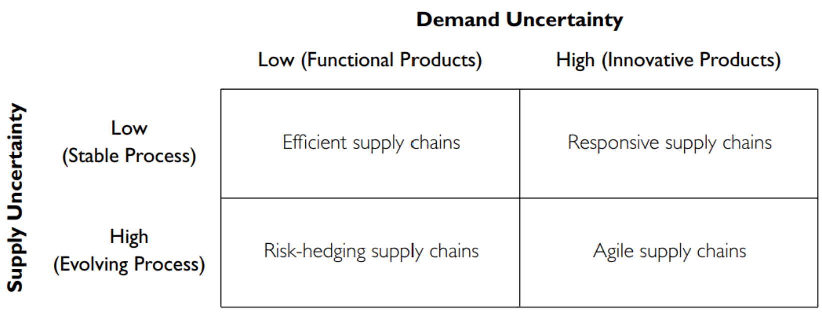

Figure 3.6: Lee's adapted Fisher model.
Note. Sourced from Lee (2002).

3.4.2 The Kraljic Matrix and Purchasing Portfolio

For the analysis of which segmented supplier items would be best suited for consolidation, the Kraljic matrix purchasing portfolio was used. The Kraljic matrix is a widely accepted purchasing portfolio in supply chain management research (Pagell et al., 2010). In his original article, Kraljic (1983) presents four different theories for how various purchasing strategies should be structured depending on the supplier- and item characteristics. In Figure 3.7 the purchasing portfolio, the Kraljic matrix, is illustrated. Here, the four quadrants represent the categories suppliers and their parts are placed in depending on the degree of risk and the profit impact they have on the company in question (Kraljic, 1983). Thus, classing them either as non-critical-, leverage-, strategic-, or bottleneck supply. The original work of Kraljic (1983) has since been revisited and reworked as organizations modernize (Hesping and Schiele, 2016). An example of this is the work of Caniels and Gelderman (2005), who presents a more modern approach where the influence of power and dependency between buyer and supplier is present.

Below describes how the basics from Kraljic's matrix were considered as a part of the analysis of FläktGroup's inbound logistics, supporting both the establishment of the purchasing portfolio and the following suggestions of consolidated routes.

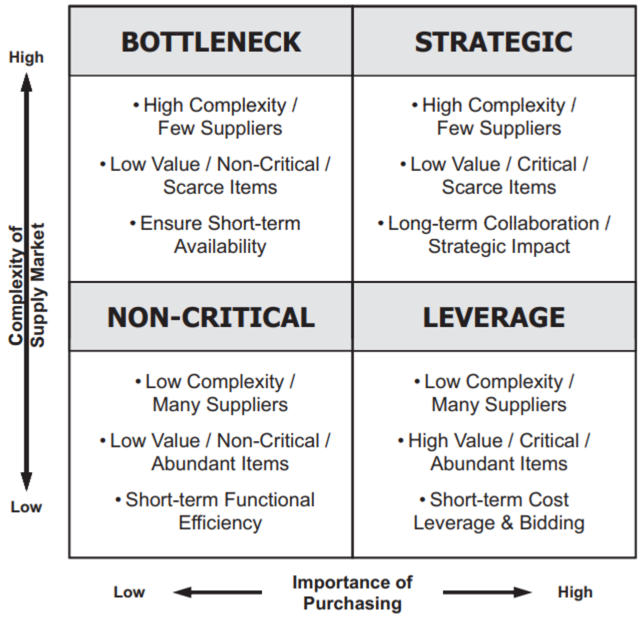

Figure 3.7: Purchasing portfolio.
Note. Sourced from Cox (2015), adapted from Kraljic (1983).

The suppliers and commodities with the highest potential for consolidation according to the empirical findings were each placed into one of the four quadrants depending on requirements as described by Kraljic (1983), to be viewed in Figure 3.7. Firstly, the focus was put on analyzing the risks within FläktGroup's strategic sourcing activities. For instance, suppliers who were single-sourced or those items where there were only a few supplier options, were classified as high sourcing risks. Furthermore, components that were multiply sourced, or had multiple suppliers available on the market, were instead classified as low risks. Secondly, analyzing the profit impact instead depended on how tailored the product was for FläktGroup. Components developed specifically for FläktGroup or requiring unique, expensive tools during assembly and production, were classified as having high-profit impacts. Standard components were instead classified as having a lower profit impact. By gathering information in the qualitative data collection- and interview phase with FläktGroup's employees in strategic sourcing and procurement, the categorizing of quadrant groups was thus supported. In this case, the different quadrants represent further route consolidation opportunities and tactics.

Conclusively, the purchasing portfolio supported the mapping and categorization of suppliers and their items to deliver. It enabled insight into whether route consolidation options would be affected by the constraint of not consolidating too many items of the same quadrant in one shipment. For instance, all deliveries categorized as bottlenecks or strategic items might not be viable to consolidate together as they will have a higher complexity in the supply market and might lead to stops in production if not delivered in time. Furthermore, for non-critical- and leverage items, where supply was more secure, the potential for consolidation with any other item was significantly better and enabled more route options to further recommend.

3.4.3 SWOT Analysis

The SWOT analysis is a useful tool for businesses to identify and analyze both internal and external characteristics within the company (Gürel and Tat, 2017). It involves answering four simple questions asking what the strengths, weaknesses, opportunities, and threats are of the analyzed subject. The SWOT analysis was used both to investigate what strengths and weaknesses the current inbound logistics system has, as well as to realize the opportunities and threats of the collected data.

By considering the analysis and categorizing made with the help of Fisher's model, the Kraljic matrix, freight and packaging findings and calculations, and transport characteristics data, the SWOT analysis supported the next step towards suggesting relevant routes for optimization and consolidation. For all categories to be analyzed with the SWOT method, each of its four questions was systematically asked and answered from the perspective of route consolidation opportunities and constraints, the objective for the analysis in this case. For instance, regarding applying the SWOT questions to the developed purchasing portfolio, the analysis provided reflections on what weaknesses bottleneck commodities might have if being consolidated together with parts delivered from suppliers considered as leverage, or other quadrant combinations. Furthermore, information on product- and freight characteristics were considered when answering the four questions of the SWOT analysis, as were the geographical location of suppliers with consolidation opportunities. Thus, the SWOT analysis helped form the answer to where the routes with the most strengths and opportunities lie, and what items should and should not be consolidated.

3.4.4 Suggesting Routes

The number of route planning methods and algorithms that are used within logistics optimization in the industry and within the academic world is large (Lovelace, 2021). They often uses advanced calculation formulas and highly developed software behind them. Since simulating routes and using route planning algorithms was beyond the thesis purpose and scope, partly due to time constraints and the absence of a proper routing software program, an arguably more basic method enabling rougher route suggestions was followed instead.

Initially the most optimal route options were identified, based both on the empirical findings, and the Kraljic-, Fisher- and SWOT analysis. Thus, the focus was on analysing the route consolidation possibilities provided by the quantitative research model with consideration of the qualitative findings and the established analyzing tools. All possible routes according to the determined relevant terms from the qualitative- and quantitative data processing, were calculated, mapped, and visualized. Here, the software from Google Maps were used to support a route visualization. The online navigation service Google Maps allowed an easily accessed geographical modelling of the routes between different stops, the travel times, and distances. Additional excel calculation of total average volumetric weight supported the determination of what route could be possible to plan or not. Routes considered possible for calculation was based on whether the total amount of distance would to decrease if implementing the route, followed by an assessment of whether the route was kept within time- and weight limitations of freight standards. Furthermore, information regarding packaging dimensions, packaging characteristics, and supplier compatibility and relations to inbound logistics, all gathered from the qualitative data, were also considered in order to find each potential route. Especially relevant were the freight packaging details, the understanding of whether the goods was packed in ways available for stacking. By having some of the packaging stacked on top of each other, more volume can be filled and the truck achieve a higher volumetric weight. By considering such characteristics as well, not only the external, geographical ability was the basis of the route suggestion, but the internal, physical product freight needs considered as well.

3.5 Calculation Formulas

The quantitative data findings were used as basis for calculations to support the analysis of the inbound logistic in, and transports to FläktGroup Jönköping. Some calculation formulas were used during the empirical findings, some are more advanced and require inputs developed during the analysis. Simple calculations such as average volumetric weight of deliveries from certain suppliers or pick-up addresses were argued rather straight forward and does not need to be further introduced or explained. However, less common calculations and formulas used are described below. The EOQ formula was used during the empirical findings, and the findings from it further analyzed. Environmental calculations on greenhouse gas emission were not done until a large part of the analysis had been established instead.

3.5.1 EOQ and Delivery Frequency

In order to analyse profitability of possible SCL policies, calculations were done using the EOQ formula. The EOQ formula is a very simple order quantity calculation that is used by a lot of both small and big companies (Cargal, 2003). The formula uses four parameters; demand per time unit, fixed order cost, cost of item, and cost of warehousing per item per time unit. These parameter give the optimal order quantity assuming constant order rate. By using the optimal order quantity, the optimal yearly amount of deliveries was calculated by dividing the annual demand with the calculated EOQ.

$$\textit{EOQ orders/year} = \frac{D}{\sqrt{\frac{2*C*D}{h}}} \tag{3.1}$$

Where:
D = Yearly demand
C = Fixed order cost
h = holding cost ($C_i * I$ where C_i = cost per item and I = warehousing cost)

3.5.2 Environmental Impact Calculations

The number of pollution emissions from freight was decided to be calculated using an easily accessible LCA tool, with distance and weight metrics from the route suggestions as inputs. Therefore, the tool NTMCalc 4.0 was selected to be used in the analysis, which is a software provided by NTM (2023) and based on models following the ISO14083 standard (ISO, 2023). The basic version of NTMCalc 4.0 was available online for free and provided a simplified way to estimate the environmental impact and potential future improvements of the studied road transports. A complete LCA analysis of the mapped incoming deliveries was beyond the scope and time frame of this master's thesis. Instead, the primary focus was to investigate whether the environmental impact of freight within FläktGroup's inbound logistics could be reduced by developing optimized routing strategies. By comparing the developed map of current inbound logistics with potential route options developed in the analysis, the emissions calculation supported the establishment of the final route suggestions. The route option with the largest reduction compared to the current transport solution was, from a pollution emission perspective, the route to prefer.

In more detail, the output retrieved from the software consisted of each transport route's amount of total carbon emissions, thus the amount of CO2 coming from biogas, and the amount coming from fossil fuel, as well as the amount of emitted methane gas, CH4, and the of nitrous oxide, N2O. A reduction of each of these greenhouse gases for a developed route option would lead to an overall reduction of environmental impact. Part of the software is illustrated in Figure 3.8.

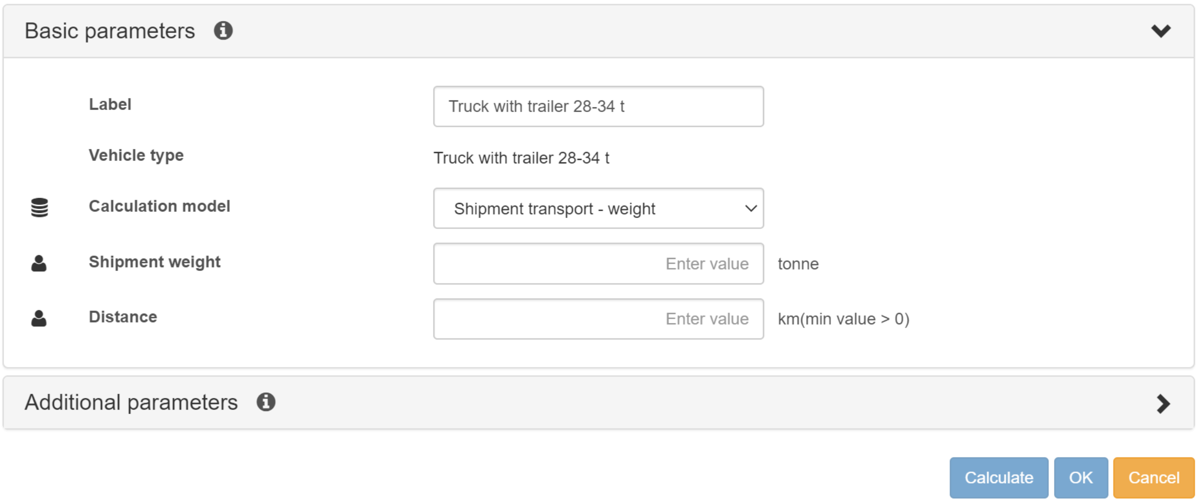

Figure 3.8: Illustration from NTMCalc 4.0 Basic, during input transport activity. *Note.* Sourced from NTM (2023).

To establish as correct output result possible, the inputs to use in the NTMCalc calculations had to also be as accurate and objective as possible. One of the inputs was the distance for each route and delivery. As consolidated route options were established earlier in the analysis, the total distance of several direct deliveries from some pick-up addresses differentiated to the distance a route option involving the same addresses would have. Thus, the difference in the distance input for each route calculation, leads to a difference in the emission output, and a comparison of environmental impact could be done thereof. The distances of the current direct deliveries and future potential route options were, before the environmental calculations, established using Google Maps.

Another input was the shipment weight, affected by the total weight (kg) of goods, in each freight. The total weight of the truck carrying and delivering goods would influence the amount of pollution emitted for each distance. For instance, one truck with a maximum total weight of around 28-34 tons, including max. shipment weight would produce fewer emissions shipping its full weight capacity compared to two equally large trucks shipping half their capacity each. This considering all traveling the same distance, and with the same type of fuel.

Seeing as part of this master's thesis objective is to understand the potential environmental effects of optimizing transport consolidation via route planning (*see RQ3*), both distance and weight are important parameters to consider. However, focusing on one parameter at a time will enable a deeper understanding of how each input affects the emission outputs. Therefore, the initial focus on the environmental impact of route consolidations was laid on the difference in distances. Thus, the weight of each transport and truck was set as constant for each route and comparison. Moreover, since the current freight solutions for FläktGroup were managed mainly by one 3PL providing actor, which to some extent utilizes FläktGroup's incoming freight by consolidating their goods with other external goods, the utilization rate of each transport in the current freight solutions was interpreted to be the national average rate 55% (Eurostat, 2022*a*,*b*). Such generalization of the rate was done for simplification reasons, but also because of a lack of external data on the 3PL service provider's own average utilization rate. The 55% utilization rate was then applied as an input in the calculations of the developed optimized route options as well.

Furthermore, to additionally compensate for the different delivery frequencies from each pick-up address, the distances from the collection points to FläktGroup Jönköping were calculated on a yearly basis, with each distance multiplied by the number of deliveries per year. For the consolidated route suggestions, their distances were set to be constant as that of the whole route, and the delivery frequency was set to that of the suppliers with the highest frequency of deliveries. This means that the emissions from the consolidated route suggestions are from a worst-case scenario perspective.

4. Empirical findings

The chapter presents the findings from the quantitative- and qualitative data collections. The first part is initialized with the processing of raw data by following the developed steps of the Quantitative Data Process. The result from the process is complemented with the findings from the qualitative interviews, followed by weight- and EOQ calculations, which eventually establish a holistic base for the analysis.

4.1 Current State of FläktGroup

Currently, FläktGroup has 450 suppliers located throughout Europe who deliver around 16,000 components to their manufacturing facility in Jönköping, Sweden. The production facility in Jönköping has a central inbound logistics location where each item passes through for registration before being assigned and transported to various storage locations. This internal location for storing parts and products before production is explained to have a low capacity, with limited inventory space and a low ability to expand.

Regarding the inbound freight, FläktGroup's suppliers are in most cases individually responsible for organizing their deliveries together with FläktGroup's contracted 3PL service provider. When an order is placed by FläktGroup, each supplier contacts the 3PL service provider and arranges for pickup individually. The transport provider is then responsible for the delivery to FläktGroup. No central coordination of all incoming deliveries is therefore in place at the moment of writing for FläktGroup, at least no more than what might be arranged internally by their major logistics provider. Furthermore, before this master's thesis, no mapping of the national deliveries to FläktGroup's inbound logistics operations in Jönköping has been made. Therefore, there have not been any advanced, in-depth attempts toward finding solutions for route optimization either.

4.2 Quantitative Data Findings

The following findings is structured according to the Quantitative Data Process established in the methodology section above. By collecting data following the first step of the data processing, each pick-up delivery location and postal number, name of the sender/receiver, average and median volumetric weight, and delivery frequency were extracted and combined from the various raw data sources that were provided by FläktGroup. Full description of the raw data files can be seen in appendix A. The combined file consisted of 33 459 data points. After the second step where outbound logistics, deliveries originating outside of Sweden and duplicate values were removed, 2 447 data points remained.

The remaining data points were visualized in the third step of the Quantitative Data Process, the numerical data is presented in Appendix B. The visual analysis platform Tableau (2021) was used and plotted each pick-up location. This visualization is demonstrated in the Figure 4.1.

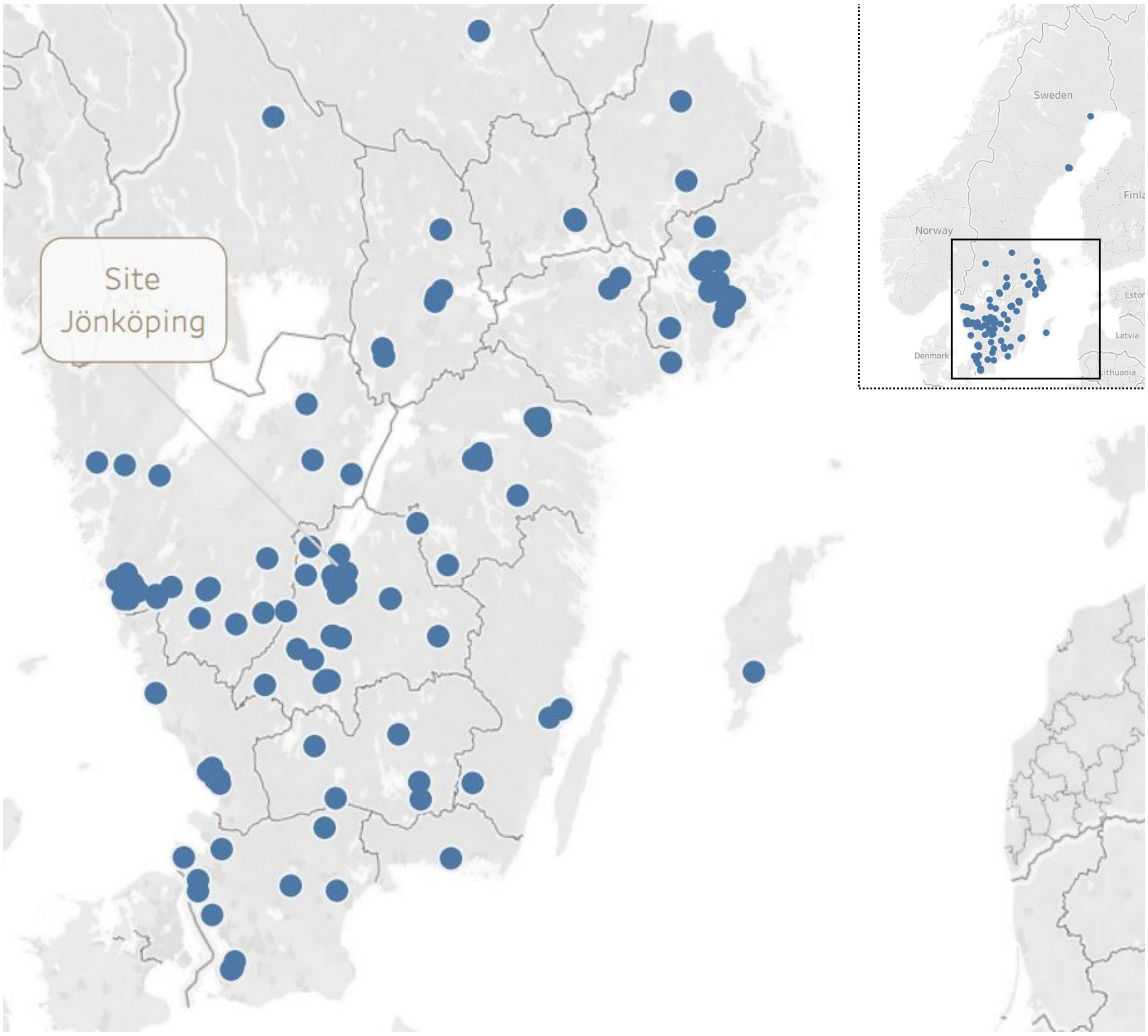

Figure 4.1: Locations of FläktGroup's Swedish Suppliers with deliveries to JKP.

A total of 136 different pick up locations were present all over Sweden with 97% being located in middle and southern Sweden. Using the Tableau software, further filtering were applied and visualized simultaneously. Each collection with freight interpreted as LTL was kept, and the rest withdrawn from further visualization and analysis. This resulted in a few suppliers and pick-up locations being filtered out, and the number of locations achieving the sorting requirements decreased to 131. In other words, 5 pick-up locations were removed in this part of the step.

The pick-up points left was sorted according to delivery frequency. The sorting was made visual with color-coded grouping, starting with red marks for those suppliers with a high frequency of orders being collected at least once a week or more, following with yellow marks for medium frequency orders being collected once a month to once a week, then green marks for low frequency order being collected semi-annually to less than once a week, and grey marks for one-time deliveries that were only collected once last year.

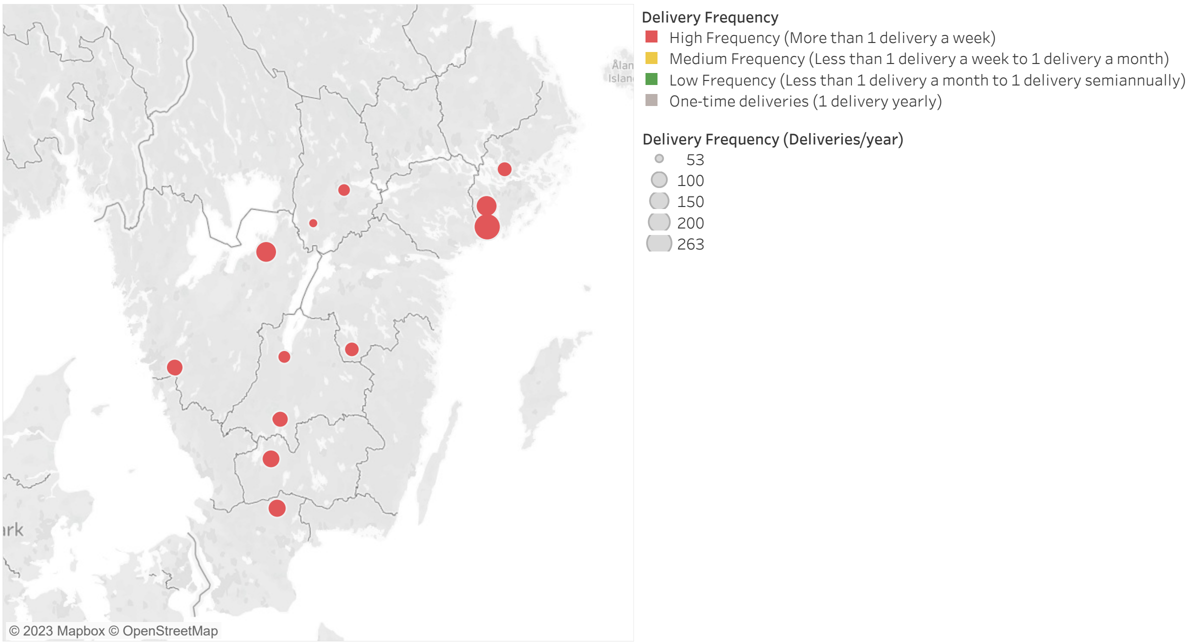

Figure 4.2: Locations of FläktGroup's High-Frequency deliveries.

FläktGroup have 14 high-frequency pick-up locations that delivers goods at least weekly. The high-frequency deliveries are located in four main areas in Sweden, north, east, south, and west of FläktGroup's production site in Jönköping. Two of these clusters, the east and west clusters, are located in major densely populated areas. The other two, the north and the south, are located close to major roads, which are demonstrated in Figure 4.6. Their geographical positions are presented in Figure 4.2.

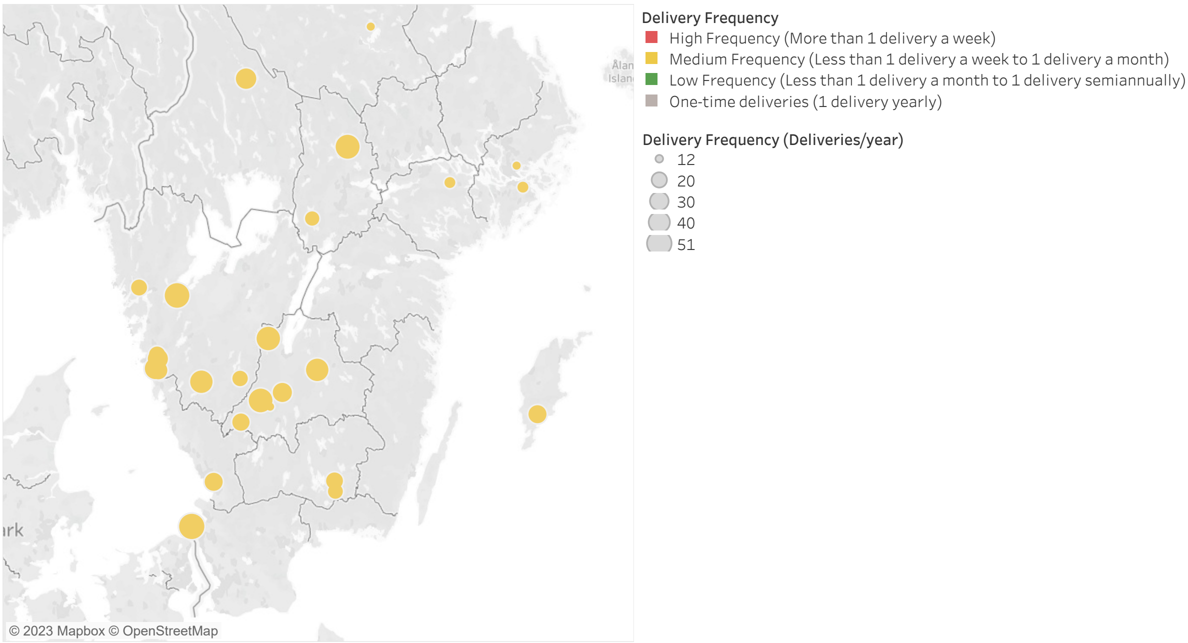

Figure 4.3: Locations of FläktGroup's Medium-Frequency deliveries.

There are 27 medium-frequency pick-up locations. The medium-frequency deliveries are almost entirely clustered in close proximity to the high-frequency deliveries, with most of them being in the south and west clusters in relation to Jönköping. Some medium-frequency deliveries are outliers and not close to any other pick-ups. Their geographical positions are presented in Figure 4.3.

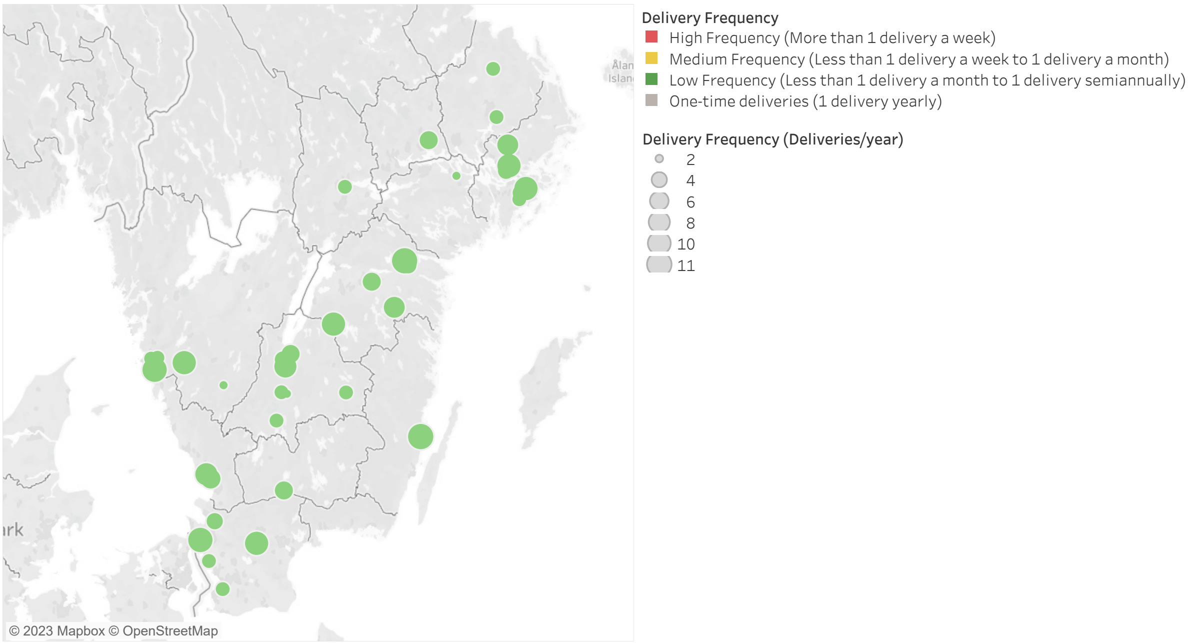

Figure 4.4: Locations of FläktGroup's Low-Frequency deliveries.

FläktGroup has 48 low-frequency deliveries. The low-frequency deliveries have a higher spread in comparison to the medium-frequency ones. They are mainly spread out in between the high-frequency deliveries with large clusters of outliers northeast and southwest of Jönköping. Their geographical positions are presented in Figure 4.4.

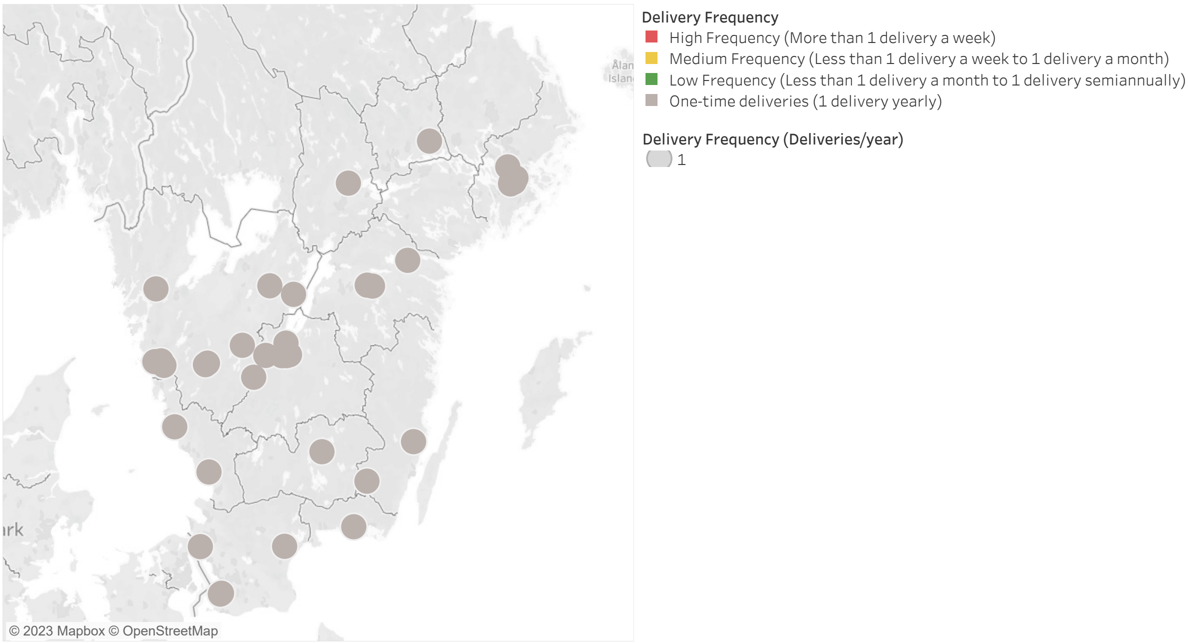

Figure 4.5: Locations of FläktGroup's One-Time deliveries.

The results additionally demonstrate that FläktGroup had 42 one-time deliveries during year 2022. These are spread out mostly next to other low- and medium-frequency deliveries with some outliers located in the south and far up in the north of Sweden (see Figure 4.1). Their geographical positions are presented in Figure 4.5.

With all the delivery frequencies pictured together in Figure 4.6, we can visually deduct that most suppliers and pick-up locations within the thesis scope are close to major roads moving between major urban areas in Sweden.

To further sum up the result from the initial quantitative data processing, it illustrates a relatively large spread of delivery frequency to the Jönköping production site. While the high- and medium frequency deliveries are only 31% of the total deliveries, their average volumetric weight add up to 52% of the total average volumetric weight of all deliveries. This combined with the regular frequency of their deliveries means that they are significantly responsible for the majority of the incoming flows arriving at FläktGroup Jönköping.

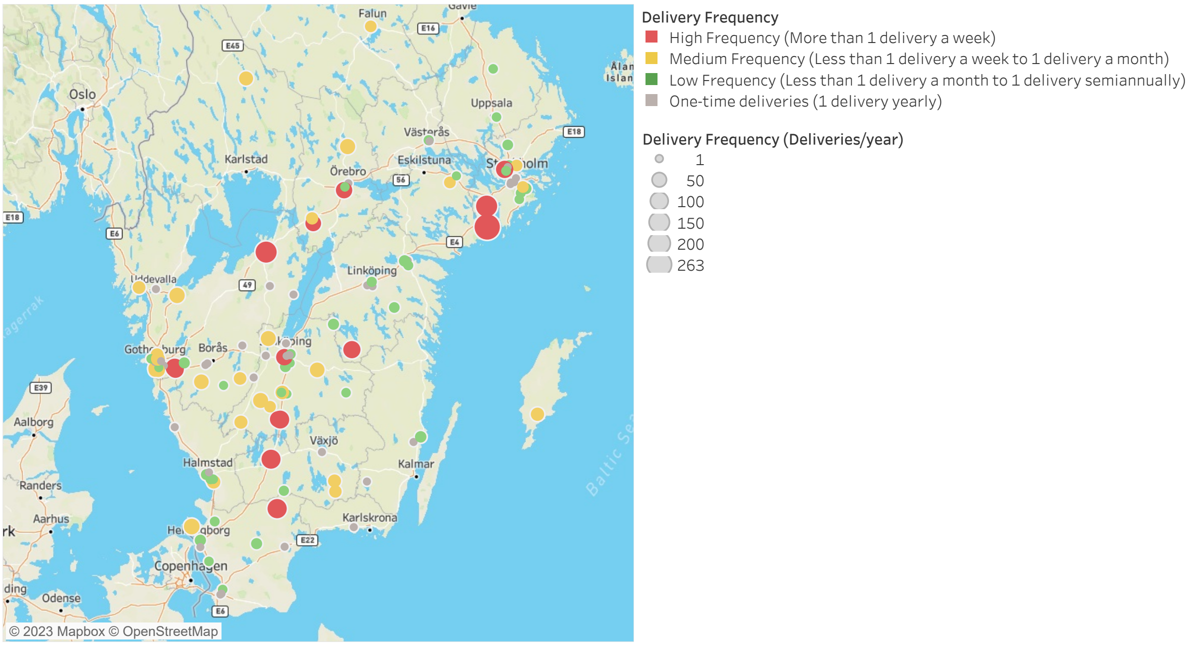

Figure 4.6: Road map of FläktGroup's Swedish pick-up locations.

4.3 Qualitative Data Findings

The results from the Quantitative Data Process were presented to FläktGroup representatives (I_1, I_2) initially during an informal meeting. Here, a decision was made to keep an onward focus on the high- and medium frequent deliveries from the quantitative findings (thus Figures 4.2 and 4.3) as the representatives foresaw the greatest opportunities there to make an impact on the company's inbound logistics. The one-time- and low-frequent deliveries were viewed to cause less impact and were said to often be the result of certain unique projects each year. Meaning that these deliveries will not for sure reoccur in the following years. Therefore, the quantitative data findings were further filtered to only include high and medium frequent deliveries (deliveries more frequent or equal to 12 times a year) for the following interviews and analysis.

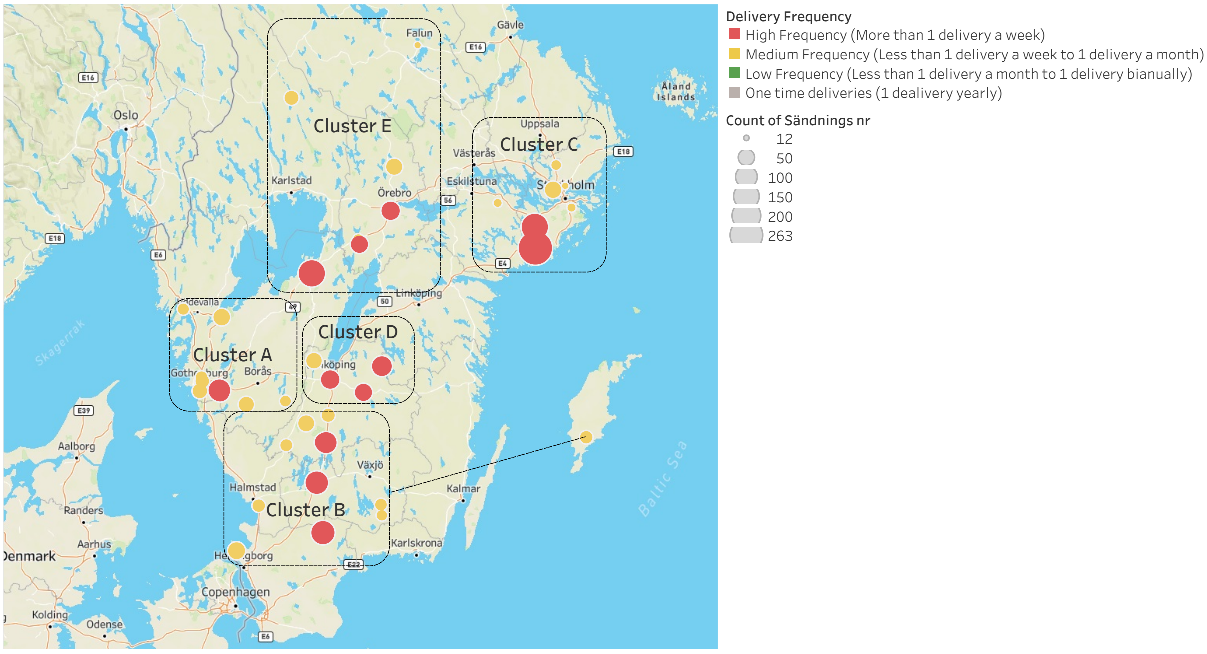

Figure 4.7: Geographically grouped clusters of High- and Medium frequency suppliers.

The meeting resulted in 41 pick-up locations from the high- and medium-frequency deliveries to further work with. Additionally, to categorize the remaining locations, the suppliers and pick-up points were divided into five geographical ”clusters”, representing their geographical placement relative to the Jönköping production site. Figure 4.7 illustrates the clusters and the locations within them. Complementary data to the delivery frequency such as supplier name, average volumetric weight, and location were extracted from the data analytic tool Tableau (2021) and is presented in Appendix B. The list in the appendix served as a base for conducting semi-structured interviews and complementary questionnaires. After the qualitative data collections with FläktGroup representatives, i.e. individual semi-structured interview (I_1, I_2, I_3, I_4), and the group interview (I_6, I_7, I_8, I_9), provided the main findings from the internal sources. The following findings from these primary data collections were interpreted, translated and then further structured and categorized according to the geographical location of each supplier/vendor into the extensive Tables 4.1 and 4.2. For every supplier/vendor, information regarding freight-, packaging-, and product characteristics as well as supplier relationships are represented in the tables. Findings regarding each area are presented and described in the following sections below.

4.3.1 Sourcing and Supplier Relationship

Regarding information on components and products being collected from suppliers, and information on power dynamics and supplier relationships, a general finding is the relatively large amount of components being produced or adjusted specifically to fit FläktGroup’s production and manufactured products. Furthermore, in some cases, such adjusted components are single-sourced, either with no other easily achieved supplier option or with just a few other options on the market. Additionally, there are several standard products being delivered to FläktGroup from the Swedish suppliers within the looked-upon frequency groups. For most of the suppliers included in the tables, however, FläktGroup work with a dual-, or multiple-sourcing strategy.

Furthermore, the supplier relationship situation can be noted to vary. In some cases, FläktGroup has a ”really bad relationship” (for instance supplier A4 in Table 4.1), whereas in others really good (supplier B2 in Table 4.2). For some suppliers in both tables, there was nothing special to comment on during the interviews, these are left blank and interpreted as neither good nor bad. Similarly, for product characteristics, those spaces left blank are interpreted as either standard or items just slightly adjusted for FläktGroup, if nothing else is commented on in the other columns. Moreover, the varying power balance can also be noted. For some suppliers, the representatives within Strategic Sourcing feel there is almost no room for negotiation, seeing as the supplier is a much larger actor than the firm (e.g., suppliers C2 and C7 in Table 4.2, and suppliers A2 and A4 in Table 4.1). In general, the common means of collaboration can be found to be a pure order relationship, with some exceptions where they have weekly or monthly meetings. These meetings are though mostly the result of suppliers that have a problem of supplying component current due to component shortages.

Table 4.1: Findings of goods characteristics in cluster A and B.

Commodity and Supplier Info.				Freight and Product Info.			Relationship and Extra Info.	
Supplier	Postal code	Source, interviewee reference	Commodity	Can be stacked?	Packaging characteristics	Product charactersitics	Supplier relationship, power balance	Other information
A1	461 38	I3, I6	Filter	Yes, but is lightweight. Not too heavy goods on top.	Pallets or loose depending on size		Similar to but less supplier power than C7, smaller actor	Deliveries extra important to arrive the date as planned
A2	436 32	I1, I8	Valve/Liquid Separator/Coil	Yes	Either pallets or more often small packages/boxes.	Small components specially designed for coolers	FG relatively small buyer for the supplier, so very small power in negotiation and wishes	
A3	511 42	I2, I6	Foam	Yes, but is lightweight. Not too heavy goods on top.	Pallets, cardboard boxes on pallets		Good relationship, frequent meetings	There's an alternative supplier
A4	514 50	I2, I6	Profiles	No, only besides	Both on specialized racks and sometimes in cardboard boxes.	Racks often 4 meter long. Takes a lot of space.	Really bad relationship due to the suppliers much larger size as an actor, very little room for negotiation.	Specially designed racks are returned after delivery.
A5	438 93	I3, I6	Silencer	Maybe light goods on top, but is heavy and unprotected	Pallets, unprotected	Non-stackable due to fragile and complete product	Important partner and supplier	
A6	451 95	I2,I9	Screws	Yes	Pallet with boxes on top	Non-adjusted for FG but patented product		
A7	415 02	I3, I6	Ball bearing		Cardboard boxes on pallets	Standard products	Nothing special to comment	Multiple sourced but largest supplier in the group
A8	438 70	I4,I9	Electronic parts	Yes, sometimes on top	EU-pallet/Cardboard boxes	Products adjusted for FG		Single sourced
A9	431 49	I2,I9	Plastic parts	Yes on top sometimes	Small Cardboard boxes	Standard products	Cost-based relationship	There are multiple supplier options but with higher prices currently
A10	425 37	I2	Parts for electronics	Yes on top sometimes	Cardboard boxes	Interpreted as standard products		
B1	263 37	I4,I8	Controller with motor, electrical product	Yes	Pallets with collar and lids	Unique type of products, standard product is adjusted uniquely for FG. Small company, FG had largest power when their partnership was more present	FG starting to phase out this partnership and start buying from another in Denmark instead.	They have a safety stock for the bought products to keep lead times low. Therefore, relatively low risk if delivered a day too late or early.
B2	302 65	I2,I6	Foam	Yes, but lightweight. Not too heavy goods on top.	Pallets and cartoon boxes on pallets	Light weight foam packed on pallets.	Really good relationship, meetings often.	There's an alternative supplier
B3	341 32	I4,I9	Cables, controllers, lego electronics	Yes	Pallets and cartoon boxes, sometimes pallets with collar	Specially produced products uniquely for FG.		Arrives already assembled and tested.
B4	331 41	I2,I8	Screws, nails	Yes, but is heavy	Smaller packages in cartoon boxes, heavy packed on pallets	Standard products. Often heavy, few goods delivered with each delivery	Okay relationship, meetings a couple times a year.	There's an alternative supplier
B5	331 35	I2,I6	Rubber profiles	Yes	Pallets	Not like other products supplied in Sweden.	Bad relationship, meetings often.	Order consolidation should not be a problem.
B6	568 32	I3,I6	Steel corner	Yes	Pallets and half pallets, are stacked and well protected			All details from this supplier are stocked, relatively low risk if delivered a little late or early
B7	333 30	I3,I6	Floor gratings (gallerdurk)	Yes, but nothing too heavy on top.	Packaged with metal bands on pallet.	Standard products but slighty adjusted for FG		Single sourced
B8	362 50	J2,I6	Plastic products	Nothing should be stacked on top of boxes.	Packed cartoon boxes on pallets, packed in plastics.	Completely unique products for FG, connected to special tools in production.		Interpreted as single sourced
B9	283 43	I4,I8	Regulators			Products adjusted for FG		Single sourced
B10	623 50	I2,I9	Plastic for electronics	Yes	Pallet	Part unique products, part standard		Relatively hard to find substitute supplier
B11	335 31	I2, I9	Prints and signs	Interpreted as yes	Large letters	Uniquely adjusted for FG	Often sent earlier than desired	There are multiple supplier options who can deliver the same.
B12	362 31	I3,I4	Filter	Yes, but nothing too heavy on top of	Pallets with specially adjusted dimensions	Unique products and unique manufacturer.	Supplier often delays deliveries by 1-2 days	Single sourced and currently no other options

Table 4.2: Findings of goods characteristics in cluster C, D and E.

Commodity and Supplier Info.				Freight and Product Info.			Relationship and Extra Info.	
Supplier	Postal code	Source, interviewee reference	Commodity	Can be stacked?	Packaging characteristics	Product characteristics	Supplier relationship, power balance	Other information
C1	175 62	I2,I9	Protective film	Yes	Pallet	Order a larger amount per order, often to fill one pallet	Bad relationship, meetings seldom.	
C2	175 62	I4,I7	Fans	No, maybe to be stacked on top of others	Fans placed on a pallet or in a cartoon box on a pallet	Unique articles, based on standard products but adjusted for FG. Delivered from swedish warehouse, production in Germany.	Large actor, FG has global deal with tis supplier, but local relationship with swedish purchaser and supplier representative, therefore still a close collaboration.	Deliveries important to arrive as planned due to lack of storage space. Long planning necessary, but short logistic mindset. All deliveries from here are sent on a routine every Tuesday.
C3	187 30	I3,I6	Coupling link/Chain etc.	Yes	Pallet with collar and lid			Relatively low risk if delivered a day late or early
C4	128 30	I2,I8	Protective caps	Yes	Unsure answer but probably in loose cartoons	Should be okay to stack and consolidate	Okay relationship, meetings relatively seldom.	
C5	195 61	I4,I9	Electronic parts	Yes, sometimes on top of each other	Cardboard boxes	Products adjusted for FG		Single sourced
C6	645 91	I3,I6		Yes	Pallets with collar and lids			Will not continue as supplier this year (2023).
C7	619 33	I3,I6	Filter	Yes, but already stacked, maybe stack on top of womething flat	Cartoon boxes stacked already on top of each other		Large actor within the commodity type, important to FläktGroup	
D1	571 41	I2,I6	Lock	Yes	Often pallets with collar and lid. Small cartoon might be put in pallets as well		Okay relationships, meetings a couple times per year.	Deliveries extra important to arrive the date as planned. There are alternative suppliers if problems would periodically arise. Supplier has several DCs in Sweden
D2	573 74	I3,I6	Filter	Yes	See C7			Probably warehouse of supplier C7. See Supplier C7.
D3	554 74	I3,I6	Bearings and belts	No	Often boxes, collies.	Both standard products and adjusted for FG		Multiple sourcing for some products, but not for all
D4	565 33	I3,I8	Parts for turning	Yes, sometimes placed on top of each other currently	Pallet, sometimes with collar and lid. Sometimes cartoon boxen placed on pallet	Uniquely produced for FG	Nothing special to comment	Currently single sourced, but there are other suppliers available on the market.
E1	683 60	I2,I6	Rubber parts	Yes, and are placed on top of each other currently.	Pallets with lid and cartoon boxes.	Completely unique products for FG, connected to special tools in production.	No comment	Interpreted as singely sourced
E2	702 36	I2,I7	Screws, nails	Yes, but is heavy	Pallets, often no more than one pallets a week.	Standard products.	Good relationship, meetings a couple times per year.	Routine delivery every Monday. There's an alternative supplier
E3	695 31	I4,I6	Fuse/ transformer	Yes, probably but unsure	Could be pallets, unsure	Standard products	Does not buy large volume from this supplier.	Orders according to safety stock levels. Relatively low risk
E4	695 72	I2,I6	Insulation profiels, stone wool insulation	Yes, but nothing too heavy can be stacked on top of	Pallets, well protected	Delivers a unqiue product, single sourced.	Bad relationship, meetings a couple times per year.	They have tried to find a substitute but without success.
E5	542 35	I3,I8	Metal	Yes, but nothing too heavy on top of, a bit sensitive	Perforated metal plate on top of each other. Long pallets a lot of weight	Products not uniquely adjusted for FG. But still a little special on the market	Relatively bad relationship. Often hard discussions and complaints. However, supply quality excellent. Important actor, single sourced with low substitute options	Relatively low risk if arriving one day too late or too early.
E6	711 34	I2,I6	Plastic details	Interpreted as yes		Standard products, similar to F5.		Harder to change to another supplier, compared to F5
E7	791 77	I2,I8	Drain traps	Yes	Pallet	Non-adjusted for FG, but relatively unique on the market		Not entirely easy to find another supplier
FG	153 35	I1,I2,I3,I4	Various products and sizes	No, cannot be stacked or have stacked goods on top.	Larger cartoon boxes, often on pallets. Some bulk which might take larger space.			

4.3.2 Freight and Packaging

The freight- and packaging characteristics of goods from each collection point or supplier is represented in Tables 4.1 and 4.2, regarding ability for the products to be stacked during freight, and how they are packaged. Following, it can be noted that almost all of the packages can in one way or another be stacked during freight. Most can be stacked without further comment, meaning that they either aren't sensitive, or they are well-packaged, some even arrives in pallets with collars and lids. Some are however lightweight or in other ways delicate, meaning that heavy goods or packages should not be placed on top of them, to avoid damage. A few of the items are placed more or less unprotected on pallets during the freight and might require certain extra caution when stacking (for instance, A5 Table 4.1, C2 in Table 4.2). But in other cases, some are heavy or again delivered in pallets with lids, enabling an greater possibility to have goods stacked on top of them (e.g., B1, B6 Table 4.1, D1, E1 in Table 4.2).

Furthermore, a few unique packaging techniques can be found in the list as well, for example, supplier A4 in Table 4.1 often delivers their components on long specially designed hedges, which are explained by the vendor planners to be collected and returned back to the supplier once in a while, either when enough number of hedges have arrived to achieve a sufficient freight load back, or when the supplier calls and is in need of them earlier. Moreover, it can also be noted that some deliveries today arrive on a weekly routine basis. One supplier for instance always delivers goods every Tuesday, another every Monday. But for most of the deliveries that were asked about, the orders are placed according to minimum storage and forecasting, and the delivery is made thereafter.

4.3.3 FläktGroup's Finished Products

Together with the company representatives I_1 and I_2, information on FläktGroup's finished products was gathered, enabling a future analysis on product characteristics and from there a matching with an optimal supply chain design. The questions asked, inspired from the Fisher's model and adaptions of it, can be viewed in Table 4.3, where the answers have been summarized as well. Furthermore, as a support in answering the question regarding late-delivery rate, data of Factory OTD for FläktGroup Jönköping in January and February 2023 is also provided and can be viewed in Table 4.4. Table 4.3 will be continuously worked with and analysed further on in the master's thesis, and findings in it will appear in an analytical form in the analysis.

Table 4.3: Interview questions and answers on finished products characteristics.

Questions on products and demand	Answers
How long would you generally say your products' **life cycles** are? More, or less than 1-2 years?	Guarantee time is 10 years but would generally say 10-30 years.
Do you have a high- or low **contribution margin**?	It varies with products but above average for manufacturing industry (4-5%).
How large is your **product variety**? Low variety = around 10-20 variants/product, high= a lot more.	20-30 base variants that each can be uniquely customized and combined with others in many ways.
How large **margin of error** would you say you have for forecasts by the time of production start?	100% certainty 5 weeks ahead due to manufacture on order. 40% sure 2-3 months after that.
Which **late-delivery rate** would you say you have?	*Supplied Factory OTD data:* Average OTD of 87.7% so far in 2023
Do you have any **end of season markdown**?	All products and sales are manufactured on contracts, so 0%.
How long/short **lead times** do you have?	Previously shorter (around 15 days) but due to component shortage the latest years, now up to 400 days.

Note. Questions inspired from the work of Fisher (1997) and Selldin and Olhager (2007). Findings translated to English, some slight interpretations and adjustment has been done from the original interview findings.

Table 4.4: Factory OTD (%) Jan-Feb 2023.

Factory OTD (%)										
Description	Week 1	Week 2	Week 3	Week 4	Week 5	Week 5	Week 6	Week 7	Week 8	Week 9
Target	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Factory OTD(%)	92%	90%	93%	79%	94%	81%	84%	88%	85%	92%

Note. Table supplied from the company's statistics.

4.3.4 Transport Characteristics

In Table 4.5, the findings from the questionnaire sent to a contracted 3PL provider is presented. Some key takeaways from the answers are information regarding general unloading-, and loading times, realistic number of stops per route and day, as well as requirements for full-load respectively part-load goods. For instance, I_{10} explain how overall a reasonable number of loading stops per day is around three to four stops. Furthermore, the limit for an order to be handled as full-load goods instead of part-load is 2 loading meters or pallets. More information can be viewed in the answer columns in Table 4.5.

Table 4.5: Questionnaire sheet and answers from contracted 3PL service provider.

Questions to 3PL provider	Answers
Do you have freight going as direct delivery or via warehouse, consolidation point or similar? If there is a mix of these, how are they shared-out?	Normally the transports to FG can be split into full-load and part-load. Generally, shipments over 2 loading meters (pallet space) are handled as full-load goods. Part-load goods are handled via terminal, full-loads are shipped directly between supplier and FG.
Are FG's orders sometimes consolidated with other customers? Would you ship orders with loading from the same regional area that are to be delivered to customeers located close to each other, in the same truck?	Yes, this is always the case, but with exceptions when FG books a full carriage.
What fill rate would you say you on average have in your carriages? Both generally in Sweden and for FG shipments.	No rate to share in the moment of writing. Would like to add that this is something that is generally worked with, bad fill rate means bad economy, two factors important to follow both for us and for our customers.
What kind of carriage do you generally drive with for FG shipments?	In Sweden both trailers and car+trailers. One trailer has 13,6 loading meters, car+trailer has 19,2 loading meters. Vol. weight are according to contract 1850 kg/loading meter in the Nordics and nationally.
How many stops would you say is realistics for a truck to have on a route, and how long does every stop take? In terms of a day long route, unloading and loading in Sweden.	Normally unloading in the mornings and loading in the afternoons, to get the routes optimized. Here, as short distances possible between loadings applies, and combining goods going to the same area. Unloading time depend on size and shipment. Simple calculated 3-4 order shipments per car, where unloading, transport, and loading is done in 8 hours.
Do you have the option to consoldiate shipments if they are booked on the same day from the same geographical area? If so, is this done by your system or could it be asked for by the customer?	To combine shipments is a must, to fill our carriages. Normally we cominbe shipments from different clients, but there are variations with clients consolidating themselves, but this is often handled as consolidated freight with extra kilometers and extra stops.
Do you have a possibility to implement a so called milk run to a customer with a lot of incoming shipments from the same area? If so, would it be better if such shipments are located in regions surrounding larger urban areas/cities or does that not matter?	Very hard to answer generally, but it is absolutely worth to look at options. You could set up a fixed milk run driving between different cities. This depends on it being enough goods to fill the truck and that it can be handled in a reasonable time.

Note. Questions and answers are translated from Swedish to English, some slight interpretations and adjustment has been done from the original questionnaire.

4.4 Calculations

In this stage, the results from two types of calculations are interpreted as important to establish for the following analysis. The qualitative data findings provided the segment of the mapped area were further calculations must be made based on the quantitative data findings.

4.4.1 Weight Calculations

Even though the geographical clusters have already been established and the segment of suppliers decided upon, some calculations and findings regarding the supplier segment are still to be further noted and presented. The established literature theory explains one of the key motives for implementing optimized route solutions in logistics is the search for higher transport utilization rates (e.g., Merrick and Bookbinder (2010)), and logistics effectiveness thereof. Thus, highlighting the average volumetric weight for the suppliers in the high- and medium-delivery frequency segment might be beneficial further in the analysis. Moreover, calculating the total average volumetric weight per delivery of all combined suppliers within each geographical cluster can arguably enable a holistic view of further possibilities for potential transport solutions. In Table 4.6 below, the postal codes, average vol. weights, and delivery frequencies are presented and connected to each supplier in the segment, according to the findings established in Appendix B.

Table 4.6: Average volumetric weights for segmented suppliers and clusters.

Cluster	Supplier	Postal code	Deliveries /year	Avg. vol. weight (kg)	Total Cluster Weight (kg)
	A1	461 38	48	672,67	
	A10	425 37	21	2,38	
	A2	436 32	15	215,00	
	A3	511 42	39	2171,47	
	A4	514 50	19	2493,95	
A	**A5**	438 93	67	6198,46	
	A6	451 95	20	19,75	
	A7	415 02	30	62,19	
	A8	438 70	93	18,88	
	A9	431 49	35	36,10	11891
	B1	263 37	51	71,65	
	B10	623 50	25	5,99	
	B11	335 31	44	4,95	
	B12	362 31	18	1143,07	
	B2	302 65	25	402,44	
	B3	341 32	102	594,83	
B	**B4**	331 41	87	165,16	
	B5	331 35	60	2323,63	
	B6	568 32	28	588,27	
	B7	333 30	23	74,39	
	B8	362 50	22	239,10	
	B9	283 43	103	8,10	5622
	C1	175 62	30	109,37	
	C2	175 62	47	325,58	
	C3	187 30	12	85,25	
C	**C4**	128 30	13	72,04	
	C5	195 61	16	4,69	
	C6	645 91	13	213,15	
	C7	619 33	262	6463,85	7274
	D1	571 41	39	308,69	
	D2	573 74	75	422,08	
D	**D3**	554 74	63	16,46	
	D4	565 33	41	41,95	789
	E1	683 60	32	574,89	
	E2	702 36	62	329,47	
	E3	695 31	17	133,59	
	E4	695 72	53	1560,00	
E	**E5**	542 35	150	3183,40	
	E6	711 34	45	19,93	
	E7	791 77	12	90,00	
	E7	791 77	12	90,00	
	FG	153 35	150	325,44	6307

4.4.2 EOQ Calculations

In order to calculate the EOQ for the different products, complimentary data was needed for the parameters of the data. FläktGroup (I_1) provided their standard fixed order cost and warehousing cost. The two provided parameters can be seen in Table 4.7.

Table 4.7: FläktGroup's fixed parameters for EOQ formula.

Fixed order cost	450 sek
Warehousing cost	13%

A calculation was then made for each product that were provided by the suppliers that were potential for consolidation using equation 3.1. The results of the EOQ calculations are presented in Table 4.8.

Table 4.8: EOQ calculations for FG's high- and medium frequency suppliers.

Supplier	Yearly Demand	Average price per product [SEK]	EOQ (Orders/ year)	Order rows/year	Deliveries/ year
A1	2154	117	6	11	48
A2	1533	92	4	16	15
A3	314046	23	30	20	39
A4	109750	5	8	8	19
A5	571	5232	19	95	67
A6	159000	1	5	5	20
A7	13202	30	7	6	30
A8	3073	407	12	39	93
A9	147726	12	15	28	35
A10	1550	59	3	6	21
B1	740	2406	15	24	51
B2	749755	7	25	57	25
B3	13654	1015	41	100	102
B4	1086631	2	15	121	87
B5	522100	6	19	22	60
B6	100100	5	8	5	28
B7	123	947	4	25	23
B8	105925	2	4	8	22
B9	546	678	7	9	111
B10	13915	93	12	10	25
B11	29791	84	17	28	44
B12	28	16133	7	12	18
C1	956	630	9	5	30
C2	2884	1271	21	53	47
C3	1029	79	3	9	12
C4	23698	25	8	4	13
C5	17600	2	2	2	16
C6	2330	175	7	4	13
D1	19664	13	6	28	53
D2, C7	15899	753	38	433	263
D3	32956	245	31	43	63
D4	7959	37	6	20	41
E1	16568	12	5	11	32
E2	4898556	0	15	81	62
E3	239	6766	14	10	17
E4	13155	65	10	25	53
E5	28993	1120	63	144	150
E6	1104100	2	16	11	45
E7	565	136	3	3	12
FG	277084	1244	204	1372	150

From the EOQ calculations in Table 4.8, several findings can be deducted. For most items, there are more deliveries and order rows than what is optimal from the perspective of direct economic costs. Furthermore, there are generally a higher number of deliveries currently than there are recommended order rows per year.

5. Analysis

The chapter focuses on analyzing the data collected from the empirical findings of FläktGroup. Various analytical tools such as Fisher's model, the Kraljic matrix, and EOQ calculations provide, together with additional empirical findings, a basis for conducting the SWOT analysis. Following the SWOT analysis, the road is finally clear for a conclusive deduction of where the inbound shipment could be optimized and how so, indicating several transport consolidation opportunities and improved routes for FläktGroup's inbound logistics. The consolidation opportunities are then mapped and calculated, and a study of their potential environmental impact follows thereof.

5.1 Product and Supply Chain Design

From the empirical findings of FläktGroup's finished products and demand, summarized in the Table 3.3, Fisher's model could be applied to initialize the analysis and to provide a recommendation of the most appropriate supply chain design.

For starters, FläktGroup's finished products are characterized by having long life cycles, categorizing them as functional according to the theory of Fisher's model (Fisher, 1997; Selldin and Olhager, 2007; Lee, 2002). As manufacturers they are therefore not required to quickly and constantly provide their customers with new products as often as producers in a responsive supply chain are. Instead, the analysis shows how the focus should be put on having an efficient supply chain and keeping the cost down for production. This is in line with how Fisher (1997) and adaptations of the model (Lee, 2002) match functional products with longer life cycles to efficient supply chain design. Efficiency also matches with the investigated contribution margin for FläktGroup, where the margin was said to be somewhere above the average in the manufacturing industry. As the average profit margin for the Swedish manufacturing industry accordingly is around 5% (Företagarna, 2018), a percentage slightly above this still places the products as functional in the margin perspective, according to Fisher's model (Fisher, 1997). Moreover, this leads again to arguing that an appropriate supply chain design would be an efficient one, where the relatively low margin might not be enough to support the additional costs of having an efficient supply chain.

With regards to product variety, FläktGroup is interpreted as a bit different from other comparable companies, as the firm has both a high width and a high depth in production, resulting in potentially millions of different combinations and ways to customize customer orders. In such aspect, the products can be defined as innovative regarding Fisher's model (Lee, 2002; Fisher, 1997), with a following recommendation for a responsive supply chain design. Because, the high product varieties arguably shorten the time frame of achieving correct predictability of customer orders, reducing the advantages of an efficient supply chain and instead calling for increased responsiveness. Additionally, as almost all of FläktGroup's products are customized, they are nearly impossible to sell to customers other than the originally ones manufactured for.

The following aspect of Fisher's model concerns the forecasting margin of error. The fact that FläktGroup is a complete MTO company with very specific products for certain projects, puts them with a very low margin of error in manufacturing. This means that they know exactly what is going to be produced five weeks ahead and accordingly enables them to plan and produce effectively. Even though the margin of error increases beyond the five-week time frame, the absence of it within the five weeks places the products as functional still. Therefore, thanks to their low margin of error when the production is committed, an efficient supply chain design is enabled to follow, as there is no need to be responsive to such fixed manufacturing orders (Fisher, 1997). So, interestingly enough, even though the product variety is said to be high, calling for responsive actions due to reduced predictability in theory, the margin of error tells us otherwise and an efficient supply chain can be argued for anyway.

Furthermore, as explained in the methodology, the company's late delivery rate was analyzed instead of the stock-out rate, similar to the procedure Selldin and Olhager (2007) follows for manufacturing companies. The late delivery rate for FläktGroup is around 10%, placing the products' characteristics somewhere in between functional and innovative if following the same scale as Fisher's model does when analyzing stock-out rates (Fisher, 1997; Selldin and Olhager, 2007). However, the combination of FläktGroup's relatively low-profit margins and their internal target of a minimum 90% late-delivery rate (see Table 4.4), makes the profit impact of having some late deliveries arguably small. Therefore, even though the products' placement as innovative or functional is more unsure than for the other aspects, the supply chain design can still be argued best being efficient in this perspective as well. The money required to reduce the last percentage of late deliveries is arguably not worth it compared to what is gained from it.

An aspect that is prevalent for a responsive supply chain is an end-of-season markdown sale (Selldin and Olhager, 2007). But, with FläktGroup being an MTO company, there is no benefit for them to markdown at the end of the season. As previously mentioned, FläktGroup sells customized products, meaning that they simply can not mark down the unsold product and sell them to someone else. This aspect in Table 5.1 is therefore arguably not as relevant as the others to analyze. However, since the answer to the end-of-season markdown sale is simply no, Fisher's model would place the products as functional and recommend an efficient supply chain design (Fisher, 1997).

A final investigation point in Fisher's model regards the lead time. In the case of FläktGroup, in past normal settings, they have had a decidedly low lead time, positioning the products as functional. Following with a suggestion for an efficient supply chain design, low lead time could mean more orders arriving and thus requiring additional resources Selldin and Olhager (2007); Fisher (1997). But, as a result of previous years' disruptions and unusual situations around the world, FläktGroup is explained to still be affected by global component shortages. Therefore, their lead times have increased significantly with some products having as much as 400 days lead time. Such a number would instead according to Fisher's model place the products in the same category as innovative ones (Selldin and Olhager, 2007). Furthermore, long lead times such as these mean that the supply chain rather needs to be optimized so that the scarce amount of component that moves toward FläktGroup in the value chain does so as quickly as possible. enabling a profitable production.

Table 5.1: Finished products- and supply chain analysis.

Empirical findings summary		Analysis summary	
Questions on products and demand	Answers	Functional or Innovative?	Matching SC?
How long would you generally say your products' **life cycles** are? More, or less than 1-2 years?	10-30 years	Functional	Efficient
Do you have a high- or low **contribution margin**?	Above average for manufacturing (4-5%)	Functional	Efficient
How large is your **product variety**? Low variety = around 10-20 variants/product, high= a lot more.	20-30 base variants, a lot more with unique customization	Innovative	Responsive
How large **margin of error** would you say you have for forecasts by the time of production start?	100% certainty 5 weeks ahead. 40% sure 2-3 months after that.	Functional	Efficient
Which **late-delivery rate** would you say you have?	Average factory OTD in 2023 is 87,7% so far	Innovative	Responsive
Do you have any **end of season markdown**?	0%	Functional	Efficient
How long/short **lead times** do you have?	Previously around 15 days, now up to 400 days.	Innovative/Functional	Responsive/Efficient

Note. A segment of FläktGroup's products analysed based on the Fisher model (Fisher, 1997), matching finished products with optimal supply chain design.

In conclusion, considering most of the aspects, a physically efficient supply chain design is to recommend FläktGroup and to further work with during the analysis and logistics optimization solutions. Some responsiveness should in the best case be present as well, like the analysis suggests, the high product variety for one call for it. This would mean working towards a supply chain where the focus is laid on increasing productivity, resource utilization, and optimization. However, in order to not make the supply chain too effective, it should cope with the innovative product characteristics as well. Emphasis is laid to keep a responsive mindset, and a process flexible enough to withstand more unpredictable changes that might occur close to the five-week time frame of full predictably. From an inbound logistics perspective, having a physically efficient supply chain would mean working towards cost limitations and increased transport utilization. However, to cope with the innovative characteristics here as well, it would also mean to not create too solid freight and delivery schedules, in order to still enable some flexibility in freight of incoming goods.

Additionally, so far a supply chain suggestion has been made by considering the demand uncertainty, placing products as either functional or innovative, and suggesting a supply chain design thereafter. To deepen the analysis and make sure all aspects are being considered before finding the most appropriate recommendation for FläktGroup's overall supply chain, the supply uncertainty should also be considered (Lee, 2002). FläktGroup's current process is mainly interpreted as stable, and the supply uncertainty as low. Why has to do with the qualitative data findings providing a general understanding of FläktGroup's network, and the stability and the relationships within. Most of the suppliers who's characteristics were investigated (Tables4.1 and 4.2), appear to be in a stable relationship with FläktGroup. A majority of them have been a part of the network for a relatively long time, and there are just a few signs of relationship disruptions or elimination. Additionally, the company has been around for a long time, they are well-established on the market and have an established production site and process. Following Lee (2002) and his interpretation of Fisher's model, a stable process and stable demand would therefore lead to, in line with Fisher, recommend an efficient supply chain design. However, the current circumstances, sudden long lead times, and global supply changes could arguably disturb this stability. One can not be sure that the market will bounce "back to normal". So, while most findings speak for a low supply uncertainty in this case, there are still aspects to take into consideration further on, and perhaps be on the lookout for, were the situation to keep changing and the uncertainty to increase. If that is the case in the future, one could instead suggest a so-called risk-hedging supply chain design (Lee, 2002).

5.2 The Purchasing Portfolio Matrix

Using the empirical findings summarized in Tables 4.1 and 4.2, each supplier could be analysed using the Kraljic matrix. The suppliers were placed in the matrix according to their profit impact for production and to their supply risk and complexity. An overview of the resulting position in the purchasing portfolio for each of the analysed 41 suppliers can be viewed in the Kraljic matrix in Figure 5.1.

5.2.1 Non-critical Items

In the lower left quadrant, suppliers with non-critical items are placed. The analysis presents some 13 suppliers out of the total 41 looked upon, with items interpreted as less critical than the rest. The reasons for their portfolio placements is based on that some suppliers' parts and components are multiple sourced or within a commodity category with a relatively low-profit impact on FläktGroup's finished product. This is in line with how Cox (2015) describe their interpretation of Kraljic's matrix (Kraljic, 1983) and how one can define items and suppliers as non-critical. Additionally, several of them are described as standard products. They are either not adjusted solely for FläktGroup as a customer, or they deliver items that other OEMs can produce and sell as well, meaning that there are similar sourcing options on the market if the supply quality were to decrease. The suppliers' portfolio placement does not necessarily mean they are altogether uncritical or that FläktGroup's finished products can achieve the same quality without them. But, in perspective of how the inbound logistics performance affects the manufacturing and the finished products, the non-critical items are argued the ones where the least difference is made if changes are done in the logistics strategy surrounding their inbound deliveries (Cox, 2015).

5.2.2 Strategic Items

For the opposite quadrant, in the upper right corner of the Kraljic matrix in Figure 5.1, 10 of the total 41 suppliers are placed as delivering strategic items. The items here are reasoned to have a relatively high-profit impact for sourcing, production, and for FläktGroup's finished products, in addition to the sourcing risk being interpreted as high. This is due to the items being single-sourced with either few or no other supplier options, often also in combination with them having a design specifically made to fit FläktGroup's products or certain manufacturing tools used in the production site in

Jönköping. For instance, in the upper middle of the quadrant, four suppliers are listed as supplying the most strategic items in the group, suppliers B3, B8, C2, and E1 (to be viewed in Tables 4.1 and 4.2). Items like the ones bought from supplier B8 and supplier E1 are placed there because of their uniqueness and compatibility with FläktGroup's manufacturing. Unique items with high complexity is by Cox (2015) presented as one of the factors for such being placed as strategic. Items from suppliers C2 and B3 are also unique, with C2 having an additional emphasis on the importance of them arriving on the correct planned date. Therefore, from a perspective of shipment consolidation and optimization, highly strategic items like these in the Kraljic matrix can be particularly essential to take into consideration when planning inbound freight deliveries. As established literature describes, logistics management involves various logistics activities and actors, and by considering the impact such have on each other, one can achieve a more competitive supply chain (Kasilingam, 1998; Stadtler, 2015; Zijm et al., 2019). If one would not consider strategic items profit impact when searching for improved route options, the risk of the routes affecting the cost of inbound logistics operations negatively would arguably increase. Thus, contradicting the overall goals of the transport optimization process (Baller et al., 2022), and the overall supply chain management competitiveness (Stadtler, 2015).

5.2.3 Bottleneck Items

For some supplier's items, the sourcing risk is analyzed as high but the profit impact is not, these are consequently instead placed as bottleneck items according to Kraljic (1983) and the adaptation from Cox (2015). A number of 10 suppliers out of the total 41 analyzed are placed in this lower right quadrant as a result of the analysis. The major difference from the strategic items is the type of commodity the items have, an aspect that can affect the analyzed degree of their profit impact (Cox, 2015). For instance, supplier B10 is explained to deliver items partly unique for FläktGroup, and the supplier options are low or almost non-existent, placing the sourcing and production risk relatively high. However, supplier B10's items are plastic parts for electronics and are interpreted to have a relatively low value in comparison to several other parts, placing the purchasing-, and profit impact relatively low, thus resulting in a bottleneck item placement in the purchasing portfolio.

5.2.4 Leverage Items

For the rest of the analyzed suppliers, their items are interpreted as having a high-profit impact in combination with a relatively low sourcing risk instead, thus placing them in the upper left quadrant of Figure 5.1 as leverage items (Cox, 2015). These are, similar to the suppliers delivering non-critical items, often multi- or dual-sourced, reducing the risk and complexity of sourcing and delivery. On the other hand, they are often still adjusted or produced more or less uniquely for FläktGroup and are in several cases within a commodity group interpreted to have a high purchasing impact. One example is supplier D1, where the qualitative findings explain how there are other supplier options if D1 were not to cooperate or if the relationship would not work out, but where the items supplied and their arrival date of delivery still is very important for the production performance. In the leverage item quadrant, the analysis resulted in 8 suppliers having such a position, including the one named FG; standing for the internal deliveries from the second FläktGroup production site in Sweden.

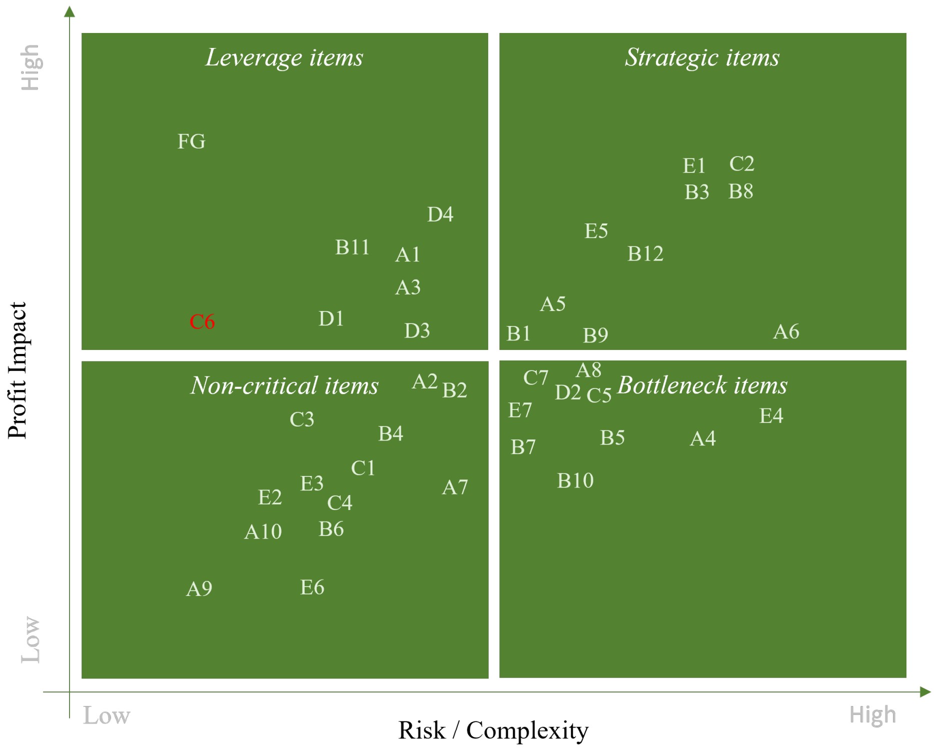

Figure 5.1: The purchasing portfolio matrix for the segmented FläktGroup vendors. *Note.* Inspired and adapted from the Kraljic matrix (Kraljic, 1983).

5.2.5 Conclusion Purchasing Portfolio

An overall note to be made surrounds the general analysis and interpretation of the Kraljic matrix. In Figure 5.1, it can be seen that many suppliers are purposely placed close to the middle or to one of the other quadrants, this to illustrate them having traits very similar or almost the same as suppliers in the quadrant besides them. Seeing as the purchasing portfolio created here is based upon a handful of interviews from employees within FläktGroup's Strategic Sourcing and Vendor Planning departments, some assumptions and decisions had to be made in order to find an as correct portfolio placement possible. However, the analysis is therefore also open for other interpretations. By placing those suppliers, with items and characteristics not entirely typical for one certain quadrant group, close to adjacent boarders, the slightly less certainty of their portfolio placement can be taken into consideration further in the analysis as well.

In conclusion, the supplier analysis resulted in a purchasing portfolio inspired by the Kraljic matrix (Kraljic, 1983) with a relatively even spread of suppliers in the four different quadrants. Such a result is arguably realistic, the segment of suppliers to analyze and place in the portfolio was not chosen for their sourcing risk or profit impact, and a relatively even spread in the portfolio is therefore a reasonable expectation. Additionally, what can be interpreted by this diversity is that it is a sign of the segment being a realistic sample of all suppliers involved in FläktGroup Jönköping's inbound logistics. Even though it is still important to note that this purchasing portfolio does not include all suppliers, not in total nor in Sweden, the wide spread still shows to be an arguably well-segmented representation and a good start for investigating further route optimization- and shipment consolidation opportunities.

5.3 SWOT Analysis

The SWOT analysis in this master's thesis captures the most essential parts the empirical findings and the analytical results, have on future shipment consolidation possibilities. As Buffa (1986) describes, recommendations of consolidation solutions should regard several aspects and be decided in relation to various parameters surrounding an inbound logistics flow. By systematically conducting a SWOT analysis for each decided-upon aspect, the collective results are compared to each other and summarized in Table 5.2. The empirical findings were divided into five categories to analyze, based on findings summarized in Figures 4.1-4.6, and Tables 4.1, 4.2, 4.5, and 4.8. Those categories are the following; road transport requirements based on the interview with the 3PL service provider, freight and packaging characteristics of each looked-upon supplied product or item, supplier- relationship and power balance, geography- and transport weight from the quantitative data process findings, and the EOQ data findings. The analytical results on which to further conduct a SWOT analysis are based on the summaries in Tables 5.1 and 5.1.

5.3.1 Fisher's Model

The most relevant findings from the SWOT analysis based on Fisher's model and the recommended supply chain design are written in Table 5.2. An essential highlight from the analysis is the fact that the products identified as neither entirely functional nor innovative in Table 5.1 above, can become either a weakness or an opportunity for the following supply chain design. As the analysis presents, the overall supply chain design to guide the following transport optimization suggestions is recommended to mainly have physically efficient traits, according to Fisher's model and interpretations thereof (Fisher, 1997; Selldin and Olhager, 2007). Such a design would arguably be even more rational to recommend if the products were identified as functional in every aspect. Instead, there are a couple of product perspectives in which it could be argued better to suggest a responsive supply chain design, achieving higher flexibility in the supply network and thus prompting the uncertain product categorization as a weakness. On the other end, instead of the products being identified as definitely innovative, they were identified as both or neither, meaning that an efficient supply chain recommendation is more reasonable to suggest in this case compared to if some aspects clearly called for responsiveness. Thus, the uncertain categorization could be prompted as an opportunity as well in the SWOT analysis. Furthermore, in a shipment consolidation perspective, all recommendations towards a physically efficient supply chain design are argued as strengths in the SWOT analysis (Buffa, 1986; Merrick and Bookbinder, 2010). This since an efficient supply chain aligns with the goals of shipment consolidation being an optimization of inbound flows according to established literature (Buffa, 1986).

Table 5.2: Summarized findings from the SWOT analysis.

Strengths	Weaknesses	Opportunities	Threats
Fisher • Recommendations towards efficient supply chain design gives opportunities for consolidation. *Kraljic* • Generally wide spread of supplier/item risk and profit impact. *Road transport requirements* • Large trucks, • Incentives; Low utilization rate = bad economy for transporter. *Freight & Packaging* • Stackable goods, • Uniform transportation modes (pallets), • Well-protected goods. *Supplier relationship & power balance* • Good supplier relationships. *Geography and transport weight* • Many suppliers close to major cities, • Many suppliers close to major roads, • Geographical clusters, • FG's geographical position in Sweden. *EOQ* • Benefits according to EOQ-calculations with order consolidation, thus increase vol. weight per shipments.	*Fisher* • Products identified neither as fully functional, nor innovative, • Responsive SC design, and made-to-order products. *Kraljic* • Strategic items with high risk and profit impact, • Bottleneck items with high risk, • Leverage items with high profit impact. *Road transport requirements* • Partial goods less than 2 pallets go via terminal with 3PL, • 3PL consolidates with other goods currently, • 3PL services beyond standard might result in extra cost. *Freight & Packaging* • Goods having special- and bulky packaging, • Lightweight goods cannot have heavy goods stacked on top of them. *Supplier relationship & power balance* • Suppliers delays deliveries by 1-2 days, • Deliveries very important to arrive the planned date. *Geography and transport weight* • Low vol. weight per shipment. • A mix of high- and medium frequent deliveries, • LTL geographically far away from each other.	*Fisher* • Products identified neither as fully functional, nor innovative, • Low margin of error the weeks before production date. *Kraljic* • Many less critical items with low risk and profit impact, • Several leverage items with low risk, • Bottleneck items with low profit impact. *Road transport requirements* • Consolidation opportunities from ordering company. *Freight & Packaging* • Mix of light- and heavy goods, • Lightweight goods stackable mainly on top of other goods, • Weekly scheduled deliveries already exist. *Supplier relationship & power balance* • Safety stocks reduce risk of late deliveries having a direct effect on production, • Multiple supplier options, were the suppliers not to cooperate, • Allowed delayed arrival days, • All deliveries done through FG's 3PL provider. *Geography and transport weight* • LTL shipments within the same geographical areas, • High frequency deliveries with relatively high vol. weight, • A mix of high- and medium frequent deliveries, • Many suppliers within same frequency group close to each other.	*Fisher* • Recommendations towards responsive supply chain design implies less opportunities for consolidation. *Kraljic* • Several suppliers within the same geographical clusters analyzed as bottleneck and strategic. *Road transport requirements* • Limited working hours, • Every stop takes up some time. *Freight & Packaging* • Non-stackable goods, • Unprotected goods. *Supplier relationship & power balance* • Really bad supplier relationships, • Large actors, unbalanced power of negotiation, • No supplier options if the suppliers would not cooperate. *Geography and transport weight* • Geographical outliers, • A relatively large number of collection points needed to achieve FTL. *EOQ* • Too much optimization if focusing only on EOQ.

5.3.2 Kraljic Purchasing Portfolio

During the analysis of the developed purchasing portfolio, the main strength to emphasize is the wide spread of suppliers, the diversity of quadrant placements. If all suppliers would have been analyzed in the same category or even just all as having high supply risk or high profit impact, the transport optimization- and consolidation possibilities could arguably have been reduced. This can be compared to the theory from Schöneberg et al. (2013), explaining how consolidated routes are dependent on reliable plans and stable demand and delivery. So, by instead having a relatively even portfolio spread of suppliers, even within the same geographical clusters, arguably flattens the consolidation risks and strengthens the optimization opportunities. It should however also be noted that any supplier placement in quadrant other than the non-critical one can oppose as a weakness and a threat to risk-free shipment consolidation, but are arguably inevitable to avoid for a such a producer like FläktGroup.

5.3.3 Road Transport Requirements

To make sure it is physically possible to implement possible consolidation strategies and changes for inbound deliveries, the requirements of road freight must be analyzed and deeper considered as well. The main threat to shipment consolidation in this perspective is the physical limitation of truck drivers, their time and working hours. If one were to try and implement a route that collects orders and delivers them within a working day, the time is the limit according to the qualitative findings from the 3PL service provider. However, economic incentives for truck utilization balance this threat and provides strength in the perspective of road transport requirements as well (Oumer et al., 2015; Merrick and Bookbinder, 2010). Moreover, other aspects to consider regard the specific regulations the current 3PL service provider has on order handling and deliveries. A potential weakness for shipment consolidation if using a 3PL service provider accordingly is the minimum loading meters an order must have for it not to go via a terminal instead of with a direct (consolidated) delivery. If the route analysis implies that some orders with a lower average weight still might pose as a relevant stop in a consolidated route, the 3PL provider's regulations must be renegotiated or avoided, thus defining a weakness in Table 5.2. Furthermore, other negotiations or requests for additional services might result in extra costs when using a 3PL provider, thus also serving as a weakness for shipment consolidation opportunities and incentives. An opportunity on the other end is that the interviewed 3PL provider answered (see Table 4.5) that they still would be able to consider consolidating orders from the same geographical areas to the same destination.

5.3.4 Freight and Packaging

Part of the empirical findings in Table 4.1 and 4.2 regard all freight and packaging characteristics of orders from the filtered suppliers. The SWOT analysis provide emphasis on what characteristics appears as strengths for consolidation, what threatens it, and further weaknesses and opportunities. The packaging characteristics can be compared to the standard characteristics as described by Delego (2019) for instance. Initially, the findings consists of many orders of stackable goods, as well as well-protected goods for transport, and generally high usage of uniform transportation modes such as standard EU-pallets. These are considered as strengths for road freight in general and for implementing further transport optimization solutions, both in terms of stackability and compared to established transport standards (McKinnon and Campbell, 1997; Delego, 2019). Oppositely, some goods are less- or not at all stackable, these orders threatens the possibilities to include their suppliers in consolidated routes and further optimization strategies. As McKinnon and Campbell (1997) presents, stackable goods increase a truck's utilization rate and decrease the environmental impact of the shipments. Following, goods with specially designed- or odd sized packaging are further analyzed as weaknesses, whereas those who are lightweight but well-packaged are analyzed as opportunities since they can be placed on top of other goods and thus increase the transport utilization rate. They could however also act as weaknesses if they hindered goods from being stacked on top of them due to their low weight and frailness (McKinnon and Campbell, 1997; Muylaert and Stofferis, 2014).

5.3.5 Supplier Relationship and Power Balance

The empirical findings imply that there is a mix of good and less good supplier relationships. Most of them appear to be well-functioning or not commented upon, posing as a strength towards shipment consolidation as supplier relationships can influence the effectiveness of the inbound logistic performance (Ferrell et al., 2020; Vargas et al., 2018; Gadde and Snehota, 2000; Minner, 2019). With some suppliers however, the relationship and power dynamics seem to be relatively bad, thus threatening the freight performance ability (Ferrell et al., 2020). The analysis identifies several opportunities nonetheless, as some goods often being ordered was explained to have a safety stock in the production warehouse in Jönköping, and some were even said not to threaten the production if they were to arrive a day later than planned. Even though eventual transport optimization solutions should not lead to late arrival dates, the impact of the risk of it leading to delay reduces with goods with a safety stock or lower manufacturing importance. But, the other way around affects the consolidation opportunities as well, for deliveries with extra importance for planned arrival date, order consolidation might weaken the production performance, and must thus be considered during the route suggestion analysis as well.

5.3.6 Geography and Transport Weight

The SWOT analysis also highlight the aspects that started it all, the geographical placement of collection points and suppliers, and the average weight of each freight. From a transport utilization perspective, some typical strengths here are the large number of suppliers located near urban areas and within close reach of major roads and infrastructure. Close to urban areas might often mean an increased geographical closeness generally to other collection points, this enable SCL according to established theory (Ülkü, 2012). The more suppliers that are geographically close to both each other and to other locations essential for the transport provider, the higher utilization rate the transport might achieve (McKinnon, 2007). Oppositely, some suppliers are so-called outliers, they are positioned at a geographically farther distance from the other suppliers, threatening the probability of finding a consolidation solution that reduces the environmental impact and cost when including them in a route. Furthermore, the second aspect the SWOT analysis highlight is the average volumetric weight of orders from each collection point in the segment. A quick calculation of all combined average volumetric weight of the deliveries within each cluster (see Table 4.6) present an average load which does not fulfill a full truck load, thus definitively threatening the ability for an applied shipment consolidation to fulfill an optimal transport utilization weight (Campbell, 1995).

On one hand, it is the LTL orders that provide opportunities for route consolidation and optimization solutions (Minner, 2019; Hosseini et al., 2014). But on the other hand, those suppliers with an average weight explicitly low are interpreted as potential weaknesses instead, since they provide the lowest possibility of fulfilling a large enough transport utilization rate if they are consolidated with one another (McKinnon, 2007). Continuously, the analysis also considers the delivery frequency, whose variety similar to the volumetric weight also can pose as either a weakness or an opportunity. For instance, if aiming to consolidate orders from certain geographically close suppliers, their delivery frequency to FläktGroup's inbound logistics affects the overall freight performance and utilization rate. If their delivery frequencies are not coherent with one another, the route might be unbalanced and less beneficial. Whereas if they appear to have very similar frequencies, the advantages of consolidating their deliveries increase. Moreover, a balanced mix of frequency groups can from another perspective provide opportunities, if there are enough geographically close suppliers within the same frequency group so that routes can be scheduled in consideration of their number of deliveries per year.

5.3.7 EOQ

Finally, the SWOT analysis concludes how EOQ calculations provide strengths and threats when investigating freight optimization and consolidation opportunities. The calculated EOQ for each item provides an additional guideline and view to consider when analyzing and developing SCL solutions. The calculations from the empirical findings present areas in the supplier segment where order consolidation could beneficially be applied, thus lower financial order costs achieved. Based on some of the EOQ values calculated, one could recommend reducing the delivery frequency from some suppliers, whereas in a few other cases increasing the frequency. Considering these values can strengthen the economic incentives of applying any future suggested routes.

5.4 Consolidated Route Suggestions

As described in the SWOT analysis, the low average volumetric weight of each shipment and cluster threatens any possibility of implementing utilized, consolidated routes for the deliveries solely based on the segmented suppliers. Therefore, to achieve higher transport optimization and load utilization whilst still using common truck sizes, it is necessary to include other external goods that can be loaded and unloaded within the same geographical areas. However, finding the freight consolidation potentials among FläktGroup's suppliers first increases the chances of a contracted 3PL service provider achieving higher utilization rates in total. The routes that are therefore to be suggested in this section are recommended to be a part of a larger system coordinating utilized transport routes in Sweden.

The rest of the aspects found in the SWOT analysis are now taken into further consideration, to provide suggestions on which suppliers and items can be consolidated with each other. The suggestions are initially based on the geographical positions of the suppliers, as it is a central part of consolidation theories. Therefore, further consolidation opportunities are investigated within each categorized geographical cluster as inspired by the SWOT analysis. Suppliers that theoretically should be possible to consolidate with one another can be viewed in the second column from the right in Table 5.3. Within each cluster, the suppliers are systematically compared to each other in all aspects the analysis has found essential. The suppliers and items who after this process still obtain consolidation potential, form the following route options presented in the columns to the left in Table 5.3. Every optional route is within the weight limit for a truck and trailer with maximum weight of 34 tons (Delego, 2019), and their total distances from the first loading points to unloading are within the time limit of a maximum of 8 working hours a day for drivers. Furthermore, during the basic route planning calculations, some pick-up locations were calculated to be more efficient not to be consolidated, as those collections would lead to an increase in total transport distance.

A few suppliers from different geographical clusters are being compared to each other as well, and in some cases combined in routes beyond the cluster borders. The results of the analysis within the clusters are developed and explained in further detail below. Furthermore, the route options' environmental impacts are to be calculated, to understand if, and in that case how much, emissions are saved by implementing each option. The environmental calculations are the last pieces towards establishing the final route suggestions.

Table 5.3: Route options to consider and calculate.

Cluster	Suppliers that can be consolidated	Do not consolidate (look for collab./3PL)	Route option 1	Route option 2	Route option 3
A	A5, A8, A3, A9, A7, A6, A2, A1, A10.	A4	A5, A8, A3, A9, A7	A5, A8, A6, A2, A1, A10	-
B	B8, B1, B3, B9, B4, B6, B2, B5, B12	B7, B11, B10, B2	B9, B3, B4, B5, B1	B9, B3, B5, B4, B5	B8, B12
C	FG, C2, C7,	C6, C4, C1, C3, C5	FG, C7	C2, FG, C7	C2, FG, C7 + D1
D	D1, D2	D4, D3	D1, D2	D1 + C2, FG, C7	D4 + E2, E4, E3, E5
E	E5, E4, E6, E2, E3	E1, E7	E2, E4, E3, E5 + D4	E6, E2, E4, E3, E5 + D4	-

5.4.1 Cluster A Opportunities

In cluster A, four suppliers, A4, A5, A6, and A8, were identified as either strategic or bottleneck in the purchasing portfolio analysis. Thus, if all four supplier deliveries were to be consolidated together, the risk of the transport affecting the inbound logistics negatively would increase by a relatively large amount. Instead, to spread the risk in combination with aiming for geographical closeness, the strategic- and bottleneck supplier deliveries in this cluster were divided into two transport routes. The first route option includes suppliers A5 and A8, which are both geographically close to each other and have similar delivery frequencies. The other suppliers to consolidate in the route are A3, A7, and A9, as they are geographically close to each other and originate from the Gothenburg metropolitan area. However, the delivery frequencies of the three latter suppliers are lower than that of the two with high-frequency deliveries, A5, and A8. Thus, shipments from the medium-frequency suppliers will not be able to be loaded on every truck that picks up the high-frequency deliveries, as there won't always be any orders to collect. A solution to this frequency imbalance is to every other week ship the remaining medium frequency suppliers, A1, A2, A6, and A10, with A5 and A8. Thus matching the frequency of both supplier groups while maximizing truck utilization.

On another note, supplier A4 is decided to not be included in any of the routes as its geographical location is not beneficial for an optimal routing. Additionally, the special packaging led to trouble in stacking, and the risk did not justify consolidation, as A4 was identified as supplying bottleneck items. The two suggested combined routes for the A cluster can be seen as green and blue in Figure 5.2.

Table 5.4: Cluster A - route option 1.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
A5	67	135	9024	10095	9468	627	9936	8925	824
A8	93	124	11502	12868	12069	800	12666	11377	1050
A3	39	110	4308	4820	4520	300	4744	4261	393
A9	35	153	5339	5973	5602	371	5879	5281	488
A7	30	150	4506	5041	4728	313	4961	4457	411
Total		672	34679	38798	36387	2411	38186	34300	3167
Consolidated	93	208	19344	21642	20297	1345	21300	19133	1766
Change				**-44%**	**-44%**	**-44%**	**-44%**	**-44%**	**-44%**

Table 5.5: Cluster A - route option 2.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
A5	67	135	9024	10095	9468	627	9936	8925	824
A8	93	124	11502	12868	12069	800	12666	11377	1050
A6	20	198	3954	4424	4149	275	4354	3911	361
A2	15	153	2291	2563	2403	159	2522	2266	209
A1	48	153	7344	8216	7705	511	8086	7263	671
A10	21	155	3256	3643	3417	226	3586	3221	297
Total		917	37370	41810	39211	2598	41150	36963	3413
Consolidated	93	310	28830	32254	30250	2005	31746	28515	2633
Change				**-23%**	**-23%**	**-23%**	**-23%**	**-23%**	**-23%**

The environmental calculations in Tables 5.4 and 5.5 implies that implementation of either route option in cluster A would result in a reduction of greenhouse gas emissions compared to individual deliveries. Route option one lead to a larger percentage of emission savings than route option two, arguably due to more suppliers in option one are located at shorter distances to each other, thus the total distance saved by route consolidation is larger, thereof increased savings. Although in this case, the suggestion is to implement both routes combined, just scheduling them to ship on different dates.

5.4.2 Cluster B Opportunities

Cluster B includes suppliers located in the south of Sweden. It consists of several identified strategic suppliers, B1, B3, B8, and B9, and bottleneck suppliers, B5 and B10. The rest (B2, B4, B6, and B11) were either identified as supplying leverage- or non-critical items. Supplier B10 is too far away geographically from the other suppliers for it to be effective to consolidate its deliveries with the others.

Suppliers B3 and B9 form together an attractive base point for the route as they have high delivery frequencies and are located geographically close to each other. Suppliers B4 and B5 are also good candidates for consolidation as they have similar properties as B3 and B9. They are in the same frequency groups, and as far as the empirical findings show, they are often delivered with similar freight- and packaging characteristics. Furthermore, supplier B6 has an excellent geographical position to be included in a consolidated route with the southern suppliers, as a truck driving such a route would pass by B6 anyhow. However, compared to the other suppliers with consolidation potential (B9, B3, B4, B5, and B1), supplier B6's delivery frequency is notably lower. The recommendation is to include supplier B6 in the route options but to emphasize that it does not necessarily mean that goods must be collected every time the truck passes. Instead, the routes are suggested to schedule for loading B6 orders only once in a while in accordance with the supplier's delivery frequency.

Supplier B2 is decided not to be included in a consolidated route with the other suppliers in the segment. The reason mainly has to do with its items' characteristics, since B2's items do not allow for additional goods to be stacked on top. Such characteristics would be a problem specifically for this case as B2 would have to be one of the first stops in a consolidated route due to its geographical distance to JKP. Having non-stackable goods as early stops in a route reduces the chances of a successful consolidation. To further increase the utilization of the truck, the medium frequency supplier B1 could be consolidated with the other suppliers with consolidation potential every other week, similar to supplier B6. Thus, in Tables 5.6 and 5.7, the route options involve the same five suppliers with analyzed consolidation potential, but additionally include supplier B1 as a starting point in route option 1.

Two additional suppliers in cluster B are suppliers B8 and B12. While these are too far away geographically to be effectively consolidated with the other suppliers, the two are very close to each other geographically and have similar delivery frequencies. This means they could effectively be consolidated in a joint shipment. As B8 is a high-risk supplier, it would be strategically beneficial to always have the orders being directly delivered to FläktGroup. In the case of FläktGroup's current transport provider, having two pallets will ensure direct delivery instead of via a warehouse. Consolidation of shipments from B8 and B12 will help ensure this and lower the risk of the shipment. The consolidation potential is illustrated in Table 5.8.

The suggested routes for cluster B can be seen in orange and yellow in Figure 5.2. Route options 1 and 2 are combined in the figure as the orange route, route option 3 can be seen in yellow.

Table 5.6: Cluster B - route option 1.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
B9	111	180	19980	22353	20964	1389	22001	19762	1825
B3	102	110	11220	12553	11773	780	12355	11098	1025
B4	87	67	5855	6551	6143	407	6447	5791	535
B5	60	66	3942	4410	4136	274	4341	3899	360
B1	51	237	12087	13523	12682	840	13310	11955	1104
B6	28	39	1095	1225	1149	76	1206	1083	100
Total		699	54179	60614	56847	3767	59659	53588	4947
Consolidated	111	410	45510	50916	47751	3164	50113	45013	4156
Change				**-16%**	**-16%**	**-16%**	**-16%**	**-16%**	**-16%**

Table 5.7: Cluster B - route option 2.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
B9	111	180	19980	22353	20964	1389	22001	19762	1825
B3	102	110	11220	12553	11773	780	12355	11098	1025
B4	87	67	5855	6551	6143	407	6447	5791	535
B5	60	66	3942	4410	4136	274	4341	3899	360
B6	28	39	1095	1225	1149	76	1206	1083	100
Total		462	42092	47092	44165	2927	46349	41633	3844
Consolidated	111	270	29970	33530	31446	2084	33001	29643	2737
Change				**-29%**	**-29%**	**-29%**	**-29%**	**-29%**	**-29%**

Table 5.8: Cluster B - route option 3.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
B12	18	162	2916	3262	3060	202	3211	2884	266
B8	22	155	3410	3815	3578	237	3755	3373	311
Total		317	6326	7077	6638	439	6966	6257	577
Consolidated	22	170	3740	4184	3924	260	4118	3699	341
Change				**-41%**	**-41%**	**-41%**	**-41%**	**-41%**	**-41%**

Looking at the emissions reduction from the two different alternatives the orange route has a much larger reduction in pollution emissions if B1 is not consolidated. However as B1 has lower frequency than the other suppliers and will not be picked up every time, the reduction will be greater for the suggested route. The reduction in emissions from the yellow route is almost 50% as both suppliers are close to each other and have similar frequency which means that the reduction should be close to half.

5.4.3 Cluster C Opportunities

Cluster C includes suppliers located in the central Stockholm area. Supplier C6 is going to be replaced next year and will therefore not be further considered for consolidation. Out of the other suppliers, one is strategic (C2) and its goods cannot be stacked. Two of the suppliers are considered bottlenecks, suppliers C5 and C7. FläktGroup's other production site, FG, are identified to deliver leveraged items to Jönköping. The rest are considered non-critical (suppliers C1, C3, and C4). The two most attractive suppliers to consolidate are FG in combination with C7. These two both have high-frequency deliveries and are located geographically close to each other. They also fulfill a relatively large volumetric weight and are suggested therefore as cluster C's first route option. FG's items might be bulky but are explained to still enable stacking of other goods on top, which could be a good combination with C7's lighter goods. Currently, these deliveries are going almost daily. From a weight and EOQ perspective, having less frequent deliveries could be better from a truck utilization and coordination perspective.

Furthermore, suppliers C1, C3, C4, and C5 could also be consolidated in a route in the perspectives of freight- and packaging characteristics, risks and impact, and geographical closeness. However, these suppliers have significantly low average volumetric weight and are positioned in a dense urban area, arguably adding a lot of traffic time for loading. Forcing the orders to be collected all at the same time might therefore result in neither reduced delivery distance nor significantly increased volumetric weight. Therefore, they might not be as beneficial to initially include in a consolidated route option after all.

Supplier C2 could, because of its strategic advantage, be consolidated with the other high-frequency suppliers FG and C7. However, the items delivered from supplier C2 are explained as light and should not have goods stacked on top of them. Additionally, supplier C2 orders are being delivered with a medium frequency. So, is the supplier to be consolidated with FG and C7, it would be a shipment going once a week if there is space in the truck for more fragile goods, enabling route option 2 for the C cluster.

Additionally, the suggested route options 1 and 2 for cluster C have opportunities for consolidation with suppliers in cluster D, which is why this combination is presented as a third route option in Table 5.11. The route options are presented together as the purple route in Figure 5.2.

Table 5.9: Cluster C - route option 1.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
FG	150	284	42600	47660	44698	2962	46909	42135	3890
C7	263	273	71799	80327	75335	4992	79061	71015	6556
Total		557	114399	127987	120033	7954	125969	113150	10447
Consolidated	263	302	79426	88860	83337	5523	87459	78559	7253
Change				**-31%**	**-31%**	**-31%**	**-31%**	**-31%**	**-31%**

Table 5.10: Cluster C - route option 2.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
FG	150	284	42600	47660	44698	2962	46909	42135	3890
C7	263	273	71799	80327	75335	4992	79061	71015	6556
C2	47	342	16074	17983	16866	1118	17700	15899	1468
Total		899	130473	145970	136898	9072	143669	129049	11914
Consolidated	263	369	97047	108574	101826	6748	106862	95988	8862
Change				**-26%**	**-26%**	**-26%**	**-26%**	**-26%**	**-26%**

Table 5.11: Cluster C - route option 3.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
FG	150	284	42600	47660	44698	2962	46909	42135	3890
C7	263	273	71799	80327	75335	4992	79061	71015	6556
C2	47	342	16074	17983	16866	1118	17700	15899	1468
D2	75	80	6008	6721	6303	418	6615	5942	549
D1	53	48	2560	2864	2686	178	2819	2532	234
Total		1027	139040	155555	145887	9668	153103	137523	12697
Consolidated	263	437	114931	128582	120591	7991	126555	113677	10495
Change				**-17%**	**-17%**	**-17%**	**-17%**	**-17%**	**-17%**

For cluster C, the greatest emissions are achieved when consolidating the highest delivery frequencies. If C2 is added as in route option 2, it is still a large reduction in emissions. If the two suppliers from cluster D are added as in route option 3, a truck will have to take a longer turn to pick them up, but there are still reductions in emissions. However, the frequencies of these two suppliers are low, meaning that the total reduction for the route will be higher and closer to that of suggestion cluster C - route option 2.

5.4.4 Cluster D Opportunities

Cluster D considers suppliers close to the Jönköping manufacturing plant. Two suppliers, D3 and D4, are very close to the factory and delivers shipments with low weight, meaning they might not benefit from being consolidated but could potentially be picked up if a truck is passing by the same day. This is the case for D4 who is in the path of cluster E, if there is still room in that truck. Regarding the other suppliers, D2 is identified as a bottleneck and D1 as leverage. Supplier D2 delivers the same product as C7 and has good consolidation opportunities as the route from Stockholm could pass through and pick up D2 without losing a lot of time, as described from cluster C - route option 3 (Table 5.11). In addition to this, after D2 the truck has to pass through D1 which makes it a good candidate for consolidation as well. The routes for cluster D are part of the purple and red routes Figure 5.2.

Table 5.12: Cluster D - route option 1.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
D2	75	80	6008	6721	6303	418	6615	5942	549
D1	53	48	2560	2864	2686	178	2819	2532	234
Total		128	8567	9585	8989	596	9434	8474	782
Consolidated	75	103	7725	8643	8105	537	8506	7641	705
Change				**-10%**	**-10%**	**-10%**	**-10%**	**-10%**	**-10%**

The reduction in emission for consolidation of the goods in cluster D is not large on its own but combined with the route C it can give better utilization of the truck and still a larger reduction in emissions.

5.4.5 Cluster E Opportunities

Cluster E includes suppliers located north of FläktGroup Jönköping. In this cluster, suppliers E1 and E5 were identified as delivering strategic items in the purchasing portfolio analysis, and suppliers E4 and E7 bottleneck. The other suppliers in the cluster were identified to deliver non-critical items (suppliers E3, E2, and E6). Moreover, there are two outliers in the cluster, suppliers E1 and E7. Both suppliers' deliveries arrive with a medium frequency and maybe would be considered worthy to be consolidated if their frequencies increased. But, in the current setting, the additional distance needed to be covered is not justifiable for consolidation.

Regarding the other, closer suppliers there is a good mix of high-frequency deliveries, strategic-, bottleneck- and non-critical items, and all are stackable or can have goods stacked on top of them. Supplier E2's items are described as heavy, they have thus a good potential to be loaded early in the route, to enable consolidation with other lighter goods stacked on top. For instance, E4's goods could be stacked on top of E2's.

However, supplier E6 is located north of supplier E2, but close enough for its goods to be beneficial to be consolidated as well. The delivery frequency for supplier E6 is a bit lower than for supplier E2 and could be included in a consolidated route when the orders allow for it. Therefore, cluster E's route options are divided into two; one option including supplier E6 as a first stop in the route, and one not including E6 with the other suppliers with consolidation potential. Furthermore, supplier E5 produces heavy and unprotected items and should thus not have too heavy goods stacked on top. From a geographical perspective, supplier E5 is positioned late in a route option towards Jönköping, so its product characteristics can still be considered when being planned for loading with other goods. However, the relationship with E5 was said to be a bit tricky which might result in complications when wanting to consolidate. If the relationship does not allow for changes in freight operations, route options 1 and 2 can be suggested to be implemented without supplier E5 instead.

The route options and their environmental impact are presented in Tables 5.13 and 5.14. The visualization of the cluster's routes is combined and illustrated as the red route in Figure 5.2.

Table 5.13: Cluster E - route option 1.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
E2	62	211	13082	14636	13726	910	14405	12939	1195
E4	53	185	9805	10970	10288	682	10797	9698	895
E3	17	193	3281	3671	3443	228	3613	3245	300
E5	150	126	18900	21145	19831	1314	20812	18694	1726
D4	41	33	1365	1527	1433	95	1503	1350	125
Total		748	46433	51948	48720	3229	51130	45926	4240
Consolidated	150	253	37950	42458	39819	2639	41788	37536	3465
Change				**-18%**	**-18%**	**-18%**	**-18%**	**-18%**	**-18%**

Table 5.14: Cluster E - route option 2.

Supplier	Deliveries/ year	Distance to site JKP [km]	Distance per year [km]	CO2 total [kg]	CO2 fossil [kg]	CO2 biogen [kg]	CO2e [kg]	CH4 [g]	N2O [g]
E2	62	211	13082	14636	13726	910	14405	12939	1195
E4	53	185	9805	10970	10288	682	10797	9698	895
E3	17	193	3281	3671	3443	228	3613	3245	300
E5	150	126	18900	21145	19831	1314	20812	18694	1726
D4	41	33	1365	1527	1433	95	1503	1350	125
E6	45	258	11610	12989	12182	807	12784	11483	1060
Total		1006	58043	64937	60902	4036	63914	57410	5300
Consolidated	150	302	45300	50681	47531	3150	49882	44806	4137
Change				**-22%**	**-22%**	**-22%**	**-22%**	**-22%**	**-22%**

With cluster E having large distances the decrease of emissions are large but not as large if each suppliers where grouped together more. It has an advantage that the suppliers are located close to major roads and follows a path that the delivery truck would otherwise follow. This results in as shown, a good reduction of pollution emissions.

5.4.6 Final Route Suggestions

The suppliers and pick-up points are mapped together with the suggested route options in Figure 5.2. A note to again take into consideration here is that the routes in the figure combine several route options from each above-described cluster, and are illustrated accordingly. However, all collection addresses in each route are not necessarily to be consolidated together in one shipment, but instead according to the suggested route options in each clusters, represented in their respective tables with environmental calculations above. For instance, the collection points colored in blue in Figure 5.2 represent suppliers to be consolidated from cluster A, but this either according to cluster A's route option 1, which is illustrated as blue lines in the figure, or according to cluster A's route option 2, the route colored in green instead. Similarly, the collections points in cluster B are presented with an orange color, with the cluster's route options being either orange or yellow. Here the orange-lined route represents two options, options 1 and 2, where the only difference is whether to include and start with supplier B1 or not. Cluster B's route option 3 is instead colored in yellow on the map.

Figure 5.2: Different route suggestions for inbound deliveries to FläktGroup JKP.
Note. Visualized using the VeRoViz (2023) software.

6. Discussion

Following the analysis, there are some discussion points to highlight, enabling reflections on the contributions of the master's thesis and the execution of the work. First, some reflections are to be made surrounding the interpretations of the empirical findings and the development of the analysis thereof. Moreover, connections between the analysis and already existing theory from the frame of reference are to be drawn, the connection points illustrate the relevance of the analytical findings and route suggestions. They also enable reflections on possible areas of improvement, and how changes in the methodology and execution of the research and analysis would have affected the outcome of the master's thesis.

6.1 Discussion on Findings

A discussion can be made of why the analysis was initialized from the perspective of FläktGroup's finished products. Although these were not within the scope of the master's thesis, a brief analysis of the finished products provided an holistic objective of what would be an optimal supply chain design. Thus, it determined a direction that could be followed for the remainder of the analysis. By proposing an efficient supply chain as the most optimal supply chain design according to finished product characteristics, the continuous search for route consolidation opportunities was motivated. As the methodology explains, for functional products, that is efficient supply chains, the focus should be on working with optimization activities, for instance consolidated transport solutions.

Several parameters were understood to affect or constrain freight consolidation possibilities in various ways. However, the factors investigated in the data processes and the analysis are arguably not the only ones possible to consider, or that influence operations within inbound logistics. As theory explains, transportation is tightly integrated and correlated to overall logistics solutions, thus the number of related factors is larger than what could be included in this thesis. The factors decided to be investigated deeper were merely the aspects interpreted most fitting for this specific case to start analyzing. The selection of them was supported by established literature theory as well.

Regarding the SWOT analysis, it provided an understanding of several potential areas of improvement surrounding consolidated transport solutions. Such areas include not only external ones that could be improved by strategical suggestions on optimized transport flow and changes in freight coordination, but also internal areas of improvements that could be achieved without requiring changes for external actors or freight. One of the highest potentials for internal improvement in their inbound logistics flows FläktGroup themselves can impact is the coordination of orders and order placements. The findings from the data collection indicated that most inbound flows are ordered and moved independently to the factory. Would orders instead be coordinated and consolidated, large improvements could be made to increase the utilization of the inbound transportation trucks.

A question to answer is whether the suggestions for improved transport optimization would affect manufacturing effectiveness and logistics costs or not. To begin with, it is hard to entirely know for sure all the effects that operational changes can have on a well-established logistics system. But, the analysis has focused on making sure the right type of supply chain design is followed in accordance with FläktGroup's deliverables and created value. This in addition to considering the manufacturing policy of FläktGroup as well. Therefore, the search for optimized transport solutions via consolidation does potentially not conflict with the overall design that would be recommended for FläktGroup if they were to investigate such overall changes in the future. Thus, they would arguably not negatively affect the manufacturing effectiveness. Regarding logistics costs, one could argue that if anything, the inbound logistics costs have large potential to decrease with the final route suggestions made in the analysis. The calculations indicate a reduction of distance traveled per delivery if implementing such consolidating routes. As the fixed cost for fuel and driving time for the 3PL service provides decreases, so should the price of transport. Additionally, there are no recommendations requiring a change of 3PL service provider, if that is not the company's wish. Therefore, one could instead argue that by finding route optimization solutions and communicating such to the 3PL provider, the buyer could have a better position in future price negotiations, and potentially reduce transport costs. However, there is a risk that the 3PL service provider regards the route suggestions as demands for extra services, and might argue grounds for charging for extra service costs. In that case, it is important to take the risk of such costs into consideration as well and to make an extensive evaluation of potential cost changes before implementing any transport-changing requirements.

While FläktGroup has the potential to consolidate goods it is important to remember that all goods do not necessarily need to be consolidated to improve inbound logistics effectiveness and environmental impact. Because, some suppliers or components were presented to either be too far away geographically or have product characteristics not fit to be consolidated with others. Besides, the recommendation for their supply chain design also demands for some flexibility, due to the innovative traits that are present in their finished products.

6.2 Connection to Frame of Reference

The mapped current delivery system partly have traits equal to an area forwarding service. This since the contracted 3PL service provider occasionally uses their own hubs as consolidation points before final delivery, at least when the order volume is below a significantly low weight limit. Continuously, it can be argued that the analysis had such weight limit for AF services in consideration when establishing consolidated route options, thus avoiding any consolidation point services.

The proposed route options for optimizing inbound logistics at FläktGroup share several similarities with consolidated delivery systems described in existing literature. The final route suggestions take inspiration from and can be compared to systems such as milk-run deliveries, cross-docking, and consolidation hubs. The analysis does however not primarily consider consolidation points or cross-docking facilities as part of the suggested routes. This has to do with the fact that optimizing such a system would require increased information flow and coordinating activities with additional external actors.

Besides, FläktGroup has expressed no interest to reduce storage ability currently, an otherwise common incentive for using a form of consolidation hub in route planning. Instead, the final route suggestions have more traits in common with a milk-run delivery system. The routes are planned to be delivered directly without any additional handling of goods between loading and unloading. Furthermore, they involve several pick-up locations and suppliers, in a schedule always involving the same actors for each route. Compared to different MR systems, the routes have most in common with an open tour MR, where the 3PL service provider should be recommended to return freight from the unloading point location (Jönköping), back to the urban areas where most of the routes' starting points are located. However, a difference from an MR system is that the routes also still have room left for a 3PL service provider to include additional goods in the forward transport freight. This as long as the goods in external networks have consolidation potential with FläktGroup's goods as well. Another difference to a typical MR system is that the final route suggestions in the analysis does not include a suggestion of a concrete time schedule. Such schedules could however be recommended to investigate further before any future implementations.

The final route suggestions can also be connected to established policies in SCL theory. Since the focus has been to optimize road transport solutions for the current external inbound logistics flow, the main policy that has been followed has been to consolidate freight but keep the order sizes intact. However, the actual order- and delivery frequencies are generally higher than that of the optimal according to EOQ calculation. This must not mean that anything is at fault as the company produces with an MTO policy only, and not having every item in stock could yield high economical advantages therefore. But, there are EOQ calculations for some components that indicate positive effects if the solutions were to follow a hybrid policy instead. Thus also reducing the number of orders per year. Although for now, the suggestions relate mainly to a freight consolidation policy. Furthermore, while implementing a reduction in freights per year for a product could result in benefits, it implies that the suppliers can carry it out. There are uncertainties and future investigation potential regarding if the suppliers are able to send everything that is ordered with one shipment. In the suggested solutions, some orders are being divided into several deliveries instead. Another threat is that the suppliers might not be able to facilitate potential fixed order dates of the suggested routes, which increases the risk of unplanned delays instead. This is part of why it is important to work on a collaboration with suppliers so that communication and information sharing surrounding such problematic areas can be resolved.

6.3 Potential Improvements

The recommendation of the most optimal supply chain design, that influenced the suggestions on improvements in the inbound logistics flow, can be further discussed. Since information regarding the characteristics of FläktGroup's finished products was gathered based on one semi-structured interview and an informal meeting, the risk for potential misinformation or faulty interpretation of the answers is relatively high. A potential improvement would be to interview a larger number of actors within FläktGroup that has insight into the products manufactured for customers, to make an even more qualitative base of information. However, the investigation of the optimal supply chain design was not the main focus of the master's thesis. It was merely an extra step to make sure the direction was kept fairly correct. Therefore, the data-gathering process regarding the finished product is argued to still be sufficient enough for fulfilling the purpose of the master's thesis.

While the master's thesis focuses on the improvements of the inbound logistics, it is important to remember that it is only a part of the entire value chain. Opportunities to coordinate outbound logistics with inbound logistics have not been explored. In addition to this, no further exploration has been made on possible external vertical or horizontal collaborations outside the company. Logistics collaboration could lead to a streamlining of operations and cost reductions. Therefore, mapping and analysing both suppliers- and competitors potential impact on the network's sustainability, could be done as a next step as well.

The scope of the freight data gathering was limited to involve solely data points from the largest contracted 3PL service provider of national incoming goods to FläktGroup. However, there are additional freight flows within inbound logistics carried by other logistics service providers. These could potentially be consolidated or optimized as well, even though they are in smaller volume. Therefore, a potential point of improvement in the master's thesis is to also identify those shipments and include them in the mapping of the current transport flow. By doing so, the outcome of the analysis and suggested route option might have had a slightly different result.

Additionally, the data gathered from the 3PL service provider only included numbers from last year's (2022) freight. Thus, an even more accurate map of the current flow could have been achieved if the numbers were traced back several years. On the other hand, FläktGroup's representatives expressed that last year's freight represents their freight accurately, and almost all suppliers including in last year's deliveries are to be kept with similar demand this year as well. So, by only including last year's data points, unnecessary data potentially regarding suppliers being out of date is avoided.

In the report, the suggestion for consolidation only addresses the medium- and high-frequency deliveries. This does not mean there are no opportunities for the low frequency groups. However, their impact is not as significant. With the given route suggestions and constant routes that are driven, opportunities to consolidate them into the routes could be explored further. Of course, a further suggestion could be to look into areas of improvement for the freight of the lower frequency groups as well. But, the higher groups can be argued as the best approach to start with. It is reasonably not efficient to consolidate goods from radically different frequency groups, like one time and high for example, as an effective freight and order placing flow would be hard to achieve. In such an aspect, it could also be discussed whether it is optimal to consolidate goods from the high delivery frequency groups with goods from the medium. If there were more volume within both the two frequency groups, a more optimal solution could be to consolidate them separably.

Another aspect of uncertainty within the consolidation opportunities is the spreading of the risk according to the developed purchasing portfolio. On one hand, there is a higher risk of consolidating more high-risk components together, as there is a risk that something happens to the truck. However, on the other hand, there is a lower risk of consolidating high-risk components as it then results in direct deliveries to FläktGroup according to their current 3PL provider. Lowering the risk as they do not pass through a 3PL consolidation hub. There is a need for further exploration to determine what method is the best for the risk.

Regarding working with a 3PL service provider, an uncertainty is that they have other customers that they consolidate with. They also keep their information on utilization-rate and statistics mainly internal. This means that FläktGroup might not be able to know exactly what impact the freight activities within their inbound logistics have on the environment. This is also connected with the uncertainty of which truck size should be used for transport. FläktGroup's transport flow could benefit from the carrier using a smaller truck for most of their deliveries, in terms of utilization-rate. Even consolidated, their shipments does not even reach half the volume for a larger truck. Using smaller trucks could potentially decrease environmental impact and would lead to less external goods needed to be consolidated, lowering the risk of transport for FläktGroup.

Concerning the environmental impact calculation, it only currently considers the factor of distance as an input. To get a better overview and more accurate results, the aspect of weight should be considered as well. However, due to the information uncertainty from using a 3PL service provider, an accurate estimation of the utilization-rate was deemed too hard to estimate. Therefore, the environmental analysis was merely done to compare the final route suggestion with the current inbound logistics system. Additionally, for an even thorougher environmental impact analysis, an LCA would be required to analyze all environmental aspects of the inbound logistics.

7. Conclusions and Recommendations

The master's thesis set out to analyse the current solution of FläktGroup Jönköping's inbound logistics. Where and how this could be approved without hurting the companies performance, and what effect the improvements would have. With this purpose in mind, three research questions outlining the work of the thesis was established:

RQ1 How do the present inbound logistic solution look like for FläktGroup in Jönköping?

RQ2 Where in the inbound logistics are there opportunities for improvement through consolidation, without affecting the manufacturing plants effectiveness and logistics cost?

RQ3 How can the current inbound logistics be improved with a suggestion of consolidation via route planning, and what environmental effect does it have?

The methodology was a combination of both quantitative and qualitative data collection from primary and secondary data sources. Strategic analytical tools such as Fischer's model, the Kraljic matrix and a SWOT analysis, enable the data to be accurately interpreted. Finally, the potential environmental improvement was analysed using the NMTCalc calculator to asses greenhouse gas emissions from the current and consolidated inbound logistics system.

7.1 Conclusions

A map of the external freight of incoming goods from Swedish suppliers has been established. Raw freight data was filtered to create an initial and at first, a list of 136 suppliers was mapped and their geographical positions were visualized. These represented the total number of suppliers within Sweden. The study has identified how the current inbound logistics system is structured geographically and given vital insight to both the volume and frequency of the shipments for FläktGroup's inbound logistics.

The 136 suppliers were further categorized according to their delivery frequencies. A segment focusing on two of the category groups with the highest delivery frequency was continuously made. The segmentation resulted in 41 national suppliers to focus on with the highest potential for consolidated transport according to factors established from the theoretical framework. Furthermore, these suppliers were additionally categorized according to geographical clusters, to create an organized structure and to facilitate an easy way of finding consolidated route suggestions further on in the master's thesis. Following, a list of the 41 suppliers/pick-up points were supplied to internal representatives within sourcing and vendor planning at FläktGroup. A total of four semi-structured interviews, one group interview, and several weekly meetings were done to qualitatively map the present inbound logistics flow of the segmented suppliers from a perspective of supplier relationship, and product-, freight-, and packaging characteristics, and establishing a base for finding improvement opportunities. The interviews resulted in an extensive list of characteristics on the 41 suppliers, completing the answer to RQ1 and initializing the answer to RQ2.

The conclusive answer to RQ2 is a summary of the list from the empirical findings of the 41 suppliers' characteristics and consolidation potential, together with the analysis done with the introduced analytical tools and matrices. Besides the list of characteristics, the analysis was supported by and partly based on additional empirical findings regarding order quantity per year, factory ODT statistics, an external questionnaire to 3PL service providers, and findings from an additional qualitative data regarding finished product characteristics. The total result summarized is that there are opportunities for improvement for consolidation both from a holistic perspective of the entire supply chain network for FläktGroup, and from a perspective closer to the operations within their inbound logistics. The map of incoming Swedish freight to FläktGroup Jönköping present high capabilities of finding solutions that reduces the total distance of road transport, while still keeping the same pace and volume of goods and shipments to the production plant. Such capabilities are based on suppliers with similar or compatible characteristics in areas such as geographical locations, freight constraints, products demand, and order-, and delivery frequency.

Finally, to answer RQ3, the analysis enabled an opportunity to suggest consolidated route options. This resulted in a total of 11 potential route options within the 5 categorized geographical clusters of suppliers located relatively near Jönköping. The route options were then finalized and visualized into six main routes involving all suppliers included in the 11 route options. The routes have many traits similar to a milk-run delivery system. They are suggested with a recommendation to be run by a 3PL service provider who should include goods from external networks as well to increase transport utilization as much as possible. For each main route and route option, the environmental calculations resulted in reductions in greenhouse gas emissions from transport, with a decrease spanning from 10% to 44% between the route options. The environmental calculations are calculated from a worst case scenario perspective, and actual reductions are believed to be higher. In conclusion, the consolidated route suggestions are a good example on how one can start improving FläktGroup's inbound logistics.

7.2 Summary of Contributions

In the aspects of theoretical contribution, the master's thesis provides an example of case where established theory surrounding inbound logistics and road freight transport has been uniquely applied and fitted into a relatively large manufacturing company in Sweden. Thus enabling a reasoning that the development of logistics solutions is highly affected by the individual network characteristics and settings, but can be fundamentally based on generic considerations from previous studies and literature as well. The study also shows that companies can improve both effectiveness and environmental impact without adding additional resources or effecting the productiveness of the company.

The master's thesis has gathered information and reflected upon parameters and constraints affecting the inbound logistics flow for FläktGroup. To the company, it contributes an understanding of what factors that should be taken into consideration when mapping, evaluating, and improving freight transport systems. In particular, it looks at the aspects of consolidated transport solutions from a holistic perspective, starting from a view of the entire supply chain and the optimal design thereof. Then from there continuing to identify important parameters and limitations affecting the possibilities for freight transport optimization. Additionally followed by concrete route suggestions for SCL solutions. Conclusively, the suggestion is complete with calculations showing that even simple consolidation actions can lead to significant improvement both environmentally and operationally.

7.3 Future Recommendations

One suggestion for future research is to investigate the interplay between internal factors and the external inbound logistics system. For FläktGroup, this would involve looking into parameters related to the company's internal inbound logistics. The master's thesis recommend improving incoming freight flows by adjusting factors such as order volume and frequency in relation to EOQ. To determine if these adjustments would actually improve logistics effectiveness, further analysis is needed. For FläktGroup, this analysis would involve investigating whether changes to order frequency, order dates, delivery dates, or warehousing could lead to further improvements.

An additional recommendation is to investigate logistics collaboration surrounding the inbound logistics operations and freight flows. In particular, future research for vertical collaboration potentials could strengthen the sustainability of road transport solutions. By identifying external actors outside the supply chain network where a joint order- and transport consolidation could be achieved, the result could lead to an increased truck utilization rate and an additional lower environmental impact. Such research should therefore include a mapping of competitors-, and similar freight flows to and from the same geographical area as the production facility. Moreover, the recommendation suggests research to aim towards understanding potential impacts horizontal collaborations could have on the manufacturing performance and the finished product's quality.

When the entire inbound logistics has been researched and effectivized another future research suggestion is to continue looking at the outbound logistics for the company. As the effectiveness of the company is affected by the entire value chain, all different parts must interplay effectively as well. There are possibilities for future research if the utilization rate to and from the factory is improved. This means looking at different parts of the supply chain network, how they interplay, and what factors influence their possibility of collaboration. Additionally, the outbound flows should be analyzed to understand whether they give any possibilities for improved effectiveness without impairing the inbound logistics.

In conclusion, the master's thesis presents how there are sustainable improvements to be attained for a manufacturing firm in Sweden, without requiring drastic changes in the entire organizational structure. The constant need for effectiveness within logistics and supply chain management proves that there is a lot of research that could be further built upon. By holistically viewing internal and external factors, the entire value chain for both the company and all other actors involved could be improved.

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Appendices

A Given Files

Summarize of content in provided data sheets from FläktGroup

Name of data sheet	Description of contents
Spend Report	Total received volume and value of all ordered products and components to FläktGroup 2022. Including part- and supplier name and information.
List of Suppliers	List of all actors supplying parts to FläktGroup 2022, with supplier IDs, addresses and other contact information.
Supplier precision	Statistics of all supplier's performances delivering to FläktGroup 2022, including number of deliveries, and number of late or early deliveries.
Transport Statistics	Statistics from FläktGroup standard transport provider, containing information of all orders and collections, such as collection dates, addresses, freight volume, weight, volumetric weight, costs.

B All Swedish Pickup Points

Postal code	Avg. Vol. Weight [KG]	Deliveries/Year	Frequency class
554 74	16,46031746	63	High Frequency
283 43	40,23135135	111	High Frequency
438 70	18,87741936	93	High Frequency
331 35	2323,626667	60	High Frequency
542 35	3183,3976	150	High Frequency
695 72	1560	53	High Frequency
571 41	244,4913208	53	High Frequency
341 32	594,8298039	102	High Frequency
153 35	325,4389333	150	High Frequency
702 36	329,4677419	62	High Frequency
619 33	6465,960456	263	High Frequency
573 74	422,0789333	75	High Frequency
331 41	165,1609195	87	High Frequency
438 93	6198,46209	67	High Frequency
451 95	19,75	20	Medium Frequency
711 34	19,93333333	45	Medium Frequency
431 49	36,10285714	35	Medium Frequency
565 33	41,95121951	41	Medium Frequency
195 61	4,6925	16	Medium Frequency
623 50	5,9888	25	Medium Frequency
425 37	2,380952381	21	Medium Frequency
335 31	4,954545455	44	Medium Frequency
333 30	74,39130435	23	Medium Frequency
362 50	239,1018182	22	Medium Frequency
461 38	672,6666667	48	Medium Frequency
568 32	588,2714286	28	Medium Frequency
683 60	574,88625	32	Medium Frequency
415 02	62,18666667	30	Medium Frequency
514 50	2493,947368	19	Medium Frequency
436 32	215	15	Medium Frequency
695 31	133,5882353	17	Medium Frequency
511 42	2171,466667	39	Medium Frequency
302 65	402,44	25	Medium Frequency
128 30	72,04	13	Medium Frequency
645 91	213,1538462	13	Medium Frequency
362 31	1143,068889	18	Medium Frequency
263 37	71,65098039	51	Medium Frequency
175 62	325,5829787	47	Medium Frequency
187 30	85,25	12	Medium Frequency
175 62	109,3666667	30	Medium Frequency
302 50	17527,69231	26	Medium Frequency
791 77	89,99666667	12	Medium Frequency
136 50	22,66666667	3	Low Frequency
573 42	26,57142857	7	Low Frequency
302 41	41,9	8	Low Frequency
431 35	17,5	2	Low Frequency

512 53	33,6	2	Low Frequency
436 32	15,83333333	6	Low Frequency
266 32	42,7	4	Low Frequency
574 53	27,33333333	3	Low Frequency
142 50	12,37	4	Low Frequency
436 34	17,736	10	Low Frequency
556 52	7,465	8	Low Frequency
383 32	3	2	Low Frequency
431 53	6,102222222	9	Low Frequency
135 48	2,311111111	9	Low Frequency
721 37	7,4	5	Low Frequency
163 53	3,72	4	Low Frequency
438 54	7,462222222	9	Low Frequency
261 51	6,346666667	3	Low Frequency
582 73	4,25	4	Low Frequency
341 32	5,728	5	Low Frequency
568 31	5	3	Low Frequency
331 53	10,33333333	3	Low Frequency
254 66	5	10	Low Frequency
573 42	1,9	2	Low Frequency
554 63	1,496	5	Low Frequency
302 60	120,4	9	Low Frequency
565 33	65,94	2	Low Frequency
748 50	797,7866667	3	Low Frequency
556 28	780	4	Low Frequency
232 61	248,0133333	3	Low Frequency
602 23	356,7272727	11	Low Frequency
431 53	318,82	10	Low Frequency
335 73	296	3	Low Frequency
568 91	394,5	2	Low Frequency
602 29	780	3	Low Frequency
597 26	62,76	7	Low Frequency
754 50	92,86666667	3	Low Frequency
702 27	203,96	2	Low Frequency
555 92	220	2	Low Frequency
417 29	77,18666667	3	Low Frequency
422 46	2210	3	Low Frequency
153 35	1462,5	2	Low Frequency
383 32	54,82222222	9	Low Frequency
282 71	124,0711111	9	Low Frequency
335 73	943	9	Low Frequency
343 34	399,664	5	Low Frequency
431 53	68,58666667	6	Low Frequency
603 61	87,75	4	Low Frequency
432 32	17,92	1	One-Time Delivery
645 41	35	1	One-Time Delivery
553 03	25	1	One-Time Delivery

126 30	20	1	One-Time Delivery
523 72	3	1	One-Time Delivery
352 46	3	1	One-Time Delivery
645 41	5	1	One-Time Delivery
703 63	7,56	1	One-Time Delivery
451 55	7	1	One-Time Delivery
213 77	4	1	One-Time Delivery
291 62	8,96	1	One-Time Delivery
514 55	3,36	1	One-Time Delivery
331 79	7	1	One-Time Delivery
361 31	3	1	One-Time Delivery
582 73	8,96	1	One-Time Delivery
901 33	6,72	1	One-Time Delivery
602 38	5	1	One-Time Delivery
302 30	6	1	One-Time Delivery
417 55	6	1	One-Time Delivery
554 75	1	1	One-Time Delivery
541 34	1,68	1	One-Time Delivery
141 71	1	1	One-Time Delivery
584 22	1	1	One-Time Delivery
164 74	1	1	One-Time Delivery
372 38	305,2	1	One-Time Delivery
587 34	3900	1	One-Time Delivery
903 22	14040	1	One-Time Delivery
565 76	120,4	1	One-Time Delivery
302 50	15600	1	One-Time Delivery
564 35	2145	1	One-Time Delivery
504 64	55,72	1	One-Time Delivery
504 94	1170	1	One-Time Delivery
544 50	416	1	One-Time Delivery
213 76	201	1	One-Time Delivery
906 54	390	1	One-Time Delivery
435 33	192	1	One-Time Delivery
415 02	23400	1	One-Time Delivery
129 44	390	1	One-Time Delivery
200 01	16575	1	One-Time Delivery
252 32	1170	1	One-Time Delivery
973 45	91,28	1	One-Time Delivery
554 57	100	1	One-Time Delivery
721 36	4095	1	One-Time Delivery
702 27	780	1	One-Time Delivery
384 30	381	1	One-Time Delivery
112 28	2925	1	One-Time Delivery

C Interview Questions

Anna Skötte & Filip Vallin, Feb. 2023

Interview questions for Purchaser within FläktGroup in Jönköping

Intro of our master's thesis and aim of our work.

We will describe in brief what we have done until now, and how we have handled and categorize the data according to our scope and requirements.

Listed products/components and suppliers are those identified as LTL, and high- to medium frequent deliveries, presented in the provided Excel data sheet.

Overview of purchaser and the commodities she/he is responsible for

1. Describe your role within FläktGroup, how long have you worked at the company, and how long have you worked in your current position?

2. What are your key responsibilities?

3. If you were to reflect upon this, what would you say are the inbound logistics strength, weaknesses opportunities and threats at FläktGroup Jönköping?

Questions about listed products- and components of responsibility.

1. What kind/kinds of products are within your purchasing responsibilities? In general, describe their width, height, and general weight.

2. Is any of the components you're responsible for more important for the production than others?

3. How is the demand of the products you're responsible for. Do you have any components that are tailored specifically for you or only one supplier can supply.

Questions about listed suppliers of responsibility.

1. How close collaboration would you say you have of the supplier of interest? (Going through all suppliers high-medium frequency within the purchaser's area)

2. How would you describe the balance of power between your requirements and the supplier's? Are there any of the suppliers listed that puts high demands on FläktGroup as a customer instead of the other way around?

3. Are there several suppliers listed supplying similar products or components? If so, which?

Questions deeper about the freight of the listed products/components

1. How does the products/components usually arrive to you in Jönköping?
    a. By standard truck, smaller vehicles etc?
    b. In packages, Euro-pallets, specially designed packages, unpacked, etc?
    c. (If you don't know, who knows within FläktGroup instead?)

2. Can the product/component be delivered together with others? If not, why?

3. Do the listed deliveries usually arrive with other orders from the same areas in Sweden? Or with other products of a certain type?

4. We have noted that there are many LTL collections delivered with a high frequency in some cases. For each of these, are there possibilities for changing the placements of the orders to more seldom and with higher volume? This could be decided by storing possibilities, freight storing capabilities, demand knowledge, etc.

5. How many days too soon or too late is "okay" for the orders to be delivered? Does this number differ depending on what kind of products/supplier ordered? If so, which products of your responsibility is the most essential for arriving on time?

Discussion of our current route consolidation suggestions

Do you see any strengths or weaknesses in each of the routes we have suggested for now?

Checkboxes that should now have been answered:

- What are important aspects according to the purchaser for enabling route consolidation or optimization for them?

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