ASSESSING TRANSPORTATION MODES IN DISTRIBUTION NETWORKS

Lappeenranta–Lahti University of Technology LUT

Master's Thesis

2023

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Examiner: Professor Janne Huiskonen

ABSTRACT

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Master's thesis

2023

52 pages, 9 figures and 13 tables

Examiner: Professor Janne Huiskonen

Keywords: Supply chain management, distribution management, performance management, green supply chain management

In distribution management, transportation mode decisions have impacts on costs, environment, and service. The growing significance of environmental impacts in business encourages companies to embrace green supply chain management, enhancing both their image and profitability.

This thesis examines how changing transportation modes in current distribution would impact these factors for the case company. The aim of creating scenarios based on the data of the current transportation model is to identify how performance factors would be affected if volumes from direct truck deliveries were shifted to sea transportations.

The outcome of the research was costs and CO_2 emissions for each delivery route by the transport modes used in the company. It was found that the longer the delivery distance, the more sea transportation benefits when a significant share of the route is over the sea. In shorter distances, truck deliveries are more profitable from cost perspective but in terms of sustainability aspect sea transportation is more efficient. From service perspective road deliveries are more flexible compared to sea transport, which is dependent on the schedules of ships. Additionally, delivery times for road transportation are shorter than sea transportation because the sea route consist of multiple legs, whereas road transit usually involves only one leg directly from the mill to the consignee.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUT Teknis-luonnontieteellinen

Tuotantotalous

Elina Kummala

Kuljetusmuotojen arviointi jakeluverkostossa

Tuotantotalouden diplomityö

2023

52 sivua, 9 kuvaa ja 13 taulukkoa

Tarkastaja: Professori Janne Huiskonen

Avainsanat: Toimitusketjun hallinta, jakelun hallinta, suorituskyvyn johtaminen, vihreän toimitusketjun hallinta

Jakelunhallinnassa kuljetusmuodon valinta vaikuttaa kustannuksiin, ympäristöön ja palvelutasoon. Ympäristövaikutusten kasvanut merkitys liiketoiminnassa kannustaa yrityksiä vihreään toimitusketjuun vahvistamalla sekä yrityksen mainetta että kannattavuutta.

Tämä lopputyö tutkii, kuinka kuljetusmuotojen vaihtaminen case yrityksen nykyisessä jakelumallissa vaikuttaisi näihin tekijöihin. Nykytilatietoihin perustuvissa skenaarioissa tarkoituksena on tunnistaa, kuinka suorituskyvyn tekijöihin voidaan vaikuttaa, jos suorien rekkatoimitusten volyymit vaihdettaisiin merikuljetuksiin.

Tutkimuksen tuloksena saatiin yrityksessä käytetyille kuljetusmuodoille kustannukset ja hiilidioksidipäästöt jokaiselle toimitusreitille. Huomattiin, että mitä pidempi toimitusmatka, sitä enemmän merikuljetuksen hyöty kasvaa, kun merkittävä osuus reitistä on meriosuudella. Lyhyemmillä etäisyyksillä rekkatoimitukset ovat kannattavampia taloudellisesta näkökulmasta, mutta kestävyysnäkökulmasta merikuljetus on tehokkaampi. Palvelunäkökulmasta maantietoimitukset ovat joustavampia toisin kuin merikuljetukset, jotka perustuvat laivojen aikatauluihin. Lisäksi maantiekuljetusten toimitusaika on lyhyempi kuin merikuljetus, jonka reitit sisältävät useita osuuksia, kun taas maatiekuljetus kulkee suoraan tehtaalta vastaanottajalle.

SYMBOLS AND ABBREVIATIONS

Abbreviations

BAF	Bunker adjustment factor
CAF	Currency adjustment factor
CO_2	Carbon dioxide
ERP	Enterprise Resource Planning
GHG	Greenhouse gas
GSCM	Green Supply Chain Management
KPI's	Key Performance Indicators
NO_x	Nitrogen oxides
OTIF	On-Time In-Full
PM	Particulate matters
PMS	Performance measurement system
RFL	Ready for loading
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SO_x	Sulphur oxides
3PL	Third-party logistics

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1 Introduction

Motivation for improving transportation in the financial aspect is obvious, but the effects of freight transportation on the environment and society have become increasingly relevant. The increase in transport volumes has led to negative side effects, including the fragmentation of freight flows, overall population growth, and higher living standards. Emissions are a significant environmental harm caused by freight traffic, as the greenhouse gas effects on climate change are well-known. Negative societal effects of transportation include contribution to congestion, emissions impacting health, noise hindrance, and traffic safety. (Zijm et al., 2019, p. 478)

Decisions related to transportation are no longer made solely based on financial aspects. Legislation encourages or enforces the consideration of sustainability aspects, and organizations have become more aware of sustainable business practices and their public image. (Zijm et al., 2019, p. 478)

Maritime transport requires less infrastructure investment than, for example, rail, and it offers unlimited capacity. Intermodal transport, where cargo is transported by several transport modes, enables more sustainable traffic options than road transport. For example, utilizing rail, sea, and inland waterways could reduce external costs, air pollution, congestion, and accidents caused by transportation services. (Christodoulou et al. 2019)

1.1 Research background

This research assignment is for the case company that operates worldwide but the research scope is limited to Finland and continental Europe. This study specific focus is on optimizing the existing transportation model. The organization is utilizing a range of transportation modes for delivering goods through numerous ports and inland terminals. The current transport model has been causing occasional congestion in warehouses and terminals as well as complexity is not generating centralisation benefits in addition to having multiple contracts with several suppliers. To achieve the company’s goal of carbon neutrality, the logistics department needs to also consider the sustainability aspect. This research aims to identify effective options to enhance the overall logistics performance of the company reducing emissions simultaneously.

1.2 Objectives and limitations

The aim of this study is to contribute to the target company's efforts in achieving a more efficient, sustainable and streamlined supply chain. Using the current transportation model as a baseline, it is essential to understand the company's material flows. As-is analysis creates this baseline. New transportation model options are created using the results of as-is analysis. Without changing the volumes and material flows, the study examines how different transportation modes influence costs, CO_2 emissions, and service.

The scope of the research is limited to material flows from Finland to Europe, focusing only on one division the organization. This study is part of three research projects aimed at improving the distribution network, in which the divisions within its scope have already been defined. Geographical limitation is chosen to assess transportation modes observing short sea possibilities in Europe distribution. The review period is year 2022. During the review period, demand was high in the fluctuating market where the company operates. The volumes of high demand were optimal in this research as different transportation modes were required, and the delivered volumes were high as well.

To achieve the objective of the study, the main research question is stated, and it is divided into four sub-questions to help find the solution.

The main research question:

RQ: Can the distribution model be improved by changing transportation modes?

Sub research questions:

SRQ1: What are the outbound flows from Finland to Europe?

SRQ2: What are the costs of transportation models?

SRQ3: What are environmental impacts of current transportation model?

SRQ4: How does increasing sea transportation volumes impact the distribution model?

1.3 Research methodology

The research process started with a review of the relevant literature and an understanding of the transportation operations of the organization. As company was used several different transportation modes, specifications of each transportation modes were learned. Data processing and collecting was done independently once the data was available. Throughout the research process, there was an opportunity to engage with multiple supply chain professionals within the company, obtaining valuable insights through informal discussions.

For As-is analysis the data was got from the target company's Enterprise Resource Planning (ERP) system and internal Power BI datasets. The data was analysed and visualized using Excel and Power BI. The findings from the as-is analysis were used to create transportation modes, which are referred to as *scenarios* in this context. Scenario options were chosen in collaboration with logistics professionals from the target company. There were considered only existing routes which the company was already used in distribution, and new transportation routes were not under consideration. The primary objective was to optimize and standardize the transportation model based on current variables.

1.4 Structure of the thesis

After introduction chapter, there is a literature review that focuses on distribution management and represents the specifications of maritime transportation. The review examines the factors that influence the selection of an appropriate mode of transportation. The background for the literature review is supply chain management (SCM) from a planning perspective.

Chapter 3 focuses on performance management and represents Key Performance Indicators (KPI's) in SCM. The next chapter include a case study that begins with an as-is analysis, and in Chapter 5, new transportation models are created and assessed. The last chapter presents conclusions and recommendations for further actions. The structure of the thesis is presented in Figure 1. Each chapter has input and output boxes that descirbes purpose of the chapters.

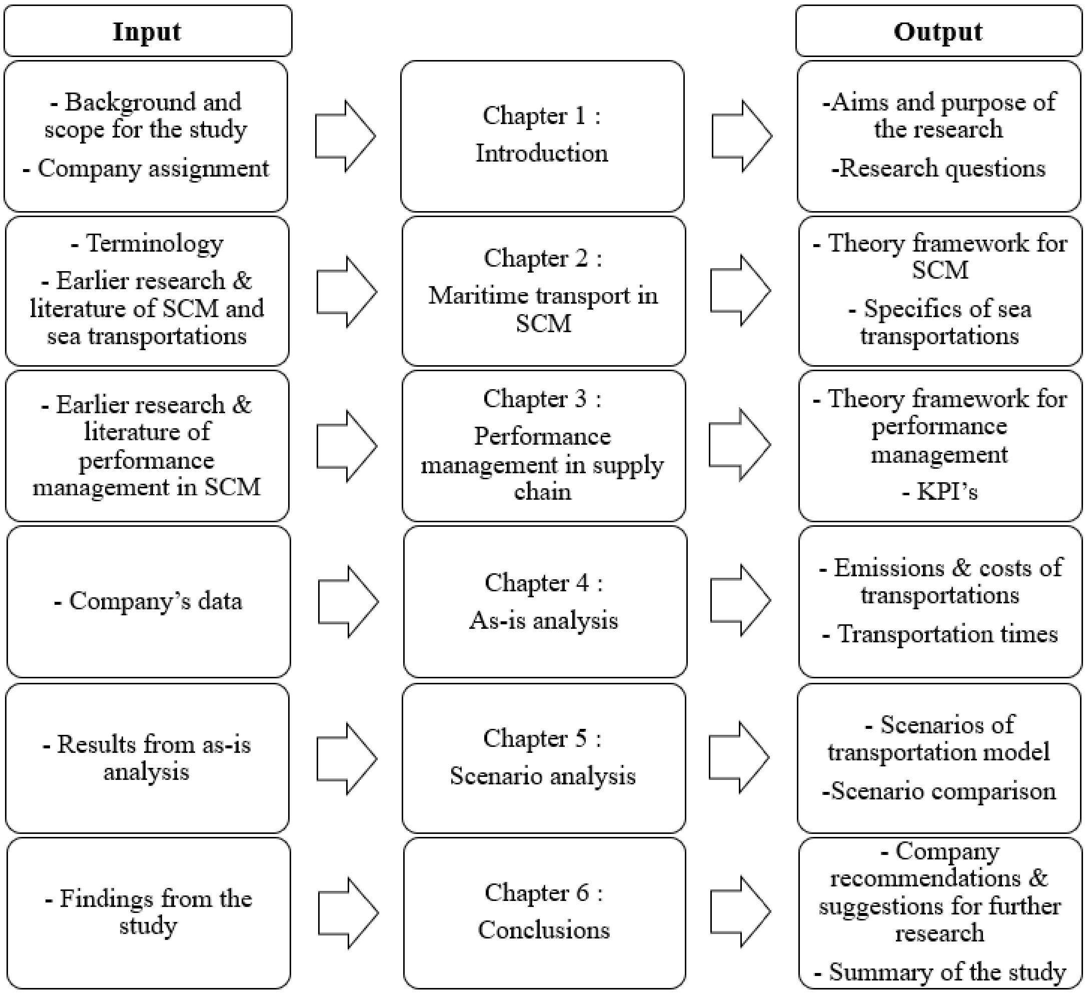

Figure 1. Thesis's structure including inputs and outputs for the chapters

2 Maritime transport in supply chain management

The idea of SCM is to integrate key operational processes at all levels in supply chain between original suppliers and the final users simultaneously creating added value for the customers and other stakeholders. SCM coordinate operational functions systematically and strategically both within the company and between other partners within the supply chain. Purpose is to improve performance of each stakeholder within the chain in a long-term. (Panayides, et al. 2018)

Theory is focusing on transportation management and comparison of transportation modes which are reviewed in empirical case study. After the terminology has been introduced maritime transportation mode is described more detailed due to its specific features compared to other most common modes like road and rail transportations. In addition, sea transportation is an essential option in the case study. The final sub-chapter describes motivators and barriers for a sustainable supply chain.

2.1 Terminology

Supply chain

Supply chain contain all operations needed to obtain the final product from the raw material. Supply chain operations are for example raw material sourcing, production, distribution and logistics. In addition, handling of return flows is included to supply chain. Supply chains encompass several jointly operating organizations that generally forms supply chain network. Also known as end-to-end supply chains. Supply chain management is planning and managing all supply chain operations and coordinating in collaboration with the stakeholders. (Zijm et al. 2019, p. 33)

In global markets efficient supply chain is essential to provide goods and service customer fast and cost-efficiently. Logistic risks and vulnerability in supply chain has increase by the globalization. Interruptions in supply chain parties causes a domino effect into the different stages of supply chain. (Song & Panayides 2012)

Logistics

Logistics encompasses transportation and material storage of both parts and products (Zijm et al. 2019, p. 33). Shortly it includes materials management and distribution (Ruston et al. 2017, p. 4). In logistics is managed inbound and outbound processes in warehouses and internal and external operations of transport and material handling. Informing about stages of supply chain is done by logistics as well. As part of supply chain management, the logistics management implements and controls flows, storage of materials and information between origin point and the departure. Flows' efficiency and meeting the customers' requirements are the goals in logistics. Logistic management includes inbound and outbound transportation management, fleet management, warehousing and inventory management, material handling, order fulfilment, logistics network design, supply and demand planning and managing services of external service providers. (Zijm et al. 2019, p. 33-34)

Key aspects of supply chain and logistics:

- availability of materials, products and information
- cost-efficiency
- customer orientation
- speed
- effectiveness
- environmental sustainability
- social aspects

  +7R: right goods, right quantity, right quality, right time, right place, right cost, at right sustainable impact (Zijm et al. 2019, p. 35). It is known also as the seven rights of customer service (Rushton, et al. 2017, p. 35).

Transportation management

Transportation management include such tasks like carrier selection, monitoring inbound and outbound logistic, pricing, scheduling and transport routing. (Ross 2015, p. 713) Selecting transportation mode for each option is considered costs, service level requirements, environmental goals and competitiveness. (Zijm et al. 2019, p. 474)

Transportation network

Transportation networks consist of logistics services that are used to transport goods from its origin to the destination. Transportation network is presented with two factors, physical locations and signifying transportation services. Locations are divided to origins (pick up points for goods), transfer hubs (where transportation mode of goods can be changed to another) and destinations (for example customer). Transportation management may arrange direct transports usually by truck straight from origin to the destination or transportations via transfer hubs utilizing combine of trucks, trains and container vessels. Longer distances require more use of transfer hubs while shorter distance deliveries are delivered directly from the origin to the destination mainly by trucks. (Zijm et al. 2019, p. 471-472)

Long-, short-, pre- and end-haulage

A long-haul transportation is often defined by its transport mode because determining by distance is depending on the context. If vessel or rails are considered as a transportation mode it can be defined as *long-haul transportation* (or primary transportation (Ruston, et al. 2017, p. 147, 564)). Term of *short-haul transportation* is used to refer a segment of longer distance transportation where actual distance is depending on the context as well.

The first transportation from the origin to the first transfer hub is called as *pre-haulage* and similarly the segment from last transfer hub to the destination is *end-haulage* (or delivery transport or final delivery (Ruston, et al. 2017, p. 147, 564)). (Zijm et al. 2019, p. 473)

2.2 Features of short sea logistics

Shipping supply chain includes sender, peripheral port, port hub, shipping liner, port hub unloading, peripheral port, and receiver in general. The chain is illustrated below (Figure 2). Peripheral port is referring to smaller ports that gather cargo from other transportations to port hubs. Port hubs serve larger vessels. Peripheral ports and port hubs can create a coalition and operate in close cooperation. (Lezhnina & Balykina 2021) In this research is not considered peripheral ports and port hub separately as focusing on short sea shipments. Paying attention to supply chain management it is possible to avoid issues of shortages or surpluses of goods and issues in case of supply chain disruptions. Horizontal cooperation between several participants can be done at each stage and in addition vertical cooperation can bring together more participants from different parts of logistics chain. (Lezhnina & Balykina 2021)

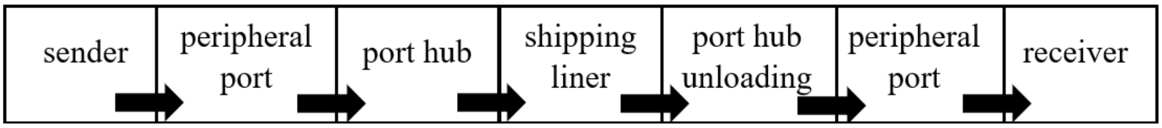

Figure 2. Shipping supply chain (Lezhnina & Balykina 2021).

Short sea shipping (SSS) can be defined in several ways for example by geographical, supply oriented or demand oriented (type of container size or traffic) or legal oriented which means defining by member ports of the same member state. In Suárez-Alemán's article (2016) research area is limited geographically to include ports situated in Europe and ports situated in non-Europe countries but having coastline on the enclosed seas bordering Europe (according to EU suggestion). Geography is an obvious advantage for maritime transport in Europe because 70% of industrial production is located near by the sea. SSS is a proper alternative in freight market by its capacity and potential in Europe. (Suárez-Alemán 2016)

Competition issues is another arising topic in maritime transport. Port operations may develop market power in cartelized manner if the same company owns significant shares of assets in neighbouring ports. There is a risk that operators abuse their power by excessive pricing or refusing to supply. (Suárez-Alemán 2016)

Consisting different entities and players (like shippers, distributors, shipping liner, port operators, inland transport operators and end consignees) makes sea transportation complicated. Success in managing supply chain risks insists understanding of its need and collaboration between supply chain members. (Song & Panayides 2012, p. 123)

2.3 Choosing transportation mode

In transportation decision making process is taken in consideration seven factors to achieve cost effective and optimal utilization of transportation capabilities. The first factor is *distance* that products are dispatched from point of origin to the destination. The tapering principle suggests that for longer distances, the fixed and variable costs of transport are spread out over the total trip. Vice versa, when more distance is covered with the same fuel and labour in less stops, the cost decreases. (Ross 2015, p. 713)

Volume factor should be considered because transport cost per unit of weight increases as volume decreases. Factor of *density* considers weight and space in transportation planning. Usually, transportation pricing is based on the weight. Products on higher density have a lower impact on price due to variable costs are not significantly impacted but space of transport vehicle can be a limiting factor. (Ross 2015, p. 713)

Stowability factor means actual volume cube of the product. If product cannot be shipped in optimized standard transport vehicle capacities, specialized vehicles, or inability to optimize vehicle shipping costs will increase costs. *Handling* factor includes costs of loading and unloading which may require extra handling costs or equipment. *Liability* factor considers damage prevention and product perishability. Transport *safety* can be ensured by insurance to guard against damage or theft or container utilization or special marking and handling which all will increase transportation costs. (Ross 2015, p. 713)

Last factor is vehicle *profitability*. It means the return trip of container back from the destination to its origin location. The return trip is usually made without cargo which is a waste of assets and variable cost are often added to the original transportation price. It would be avoided by balancing transport directions planning the transportation in such a way that when the load has been delivered the vehicle can pick up another load or get a back-haul to the point of origin. (Ross 2015, p. 713)

Following are presented the advantages and disadvantages of transportation options. Vessels are cheap transportation modes and has a huge capacity but low travel speed and inaccessibility for many destinations are downsides of vessels. (Zijm et al. 2019, p. 474) In addition, shipping lines choose ports where containers are centralized, and vessels need to move between several ports for loading and discharging which makes sea container transportation relatively slow (Sandler 2007, p. 84). Significantly faster than waterway and lower cost than road transportation mode is a railway transportation. Instead, railway transportation is not flexible choice due to railway network infrastructure and limited availability of time slots. Road transportation is flexible because practically every location is reached by road network. Due to its capability for all locations, it is the most common transportation mode even though its relatively high costs. Air transportation’s main benefit is high speed and therefore a high service level. It is expensive transportation mode and has limited locations for direct deliveries. (Zijm et al. 2019, p. 474)

In sustainability aspect SSS is considered the most environmentally friendly transport mode reducing air pollutions. Comparing to road transportation low external transport cost per tonne-kilometre is advantage for SSS. External costs include damage caused to societies like air pollutions, climate change, noise, accidents and congestion. Mentioned cost component are pointed out for rail and road but for SSS external cost components are only air pollution and climate change. Results for external cost calculations depend on vessel types and used fuel which may cause higher cost for SSS than road transport. (Suárez-Alemán 2016)

2.4 Motivators towards green supply chain management

Typical factors that drive the adoption of actions into the supply chain could include cooperation and engagement among stakeholders to enhance environmental improvements while simultaneously achieving cost reduction and increased efficiency. Furthermore, it may be beneficial to require providers to adopt an environmental management system to mitigate environmental risks in the supply chain. (Testa & Iraldo 2010)

Drivers that encourage adopting green supply chain management (GSCM) are environmental conscious, regulations and institutional forces, security, top management and mimetic pressures. (Jasmi & Fernando 2018) An article of Testa and Iraldo (2010) have arisen following factors to encourage organization to adopt GSCM management in their strategy: cost saving, product or process development, a “follower” strategy and it could contribute to a positive corporate image. According to research of Notteboom et al. (2020), companies’ top motivation factors for GSCM are (1) company’s image, (2) using greening as a value creation activity, (3) influence of society, (4) demand and (5) competitiveness. Determinants for green supply chain management may be internal or external. External pressures are linked to stakeholders’ pressure and internal pressures for example specific strategy choices of the company. (Testa & Iraldo 2010)

As a limitation for adopting GSCM in maritime can be seen that green technology adoptions are expensive, so it is not feasible for short-term profitable operations (Jasmi & Fernando 2018). As a main barrier for GSCM have been seen uncertainty about green solutions and government policy, company’s profitability and competitiveness of company. Competitiveness is viewed as both a barrier and a motivating factor for adopting green supply chain management. In the survey of Notteboom et al. (2020) is concluded that greening is necessary to sustain a company's competitive advantage. However, not all respondents are convinced that greening adds to the profitability of the company, as some consider it to be an added cost only. (Notteboom et al. 2020) Green supply chain management should be long-term process due to its adoption increases cost and do not make profits in short-term (Testa & Iraldo 2010).

3 Performance management in supply chain: Metrics and management in distribution

In supply chain, flows of products and services from a point of origin to destination should be managed effectively to make profit for all stakeholders and at the same time meet customer needs on time. Measuring the performance of the supply chain can improve efficiency and contribute to making chain-wide improvements. In some logistics areas customer service and delivery performance rise more crucial factors than turnover figures. (Sandler 2007, p. 60) Selected metrics should be in balance between financial and non-financial measures observing organizational objectives (Arif-Uz-Zaman & Ahsan 2014).

Performance management can be defined as *the process of quantifying the efficiency and effectiveness of action*. Effectiveness refers how well the client needs are met. Efficiency measures how economically efficiently the resources are used to meet a specific level of customer satisfaction. Performance measurement system (PMS) is overall set of measures which indicate efficiency or effectiveness of individual actions. PMS can be examined in three levels: (1) measuring efficiency and effectiveness of individual actions by indicator, (2) assessing overall organization by set of measures and (3) supporting infrastructure that enables acquiring, collecting, sorting, analysing and sharing the data. (Pekkola & Ukko 2016) Performance indicators and organization's strategy are tightly linked to each other. Indicators should be based on company's goals. Implementing strategy or mission of organization it is crucial to choose the right indicators because strategy is useless without indicators and indicators are meaningless without strategy. (Franceschini, et al. 2019, p. 8)

Distribution provides the correct quantity, quality, and type of items as defined in a customer order for the end customer in the value chain. Since distribution is the function where customer satisfaction, quality, service appeal and brand quality are eventually evaluated it is crucial part of the supply chain. Distribution management includes planning, implementation, evaluation and control of goods' physical flows, from its source to the customer in addition to the related information, financial flows and return flows of goods. (Zijm, et al. 2019, p. 306)

This chapter introduces performance measures for monitoring performance in supply chain. Supply chain performance is a broad concept having wide range of performance metrics. This review is limited on distribution management and specially on transportations.

The metrics have been categorized into financial, sustainability, and service performance. At first it is described features of each performance perspective in distribution point of view. In the end of the chapter has been collected Key Performance Indicators (KPI's) for all these categories as a summary in Table 1. Introduced metrics can be applied to the case study.

3.1 Efficiency – Economical performance

Before planning the logistics structure, it is essential to understand the interaction between various distribution costs especially how they vary across different site options in terms of number, size, type and location, and also to determine what the actual costs will be. Costs are generated from warehousing and storage, transportation, inventory holding costs (capital, service and risk costs of the warehouse) and information system costs. These costs are affected by the number of distribution centres. (Ruston, et al. 2017, p. 145)

In general, transportation carriage is associated with several cost types. Fixed costs arise from the ownership of transportation assets, such as vehicles, trailers, terminals, ports, handling equipment, and taxes, among others. These fixed costs remain constant regardless of shipment volumes. On the other hand, variable costs are incurred when transportation equipment or services are used for shipments and are influenced by shipment volume. Examples of variable costs include fuel, labour, and vehicle maintenance expenses, which are often expressed as a cost per kilometre or per unit of weight. Additionally, there are joint costs, shared between shippers and carriers, as well as common costs, which are expenses spread among all shippers using shared services like terminals or management expenses. (Ross 2015, p. 715)

Transportation costs are determined by the volume of shipment and the distance from the point of origin to the destination location. As the volume and distance increase, the total transportation cost also increases. However, the average cost per transportation unit decreases with higher volume and longer distances. (Ross 2015, p. 715)

The total logistics cost is the sum of following functional costs: Delivery and primary transport costs, distribution centre storage costs, stock holding costs and system costs. Adjusting number of distribution centres can be affected to functional logistic cost and so on to total logistic costs. Any change in one cost element of logistics system has a significant effect on the other elements and the overall system. It is possible to achieve savings in one element that may lead to additional costs in another, but this approach could provide an overall cost benefit in the logistics system. This concept is known as trade-off analysis. Figure 3 visualize the idea of trade-off analysis. (Ruston, et al. 2017, p. 145 – 152)

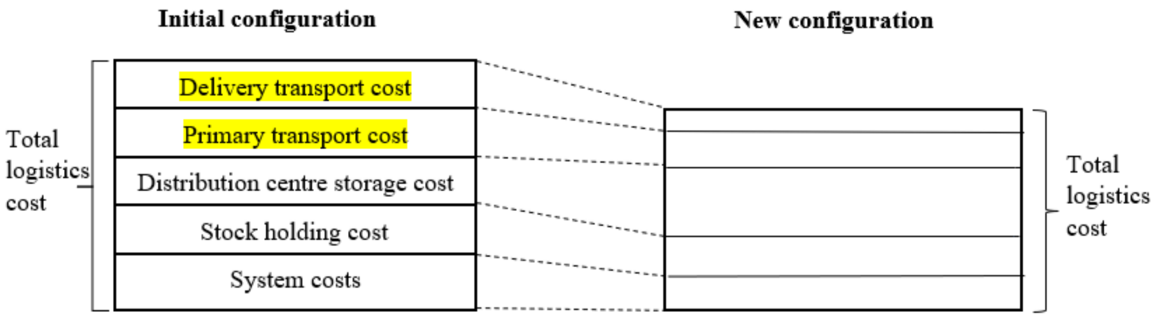

Figure 3. Trade-off analysis represents that while some elements increase and others reduce, a change in one functional cost can lead to a reduction in total costs (Ruston, et al. 2017, p. 152).

Having a higher number of distribution centres results in a linear increase in total storage costs. However, in the case of road transportation costs, a higher number of distribution centres can decrease total transport costs exponentially if the centres are closer to the delivery points. On the other hand, inventory holding costs and information system costs increase linearly as the number of centres increases. (Ruston, et al. 2017, p. 148 – 151) Aim of distribution centre terminals, seaport and airport terminals is to minimise the turnaround time of the modes. (Song & Panayides 2012, p. 176)

This research examines especially *Primary transport costs* (full loads from mills to the distribution centre) and *Delivery transport costs* (from delivery centre to the customer or end-user). Possible impacts on other functional costs (*Distribution centre, Stock holding and System*) should be identified as well. In this review they are left out of the scope from case study assuming that the case study options can be implemented using the same distribution centre model and using existing stocks with current systems. Suggestion for case company is to review also other functional costs as further research. Following, a few specific cost elements for maritime transportation are introduced.

For both breakbulk and container deliveries, sea transportation provides a low cost per kilometre for both overseas and local coastal destinations. Roughly estimated, for journeys that exceed 2500 kilometres, sea transportation is a more cost-effective mode compared to other options. (Sadler 2007, p. 85)

Sea transportation costs consist of fuel costs, manning costs, capital, and other expenses such as maintenance costs. In addition, there are costs related to ports, including cargo handling, navigation, and harbour fees. (Andersson & Ivehammar 2017) BAF (Bunker adjustment factor) is a typical surcharge charged by shipping lines on marine freights. It aims to offset variations in marine fuel across the world which changes over time. For global transportation there is a surcharge known as CAF (Currency adjustment factor) which is designed to account for variations in costs incurred by shipping lines due to currency exchange fluctuations for services purchased in foreign currencies. BAF and CAF are surcharges that may be applied in addition to the basic cost of sea freight. (Ruston et. al 2017, p. 453)

In the research by Christodoulou et al. (2019) it was found that high cargo handling costs at ports are the most significant barrier for RoRo-service use. Handling costs account for nearly 60% of total transport costs.

Reducing the cost of delivery is achieved through cooperation between different supply chain parties, enabling the use of larger vessels for transporting bigger quantities of goods. Maritime transportation becomes more profitable than road transportation when the consignment of goods is large enough. The standard container size rarely matches individual customer batch sizes, allowing joint orders that provide more flexibility in determining the frequency and size of orders. (Lezhnina & Balykina 2021)

3.2 Sustainability

Nowadays society and customers are demanding sustainable distribution solution. Sustainable distribution solutions concern low carbon emissions, noise, congestions and smog reductions as well as corporate citizenship and social responsibility. (Zijm, et al. 2019, p. 308) In green supply chain management (GSCM) environmental aspects have been integrated into the inter-organizational practices of supply chain management. Environmental concerns have come more fore in operations and it has been recognized for providing a competitive advantage and financial benefit. GSCM aim is to reduce environmental impacts by focusing on series of R's: reducing, re-using, remanufacturing, implementing reverse logistics in supply chain. Green logistics in GSCM requires actions in following areas:

- eco-friendly packaging
- eco-friendly choice for transport mode
- load and route optimization
- green distribution networks and hubs
- eco-friendly combinations of transport modes and following to synchromodality. (Notteboom et al. 2020)

Synchromodality is a service concept that utilizes intermodal transport modes (Lahtinen, 2016). It requires cooperation between several parties, such as shipping liners, terminal operators, inland terminals, transport operators, third-party logistics providers (3PL), shippers, and public authorities, to develop and create synchromodal solutions. The use of digital and integrated data solutions, as well as coordination and cooperation among supply chain parties, are important supporting factors for the success of these mentioned actions. (Notteboom et al. 2020)

Following environmental impacts of different transportation modes are compared. After that it is taken a closer look for maritime sustainability concerning port operations as well. This point of view is chosen to give some perspective on the case study.

Transportation activities causes 25% of European greenhouse gas (GHG) emissions. Road transport emissions cover more than half, 71% of GHG emissions caused by transportations. Air transportation takes 14,4%, ships 13,5%, trains 0,5% and others the rest of the transportation GHG emissions. (European Union 2022) Energy efficient of rail and truck is 0,043-0,18 kilowatt hours per tonne-km (kWh/tkm). For container vessel it is 0,014-0,018 kWh/tkm which is considerably lower compared to rail and truck energy efficiencies. Bookbinder (2013, p. 195) have compared carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x) and particulate matters (PM) emissions of transportation modes. CO_2 and SO_x emissions per tonne are lower for container vessel than rail and truck. Truck's CO_2

emissions per tonne are much higher than rail. Instead, transportations by vessel causes more NO_x emissions than rail and truck (vessel 0,12-0,16 g/tkm, electric rail 0,1 g/tkm, diesel rail 0,00005 g/tkm and truck 0,00006 g/tkm). PM emissions among these three transport modes are almost equal. When comparing energy efficiencies and emissions between transportation modes, container vessels appear to be the best option, as stated by Bookbinder (2013, p. 195). However, this result can be misleading due to speed of vessels. It should be noted that container vessels are actually the most energy-consuming type of ships. (Bookbinder 2013, p. 195-196) In case study sustainability performance is measured by CO_2 emissions. CO_2 is the most common emission of GHG; CO_2 emissions share of total GHG emissions was about 80% in the European Union 2023 (European Parliament 2023). Additionally, the data of CO_2 emissions was easily available in Case company.

Shipping covers over 80% of total global trade volume (Stalmokaitė & Yliskylä-Peuralahti 2019) due to growth of international trade which have led increased demand of maritime services. It has increased negative impacts on the environment as well. Sustainability issues in sea transport have been identified in last decades. (Christodoulou & Woxenius 2019)

SO_x and NO_x emissions increases acidification levels of land and seas, eutrophication and has a negative effect on human health. Stricter sulphur and nitrogen emission level requirements in the Baltic Sea area have been a driver for reducing emissions caused in maritime transportations. Aim is to replace existing fossil fuel-based energy sources to alternative energy technologies. There are shipping companies that have experiment of gas cleaning technological solutions like scrubbers or have used alternative energy sources such as methanol and liquified natural gas. (Stalmokaitė & Yliskylä-Peuralahti 2019) Emissions can be reduced by substituting traditional fuels with liquified natural gas (LNG). It requires investments for LNG bunkering infrastructure at ports and willingness of other shareholders for greener supply. (Notteboom et al. 2020)

In maritime transport should be considered the environmental impact of ports. Potential impacts on biodiversity are degradation, fragmentation or loss of ecosystems and pollution or intrusion of invasive species due to port infrastructure. (Suárez-Alemán 2016) By optimizing maritime transport management systems, emissions can be reduced through decreasing waiting times and turnaround times in ports. Instead of bunker fuels, vessels could use shore power for auxiliary engines at berth to reduce emissions. It requires implementing cold ironing or other alternative marine power to turn off vessels' main and auxiliary engines at berth. (Notteboom et al. 2020)

Carefully made voyage planning and high utilization rate of services enable lower GHG emissions per transport unit. For all vessels is given a guidance of Ship Energy Efficiency Management Plan in 2013 where is given instructions to optimise operational efficiency performance in technical details, voyage planning, just in time arrival of vessels at ports and speed optimization. (Christodoulou et al. 2019.) Low-sulphur fuel use, low operational speed and high utilization rate of RoRo services have been the greenest transport option in Christodoulou et al. (2019) study.

3.3 Effectiveness – Service performance

Performance characteristics that shippers consider selecting a proper mode of transportation are speed, completeness, dependability, capability, frequency and cost. Transportation *speed* is evaluated in time that is used in loading of goods onto the transport vehicle at the shipping terminal, travel from point of origin to the receiving point including time used in intermediate terminals. *Completeness* describes ability of delivering products from one location to another using only one transportation mode. It reduces material handling time and costs in different parts of supply chain. *Dependability* (reliability) performance characteristic indicates how well a particular mode performs in terms of fulfilling expected on-time delivery. *Capability* refers how well one transportation mode fits for the goods considering the features of the product. For example, liquid product and packaged product requires different factors from the transport mode. *Frequency* is a performance factor that measures how often items are picked up and delivered. In general, for shorter transport distances flexibility is better. Frequent transports decrease needed size of transport modal and inventory. Last characteristic is *cost*. Generated costs in transportation are from using the mode itself, indirect costs like labour and handling during the loading and unloading, damage and spoiling incidents, insurance to prevent possible loss and goods' transportation costs. (Ross 2015, p.699 – 698)

It is crucial to identify the key criteria for the company's logistics needs to find potential third-party providers. In definition of outsourcing of 3PL providers one or several logistics services are based on contract provision by a supplier. 3PL are responsible of traditional logistics functions like inbound and outbound transport, warehousing or return services. (Qureshi, et al. 2008)

In article of Qureshi, et al. (2008) is stated same criteria for 3PL providers than Ross above as well some additional criteria and in different view. Additional characteristics for previous chapter: *Quality* of service and management are to enhance perceived quality of customer and ensure high service level. *IT capabilities* can improve productivity by integrated software as vehicle routing packages, enterprise resource planning environments or hardware as code printers, scanners, etc. *Information sharing and trust* meaning data visibility at each stage and trust supports compatibility between the 3PL provider and the shipper. *Compatibility* is a criterion as well, including partners compatibility of culture and values as the key factors for success of cooperation in the long-term. *Operational performance* ensures effectiveness and efficiency of 3PL service provider. Other criteria for selecting 3PL providers are *financial stability, geographical spread and range of services, the long-term relationship, reputation, surge capacity* (during sudden rise in demand) and *flexibility in operation and delivery.* (Qureshi, et al. 2008)

There were variations in the naming of performance characteristics across the articles. Ross (2015) referred *capability* which Quereshi et al. (2008) mentioned as *size and quality of assets* regarding to the equipment of 3PL service provider. In text of Quereshi et al. (2008) speed and dependability were included in the delivery performance criteria, while Ross (2015) considered them as specific performance characteristics when selectin transportation mode.

Choosing the right transport mode, the required customer service level should be considered. (Zijm, et al. 2019, p. 105) Each supply chain and business state their own service levels. In Sandler's (2007) book has identified the nine most important aspects of customer service: on-time delivery, order accuracy, price, no product damage, ease of order placement, customer enquiry handling, quality, availability and order status information. Relative importance between these aspects varies depending on the company and product or service. (Sandler 2007, p. 72) OTIF (On-Time In-Full) is a key performance indicator which requires the ordered product or service to be delivered at the right time as it is determined in the order including right quantity, packaging and other possible requirements in the order. (Zijm, et al. 2019, p. 307)

As an example of performance management system for supply chain here is introduced Supply Chain Operations Reference (SCOR) model. It is an approach for monitoring costs and performance in supply chain. SCOR processes are divided to five decision areas: PLAN, SOURCE, MAKE, DELIVER and RETURN. These decision areas are monitored in four levels from general level to more detailed review of processes. The four levels are following: (1) *Competitive advantage*: scope and content definition of model and competition performance targets are set, (2) *Strategy implementation and process definition*: describes the features of key processes in three categories: planning, execution and enable, (3) *Detailed process elements*: description of essential process elements' flows including inputs and outputs and indicators are set (4) *Implementation*: implementing specific SCM practices. Aim is to benchmark, enhance and improve key operational processes. After identifying key operational processes, the key indicators are introduced to monitor the set of cost and performance targets. Individual indicators are defined under the different categories. The main categories are assets, cost, data, flexibility, inventory, orders, productivity and time. (Ruston, et al. 2017, p. 706; Lockamy & McCormack 2004) It should be noted that SCOR model does not consider the sustainability aspect. SCOR model was not used in the case study due to the importance of sustainability as an essential factor. Additionally, the model's in-depth nature is not aligned with the desired focus of this research.

In Table 1 is introduced some KPI's for distribution management. From the list is chosen few indicators for use in the case study. It is notable that case study won't concern warehouse and distribution centre costs but as they are essential cost elements in distribution management, so they are included in the table. Collected metrics can be applied in different units according to the meter's intended use.

Table 1. KPI's in distribution management.

Indicator	**Unit**	**Source**
Sustainability		
CO_2 emissions	g/ton-km	Bookbinder 2013, p. 213
SO_x emissions	g/1000 ton-km	Bookbinder 2013, p. 213
Costs (delivery/primary transport cost)		
Transportation cost	€/ton	Gunasekaran & Kobu 2007
Relative transport cost	€/ton-km	Bookbinder 2013, p. 213
Warranty cost	€	Gunasekaran & Kobu 2007
Stock holding costs		
Through put cost	€/ton or €/unit	Rushton, et al. 2017 p. 724
Obsolescence cost	€	Gunasekaran & Kobu 2007
Distribution centre costs		
Handling costs	€/ton	Rushton, et al. 2017 p. 724
Storage cost	€/ton	Rushton, et al. 2017 p. 724
System cost		
ERP system	€/year	Rushton, et al. 2017 p. 101
Service		
Frequency	number/year	Bookbinder 2013, p. 213
Lead time for procurement and/or manufacturing	Hours or days	Gunasekaran & Kobu 2007
Service level	%	Qureshi, et al. 2008)
Reliability (on time deliveries)	%	Bookbinder 2013, p. 213; Gunasekaran & Kobu 2007
Product/service variety		Gunasekaran & Kobu 2007
Process cycle time	Hours or days	Gunasekaran & Kobu 2007

4 As-is analysis

The case study focuses on transportations from Finland to continental Europe excluding delivery countries of Scandinavia and Baltics. This review is limited to one division of the organization. The analysis period is year 2022. The aim of the study is to enhance the logistic performance of the case company, streamline the logistic network, reduce emissions, and achieve cost savings. Based on the findings of as-is analysis, the objective is to determine if it is feasible to reduce CO_2 emissions and understand the potential impact on costs and service quality by centralizing outbound volumes onto liner vessels.

The purpose of as-is analysis is to determine material volumes and flows, transportation costs and CO_2 emissions for transportations from Finland to Europe where the mills are the origin points, and the client or last distribution centre is the destination point. Features of each transportation mode have been identified including break bulk, liner systems, shortsea containers, ocean containers and direct truck deliveries. A closer examination has been conducted regarding the specifications of the liner system, as it handles the largest volumes in sea transportation. Furthermore, liner is a significant transport mode in the following scenario analysis where transportation model options are created.

Water way transportations are divided in transportation legs. The first leg is from mill to the loading port except from mill A the goods are transferred to the port by conveyor, so the first leg is sea leg for goods of mill A. For simplicity this review does not consider converter units which would be additional transportation legs. The second leg is the sea leg from loading port in Finland to discharging port in Europe. The third leg is from discharging port to consignee (destination) or to inland terminal. If the third leg ends to inland terminal the fourth leg is from inland terminal to the consignee. For some orders, the inland terminal or discharging port is specified as the destination. To mention one deviant route, orders to United Kingdom have two separate sea legs. The first sea leg is from Finland to Zeebrugge and then from Zeebrugge to United Kingdom. The distribution network is visualized in Figure 4. This research considers each leg reviewing the volumes, costs and CO_2 emissions.

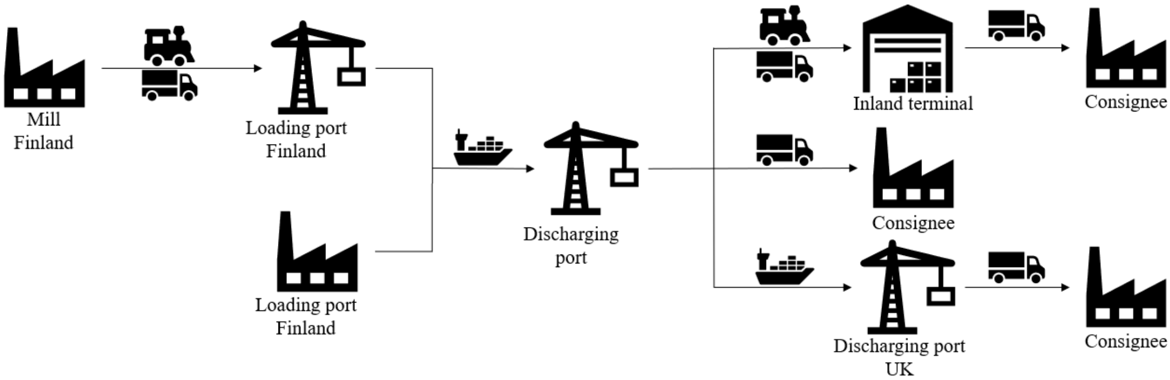

Figure 4. Visualization of sea transportation distribution channel.

After the used terminology is represented, the case study begins with an as-is analysis, where the current material flows from Finland to Europe via vessels, trucks, and intermodals, including rail transportation, are determined. To evaluate service aspect, the transportation times and frequencies of possible shipments for truck and liner are assessed. Limitations for service analysis is chosen by the available data and due to aim of the scenario analysis. It is noted in the next chapter that there are limited route options for break bulk and train deliveries so only truck and liner transport modes are taken into a closer look in service perspective.

Later in this study, the scenarios are created as options to re-design the transportation model. Results from as-is analysis are a baseline for transportation model options where different transportation modes are considered.

4.1 Transportation terminology used in case company

Transport modes

In general, the sea transportation in this research can be categorized as short sea deliveries, as oversea deliveries have been excluded from the study. However, it is important to clarify that the term *short sea* is not used in this study in the sense as defined in the theory, because it refers to another transportation mode within the company. The case company has defined three waterway transport modes: Liner Systems, Break Bulk, and Ocean Container.

Liner Systems refers to regular deliveries, while *Break Bulk* involves transportation of bulk goods. *Ocean Container* is a transportation mode where goods are stowed into standard containers and shipped over the ocean.

In addition, there is *Road* transportation mode which means direct truck deliveries. *Short Sea containers* represents loaded containers that are transported on trucks. Short sea deliveries are different delivery services than other direct truck transportations, so they are categorized separately in the company but in this study transportation modes of short sea and road are considered as the same. Case company has also *Multimodal* transportations which means that the goods are delivered using several different transportation modes which were also included in road transportation in this study.

Stowage mode

Products can be loaded onto vessel in three different ways: Ro-Ro, StoRo and Lo-Lo. StoRo is abbreviation for Stowable Ro-Ro where cargo is brought alongside the vessel in the case of side ports. If vessel has a stern ramp cargo is brought into the vessel by forklift, truck, cassettes or roll trailers. Single products are stowed directly in the ship's holds by forklifts. Advantage of StoRo is that it allows tighter and higher stowage which increases carrying capacity of vessel. (Logistiikan maailma 2023)

It is possible to tranship containers or other stackable intermodal loading units to the vessel either horizontally on wheels or vertically using cranes. In Ro-Ro shipping (Roll on – Roll off) the loading unit is transhipped on wheels into the vessel. (Radojčić 2020, p. 35) Cargo is loaded upfront on the transport unit and then it is driven, pulled or pushed onboard via the ship's stern ramp. While Ro-Ro loading reduces the port-time of the vessel, it may reduce the carrying capacity of the vessel (Logistiikan maailma 2023).

In Lo-Lo shipping (Lift on – lift off) the cargo is loaded and unloaded by cranes. (Christodoulou et al. 2019; Radojčić 2020, p. 35) Lo-Lo vessels have flexible cargo space which enables loading wide range of products, but it is time-consuming and subjected to weather conditions as well (Logistiikan maailma 2023).

In intermodal freight transport the cargo is transported in one loading unit, using one or several transportation modes without the need for handling products themselves. (Christodoulou et al. 2019; Radojčić 2020, p. 35) This approach is also known as intermodal transportation and under its definition are following examples:

(1) Goods can be transported in several trucks to the transfer hubs, where they are then loaded into containers.

(2) Containers can be transported partially by ship and train.

(3) There are other available delivery options, but the goods are ultimately delivered by a single truck. (Zijm et al. 2019, p. 476)

Transport unit types

Containers or trailers are the most common transportation units which are used to contain and transport goods. Standardized containers can be transferred by trains, ships and trucks. Its size is expressed with TEU (twenty feet equivalent units) volume of 38.5 m^3. 2 TEU is the most common size for standardized containers. Standardization allows for the efficient stock handling and transportation, especially when the same handling equipment can be used for loading and unloading both trucks and ships. Containers can be stacked which increases transported capacity. (Zijm et al. 2019, p. 475)

Trailers are transportation units on wheels. It can be rolled on and out of the ship or train and connected to truck. Trailers cannot be stacked. Handling trailer requires equipment such as ramp or forklifts for loading and unloading. Therefore, it's important to check the capabilities of the unloading area before shipment. (Logistiikan maailma 2023).

Loading units

Combining goods into loading units makes handling easier. Loading units could be boxes, reels, barrels, bags, or pallets. Among these, pallets are the most common choice due to their standardized form and the ability to load a variety of different goods. Pallets are easy to handle using forklifts or pallet jacks. (Zijm et al. 2019, p. 475)

4.2 Current distribution model

First, sea transportation volumes are presented, followed by road transportations. Data for sea transportation volumes was got from internal Power BI data set.

Case company’s mills are located in 5 different locations which are named here as A, B, C, D, and E mills. A total of eleven loading locations, including inland terminals, were used for shipments during the review period. The company used 5 different ports in Finland which are referred here a, b, c, d and e ports. Ports a, b, d, and e are defined as ports in Southern Finland and port c is considered as a port in Northern Finland due to its separate location from the other ports. Mill D, which has the largest production capacity of all mills in Finland, has been shipped the largest volumes through several ports.

Port a appears to be the most significant in volume aspect. Via port a have been shipped over several hundred tons which accounts for 51 percent of all sea transports of the company. Other significant ports include b, e and d. Port e has been a significant port for break bulk shipments, while the volumes of the other mentioned ports were primarily used for liner shipments. Port c also had a significant volume, accounting for almost 20 percent of all departures from Finland.

Road volumes were got from company’s ERP system reports. The focus of road transportation is on routes that could potentially be served by liner vessels, including destinations in both West and East Europe. Road deliveries are considered as direct truck deliveries from mill to the customer. Figure 7 visualizes outbound flows from Finland to West and East Europe.

Figure 5. Road volumes from Finland to West and East Europe.

Approximately 80% of all outbound volumes were delivered by vessel while the remaining 20% were transported by trucks in 2022. The largest delivery country for sea transportations is in West Europe, constituting 16% of sea transportations. The second and third largest destinations in Southern Europe both account for 15% of sea transportation volumes.

The largest volume of truck deliveries, approximately 30% of all truck deliveries to Europe, was to a destination country in Southern Europe. For comparison, it can be mentioned that approximately 12% of direct truck deliveries were sent to another significant destination country in Eastern Europe."

4.2.1 Service analysis

To assess the service perspective of liner shipments, the frequencies of shipments and the agreed vessel capacities in 2022 were taken into consideration. Shipment frequencies by departure and discharging ports are collected in Table 2. Departures from ports of a, b and c were in accordance with annual contracts and occurred every week. During periods of high demand, additional departures from ports a and d to Travemunde were scheduled. These additional departures were agreed separately based on the current demand. In summary, there were more frequent departures from b and d ports than from port a. However, the agreed capacity of shipments via port *a* was higher.

Table 2. Frequencies of liner vessels.

Departure port	**Discharging ports**	**Shipment frequency**
a	Travemunde-Zeebrugge-Tilbury-Bilbao	1 per week
a	Travemunde (additional)	1 per week
b	Gdynia	4 per week
d	Travemunde (additional)	3 per week
d	Aarhus	
c	Trevemunde-Tilbury-Zeebrugge	3 per week

Frequencies and transportation times for break bulks have also been identified. In Table 3 can be seen break bulk routes used in 2022. There were departures once a week from port e to Teneuzen, Zeebrugge, and Stettin, while departures from port c and port a to locations in Spain occurred every four weeks. Weekly frequencies from e are determined here based on the company's 2022 route utilization, but they are flexible in practice. During periods of high demand, it is possible to request additional shipping services. Each break bulk vessel is ordered separately based on the company's needs.

Table 3. Break bulk vessels frequencies and transit times by destinations.

Departure port	**Discharging ports**	**Shipment frequency**	**Transit time (day)**
e	Terneuzen	1 per week	5
e	Zeebrugge	1 per week	6
e	Stettin	1 per week	3
c	Almeria-Gandia-Tarragona	1 per month	20–22–24
a	Almeria-Gandia-Tarragona	1 per month	16–18–20

Lead time is a remarkable service factor in logistics. In this review, transportation times between mill and the consignee are considered as the aim is to compare the benefits of different transportation modes. To meet the requirements of the scenario analysis, liner and road deliveries have been examined more closely. Transit times for sea legs are presented in Table 4. Liner suppliers determine the liner route based on demand, so the route may not include all available port options. In Table 4, all loading and discharging port combinations used in 2022 are collected.

Table 4. Transit times for liner sea legs (days).

Lead time (days)	Travemunde	Zeebrugge	Tilbury	Bilbao	Gdynia	Antwerp
Port c	4	7	8			
Port d	2					
Port a	2	6	8	10		7
Port b					1	

In Table 4, the sea leg transit time considers only the travelling days. When selecting sea transportation, it should be noted that the goods need to be at the loading port before the closing time. Closing time is one or several days before the departure. For example, the closing time for Tilbury orders is three days before departure and for Travemunde, the closing time is one day before departure in port a. Closing times depend on the order in which the unloading will be done. In this example the vessel arrives in Travemunde earlier than in Tilbury, so the goods should be organized accordingly. Other factors that affect closing times are vessel capacity, stowage mode and resources of the port.

In discharging port, it should be considered when the goods are Ready for loading (RFL). This depends on the port's recourses once again. For example, the opening hours may significantly affect the RFL day if the port does not operate on weekends at all. To provide some examples, in Zeebrugge goods are ready for loading in one day, while in Bilbao, it takes three days after the vessel's arrival at the port.

The first leg between the mill and the port should also be taken into consideration when reviewing total transportation times. It varies depending on mill's location and the transportation mode (train or truck). In addition to that, there are limitations in loading times at mills and in train schedules that should be noted. As a result, total transportation time from mill to customer is longer than the given transit times in Table 4.

To provide some perspective on the actual transportation times, both liner and direct truck services are presented in Table 5. Transportation times were examined by each delivery country for the company, but here they are presented as divided into Eastern, Western and Southern Europe to hide some sensitive information about the company.

Transportation times for truck deliveries were obtained from the case company's ERP system. Liner transportation times were calculated using values from the ERP system and other information from the company. When calculating liner transportation times, the factors that were mentioned earlier were taken into account: closing times, RFL days, sea leg transit time and transit time of first leg from mill to the loading port as well as the last leg from unloading port to the consignee. Due to consideration of many factors, the transit time is expressed as a range of several days including the fastest possible and the maximum time without disruptions in distribution.

When considering all legs of a liner delivery, the transportation times can be compared to direct road deliveries, which include only one leg from the mill to the consignee. There is one exception made for deliveries to Italy and Germany. Truck deliveries to Italy are transferred to the inland terminal in the North Italy and have a final delivery to the consignee which has been added in the transit time of truck delivery. Germany is divided into North and South Germany where transportation times vary significantly.

The routes for transportation time review were chosen based on direct road deliveries used in 2022 to East and West Europe utilizing available data and taking into consideration that other information would not be necessary for further research. Transit times from mills in Southern Finland were generally the same, except for a few destinations that showed deviations in transit times. Transportation times from Northern Finland are not presented in Table 5, but they can be considered one day longer than those from the Southern Finland locations.

Direct road deliveries are simpler than sea transportations as they involve only one transportation mode, and the handling of goods is minimized. Factors that impact on road transportation times are mills' loading times, consignees' unloading times and the availability of the supplier. These factors are not specially considered in transit times. However, it can be observed that sea transportation extends the lead time. Regarding to shipment frequencies it can be stated that direct truck deliveries are more frequent than sea deliveries as the only limiting factors are the same as those mentioned here, which impact transportation times. It is considerably more often than sea delivery frequencies listed in Table 2.

Table 5. Road and Liner transportation times between mills and consignees.

Mill	**Destination**	**Transit time (Road)**	**Transit time (Liner)**
Southern Finland	South Europe	7 – 12 days	10 – 20 days
Southern Finland	Eastern Europe	5 – 7 days	5 – 14 days
Southern Finland	Western Europe	4 – 8 days	6 – 17 days

4.2.2 Transportation costs

Road transportation costs were obtained from case company's ERP systems reports. Road transportation costs were based on one leg: mill to consignee whereas sea transportation costs were calculated leg by leg. Sea transportation costs were collected from several data sources. Some of the sea freights were *standard costs* according to contracts for the year 2022. The rest were *cost-in cost-out* prices obtained from the ERP system which included BAF. Only standard cost did not include BAF, so it was added in sea freight using average of year 2022 for the specific supplier. Other legs of sea transportation deliveries involved land transportations, included legs between the mill and the port, discharging port and consignee or inland terminal. Land transportations were multimodal or road transports after discharging port. The data was available in ERP system where the cost was stated per load. The cost unit used in the study was euro per ton. It was calculated as follows for each route:

Total costs 2022 (€) / Actual volume 2022 (t)

Total costs 2022 represent the sum of all costs, and *Actual volume 2022* represents the sum of all delivered volumes in 2022 for a specific route. Using this formula, it was possible to reduce the significance of special loads better than using the average price on a specific route. In addition, loads of less than 15 tons were excluded from the data. Handling costs were included in the sea transportation costs but in case of road transportations, handling cost were considered to be part of the mill operations.

4.2.3 CO_2 emissions

The case company already reports the logistics' CO_2 emissions. This review was based on the same assumptions and emission factors as the company has used in their emission reporting. However, the company's report was not directly suitable for the scope of this study, so the emissions were recalculated to obtain more detailed results. The following formula was used for CO_2 emission calculations:

*Volume (tons) * Distance (km) * CO_2 emission factor (g/tkm)*

Emissions were calculated for each leg. Assumptions were necessary due to limitations in the available data sources. For example, suppliers can use multimodal transportation in continental Europe, and currently, there is limited visibility into which mode of transportation has been used for each route. There are extensive railway connections that are widely utilized in addition to road transportations. The assumptions used in emission calculations are listed below:

- Mill – loading port leg: 73% of volumes transported by train and 27% by truck
- Discharging port – Consignee legs transported by truck
- Discharging port – Inland terminal leg: 80% of volumes are transported by train and 20% by truck
- Truck transportations from Finland have an emission factor of Nordic Truck (60 t) and transportations from other European countries have an emission factor of Europe Truck (40 t). The factors can be seen in Table 6.

Due to Finland's geographical location, truck deliveries also involve sea travel by ferry. When calculating road transportation emissions, it was assumed that the sea leg was between Hanko and Rostock except deliveries to Eastern Europe, sea leg was between Helsinki and Tallinn. The emission factors used for different transport modes are presented in Table 6. In the case company, the used emission factors are based on transport modes considering the most common equipment type in different geographical areas. CO_2 factors are average factors in the industry defined by an external consultant.

Table 6. Emission factors for transportation modes.

Transportation mode	Emission factor (g/tkm)
Road (Nordics Truck)	45,77
Road (Europe Truck)	59,17
Rail (630m DieselB0EU)	29,90
Liner	38,40
Break bulk	8,49

For the company was calculated total volumes, costs and emissions in 2022 but here is presented only cost shares by transportation modes in Table 7. The highest volume was shipped via liner vessels. As it could assume the cost and emission shares are in accordance with volumes shares.

Table 7. Summary of as is analysis: Volume, cost and emission shares of total deliveries by transport modes.

AS IS	**Volume (ton)**	**Cost 2022 (€)**	**Emissions 2022 (ton)**
BB	18%	12%	7%
LINER	64%	69%	72%
ROAD	19%	19%	20%

5 Scenario analysis

Scenario analysis is based on the results of the As-is analysis. The aim was to determine how cost and emission factors would be affected if the same volumes were transported using different transport modes. New routes were not considered in this review; optional routes already existed and were in use during the review time, except for a few combinations of mills and delivery countries. Theoretical cost and emissions were possible to estimate by calculating them leg by leg.

The case company has utilized several routes and transport modes to reach the same destinations. It has been observed that long distance deliveries are also handled by trucks. As a background for this review, the company considered the potential impact on profits and emissions if road deliveries were reduced and replaced with liner vessels. During high demand direct trucks congest loading stations at the mills. In the literature review, in chapter 2.3, it was found that maritime transportations, with its high capacity, could be a cheaper alternative to truck deliveries. Additionally, from an environmental point of view, sea transportation was considered a more environmentally friendly mode than road transportation.

The idea of the first scenario was to consider what would be the outcome if liner vessels were used for all deliveries. The aim was to find out the impacts on the factors if all transportations during review period were conducted using liner. For all routes defined in the as-is analysis, alternative liner routes were explored. As a result of the first scenario, emissions and costs of the original transportation mode and liner transportation modes can be compared for each route.

The second and the third scenarios were created from a market area perspective. The company had divided its customers into country groups based on delivery countries. In the second scenario, using the same grouping: *Direct road deliveries to East Europe on liner* all direct road deliveries to East European countries were conducted using liner vessels. In the third scenario: *Direct road deliveries to West Europe on liner* all direct road deliveries to West Europe country groups were transported via liner.

Using the results from the first scenario, two additional scenarios the fourth and fifth scenarios were developed. In the fourth scenario: *Emission-based*, the choice was based on emissions and the routes selected for liner transportation had lower emissions than their original routes. In the fifth scenario: *Cost-based,* the most cost-effective routes on liner were chosen for liner transportation, leaving the others on their original routes. The following chapters introduce the results of these scenarios in more detail.

It is important to note that the results of the scenarios are theoretical. In practice, it is not possible to entirely eliminate truck deliveries to specific delivery destinations, as disruptions in other phases of the supply chain can lead to interruptions. Furthermore, for urgent orders, direct truck delivery is often the best option. Scenario analysis helps identify routes that might be more suitable for transfer using a different mode. In the final sub-chapter, the impacts of scenarios on service factor as well as other consequences that would arise if the scenarios were implemented, are considered.

5.1 All on liner

The aim of the first scenario was to determine the cost and emission impacts of conducting all deliveries via liner. It would increase liner volumes by 57%. Cost and emissions were calculated for each route between mills and consignees. Compared to the baseline from the as-is analysis costs increased about 11,8%, and emissions increases by about 15%. Change compared to as-is analysis results is presented in Table 8.

Higher liner volumes would put pressure on the ports. The first scenario would increase the weekly volumes by 45,5% than in as-is analysis in Southern Finland. It should be noted that the research does not consider market varieties. In reality, volumes do not remain stable on a weekly basis. Other impacts on the port and mill operations are discussed in a later chapter in the conclusions.

Table 8**.** Results of the first scenario compared to the base line, As-is analysis.

1. Scenario compared to as-is results	**Volume (ton)**	**Cost 2022 (€)**	**Emissions 2022 (ton)**
As-is analysis	1	1	1
ALL LINER	156,7%	111,8%	115%

5.2 Direct road deliveries to East Europe on liner

In the second scenario, cost and emission factors were defined as if the direct road deliveries to East Europe were conducted by liner vessel. Figure 8 illustrates the flows to East Europe delivery countries. The other routes remain the same as in the as-is analysis.

Figure 6. Direct road deliveries to East Europe.

In Table 9, *LINER* volume represents summary of liner volume and East Europe truck volumes compared to liner volumes in the as-is analysis. In the row labelled *ROAD*, it represents deviation of road deliveries compared to the as-is results while BB volumes are the same in the scenarios. On a weekly basis, there would be approximately 7% more shipments in South Finland. This signifies an increase of about 0,76% in total cost and 0,69% in total emissions compared to the baseline.

Table 9. Total results in scenario in which East Europe road deliveries is delivered on liner vessel.

EAST to Liner	**Volume (ton)**	**Cost 2022 (€)**	**Emissions 2022 (ton)**
ROAD	71,0%	73,7%	75,7%
BB	1	1	1
LINER	108,4%	108,2%	107,6%
Total	**1**	**100,76%**	**100,69%**

5.3 Direct road deliveries to West Europe on liner

Another scenario from market area perspective considers delivery countries in West Europe. The delivery countries are illustrated in Figure 9.

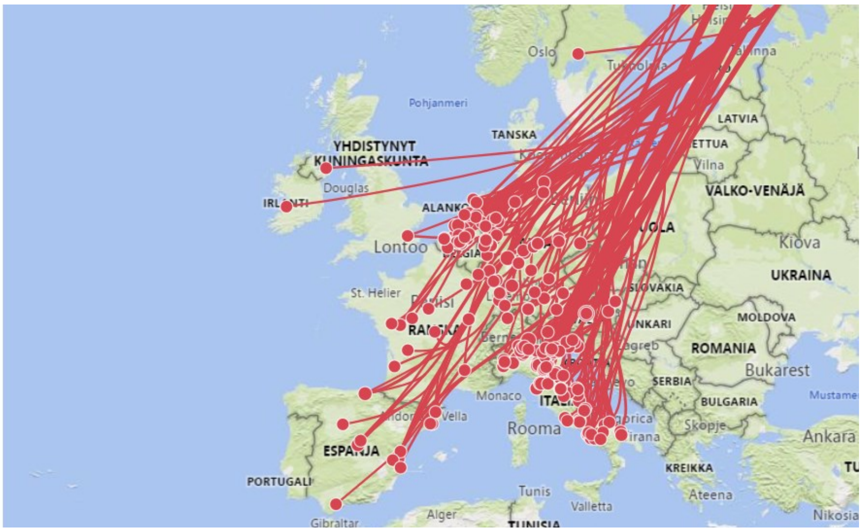

Figure 7. Direct road deliveries to West Europe.

The results of the third scenario are presented in Table 10, where the percentages represent the difference from the baseline values. In the as-is analysis, road volumes to West Europe were approximately 71% of all road volumes to Europe. The total costs increased by 0,42% and emissions decreases by 1,2%. The result of this scenario would increase weekly shipment volumes by nearly 20,9% in Southern Finland.

Table 10. Total results in scenario in which West Europe road deliveries is delivered on liner vessel.

WEST to LINER	**Volume (ton)**	**Cost 2022 (€)**	**Emissions 2022 (ton)**
ROAD	29,0%	26,3%	24,3%
BB	1	1	1
LINER	120,7%	120,7%	119,5%
Total	**1**	**100,42%**	**98,84%**

5.4 Emission-based

According to the first scenario, where the cost and emissions for all distribution routes were found for both as-is and liner options, the fourth scenario selected the routes that resulted in lower emissions. These delivery countries include Belgium, Czech Republic, France, Germany, Ireland, Italy, Netherlands, Poland and Spain. Figure 10 illustrates the flows to these mentioned delivery countries.

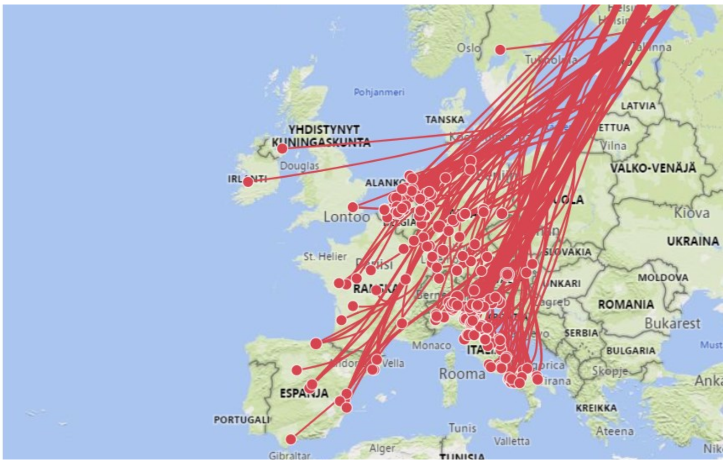

Figure 8. Delivery countries that would cause less emissions delivering by liner.

In Table 11, the results are presented. That would cost 1,3% more than as-is scenario but would decrease total emissions by 1,9%. This Emission-based scenario would increase weekly shipments by nearly 20% in Southern Finland.

Table 11. Total results of the Emission-based scenario.

Emission-based	**Volume (ton)**	**Cost 2022 (€)**	**Emissions 2022 (ton)**
ROAD	20,8%	23,9%	19,5%
BB	1	1	1
LINER	123,0%	122,5%	119,9%
Total	**1**	**101,28%**	**98,14%**

5.5 Cost-based

The final scenario is based on the costs: the routes that were cheaper with liner transport than the as-is option were chosen to be transported via liner. The delivery countries for which it would be more profitable to deliver by liner instead of direct road deliveries are Austria, Belgium, Bulgaria, Czech Republic, France, German, Hungary, Ireland, Netherlands, Romania, the United Kingdom and Spain. They are presented in Figure 11.

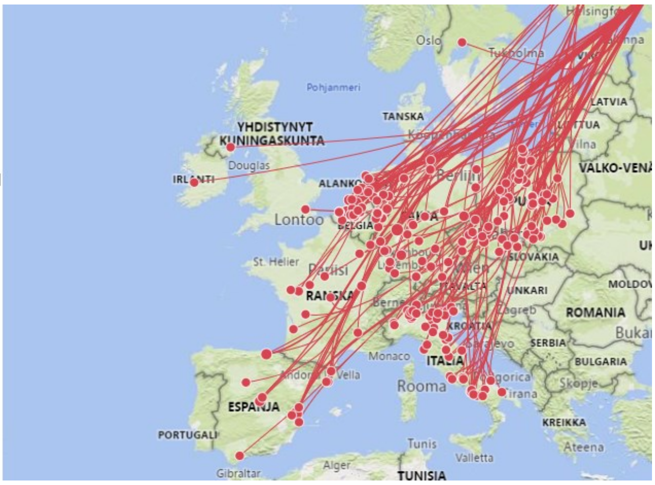

Figure 9. Delivery countries that would be cheaper delivering by liner than truck.

As a result, compared to the as-is scenario the savings would be 1,9% but emissions would increase by 1,1% in the scenario 5. Summary for scenario 5 is presented in Table 12. This scenario would increase the weekly shipment volumes by 8,4%.

Table 12. Total results of the Cost-based scenario.

Cost-based	**Volume (ton)**	**Cost 2022 (€)**	**Emissions 2022 (ton)**
ROAD	66,3%	61,1%	66,5%
BB	1	1	1
LINER	108,3%	107,9%	110,7%
Total	**1**	**98,13%**	**101,11%**

5.6 Service aspect and conclusions of scenario analysis

Referring to Table 5 in as-is analysis, it is stated that transportation time by liner vessel is longer than by truck. Additionally, in the literature review it was found that maritime transportation's disadvantage is its slow speed compared to other modes. Transportation time has a significant impact on total lead time, resulting in a negative effect on the service level.

When considering the frequencies of maritime and road transportation modes, the benefits lie with the truck deliveries. The only limitations are the loading times at the mill, unloading times at the consignee and the suppliers' schedules. Theoretically, truckloads are possible to ship every day while liners have shipments only once a week to some locations.

In the first scenario, where all routes were compared to liners routes, it was found that break bulks are cheaper and cause fewer emissions than liners. Lower emissions are explained by the fact that break bulk has lower emission factor than liners, and the reason for higher costs is that sea freight cost more for liners. As a result of as-is analysis it can be said that break bulk shipments are less frequent than liners according to company's use of break bulk vessels. However, it cannot be stated for certain because this review did not investigate all the possible break bulk shipments available to the company. The case company has used break bulk services according to demand and not as regularly as liners. Consequently, in this review service factors of liners and break bulk cannot be directly compared. Further research would be interesting to compare supplier contracts and, in more detail, third-party logistics provider's services at the port and vessel suppliers.

According to the second and third scenarios defined by market areas, emissions would decrease if direct road deliveries to West Europe were delivered by liner instead. However, emissions to East Europe and costs for both market areas increase compared to the as-is model. The results of the scenarios are compared in Table 13, where it can be seen, that costs are higher in the scenario of East Europe.

The most interesting findings were obtained from the last two scenarios, where in the former, a less polluting route options were chosen, and in the latter scenario, a more cost-effective routes were selected by using liner transport instead of direct road deliveries. In the emission-based scenario was found that this model could reduce CO_2 emission by 1,9%, but it would cost 1,3% more than current model. In the cost-based scenario, savings would be 1,9% of baseline, but it results in higher emissions. The results are collected in Table 13.

Table 13. Summary of scenarios.

Scenario	Baseline As-is	1. All in liner	2. Direct road deliveries to East European on liner	3. Direct road deliveries to West European on liner	4.Emission based	5. Cost based
Cost (€)	1	111,82 %	100,76 %	100,42 %	101,28 %	98,13 %
Emissions (ton)	1	115,01 %	100,69 %	98,84 %	98,14 %	101,11 %

According to the results, it would be beneficial to use liner vessels for deliveries to countries located on the western coast of Europe or to Mediterranean countries. In terms of costs, direct trucks to Eastern Europe are generally more cost-effective. The higher total costs in the scenarios result from the fact that the sea route is divided into multiple legs. Sea transportation include handling costs in the loading and discharging ports. Additionally, the first leg from the mill to the loading port and the legs in Europe (from the discharging port to the consignee or inland terminal and from inland terminal to the consignee) were taken into account. Consequently, part of the direct road deliveries from the mill to consignee were more cost-efficient as handling costs were considered as the responsibility of the mills and the consignees. In the literature review, it was noted that the cost advantages of maritime transport arise due to higher capacity, which leads to a lower cost per ton.

The scenario results are theoretical and would require further analysis before decisions are made but they provide a direction for future research. Having the cost and emissions for each route advice the company to choose the transport mode that benefits the most.

6 Conclusions

The purpose of the thesis was to examine whether the transport model could be improved by changing the transportation modes. This research is part of a broader review of distribution improvement in the case company. The focus of the study was to examine the impacts on cost, emissions, and service factors if the volumes of direct truck deliveries were shifted to liner vessel routes.

Insights for sea transportation features were gained and key performance indicators for distribution were identified in the literature review. To measure cost efficiency, the cost per tonne and total costs per year for each transportation route were evaluated. Sustainability performance was measured by CO_2 emissions, and service perspective was evaluated by transportation time and shipment frequencies.

In the as-is analysis, the current transportation mode was analysed. Costs and emissions for each route were collected and service factors were determined. The reliability of the costs was influenced by the fact that the costs for different modes of transportation were defined differently, either on a tonnage basis or a load basis. Additionally, some costs already included the BAF, while others did not. The values were adjusted to make them comparable. Regarding emission results, it should be noted that, according to the assumptions, the leg after the discharging port, the final delivery is done by European truck which has an emission factor of 59,17 g/tkm, and the direct truck from the Finland has emission factor of 45,77 g/tkm. Results would be more realistic if there was visibility into the details of the actual transport mode in each leg of the routes.

Results of the as-is analysis served as the base line for the created scenarios. In the scenario analysis, five scenarios were created: (1) All on liner, (2) Direct road deliveries to East Europe on liner, (3) Direct road deliveries to West Europe on line, (4) Emission-based, and (5) Cost-based. The most cost-efficient scenario was Cost-based scenario as cost decreased by 1,9%. From sustainability perspective, the best scenario was the Emission-based, as emissions decreased by 1,9% compared to current model. The *All on liner* scenario had the highest costs. Emissions decreased in scenarios 3 and 4, while costs decreased only in scenario 5.

In the literature review, it was found that costs decreases when the same fuel and labour cover more distance with fewer stops, according to tapering principle. This phenomenon was identified through a case study reviewing cost of the deliveries to delivery country in Eastern Europe. For example, delivery from mill D to this certain delivery country cost between 46€ and 61€ by truck and between 71€ and 92€ by liner. The liner's higher cost includes dispatch from mill to the port, handling costs at the port, sea freight, handling costs at the discharging port and the cost of the final delivery from discharging port to the consignee. In contrast, truck delivery includes only one leg, the primary delivery from the mill to the consignee, which uses only one type of fuel, and the handling costs are considered as zero, belonging to mill and consignee operations.

On the other hand, according to the results, CO_2 emissions will decrease by about 250 tons if all direct trucks to this certain delivery country were delivered by liner. As a conclusion, sea route causes less emissions but costs more than truck delivery. In terms of service, the delivery time is not remarkable longer on liner when it is at its shortest, 5 days, the same time as by direct truck. Here, the company has an opportunity to make a strategic choice, whether the emphasis is on costs or emissions.

Assessing each route separately they were categorized into groups based on whether the costs would increase or decrease and whether the emissions would increase or decrease if delivery were on liner. The company confirmed that the liner routes, which are cheaper than road routes, were already set as the default route. Next, the company could consider the possibility of using liner deliveries more frequently for these specific destinations instead of trucks. However, this review stated that all truck deliveries are not avoided due to urgency or the specificity of order requirements. Nevertheless, the company could set a goal for the share of sea and road deliveries.

When assessing scenarios, the impacts on 3PL cannot be ignored. All scenarios increase liner volumes, which increases volumes through the ports as well. The largest volume increase is in the scenario of *all on liners* by 45,5% weekly volumes in South Finland. The lowest is 7% increase per week in scenario of *Direct road deliveries to East Europe on liner*. It should be considered which port would be affected and what their capabilities are to receive larger volumes. Resources impacted in port operations include operating hours, human resources, equipment, and other customers of the port.

In the addition to port recourses, the capacity of vessel suppliers should be noted. In 2022, the company had one significant liner supplier. As vessels have limited capacity, the supplier's capabilities to take on a larger volume should be negotiated. It is also affected by the demand of other companies for supply. The assessment of suppliers was outside the scope of this thesis but would be interesting for further research: What are their capabilities for handling larger volumes? Is the current supplier the only one that meets the company's needs?

Assessment of ports and suppliers would require more detail information, as it is recognized that maritime transportations have many specific requirements for stowage modes and transportation units. The services offered by the ports vary because stowage modes and transportation units require different equipment. In the conversations with the supply chain specialists of the company, differences in information sharing between the company and the ports emerged. This was identified as a significant factor in efficient shipping because inadequately linked systems require extra manual work. Investment in system development could be useful if the volumes transported through the port increase.

In this research, the outbound volumes from mills are assumed to be the same as in 2022. Higher liner volumes would lead to increased transportation volumes between the mill and the port. In further research, capabilities of the mills loading and transportation to the port should be considered, as they currently utilize both road and rail transportation modes. Trucks are faster, but there are limitations in loading times and areas in the mills. Train transit times depend on the schedules but can transport larger volumes at a time. In the company's earlier research, it was found that CO_2 emissions can be reduced by increasing rail transportation in the first leg using a modern pendulum model instead of the traditional rail transportation model. Higher rail volumes in port transportation would align with the company's strategic goals towards carbon neutrality. Additionally, concerning transportations from mills to ports, the distances between mill and port should be assess if the company has a desire to centralize port operations, as company currently uses several ports in South Finland. Distance is a significant factor in emissions and transportation times.

The company did not have precise visibility into European land transportations. In the dataset, the transportation modes from the port to an inland terminal were defined as rail, road, or multimodal. Multimodal encompassed both rail and road transport modes. European land transportation costs were based on load costs, defined as cost per tonne without classifying transport modes, as we were uncertain about the actual model used in multimodal transportation. Due to that lack of visibility, when estimating emissions, it was assumed that rail accounted for approximately 80% of European transport to inland terminals. A more comprehensive examination of the actual transportation modes in European land transport would be a valuable area for further research. Gaining visibility into land transport operations in Europe would be crucial, as increasing rail deliveries could enable the company to reduce emissions.

Demand in the packaging material industry is volatile. Companies in volatile markets should be flexible in changing environment: during lower demand the company should take actions in cost savings and be prepared to peaks in demand when it increases. Volatile markets are not taken into account in calculations of this study. The year 2022 was successful for the company, so the volumes can be considered to be from a time of high demand. Logistics should recognize the fluctuations in demand as well. In decision-making it is challenging that contracts with the suppliers are made for the entire year. Demand forecasts help in the decision-making, but there are still many uncertainties related to future needs.

To achieve the company's carbon neutrality goal, the weighting between costs and emissions should be considered in decision making. Cost savings are clearly significant during periods of low demand, but it must be noted that the strategic decisions are long-term objectives that also need to meet the customer expectations. By promoting green supply chain management, a company enhances its image. Legislation and emission restrictions may be questioned if they do not currently support companies in choosing environmentally friendlier options from an economic perspective as well. The company could also consider together with the stakeholders, whether the adoption of green supply chain practices could provide added value to customers.

Whitin the organization, increased interest in the environmental impacts of the supply chain by the customers was identified already. It implies that it is not meaningless to investigate these effects. Although maritime transport was identified on several routes as a less emissions-intensive transport mode compared to truck delivery, it is not purely an environmentally friendly delivery method. Maritime transport was also recognized to have other significant emissions than CO_2, such as NO_x, SO_x, PM emissions, and other environmental impacts, for example, diversity effects related to ports.

Direct trucks were identified as the most profitable option from a service perspective due to their flexibility. The company could consider trucks that operate on alternative fuels for its deliveries, such as biofuel-powered trucks or electric vehicles in the future. The company, together with its stakeholders, could explore more environmentally friendly truck deliveries, which would enhance the company's reputation and possibly find new solutions for sustainable delivery alternatives.

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