UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Intermodal Freight Transport

Evaluating the Suitability of Future Potential Implementations

A Case Study of Volvo Car Corporation

Master Thesis
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Abstract

Environmental awareness has become increasingly more important for governmental and non-governmental organizations throughout the years, pushing organizations to better their operations with the aim to reduce environmental impact. One of the organizations aiming to reduce their environmental impact is Volvo Cars, which, through various organizational improvement efforts, has managed to reach environmental sustainability-related goals. Therefore, this thesis was established to provide Volvo Cars with a generally applicable evaluation method used for assessing potential intermodal rail-road transportation setups, with the aim of improving organizational environmental sustainability and maintaining operational quality excellence. The evaluation method was generated through a combination of theoretical and empirical findings, resulting in 12 main parameters needed to take into consideration when operating a rail-road intermodal network. The parameters generated from the results were; Volvo Cars' Volume, Clustering Volume, Infrastructure, Terminal, Risk Management, Delivery Accuracy, Lead Time, Economic-, Social-, and Environmental Sustainability as well as Distance and Border Simplicity. Each parameter was given an individual weight, depending on its importance when evaluating the attractiveness of a potential setup. The established weights were critical, major, and preferable. Additionally, each parameter could be given a maximum overall score of 6, where a score of 3 was the critical level for meeting Volvo Cars' expectation criteria. Each evaluation could also be visually illustrated in a pie radar chart diagram for easy interpretation.

Keywords: Rail-road Intermodal Freight Transport, Intermodal Freight Transport, Volvo Cars, Rail Freight, Road Freight

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1. Introduction

This chapter aims to introduce the topic of intermodal freight transportation to the reader. Here, the incentive of improving environmental sustainability is highlighted together with the problem description and empirical case description introducing the company Volvo Cars. The chapter will also include the purpose of the thesis, which includes the contribution to potential increased organizational performance. Lastly, the research questions will be stated followed by relevant definitions, scope, and limitations of the thesis.

1.1 Background

Environmental awareness continues to increase across nations, pushing governments, governmental- and non-governmental organizations to better their operations with the aim of reducing environmental impact. The combination of increased customer environmental awareness, initiations, and regulations implemented by governments has created competitive advantages for companies succeeding to reduce their environmental impact. As a result, shareholders and customers tend not to want to invest in or support companies not taking environmental action (Sheffi, 2018). Therefore, a reduction in organizational environmental degradation is essential for organizations worldwide, something which is oftentimes measured in kilograms of CO2 emissions discharged (Lash and Wellington, 2007).

The transportation industry is no different. With every increasing supply chain network and global operations, the industry has over the last 100 years vastly grown in complexity, contributing to approximately one-fifth of the world's total CO_2 emissions discharged (Ritchie, 2020). Increased complexity has been a result of improved logistical technology and various standardizations implemented, expanding global trade networks and supply chains throughout the years (Levinson, 2006; Ortiz-Ospina and Beltekian, 2018). The rapidly growing supply chain networks have led to companies prioritizing cost-effective transportation solutions, as opposed to environmentally sustainable logistics alternatives, strategies that have recently been argued against. Resultantly, the literature argues that environmental sustainability is only considered when such strategies also promote cost reductions (Sheffi, 2018). Arguably, financial gain is the motivating factor to improve organizational environmental sustainability, factors that perhaps can be met as a result of increased governmental action and societal pressure (Sheffi, 2018).

The environmental degradation, calculated in CO_2 emissions emitted, shows vast differences between sectors, where the transportation sector, as previously mentioned, accounts for vast amounts of the world's total CO_2 emissions, not considering the manufacturing and production of such vehicles (Ritchie, 2020). Of this share, road transportation accounts for as much as three-quarters of total transport emissions, where passenger vehicles contribute to 45.1 %, and freight carrying trucks to the remaining 29.4 %. Rail, on the other hand, only accounts for 1 % of total transport emissions, highlighting the benefits of trying to substitute road freight using more rail transportation to improve environmental sustainability (Ritchie, 2020).

However, although intermodal freight transport solutions became more effective already in the mid-20th century, it has not yet become the most popular transportation solution despite their many perks (UIC-ETF, 2019). When looking specifically at European transportation, it can be seen that road transportation has remained the most popular mode in tonne-kilometers for European freight for decades (UIC-ETF, 2019). On the contrary, although road transportation has played the most dominant role for so long, companies operating in Europe will have a tough time relying only on road freight due to capacity constraints in the future. In recent years, road transport performance seems to have weakened due to increased fuel prices, congestion, taxation, and raised environmental awareness (UIC-ETF, 2019). As a result, initiations and conferences now push countries and organizations to, at an increased rate, reduce their environmental footprint (European Commission, 2022; United Nations, 2015).

In December 2019, the EU Green deal was presented. This involved a proposal on how to decarbonize industries that are highly energy-intensive, through introducing clean technologies and pushing for further implementation of for example intermodal freight transport (European Commission, 2022). As proposed by the EU Green Deal, doubling rail freight by 2050 is a feasible request that will potentially contribute to an increased EU introduction of rail-intensive intermodal transportation routes (European Commission, 2022). Arguably, to reach the goals presented, these initiatives need to be supported by company contributions, putting effort into reducing their carbon footprint.

As previously argued, financial gain is the motivating factor to improve organizational environmental sustainability (Sheffi, 2018). If a greater implementation of intermodal freight transportation could act as a substitute to only using road freight, whilst keeping costs and quality aspects at anticipated levels, companies might want to make such modal shifts. When implementing intermodal transportation solutions, many parameters need to be taken into consideration as of their pure complexity. Because of this, this thesis aims at finding a generally applicable evaluation method used to assess potential future intermodal transportation routes, to ease future selection and implementation processes.

1.2 Problem Description

Freight transportation can be described as one of the bases of today's society. Today we are reliant on the supply of goods from various sources to subsist as the movement of goods means accessibility to society's most basic functions, food, and healthcare (BTS, 2002). In 2011, the European Union claimed that freight volumes were to be doubled over the next couple of decades (European Commission, 2011). Although road transportation today is the number one mode used for freight transportation in mile-tonnage in Europe, the increase in freight transport will mean a huge strain on infrastructure and serious increases of congestion and environmental damage (UIC-ETF, 2019). This, together with raised environmental awareness and incentives pushed by governments and organizations, forces companies to reconsider freight transportation activities already pointing toward a modal shift (European Commission, 2022). Arguably, companies need to align their operations with such incentives for Europe to see a fully developed intermodal freight system in the future.

1.3 Empirical Case

Volvo Cars, one of the leading manufacturing companies in Sweden, is constantly undergoing various processes of improvement, many of which focus on environmental sustainability issues. The company was founded in Gothenburg, Sweden, in 1927 when the first car was launched. Since then, the company has increased its business and car development, majorly focusing on security and sustainability. According to their 2020 Sustainability report (Volvo Car Group, 2020a), the organization works toward meeting several challenges and standards continuously set by governments and organizations, to help reduce operational environmental damage. In 2000, Volvo Cars became a member of the UN Global Compact and have since observed and worked toward its ten principles regarding human rights, labor, environment, and anti-corruption (United Nations Global Compact, 2019; Volvo Car Group, 2020a). Additionally, Volvo Cars have expressed its support for the United Nations Sustainable Development Goals, where much emphasis has been put on improving sustainable strategies aiming to become a leader in responsible ethics and business (Volvo Car Group, 2020a).

In Volvo Cars 2020 annual report (2020b), the goal of becoming climate neutral by 2040 was stated. A goal that is continuously taken into consideration in all operational activities for it to be reached. One of the main short-term contributors to reaching this goal was implementing a reduction plan of per car emissions of 40 % by 2025. Furthermore, actions to reduce 25 % of supply chain emissions and an additional 25 % of operational activity emissions, such as transportation, have been taken (Volvo Car Group, 2020b). Volvo Cars also states that they have managed to reduce per car logistics-related emissions, where an important contributor was initiating a modal shift toward less energy-intense transportation modes.

At the beginning of 2020, Volvo Cars initiated major changes in their European transportation network and one major rail-road intermodal transportation route was established. The route initiated begins in the Czech Republic and continues by train throughout Germany to the port of Rostock. In Rostock, the trailers are unloaded from the train and shipped on sea vessels to Trelleborg where they are transported by truck to the end location in Torslanda. Trucks used within Sweden are fueled by renewable HVO diesel, enabling Volvo Cars to reduce 50 % of the route's emissions by using rail as the main transportation mode (Volvo Car Group, 2020b). The implementation of the solution has proven to keep up with stability and flexibility expectations even during the pandemic. Moreover, it is estimated to remove around 3400 trucks annually, transporting goods on roads. In addition to the environmental benefits generated, Volvo Cars state that using an intermodal freight transport solution can further reduce transportation time by 30 % (Volvo Car Group, 2020b).

Additionally, the company states the aim of reducing carbon footprint through various measures, one of which involves further implementation of intermodal freight transportation solutions; this, as the recently implemented route, has proved successful (Volvo Cars, 2020b). Various studies investigate the possibility to analyze or measure attempts to improve overall sustainability in different transportation systems (Van Wee and Handy, 2022). Although it has previously been done, this study adds the element of studying parameters used for evaluating and assessing the specific potential and existing intermodal logistics routes at Volvo Cars.

This thesis aims on generating an evaluation method that Volvo Cars can apply to, and evaluate the attractiveness of future intermodal setups. A methodology that the company lacks today. Since Volvo Cars possess a widespread supplier network, implementing more intermodal transportation routes is essential for maintaining and improving future freight efficiency and quality excellence (Majdandzic and Lundh, 2022a). Hence, this case study will be conducted, specifically, at the Supply Chain Management department at Volvo Cars in Gothenburg.

1.4 Purpose

Currently, implementing intermodal freight transportation solutions at Volvo Cars is a majorly complex operation. Though, for the company to simply enable such implementations in the future, an evaluation method could be greatly beneficial. **This thesis, therefore, aims to find a generally applicable evaluation method to assess potential future rail-road intermodal transportation routes at Volvo Cars.**

The result will be based on a number of parameters identified throughout the project, parameters that will act as the basis of the evaluation method.

To find and evaluate these, the research questions investigated will therefore be:

I. *What are the main parameters needed to consider when implementing and evaluating intermodal rail-road transportation flows?*

II. *How would a method for evaluating and assessing the attractiveness of potential solutions for future implementation of intermodal freight transport at Volvo Cars be constructed?*

The first research question can be answered using a combination of theoretical and empirical findings, whereas the second research question regards analyzing results generated from question one, enabling the development of the evaluation method.

The method generated from the results will consist of a number of parameters. A *parameter* can be defined as a measurable factor affecting the attractiveness of an intermodal transportation setup. Each parameter could consist of various components, which in this thesis are defined as *attributes*. The parameters will be weighted differently depending on how important they are considered to be. The *weight* of a parameter, therefore, reflects the magnitude of technical influence when operating intermodal. The *evaluation* method generated will be developed to assess a potential setup, for Volvo Cars to determine if it is considered attractive. The *attractiveness* of a potential setup can be defined as Volvo Cars' willingness to implement the route once it can be established if the route meets or exceeds Volvo Cars' quality expectations.

1.5 Scope and Delimitations

The scope of this project will be to produce an evaluation method that Volvo Cars can benefit from when selecting and evaluating potential future rail-road intermodal freight transportation routes. For the researchers to be able to complete this project, the final evaluation method will be based on a number of parameters, gathered from empirical and theoretical findings. The study will be delimited to European rail-road freight for the researchers to maintain relevant depth and focus on the project. The evaluation method will be delimited to potential future implementations or already existing setups at Volvo Cars since empirical data will be based on company-related aspects. Certainly, the evaluation method can be used for the implementation of other rail-road networks. What is important to note then, is that the specific method is produced in collaboration with Volvo Cars and relevant freight operators. Furthermore, the evaluation method will be used on one already existing rail-road intermodal transportation route that Volvo Cars have previously implemented as well as on one potential setup for a proper analysis to be made. This will allow the researchers to see the differences in evaluating potential routes in relation to an already established, well-functioning setup.

2. Theoretical Framework and Literature Review

This chapter presents relevant concepts used in the thesis to give the reader a better understanding of the topic and chosen scope. Furthermore, it explains the initiation of concepts and how they have been developed until this day. The concepts presented are the basis for intermodal rail-road freight within Europe and contain road freight, rail freight, and intermodal freight transportation. Furthermore, previous literature will be included, where articles and reports on rail-road intermodal freight transport will be reviewed with a focus on implementation challenges, environmental sustainability as well as hub-and-spoke systems. The importance of the included aspects is to understand the complexity of rail-road intermodal freight transport solutions and how they are generally constructed. Lastly, a key takeaway section will be added, highlighting key takeaways that will be of value for results and further analyses.

2.1 Theoretical Concepts

2.1.1 Road Freight

Road transportation has been essential for human development for thousands of years and was first seen in a very simple state in about the 4th or 3rd century BC (U.S. DOT, n.d.). Ever since improvements in road infrastructure and improved communication tools have meant vast advancements in logistics utility and international trade. Today, road transportation is an essential part of freight movement. In fact, figures show that when looking specifically at the modal split of European freight transportation in tonne-kilometers, the road remains the leader. Between 2005 and 2016, road freight accounted for approximately 75 % of European freight, and despite a vast difference in the modal share between countries, an overall number of 75 % highlights how fundamental it is in today's society (UIC-ETF, 2019).

There are many reasons why road transport has remained the main transportation mode for so long, primarily due to its simplicity (UIC-ETF, 2019). Transporting goods long distances, across borders of varied practices, cultures, laws, and regulations have been proven most simple when operating on-road (Engström, 2016). What is important to note, on the other hand, is that in recent years, European policymakers seem to push for a modal shift, making road transportation much less attractive. These policies have been a result of ongoing trends such as urbanization, globalization, and population growth, all increasing the pressure put on today's infrastructure and logistics networks. However, the main reason why such policies are introduced is environmentalization, highlighting the negative environmental effects caused by road-based transportation. Pushing toward a modal shift could therefore mean results of decreased emissions emitted, as increasing the use of rail or maritime freight is much more environmentally sustainable (Engström, 2016).

What is important to note, on the other hand, is that road freight is still considered a necessary part of freight movements. Even if a modal shift is made, road freight is especially important at the beginning and end of intermodal transportation routes. Therefore, it is also essential to optimize road-based infrastructure and push for technological improvements as it will still be an important part of European freight, despite continuous increases in fuel prices, taxes, etc (Engström, 2016). However, road freight is constantly improving in sustainability. As of increased demand for less environmentally damaging solutions, new technology continuously provides road freight with new solutions. One example is trucks being fueled by renewable diesel. In Sweden, diesel can be classified as renewable if at least 21 % of HVO or FAME is added, which are classified as renewable diesel and biodiesel (Miljöfordon, 2021). Depending on where the truck is refueled, this proportion of fuel alternatives can be even higher. Some road-based transportation modes even operate solely on HVO which can reduce CO_2 emissions by up to over 80 % (Miljöfordon, 2021). In addition to renewable diesel, technology has also enabled the use of trucks being powered solely on electricity. The main disadvantage with this, on the other hand, is the limited distance being covered before the battery needs to be recharged (Augustsson, 2021).

2.1.2 Rail Freight

Rail has been used for freight transport for nearly two centuries but saw major connection improvements in the late 20th century. Since then, European goods freight has greatly advanced, making rail freight more attractive (Böröcz and Singh, 2016). According to Gnap et al., (2019), overall European rail freight saw slight performance improvements between 2004 and 2017. During this period, Germany was defined to have increased its performance most eminently, contributing to overall figures (Gnap et al., 2019). It has also been estimated that European rail freight is to continue increasing in the future, because of the many benefits of reduced congestion and safety issues on roads and the environmental benefits rail freight contributes (Gnap et al., 2021). However, for it to continue increasing, both in terms of usage and performance, Europe must maintain and develop its rail infrastructure (Gnap et al., 2021; Rail Freight Group, 2020).

From an environmental sustainability perspective, studies show that increasing the share of electrified rail-based freight movement would be beneficial. Additionally, it is argued to be cost-effective, not only due to increased fuel prices and taxations but also because fuel-driven rail transportation is proven to be more than three times as fuel-efficient as road transportation (Zhang, Li and Zhang, 2019). These advantages have contributed to rail transportation becoming an increasingly more popular transportation mode as it is both safe, reliable, and suitable for long distances with large volumes (Collins, 2020; Zhang, Li and Zhang, 2019).

Rail freight has also come much further than other transportation modes when it comes to using electricity as fuel, this is due to constant technological improvements. Technology improvements in electrification have, together with implemented emission regulations and societal pressure, motivated the transportation industry to increase its usage of rail, by for example implementing more intermodal transportation routes (Rail Freight Group, 2020). Studies show that, by using more rail freight, environmental damage can be heavily reduced. In fact, figures show that making a modal shift from road to rail could reduce CO_2 emissions by up to 76 % (Rail Freight Group, 2020).

The European Commission also claimed in their White Paper (2011) that they aim on improving European intercontinental intermodal freight transport networks. Such an improvement would contribute to improved support in the exchange of goods and interconnections between various countries and regions (White Paper, 2011).

2.1.2.1 European Rail Freight Corridor (RFC)

The European rail network currently consists of nine rail freight corridors, RFCs (see Figure 1 below), that together help ease international freight transport movements (Rail Net Europe, 2020; White Paper, 2011).

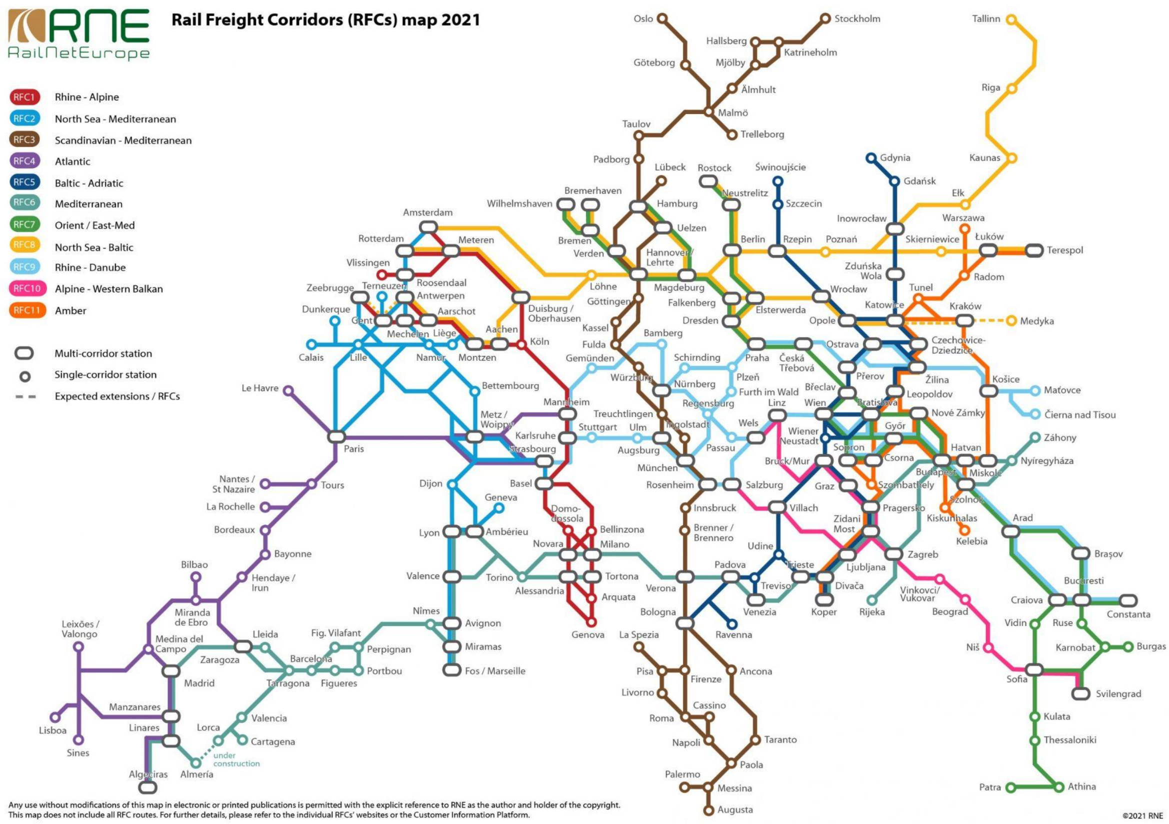


Figure 1. Rail Freight Corridor Map 2021 (Rail Net Europe, 2020)

The European Union did, in 2010, establish the No. 913/2010 regulation, incentivizing all member states to form international RFCs to reach a number of market-oriented goals. These goals included balancing freight and passenger traffic to ensure market needs, promoting cooperation between various infrastructure members as well as promoting intermodal freight networks. Since the establishment of the No. 913/2010 regulation, the last RFC was established in 2016 (Rail Net Europe, 2020).

However, as the freight traffic does not most commonly begin or end along with these RFCs, it is also important for freight operators to be able to perform smooth and harmonized intersections (Islam, 2018). For these goals to be met and for the existing RFCs to improve and expand, there is a need for coordinated and synchronized European infrastructure investments. Such investments would not only include rail networks for freight, terminals, and ports enabling more efficient links between different transportation modes, but it would also include increased demand for using these types of networks (European Commission, 2021; Islam, 2018; Rail Net Europe, 2020).

2.1.2.2 European Railway Electrification Systems

The European railway networks were established across borders during different periods, which in turn have caused variations in electrification systems used. As illustrated by different colors in Figure 2 below, European railway electrification systems can be classified into different categories depending on what voltage is used in each region (Verdicchio et al., 2019). Due to these variations, ensuring locomotive capability is essential when operating across borders. There are only a number of locomotives that can actually handle operating on more than one of these electrification systems, contributing to operating inefficiencies (Verdicchio et al., 2019). If one locomotive does not have this capability, additional locomotives will be needed, which could mean quality deviations. Such quality deviations can be explained by added intersections, most likely contributing to operational issues such as trains not arriving or leaving on time or goods being mishandled or lost, etc. (Verdicchio et al., 2019).

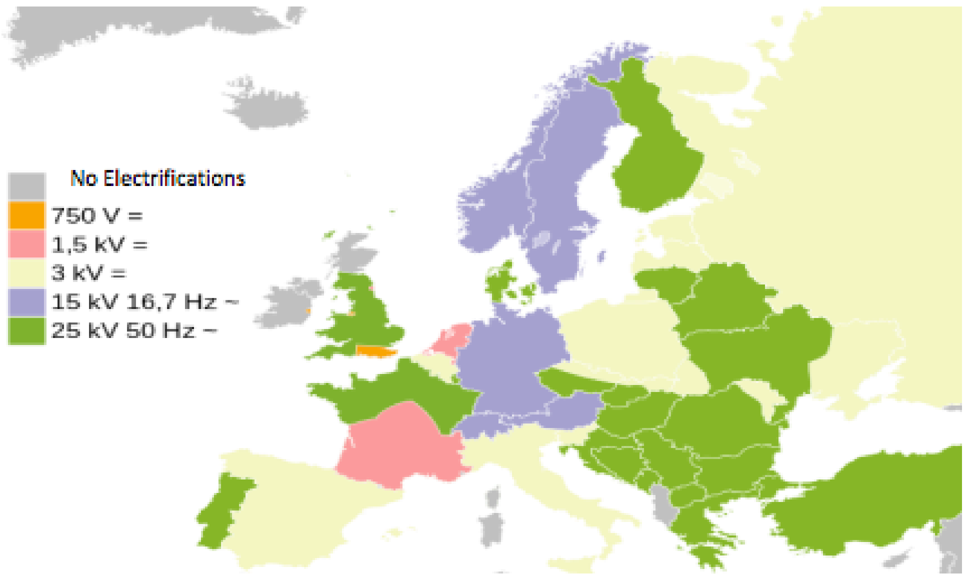


Figure 2. European Railway Electrification Systems (Verdicchio et al., 2019)

2.1.3 Intermodal Freight Transport

Intermodal freight transport refers to goods movement from one point to another using at least two modes of transport, whilst remaining the same unit load throughout the route. Intermodal freight transportation solutions have been used for a long period of time but had a major breakthrough after the development of containers in the 1950s (LaGore, 2016; Zieger, 2018). This breakthrough, along with the implementation of various standardizations, has since made intermodal freight transport much more accessible, efficient, and less costly. These effects are the result of a reduction in goods handling costs, as containers enable goods to be kept in the same unit throughout entire routes, making logistics flows much more seamless (Zieger, 2018). Containers were first introduced in ports in the 1950s and from this point on, containers were no longer manually handled and did therefore improve port effectiveness and efficiency, positively impacting freight volume capacity and profitability (Kawashima, 2017; Monios and Bergqvist, 2017).

While the use of intermodal freight transport first gained popularity within maritime freight, the concept of intermodal transportation developed relatively early (LaGore, 2016). In the 19th century, the combined usage of canal operations and rail or horse freight further advanced, enabling the development of intermodal transport units. In the early 20th century, trucks were put on rail transport and rail wagons on vessels, increasing trade accessibility (Monios and Bergqvist, 2017). This, in combination with lowered tariff barriers and increased globalization, in turn, enabled an increase in both domestic and international freight movement. After the initiation of containerization and various forms of freight standardizations, intermodal freight on land and sea is now seen all across the globe as its contribution to reduced unit costs and delivery time (LaGore, 2016; Monios and Bergqvist, 2017).

Although there are many benefits to using intermodal freight transportation, it also represents a challenge in Europe. Freight volumes continuously increase, whilst intermodal transportation, especially rail-based freight, is still seen as somewhat troublesome (Gharehgozli, de Vries and Decrauw, 2019). This perception can be explained by challenges only faced when operating intermodal, such as booking issues, waiting times, contracting issues, and its pure complexity (Gharehgozli, de Vries and Decrauw, 2019). In spite of this, it can be seen that there is an increasing demand for using intermodal freight transport. In fact, in recent years it has come to play a dominant role within various supply chains and distribution networks (Greencarrier, 2016). Lately, figures indicate a trend of companies using more smart and sustainable ways of transporting goods, as of increased societal environmental awareness pushing customers to demand more sustainable solutions (Greencarrier, 2016). To meet this demand, intermodal freight transport can be used. In 2011, the European Commission established 40 detailed incentives aiming at making European transportation systems more sustainable and competitive. One of the major goals presented was to reduce road freight exceeding 300 kilometers by 30 % until 2030 and by 50 % until 2050, a goal that would require a modal shift toward rail or maritime freight. This would hence mean the implementation of more intermodal freight transportation networks (European Commission, 2011).

Further, additional research supports intermodal freight networks possibly replacing simple road freight in the future, due to major infrastructure development investments positively affecting intermodal rail-road networks becoming more integrated. Studies also indicate two major industries making this modal shift, the automotive industry and the consumer packaged goods industry (Greencarrier, 2016). Although this shift is to be seen, this will also contribute to the overall complexity of operating intermodal, as rail-based intermodal services are tied to fixed time schedules, whilst simple road transport is more flexible. Time inefficiencies, therefore, need to be considered when implementing more intermodal freight networks. However, there is also the possibility of ensuring delivery times by combining intermodal freight routes with using only road-based transportation, in order to ensure time and volume irregularities (Sun, Yu and Huang, 2021).

2.2 Previous Literature on Rail-Road Intermodal Freight Transport

Found in literature, an increased interest in synergetic logistics can be seen as a result of constantly increasing pressure put on companies. Organizations, therefore, need to continuously improve efficiency and productivity throughout their supply chains to reduce costs and improve operational quality (Bhattacharya et al., 2014). According to Bhattacharya et al., (2014), transport-related costs are estimated to represent approximately 30 % of total costs generated from logistics activities. Thereupon, a need for cost-efficient and effective transportation throughout the supply chain is crucial (Bhattacharya et al., 2014).

2.2.1 Implementation Challenges

When implementing an intermodal transportation setup, companies need to take various challenges into account. As intermodal transportation routes involve the process of combining various transportation modes, moving freight from point A to B, intermodal routes naturally become more complex than unimodal routes (Newman and Yano, 2000). The increased complexity is a result of a combination of intersections needing to work smoothly, more actors being involved in the process that hence causes additional aspects that could possibly not work as smoothly as anticipated (Newman and Yano, 2000). Although, studies show that for distances exceeding 300 kilometers, a modal shift to using mainly rail-based freight is preferred, as of its considerably lower energy use (Reis, 2014). Furthermore, using rail as the main transport mode for longer distances also contributes to decreased labor and operating costs. This can be explained by the capacity and possibility of forwarding large volumes on one train as opposed to several road-based modes (Newman and Yano, 2000). Operating intermodal on longer distances also allows for increased complexity due to all the positive aspects it involves (Newman and Yano, 2000). It is also argued that intermodal transport networks have recently become much more effective as of increased demand for such solutions. However, although recent advances in intermodal transport efficiency have been seen, there are still a number of difficulties and challenges needed to consider when planning the implementation of an intermodal route. Some of which include strategic planning, technology, and operating permissions (Newman and Yano, 2000; Rail Net Europe, 2020; Verdicchio et al., 2019).

Although various models have been produced to facilitate intermodal freight networks throughout the years, all such networks differ from one another (Newman and Yano, 2000). Important to note from these models, on the other hand, is that most include collaborations between drayage companies, terminal design, infrastructure availability, and truck or chassis fleet size (Newman and Yano, 2000). Additionally, strategic planning challenges include interaction between freight and passenger flows, infrastructure alterations, and initiations of new governmental and industry policies (Newman and Yano, 2000). For successful implementation of intermodal transportation setups, efficient terminal design is essential. As most intermodal freight flows are time constraint, the availability, capacity, and type of equipment is essential for smooth operations to be carried out. When considering terminal design, companies need to regard operation lead time as the main performance criterion for an intermodal setup to be successful (Newman and Yano, 2000; PCC Group Product Portal, 2020).

To avoid troublesome intermodal logistics routes, it is of the essence for strategic decision-makers to invest in research regarding affected links and nodes. For large multimodal networks, Southworth and Peterson (2000) suggest that geographic information systems (GIS) yield new technological opportunities, where companies can plan such networks more efficiently. Southworth and Peterson (2000) also highlight the importance of company-specific rights using rail tracks and the importance of interlining company practices for those who operate. Additionally, similar to Newman and Yano (2000), Southworth and Peterson (2000) and the PPC Group (2020) mention the importance of considering existing infrastructure, terminal availability as well as within-terminal transfer links, and relevant equipment. Similarly, Zunder and Islam (2017) suggest that the accessibility of intermodal terminals is vital. Corry and Kozan (2006) argue that terminals can differ in storage, layout, handling equipment, and operating policies. Before implementing intermodal freight transport networks, Zunder and Islam, (2017) also state that functionality and accessibility requirements are weighted heavier than the general capabilities of handling cargo.

Reis et al., (2013) found that, for higher valued goods, time, flexibility, and reliability is of great importance. Zunder and Islam (2017) also suggest that increased use of intermodal transport solutions has been seen for semi-finished goods, such as car parts, in Europe. An increase can also be seen for completely finished products, of high value with low density. For these specific industries, cost efficiency is also of great importance. To increase the attractiveness of intermodal setups, cost efficiency, therefore, needs to meet expectations. Although intermodal setups are oftentimes seen as more cost-efficient than unimodal setups, operational complexity also means companies want to see greater cost advantages if making a modal shift (Reis et al., 2013).

Furthermore, Uddin and Huynh (2019) suggest the importance of enhancing strategic aspects in order to meet capacity uncertainties. They suggest that to ensure the reliability of intermodal rail-road networks, companies should assume that capacity is lower than it actually is when planning the route, to obtain a desired level of reliability. Additionally, it was found that the total cost of a rail-road intermodal system will increase when the uncertainty of capacity increases or when disruptions at intermodal terminals, nodes, and links appear (Uddin and Huynh, 2019). This is further elaborated on by Ertem (2011) where volume fluctuations need to be considered when operating intermodal. This is due to challenges related to managing capacity and volume fluctuations. When operating intermodal, strategic decisions need to be taken with regard to volume for companies to get reliable rail-road intermodal services (Ertem, 2011).

Important to consider when implementing intermodal freight transport routes is the gap between theoretical performance and actual performance. According to Reis et al., (2013) in theory, performance and synergies are usually calculated to be maximized, whereas waste and inefficiencies are to be minimal or nonexistent. Therefore, maximum attainable performance never equals theoretical performance, which can be explained by real-world friction. Therefore, collaborations among transport agents are vital in being able to reduce this gap (Reis et al., 2013). Investing in compatible equipment and having alignment of different processes included in intermodal freight services is also of high importance (Corry and Kozan, 2006; Newman and Yano 2000; Southworth and Peterson 2000). Reasons for such performance gaps can be explained by skill inequalities of freight forwarders caused by variations in process standards. This could hence lead to unequal performances of intermodal freight services (Reis et al., 2013). Another explanation could be the capability of managing an intermodal freight service for the forwarder. Furthermore, in theory, all modes of transport within an intermodal freight transport network are operating at optimal efficiency, which needs to be considered when implementing intermodal freight services (Reis et al., 2013). This is due to the complexity of achieving efficient and stable intermodal freight transport networks, being the reason why transportation is usually made by only one mode generating better stability (Gharehgozli, de Vries and Decrauw, 2019; Reis et al., 2013).

2.2.2 Environmental Sustainability

Literature shows that there are major positive environmentally and economically sustainable aspects of using intermodal freight transport systems, as opposed to unimodal systems (Sun, Yu and Huang, 2021). In fact, when operating intermodal, distances covered by trucks are shortened, enabling the use of trucks driven by electricity or renewable energy. Combining fuel-efficient trucks with increased use of rail, levels of CO_2 emissions emitted per transportation route can be drastically reduced (Augustsson, 2021; Lundh, 2022; Majdandzic, 2022). However, there are also ways of decreasing emissions emitted by intermodal freight transportation further. According to Islam (2018), there is a need to further enhance intermodal environmental sustainability to make it even more attractive. This would require increased efficiency at ports making intersections smoother, but could also involve locating terminals closer to end destinations (Islam, 2018). When adopting a rail-road-based intermodal transport system, energy consumption can be reduced since rail transport is considered a more environmentally friendly way of transporting goods (Islam, 2018; Rail Freight Group, 2020). As a result of different attempts in reducing emissions generated by the automotive industry, new technology innovations put pressure on the rail industry to improve its performance from an environmental point of view. Such technologies can be used without harming the performance of the transport mode (Islam, 2018).

2.2.3 Hub-and-Spoke Systems

From a European point of view, a number of studies presenting models of how to choose different chains of freight transport have been made (Jensen et al., 2019). Results found show that the choice of transport chain system is dependent on the cost and time of transportation, the value of the goods being transported and their density as well as access to infrastructure and commodity type (Jensen et al., 2019).

When looking specifically at intermodal rail-road networks, Sun, Yu and Huang (2021), argue that the hub-and-spoke system is the most suitable network system. Simply put, hub-and-spoke systems act as a transportation optimization system, where traffic planners organize routes as 'spokes' connecting volume of freight from various origins to a central 'hub'. This way, the hub-and-spoke system can form a distribution model enabling smaller volumes to be forwarded more effectively (Sun, Yu and Huang, 2021).

For intermodal transportation solutions to be feasible and cost-efficient, generating large volumes is key. Therefore, hub-and-spoke systems are commonly used to gather volumes through clustering goods from various origins to reach enough volumes to fill entire trains. These goods will hence be transported from one hub to another, closer to the final destination (Sun, Yu and Huang, 2021). By doing so, the network takes the maximum advantage of mobility and accessibility of road services to transport goods from origin to rail terminals (hubs) and further deliver goods to final destinations (spokes). Using hub-and-spoke systems, economies of scale can be reached through delivery and pickup services at the hubs. On the contrary, it is important to understand that intermodal transport systems can require more time compared to only road-based transportation, as of fixed and restricted rail schedules and container/trailer transshipments between modes (Sun, Yu and Huang, 2021).

Using a hub-and-spoke system for intermodal rail-road freight is further supported by Wang et al. (2018), who argue that such a system is suitable when combining rail and road networks. General performance results are mostly measured in time and cost. The cost and lead time, which oftentimes refer to operational quality are commonly stated as paradoxical, meaning a sacrifice of one aspect results in benefiting the other. Using a rail-road intermodal hub-and-spoke network, there is a need to reduce the trade-off between the two aspects (Wang et al., 2018).

2.3 Key Takeaways

The theoretical framework and literature review chapter highlight various aspects important to consider when operating intermodal. It presents the concepts and the development of road freight, rail freight, and intermodal freight transportation. It also pinpoints the various European rail freight corridors as well as the European railway electrification systems, all important aspects and associated challenges needed to consider when operating on rail within Europe. The literature review further discusses additional implementation challenges, environmental sustainability, and the concept of hub-and-spoke systems, all relevant specifically for European rail-road intermodal setups. From the theoretical framework and literature review, a number of recurring themes were established; *environmental- and economic sustainability, distance, planning, collaboration, terminal and infrastructure aspects as well as policies, regulations, and operational quality.*

As mentioned by Zunder and Islam (2017), some parameters are essential for an intermodal transportation route to functionally operate, whereas others can be seen as more beneficial, making the route more efficient and smooth.

3. Methodology

This chapter aims on explaining the methodology used for the thesis. There are four phases included in the research design, each of which will be described in more detail. Following the four phases, the quality of the research will be discussed, a discussion based on the chosen research design, previous studies, and empirical findings.

When determining the research design, the researchers needed to decide upon which methodology seemed most appropriate. For this thesis, the method chosen was a case study, where the methodology design was based on mainly qualitative data, where quantitative data were added only to a limited number of aspects of the research (Saunders et al., 2016).

The qualitative data collection was collected through non-numerical data using semi-structured interviews, observations, and direct participation. Quantitative data did, in contrast, consist of numerical data and was collected through Volvo Cars' internal databases. Since the case study consisted of a combination of qualitative and quantitative data, it could also be described as a 'mixed design' or 'triangulation' (Saunders et al., 2016). Triangulation is said to be an important form of ensuring the legitimacy or validity of results in a case study. This is because the basis of the results gathered consisted of qualitative data collection, where quantitative data acted as a supplement to some of the research results (Saunders et al., 2016).

When choosing this research design, it was essential to consider the ethics of the research. Since various communication tools were used to reflect Volvo Cars' operations and activities, trust was essential. The core of the ethics question relates to who is to benefit from the material gathered as well as to consider integrity and objectivity throughout the process. Specifically for the qualitative parts of the data collection, it was essential to safeguard and value the interviewees' privacy and to provide a safe environment to avoid obstructed answers and opinions (Booth et al., 2008). If ethics were not respected, results may have turned out faulty (Booth et al., 2008) negatively affecting the results generated for Volvo Cars.

3.1 Phase One

According to Tellis (1997), a case study can be conducted following four major stages. Firstly, one needs to consider the Case Study Protocol and how it is to be designed. In this stage, different skills are required to be determined and the protocol will thereafter be reviewed and developed (Tellis, 1997). In this thesis, relevant concepts and readings were identified by the researchers. Furthermore, the protocol included an outline overview and a time plan of the entire case study. The time plan was created using a Gantt Chart, see Appendix 1. Other information found in the first stage of the study was information on available data sources and where data were to be gathered from. For this thesis, data were collected from Volvo Cars' internal databases. Additionally, information sources such as previous literature within relevant fields of study were used. During this phase of the thesis, the research questions were developed.

3.2 Phase Two

The second phase of the case study was to identify the chosen case, where preparation for data collection, questionnaire distribution, and further interview gathering was made. This phase was the plan execution, where the data collection was the essential activity. There were numerous ways how to gather the data needed for this thesis (Tellis, 1997). The data collection sources later helped answer the research questions and were a combination of interviews, internal documentation, and data from Volvo Cars. Interviews were held internally with four selected employees at Volvo Cars, all working within relevant fields of study. This was enough for the researchers to generate sufficient information needed for the results. The researchers decided to limit the number to four internal interviewees since the information was recurring at a relatively early stage enabling sufficient results. The interviewees were Jessica Lundh, Martin Wettemark, Sara Sjöberg, and Amanda Fredriksson, all working at the Supply Chain Department at Volvo Cars.

Furthermore, external interviews were held with other actors knowledgeable within the field of intermodal freight transport such as the Swedish Transport Administration and freight a number of freight forwarding companies. External interviews were held for the researchers to get a wider range of data, and for the findings to become more objective. The researchers limited the number of external interviewees to five, which was considered enough for the researchers to generate sufficient results. The external interviewees were Fredrik Bärthel, Stig-Göran Thorén, Mark Iuonas, Chiel Daams and Remco Leijgraaff. In addition to the qualitative data collection, quantitative data were collected from Volvo Cars' internal databases. The reason for using different sources of information throughout the thesis was to generate more depth and to increase the validity and reliability of the study (Saunders et al., 2016; Tellis, 1997).

This particular methodology was realized to explore two research questions presented in section 1.4.

3.2.1 Interview Setup

The interviews were semi-structured, which enabled depth of the gathered data and allowed for discussion (Tellis, 1997). The semi-structured interviews were considered essential parts of the thesis as they involved accumulating primary data. The interviews consisted of a combination of standardized questions, informal- and unstructured conversations. This type of method was suitable as the researchers wanted to give room for interviewees to elaborate on answers and give complimentary comments and insights into the project.

3.2.1.1 Pre Interviews

To gain overall knowledge on how rail-road intermodal freight networks are constructed and what is important to consider when operating or building such networks, relevant people were contacted. Through the collaboration with Volvo Cars, specifically the Senior Manager for Inbound Engineering, the researchers got into contact with relevant employees and external contacts that were of relevance. Through this method, interviewees could further refer to additional people that could be knowledgeable within the field of study. This type of method could be compared to snowball sampling, where the researchers were dependent on someone else's contact network to recruit relevant interviewees (Bell et al., 2019). This also meant that the researchers gave away their own ability to control whom to contact. On the other hand, this method was beneficial in the sense that time was saved as selective sampling would more likely result in more rejections (Dudovskiy, 2018). Although snowball sampling was the method used, the selected number of employees was enough to give sufficient results to the study.

When interviewees had been contacted, the time and place of each interview were established. During this phase, the researchers gave the interviewee the ability to choose a preferred time and place, for him or her to be more comfortable (Göransson, 2019). The interviewee was also sent the questions in advance, which allowed for preparation since some of the questions required thought-through answers. For this specific research, the questions did not require an initial reaction. Hence sending the questions in advance did not affect the research quality or skewed the data, but did rather improve it. Furthermore, at this stage, the interviewees were also asked if the interview could be recorded, for the researchers to properly focus on the interview, rather than to take notes once the interview occurred which enabled better discussions (Bell et al., 2019). Interviewees were also asked if their names could be used in the report, this for full transparency.

3.2.1.2 During Interviews

The interviews were semi-structured, which opened up for discussions and further questions such as *how-* and *why-*. This interview method also enabled the researchers to gain individual thoughts of the interviewees (Newcomer, Hatry and Wholey, 2015).

Before interviews, the interviewees were asked once again to confirm if their names could be used in the report and if recording the interview was approved. As suggested by Rabionet (2014), audio recording is the most appropriate method for recording an interview and was, therefore, the method used. The positive aspect of recording an interview is the relaxed interacting atmosphere generated when no distraction from taking notes is present (Whiting, 2008). According to Bryman (2011) recording the interviews is appropriate for semi-structured interviews as the questions are flexible and might be difficult to transcribe (Bryman, 2011).

3.2.1.3 After Interviews

After the interviews were held, a proper transcript was conducted, where the interviews were re-listened for the researchers to know the material better. The most important and useful information was summarized to further be analyzed in themes, see section 4.3.1. If information turned out to be unclear, the possibility of asking additional questions to interviewees remained. According to Göransson (2019), there is no correct way to transcribe, or how detailed transcriptions must be. This rather depends on what type of analysis is to be made. Transcriptions will hence reflect the chosen level of detail (Göransson, 2019). Since this thesis did not put focus on verbal analyses or how things were presented during interviews, transcripts were only summarizing useful and vital information.

3.3 Phase Three

The third phase of the case study methodology was analyzing the evidence generated both from data collection and previous literature (Tellis, 1997). In this phase, the generated data was evaluated and connected to theory and previous studies to analyze the results using different interpretations (Tellis, 1997). For this research, themes generated from empirical and theoretical findings were evaluated to critically answer the research questions, and enable the development of the generally applicable evaluation method.

3.3.1 Thematic Analysis

For the researchers to find recurring themes mentioned by the interviewees, a thematic analysis was made and applied to the method. The themes were later on broken down into parameters that were visually illustrated in a pie radar chart diagram, see section 4.3.2. The thematic analysis tool was useful when breaking down large qualitative datasets since it allowed for identifying recurring themes and codes used to categorize common denominators seen amongst the interviews (Bell et al., 2019). A thematic analysis, therefore, helped find and analyze themes, parameters, and attributes considered important when implementing an intermodal transportation route.

3.3.1.1 Parameter Gathering

Within different themes found, a number of parameters were established, parameters that were later on visually illustrated in a pie radar chart diagram for simple interpretation. This visualization tool also enabled a simple interpretation of the suitability of a potential future route implementation, see section 4.3.2. In the evaluation tool, each parameter represented a maximum score of 6, where a score of 3 was the critical level. Meaning that, if the total score was below 3, that specific parameter did not fulfill expectations. Each parameter was given an overall score of 0-6, which depended on Volvo Cars' fulfillment expectation. Scores were given by selected employees at Volvo Cars.

< 3 = Not fulfilled
3 = Fulfilled
> 3 = Fulfilled with distinction

3.3.1.2 Attribute Gathering

Furthermore, each parameter gathered was broken down into different attributes that needed to be taken into consideration when evaluating the attractiveness of potential intermodal transportation routes. This made the evaluation process more easily interpreted and easily used, as many of the parameters did consist of different attributes. In the evaluation method, each attribute could be given a score of 0-2 depending on Volvo Cars' fulfillment expectations.

0 = Not fulfilled
1 = Fulfilled
2 = Fulfilled with distinction

Furthermore, depending on how many attributes there were per parameter, each attribute was weighted accordingly to generate a total maximum score of 6 per parameter. Depending on how many attributes there were per parameter, the attribute score was multiplied by a fraction, to maintain equal weights for all parameters and potential respective attributes.

For easy calculations and interpretation of the scoring system, see below:

For parameters with 0 attributes, a fraction of 3 was multiplied by the score given, generating an overall maximum score of 6 for that parameter.

For parameters with 2 attributes, a fraction of 1.5 was multiplied by the score given for each attribute, generating an overall maximum score of 6 for that parameter.

For parameters with 3 attributes, a fraction of 1 was multiplied by the score given for each attribute, generating an overall maximum score of 6 for that parameter.

3.3.2 Pie Radar Chart Diagram

To visually represent the empirical results, a pie radar chart diagram was generated and applied to each route selected. This diagram contained parameters found within different themes, affecting each of the chosen routes that, through the area covered in the diagram, represented each route's overall score. The reason for using a pie radar chart diagram was to more easily visualize and interpret the findings (Adam, Josephson and Lindahl, 2017; Vermeesch, Resentini and Garzanti, 2016). The pie radar chart could therefore be used as a generally applicable evaluation method for Volvo Cars. The weight of each parameter was visually illustrated as red, yellow, or green depending on how important they were considered to be.

Red = Critical
Yellow = Major
Green = Preferable

After the pie radar chart diagram was conducted, two employees at Volvo Cars were contacted to evaluate the score of each attribute or parameter. The evaluation method was applied to one already implemented rail-road intermodal transportation route between the Czech republic - Sweden, as well as one potential future implementation between Italy - Belgium. The selected employees, Jessica Lundh and Goran Majdandzic were chosen based on their experience and knowledge within the field of study. They were also knowledgeable of the implementation and performance of the already existing route and of the geographical area and opportunities of the potential setup.

3.4 Phase Four

The fourth and last phase entailed discussing the results gathered to develop the final conclusion. In this phase, all themes were discussed together with associated parameters and their impact on other parameters. Moreover, the weight of each parameter and attribute was discussed, where it was highlighted that the chosen weights might differ in the future due to priority differences within the organization. It was also discussed how the evaluation method was applied to each of the routes, along with associated application differences, as well as how the method could be further developed in the future. The fourth phase also entailed clear explanations of the aimed study, to give the reader a better understanding of the generated evaluation method. Explanations were important to make findings understandable for future users and to properly answer the research questions (Tellis, 1997). Lastly, the fourth phase included limitations of the results generated to properly describe how the evaluation method could be further revised for future research.

3.5 Research Quality

The literature used was based on a combination of Volvo Cars' published documents and previous studies investigating rail-road intermodal freight networks, and how they are to be operated. However, it is crucial to acknowledge that the results generated were based on and limited to a number of articles and reports, which means that the involvement of additional and/or different sources of information may have brought about different outcomes and results.

The chosen literature was a mix of previous studies ranging from 2000 to 2021. The reason for choosing a combination of older and newer studies was to validate concepts, practices, and operations that have been used in intermodal freight transport for decades. Furthermore, the literature chosen consisted of mainly peer-reviewed articles investigating challenges and operational aspects of intermodal freight networks. Peer-reviewed articles were used to ensure the quality and originality of the research and for the researchers to properly validate the results found. Moreover, this information was strengthened by additional sources enabling the researchers to find a wide range of results.

The case study methodology chosen was mostly based on Tellis' (1997) method. Since the case study aimed at finding a generally applicable evaluation method, the generated methodology was not based simply on one single approach but was rather produced through a combination of methods for the results to be presented in the most suitable manner. The researchers, therefore, elaborated on Tellis' methodology which acted as a foundation for its simplicity and adaptability to develop the four different phases. However, since Tellis' methodology was developed over 20 years ago, the researchers could have used and elaborated on more recent methodological approaches. Though, since the purpose of the thesis was to generate an evaluation method, Tellis' methodology acted as a great basis for generating such an evaluation tool, due to its simplicity, adaptability, and possibilities to advance.

Throughout the case study, it was also of essence that the researchers ensured the credibility and reliability of the results generated. As previously mentioned, this was partially done by combining various sorts of previous data but was also done through respondent validation during interview sessions (Bell et al., 2019). To validate the information given by the interviewees, the researchers, through the respondent validation approach, repeated back information, ensuing and solidifying understanding. As previously mentioned, interviews were also held, not only with relevant employees at Volvo Cars but also with employees at the Swedish Transport Administration and freight forwarding companies. The reason for this was to reduce the possibility of biased results as well as to confirm what was considered vital factors when operating intermodal from various viewpoints. After having performed several interviews, the researcher decided to limit the number of interviewee participants to nine since the information started to be repetitive. Although information became repetitive, this highlighted the importance of certain parameters, strengthening the results. During the research period, the researchers had weekly meetings with supervisors at Volvo Cars, where additional information validated and clarified the approach and results generated. Additionally, before publishing the report, all interviewees and supervisors were given the opportunity to read the thesis and give feedback, in order to eliminate any incorrect interpretations or confidential information.

Lastly, it was of high importance to acknowledge that the parameters generated from the thematic analysis were likely to be weighted and evaluated differently in the future depending on priorities within an organization. This was highly dependent on who performed the evaluation and what specific route was considered, which also needs to be taken into consideration once the method is applied internally at Volvo Cars. Furthermore, it was identified that additional or different parameters and attributes could impact the reliability and validity of the results and the applied methods.

4. Empirical Framework and Analysis

In the following section, the results will be presented in a thematic structure gathered from theoretical and empirical findings. Each theme consists of a number of parameters that will act as the base of the evaluation method. The parameters will be written in ***bold*** *for the reader to easily interpret the results. For some parameters, there are attributes describing various aspects of importance for that parameter. All themes, parameters, and attributes will be visually presented in Table 1 in section 4.1.2.*

4.1 Results and Analysis

4.1.1 Themes Generated

4.1.1.1 Freight Volume

When operating intermodal, the literature supports the importance of gaining enough volumes for the route to be feasible and cost-efficient. Although, as gathered from the interviews, volumes can be obtained in various ways, more or less suitable to organizations depending on viewpoint. When implementing an intermodal setup at Volvo Cars, both **Volvo Cars' volume** and **clustering volume** from the nearby areas need to be taken into account. As elaborated by Ertem (2011), companies need to make strategic decisions with regard to volume, especially when operating rail-road intermodal routes, something which was supported by all interviewees.

When interviewing the Swedish Transport Administration, Bärthel and Thorén (2022) highlight the importance of having and maintaining volumes for an intermodal rail-road route to be competitive.

"...the major difference between road-based transportation and intermodal transportation, is to decrease the costs to make intermodal freight transport competitive, which is mainly done through large volumes and filling rates on the trains" (Bärthel, 2022, Interview, 280222).

Bärthel and Thorén (2022) argue that strategic decisions need to be taken when implementing intermodal freight networks for the route to operate smoothly and that balanced and frequent volume is one of the main aspects to consider. For Volvo Cars, a balanced and large volume is indeed an important factor to take into consideration according to Lundh (2022) and Wettemark (2022), both employees working with logistics at Volvo Cars. As stated by Wettemark (2022);

"An intermodal freight network would not be implemented if we do not have enough volumes to fill the majority of the train. If you have small volumes, you need to consider the lead time" (Wettemark, 2022, Interview, 210322).

Wettemark (2022) argues that, if Volvo Cars' volumes on one specific route are not large enough for them to fill the majority of the train, the lead time will become considerably longer due to freight operators needing to find volumes to fill the train elsewhere. This can be connected to Sun, Yu and Huang (2021) who state that hub-and-spoke systems are commonly used to cluster volumes from various origins to fill entire trains. This could lead to the possibility of trailers needing to be loaded and unloaded between modes on hubs along the way, or simply being loaded or unloaded between modes at origin and destination (Wettemark, 2022). Similarly, Bärthel and Thorén (2022) argue that it is important for companies to know their role on specific routes. They state that the main disadvantage of not having the majority of the volume on a train is the loss of potential bargaining power.

According to Bärthel and Thorén (2022), it is vital to obtain the majority of volumes on a train as this will allow the company, in this case, Volvo Cars, to have a greater possibility of getting the cargo of the train when potential disruptions occur. They also argue that this allows the company to have bargaining power in terms of costs and lead time, a statement supported by both Lundh (2022) and Wettemark (2022). If bargaining power is lost, Bärthel (2022) argues that the organization becomes more dependent on the responsibility of the freight forwarder. On the other hand, he suggests that Volvo Cars might have the possibility of collaborating with other manufacturers in nearby areas, which could mean that they would, with a common interest, gain mutual bargaining power (Bärthel, 2022). On the contrary, Leijgraaff (2022), working for a freight forwarding company, argues that higher volumes do not necessarily mean increased priority on the train. He states that the prioritization depends on agreements between the company and the freight forwarder (Leijgraaff, 2022).

Although, when discussing specifically, the rail-road intermodal freight route that Volvo Cars recently implemented between the Czech Republic and Sweden, Lundh (2022) states:

"...having enough volume from the beginning was vital for Volvo Cars to generate economic benefits from the implementation" (Lundh, 2022, Interview, 220322).

A statement supported by Wettemark (2022), also states that this specific route has enabled Volvo Cars to continue to reduce internal stock levels, enabling further economic gain. However, although some interviews point toward both employees at Volvo Cars and the Swedish Transport Administration agreeing that one company should obtain enough volumes to gain the majority, Lundh (2022) believes that Volvo Cars also need to implement intermodal freight flows from locations with fewer volumes. Additionally, Fredriksson and Sjöberg (2022), also working with logistics at Volvo Cars, comply with Lundh (2022) and suggests that the organization might be more willing and confident to commit to a route with lower volumes in the future, after having implemented the intermodal freight flow between the Czech Republic and Sweden.

"Since this was the first time Volvo Cars implemented a fully intermodal rail-road transport solution, everyone was a bit nervous. For future implementations, we might be more willing to commit even to other base volumes" (Lundh, 2022, Interview, 220322).

Fredriksson and Sjöberg (2022) also state that since the Czech Republic - Sweden intermodal transportation flow has proved to be successful, there is a willingness for Volvo Cars to continue evaluating such possibilities (Fredriksson and Sjöberg, 2022). The success of the previous implementation has contributed to increased confidence in managing and operating intermodal rail-road freight transport, allowing for environmental, operational, and risk management benefits (Lundh, 2022).

As previously mentioned, volume is an immensely important factor to consider when operating on the rail. What is important to note, on the other hand, is that one company is not necessarily dependent on obtaining enough volumes for a route to be feasible (Daams, 2022; Iuonas, 2022; Leijgraaff, 2022; Lundh, 2022). Daams (2022), Iuonas (2022), and Leijgraaff (2022), all working for freight forwarding companies, say that clustering volumes from various companies on one train are a strategically better option in terms of risk management for the forwarding company.

"Fluctuating volumes is a huge problem if we rely on volumes from one company only. If factories stop, then we need to find volume elsewhere, but when the factory starts again, manufacturers expect us to forward their freight again due to contracts, which has a huge cost impact on us" (Daams, 2022, Interview, 220322).

When operating intermodal, volume fluctuation is an aspect that is very important to consider according to Ertem (2011). Something which was elaborated on during some of the interviews. When discussing specifically the Czech Republic - Sweden intermodal route, Wettemark (2022) states that in order to cope with the fluctuating volumes, there is still a portion of Volvo Cars' cargo from the nearby area transported on the roads as a backup (Wettemark, 2022). However, he admits that fluctuating volumes are indeed a problem for the forwarding company, a statement supported by Daams (2022), Iuonas (2022), and Leijgraaff (2022).

As recognized by both Daams (2022) and Iuonas (2022), only obtaining volumes from one customer is neither attractive nor commercially beneficial for the forwarder. Iuonas (2022) highlights the risks of manufacturing plants closing during Christmas, summer, and bank holidays, etc. hindering the freight forwarders' business. He also mentions the risk of orders not being placed and the volatility that comes with all the aforementioned aspects (Iuonas, 2022).

"... it is quite impossible to set up a sustainable train route for only one customer" (Iuonas, 2022, Interview, 080322).

Daams (2022) and Iuonas (2022) both mention the importance of knowing the possible freight volume in the area. If there is enough demand, then large enough volumes will be obtained, enabling the forwarding company to set up the conceived route (Daams, 2022; Iuonas, 2022). Furthermore, Iuonas (2022) states that it is preferable having more customers with lesser volumes to decrease the risk of volume fluctuations.

Lastly, when considering volume balance it is also of essence to consider the returning volumes.

"... it is highly important to balance volume, especially on rail since no train travels in only one direction" (Daams, 2022, Interview, 220322).

Daams (2022) continues and states that freight is forwarded to only one customer in Sweden, enough volumes of exports of for instance paper and wood will be needed. If such return volumes can not be obtained, the cost will be much higher for the importing company, as they would have to pay for empty return wagons (Daams, 2022). A statement supported by Leijgraaff (2022) and Iuonas (2022).

4.1.1.2 Infrastructure and Terminal Availability

Infrastructure and terminal availability are essential factors to consider operating any freight flow and will be separately considered as **infrastructure** and **terminal** parameters in the evaluation method. For intermodal rail-road networks, not only are efficient railway networks and roads of high importance for smooth operations, but one also needs to consider within-terminal transfer links and efficient terminal design (Newman and Yano, 2000; PPC Group, 2020; Southworth and Peterson, 2000). Intermodal terminals, connecting roads with rail, can also diversify in storage, layout and operating policies, etc. Therefore, it is important for freight forwarders to make strategic decisions when implementing an intermodal route, in order to have access to relevant infrastructure and terminals. According to Newman and Yano (2000), a successful intermodal freight flow is dependent on the availability of appropriate equipment that has the correct carrying capacity for containers and trailers to be loaded and unloaded effectively. Furthermore, according to Corry and Kozan (2006), operating policies on available infrastructure and terminals are also an important aspect to consider when developing an intermodal freight flow, as this could affect overall operational capacity and effectiveness.

Moreover, when operating on rail, specifically in Europe, companies also need to consider various Rail Freight Corridors, their connectivity, and conditions (Rail Net Europe, 2020). It is also important to make strategic route decisions with regard to the various electrification systems seen within Europe, as they mean differences in voltage and thus, locomotives might need to have an operating capacity for such variations (Verdicchio et al., 2019). The aforementioned aspects were also mentioned during most interviews. According to Iuonas (2022), certain limitations can be seen in terms of infrastructure and terminal availability when setting up an intermodal rail-road freight flow. He argues that if there is no available appropriate infrastructure along the imagined route, indirect paths might need to be used, potentially increasing distance, lead time, and operational inefficiency (Iuonas, 2022)

Similar to what the literature suggests, Bärthel and Thorén (2022) at the Swedish Transport Administration, argue that infrastructure and terminal availability is highly important when implementing intermodal freight transport flows. According to Thorén (2022), intermodal terminals are vital for rail-road routes, as cargo needs to be loaded and unloaded connecting the different transport modes. He continues;

> *"...the terminal does not need to be located right next to the production plant, but it is important to map distances in order to know what is geographically feasible"* (Thorén, 2022, Interview, 280222).

When discussing the Czech Republic - Sweden intermodal freight flow that Volvo Cars implemented in 2020, Lundh (2022) argues along with theoretical findings. She states that it is important to check not only the availability of infrastructure and terminals but also what the capacities are in terms of storage and equipment, as well as opening hours and contingency plans. She also mentions that the implemented route was originally supposed to carry trailers on rail from a terminal in the Czech Republic, which was later strategically changed to only operating the train within Germany, due to terminal and infrastructure unavailability (Lundh, 2022). As supported by Iuonas (2022), the key to intermodal transportation flows is the availability of terminals, terminal capacity, and rail infrastructure. He states that terminal capacity is one of the main factors influencing rail, particularly trailer freight, which highlights the importance of taking availability and capability into consideration when implementing future intermodal freight routes at Volvo Cars (Iuonas, 2022). Compared to using containers, Iuonas (2022) argues that trailers are more complex due to the inability to equivalently stack trailers, which results in the need for more terminal and storage space. A statement which is supported by Lundh (2022), who addresses that low terminal capacity can become bottlenecks for intermodal rail-road transport flows at Volvo Cars.

Furthermore, Bärthel and Thorén (2022) and Iuonas (2022) mention the complexity of getting favorable time slots at the terminals as well as the complexity of receiving favorable time slots on the rail. This is because rail freight and passenger trains share the same infrastructure, and thus need to adhere to a fixed number of time slots. According to Bärthel and Thorén (2022), passenger and freight flows are in conflict. Wettemark (2022) adds that passenger flows are always prioritized within Europe.

"It is almost impossible to get your perfect timetable. It is a question of resources, costs, availability, slot terminals, and so on. However, during the night there is less passenger traffic, which increases the probability of shorter lead times. Therefore it is rather preferable to go by train during night hours" (Iuonas, 2022, Interview, 080322).

Another aspect that was mentioned during many of the interviews was that the availability of terminals and infrastructure might decrease as a result of increased congestion on roads, and hence an increased interest in using rail as an alternative way of transporting cargo. According to Daams (2022), Iuonas (2022), Lundh (2022), Thorén (2022), and Wettemark (2022), increased pressure and demand for rail freight will most likely become a problem in the future. Thorén (2022) states that increased use of railway transportation has already been seen within Europe, which has yet created a heavy burden on existing railway networks. Although Daams (2022) agrees with Thorén, he adds that this increase in demand will most probably lead to increased investments toward improving railway infrastructure, as well as improved technology allowing for even larger volumes on trains. Iuonas (2022) complies and adds:

"In some ways, we will see this problem, but there are still some things that we can influence today with regards to the future. The possibility of extending highways and making them longer and wider is very complicated, but we see that there are already actions taken in the industry to ease the issue of rail. This is not fully overcome, but at least they are intelligently working on it" (Iuonas, 2022, Interview, 080322).

However, Lundh (2022) and Wettemark (2022) are not equally optimistic. They state that infrastructure availability might become a major problem in the future as capacity has already proved to be restricted. Lundh (2022) states that as a result of increased environmental awareness, freight and passenger flows on rail have and will become increasingly demanded, which will put further strain on existing infrastructure. She also believes that building new railways is a costly matter, one which takes time and will not keep up with increased demand. Lundh (2022) continues;

"...therefore, I think it is of high importance for us at Volvo Cars to quickly change to railway transportation in order to secure the capacity needed for the organization. I think it was favorable to implement the already existing intermodal rail-road network at an early stage in this development" (Lundh, 2022, Interview, 220322).

Wettemark (2022) complies and adds that companies will transport more on the rail in the near future due to increased congestion on roads. When organizations realize that transporting via rail can be both cost-effective, more efficient, and more environmentally sustainable compared to road-based transportation, there will be a switch towards more rail freight (Wettemark, 2022).

4.1.1.3 Strategic Planning

When planning the implementation of an intermodal rail-road transportation route, strategic planning and decision making is essential for the route to operate smoothly. Included in the Strategic Planning theme are **risk management**, **delivery accuracy,** and **lead time** parameters. According to Southworth and Peterson (2020), companies need to make strategic decisions and invest in relevant research to avoid operational trouble. Uddin and Huynh (2019) also suggest companies enhance their strategic processes in order to meet uncertainties.

Results show that theoretical and empirical findings point toward companies benefiting from strategic planning and decision making when planning an intermodal transport route, to better manage risks, cope with negative externalities, meet delivery time and obtain certain levels of reliability and flexibility. According to Daams (2022), working for a freight forwarding company, factors such as weather conditions and accidents are important aspects to consider, as it can greatly affect lead time. Moreover, as suggested by Bärthel and Thorén (2022), it is essential for companies to build robust transport systems that do not only work when all conditions are perfect. Bärthel (2022) states;

"...do not implement a transportation system that only works in optimal conditions, you need to have a contingency plan, as there are so many factors that might go wrong" (Bärthel, 2022, Interview, 280222).

Similarly, as suggested by Uddin and Huynh (2019) enhancing strategic aspects to meet capacity uncertainties is a great way to ensure the reliability of intermodal rail-road networks. They say that taking external factors into consideration, and assuming that capacity is slightly lower than anticipated is a great way to obtain desired levels of reliability (Uddin and Huynh, 2019). According to Fredriksson and Sjöberg (2022), both employees working with logistics at Volvo Cars, companies put much emphasis on strategic planning due to critical delivery times and time sensitivity. They further elaborate on the importance of implementing a contingency plan, to be prepared for unforeseen events at all times. Additionally, they add that it is of great importance for a company, like Volvo Cars, to maintain and ensure great commitment and collaboration from the freight forwarder for the route to remain durable, flexible, and reliable (Fredriksson and Sjöberg, 2022). Similar to Fredriksson and Sjöberg (2022), Daams (2022) states:

"Communication within the supply chain should be clear and proactive. Plan B, C, D, and E should always be in place and companies are to work proactively to make sure that, when something happens, the carrier can react fast to the changing situation" (Daams, 2022, Interview, 220322).

Furthermore, Iuonas (2022) argues that almost everything is possible when done correctly within logistics. He states:

"From technicality and complexity of enabling intermodal/railway transportation, the sky's the limit. We have the most complex solutions working perfectly and simple solutions not working very well" (Iuonas, 2022, Interview, 080322).

He continues to elaborate on the importance of research, planning, and route design and says that although there are many aspects to consider when implementing an intermodal freight transport flow, intelligent design is key. Moreover, he says that for a design to be intelligent, intense research needs to be done, a great partnership needs to be established, and correct route choices need to be taken (Iuonas, 2022). Similarly, Bärthel and Thorén (2022) argue that planning operational strategy also involves thoroughly setting up systems with strategically correct decisions with regard to costs and risks. Thorén (2022) suggests that to do so, Volvo Cars needs to make in-house calculations before requesting quotes from freight forwarding companies, for proper decisions to be made.

According to Bärthel and Thorén (2022), it is also necessary to consider external factors that negatively impact the efficiency of a transportation route. They say that not only is it important to establish a contingency plan together with the forwarding company to make sure there are alternative ways of operating when something happens, but it is also essential to consider what those factors could be. However, according to Fredriksson and Sjöberg (2022) factors such as weather conditions are considered an obvious aspect to regard when implementing intermodal freight routes. They argue that for weather issues there are measures already taken to reduce such impacts, making these factors rather insignificant. For example, on routes commonly affected by snow or ice, heating coils are oftentimes inducted, and in Sweden where leaf slip is a common problem, there are efforts implemented to reduce such occurrences (Sjöberg, 2022). On the other hand, factors such as accidents, delays, and track maintenance of which are most commonly relatively unforeseen, Fredriksson and Sjöberg (2022) agree with Bärthel and Thorén (2022) who say that these need to be considered in risk management and contingency planning.

As both theoretical and empirical results suggest, strategically planning and optimizing intermodal rail-road freight networks is key for smooth operation. Bärthel (2022) suggests that it would be strategically beneficial for Volvo Cars to make further implementations of intermodal freight networks, as a result of increased demand for truck drivers and pressure put on companies to decrease their environmental footprint. For the future implementation of intermodal routes at Volvo Cars, Bärthel (2022) suggests the company make a thorough investigation with regards to strategic planning and take into consideration all aforementioned aspects. He adds that it is also of essence to consider reliability and accuracy of delivery times and suggests the importance of implementing time buffers to allow for any external aspects negatively affecting the efficiency of a route (Bärthel, 2022). He states:

> *"...maybe consider implementing a time buffer or security system for the company to fully trust the reliability of the route and meet lead times"* (Bärthel, 2022, Interview, 280222).

Thorén (2022) adds that by implementing a time buffer for intermodal freight systems, potentially devastating effects of external factors can be minimized as this allows for some additional time meeting delivery deadlines, which is supported by Leijgraaff (2022). This would hence also increase customer satisfaction to better delivery accuracy (Thorén, 2022). He states:

"...a customer really does not care what time the train arrives or leaves, what is important is to know WHEN goods are to arrive" (Thorén, 2022, Interview, 280222).

Empirical findings and theory also highlight the importance of companies needing to thoroughly investigate a number of aspects for an intermodal setup to work seamlessly, with the very reason of keeping lead time (Bärthel, 2022; Daams, 2022; Iuonas, 2022; Jensen et al., 2019; Leijgraaff, 2022; Lundh, 2022; Sun et al., 2021; Thorén, 2022; Wettemark, 2022). As stated by Lundh (2022), lead time is very time-sensitive, especially within the automotive industry, due to low stock levels and fluctuating volumes. She states that:

"*If lead time is not met, production efficiency is negatively affected, which sometimes even causes production stoppage which in turn could mean huge costs for the company"* (Lundh, 2022, Interview, 220322).

According to Sun et al., (2021), it is important to consider the lead time when making a modal shift, due to the increased complexity it entails. The multimodal operation does, in contrast to unimodal routes, involve a modal shift where trailers need to be unloaded off one transportation mode and loaded onto another, essentially consuming time. This is supported by Bathel and Thorén (2022), Iuonas (2022), Leijgraaff (2022), and Wettemark (2022), who argue that lead time might need to be sacrificed when implementing an intermodal rail-road setup.

Wettemark (2022), argues that it is essential for Volvo Cars to consider the lead time when considering the implementation of additional intermodal setups. He argues that lead time might possibly need to be extended, which would in turn compromise stock levels, a concept contradicting Volvo Cars' aim in reducing safety stocks as much as possible (Wettemark, 2022). Additionally, he states that the expectation should not be that intermodal setups operate with the same lead time as unimodal ones unless working seamlessly (Wettemark, 2022). On the contrary, as stated by Daams (2022);

"If there is a possibility to extend the lead time slightly to encourage multimodal use, companies might want to do this. Sometimes a small change in lead time can give so many more opportunities when it comes to multimodal without the customer always realizing this" (Daams, 2022, Interview, 220322).

A statement which is supported by Lundh (2022) who states such a tradeoff might be acceptable if the modal shift were to generate benefits such as environmental, social, and economic sustainability. She continues to argue that this would imply a deliberation between various in-house divisions at Volvo Cars (Lundh, 2022).

However, when looking at Volvo Cars' intermodal setup between the Czech Republic and Sweden, Fredriksson and Sjöberg (2022) and Lundh (2022) states that lead time has not been negatively affected, rather, it has proved to be equivalent, and sometimes even shorter. She continues and states that at times, during the Covid-19 pandemic, lead time was considerably shorter on rail due to fewer disruptions compared to the road (Lundh, 2022). Furthermore, Lundh (2022) also argues that although lead time is not necessarily either shorter or longer by road to this date, multimodal routes might be favorable in the future due to increased congestion and disruptions seen on road (Lundh, 2022).

4.1.1.4 Sustainability

As found in both literature and empirical findings, sustainability consists of three concepts, **economic sustainability, environmental sustainability,** and **social sustainability**, all of which are essential when considering an intermodal rail-road setup. According to Sheffi (2018), the rapid supply chain growth that has been seen throughout the years has pointed toward companies prioritizing cost-effective transportation solutions as opposed to for example environmentally sustainable alternatives. Although, studies show that standardizations and technological improvements have recently made intermodal freight transport more accessible, efficient, and less costly (Zieger, 2018).

According to Bärthel and Thorén (2022), the major reason for using intermodal rail-road transportation as opposed to unimodal road freight is the reduced costs that can be reached if trains are efficiently loaded. As supported by Wettemark (2022), one of the positive aspects of Volvo Cars' Czech Republic - Sweden intermodal route is the increased cost-efficiency in terms of reduced cost per goods transported. Similarly, Reis et al., (2013) state that intermodal rail-road freight is generally considered more cost-efficient, mainly due to long rail distances decreasing variable costs related to fuel prices and salaries. They also argue that road transportation is more volatile to fluctuations in prices, increasing multimodal cost benefits (Reis et al., 2013).

As recognized by Iuonas (2022) and Leijgraaff (2022), forwarding freight mainly on rail is cost-effective due to constantly increasing fuel prices. Similarly, Lundh (2022), argues that the impact of increased fuel prices does not affect Volvo Cars' intermodal routes to the same extent as they do to unimodal road freight. Additionally, as stated by Daams (2022):

"Even if there might be an increase in cost for rail transportation due to an increase in demand, it will still be cost-efficient compared to unimodal road-based transportation" (Daams, 2022, Interview, 220322).

What was noted from the empirical findings, was that cost is an immensely important factor to consider when implementing an intermodal rail-road freight system. According to Lundh (2022), when Volvo Cars initiated the Czech Republic - Sweden route, startup costs needed to remain considerably low for the initiation to be approved, something which was successfully managed. Though, this could be argued to change in the future due to environmental aspects becoming increasingly important, reducing the paradoxical relationship between costs and environmental benefits. However, as stated by Wettemark:

"We cannot implement an environmentally more sustainable way of transporting our goods if it would be four times as expensive. This would be hard to motivate." (Wettemark, 2022, Interview, 210322).

This statement aligns with Sheffi (2018), who states that financial gain is the motivating factor to improve organizational environmental and social sustainability.

As noted by Iuonas (2022), the demand for drivers today exceeds supply, whilst simultaneously, supply chains and international trade keep increasing, also increasing the demand for drivers. According to Bärthel and Thorén (2022), the driver profession is no longer equally attractive, as of low salaries and much time spent on the road as opposed to at home with family. As supported by Daams, (2022), Iuonas, (2022), Wettemark (2022), and

Fredriksson and Sjöberg (2022), these are two of the main contributing factors to today's driver shortage. As suggested by Daams (2022) and Leijgraaff (2022), a solution to cope with the problem could be to implement more rail-road intermodal networks. A statement supported by Lundh (2022), Fredriksson and Sjöberg (2022), who argue that multimodal solutions enable drivers to operate more locally, allowing them to spend more time at home and seize better working conditions.

Lundh (2022), states that when implementing the intermodal transportation flow between the Czech Republic and Sweden, social sustainability was an important factor to consider. She argues that they wanted to get better working conditions for the drivers, enabling them to drive closer to home (Lundh, 2022). Leijgraaff (2022), Lundh (2022), and Iuonas (2022) also argue that better working conditions will most likely also attract more drivers in the future, reducing the driver shortage long term. Statements complementing previous research are included in the thesis. Lastly, as stated by Wettemark (2022), choosing intermodal transportation means a decreased need for a large number of drivers driving long distances, since train capacity means many trailers with only a small number of drivers required, also lowering labor costs, increasing economic sustainability. On the contrary, Iuonas (2022) argues that driver shortage is a problem that will still need to be tackled also on the rail, therefore there is still a need for companies taking matters to take social responsibility into consideration and attract more drivers in the long run. He says:

"The social sustainability aspect is key when implementing intermodal transport solutions"
(Iuonas, 2022, Interview, 080322).

Furthermore, the literature suggests rail freight is considerably more environmentally friendly than road freight. Therefore, increasing the use of rail-based intermodal freight networks is a great way for companies to contribute to decreased environmental degradation (Engström, 2016; Ritchie, 2020; Zhang, Li and Zhang, 2019). According to Ritchie (2020), rail freight only accounts for 1 % of the transportation sector's overall emissions, highlighting the benefits of efforts in making a modal shift. Accordingly, empirical findings point toward similar results where Daams (2022), Bärthel and Thorén (2022), Leijgraaff (2022) and Wettemark (2022), all pinpoint the environmental benefits of switching toward rail-road intermodal freight as opposed to operating solely on road.

When discussing environmental degradation within the transport industry with Iuonas (2022), he argues that a few decades ago, environmental benefits were not the main contributing factors to forwarding freight on rail. He states:

"Although we knew rail was an environmentally friendly alternative 20 years ago, nobody would have expected the impact it has today, what discussions it causes and how present it is in today's decision making" (Iuonas, 2022, Interview, 080322).

He continues to argue that the main reason the forwarding company he works for today is implementing more rail freight, is in fact the environmental benefits it contributes to, as it is also considered commercially beneficial (Iuonas, 2022). Iuonas (2022) states that today, rail freight is commercial enough to fairly compete with road freight. A statement which is supported by Lundh (2022), who argues that Volvo Cars' main reason for implementing the Czech Republic - Sweden intermodal rail-road route was because of environmental benefits. However, she continues to argue that if it would not have been commercially or economically feasible, it would not have been implemented.

As aligned with Lundhs' (2022) statement, the literature suggests that intermodal freight networks will only be implemented for environmental benefits if it aligns with economic goals (UIC-ETF, 2019). As previously mentioned, it can be argued that financial gain is the motivating factor to improve organizational environmental sustainability, something which is supported by Wettemark (2022), Lundh (2022), Bärthel and Thorén (2022).

However, Lundh (2022) argues that since the last intermodal implementation did not result in increased costs, this incentivizes the company to implement further routes in the future. She also argues that since it has proved to be successful, future implementation is much more attractive, increasing Volvo Cars' commitment to making a modal shift, and becoming more environmentally sustainable in the future (Lundh, 2022).

Lastly, Bärthel and Thorén (2022), add that implementing intermodal routes to a larger extent, will also enable more environmentally friendly trucking alternatives. They say that since moving trailers only from terminals to final destinations etc., distances will be much shorter, contributing to increased use of electrified trucks. Consequently, it would not only lower the CO_2 emissions, but also the particle emission as less strain is put on road infrastructure (Bärthel and Thorén, 2022). However, Wettemark argues that it is essential for such distances to be covered by green electricity. He states that using for example HVO or biogas also contributes to releasing CO_2, additionally depending on how the electrification is produced, environmental sustainability could be more or less attained (Wettemark, 2022).

4.1.1.5 Freight Distance

The last theme generated from the theoretical and empirical findings is freight distance which consists of both the **distance** in kilometers covered mainly by rail, as well as **border simplicity** regards the number of borders crossed for an intermodal setup and its complexity. According to Reis (2014), distances exceeding 300 kilometers are preferred when forwarding freight on rail, as of its considerably lower energy use. Additionally, according to Daams (2022), longer distances are favorable for making intermodal rail-road transportation networks economically sustainable. As the literature suggests, rail transportation has been increasingly popular and suitable for long distances (Collins, 2020; Zhang, Li and Zhang, 2019).

However, empirical findings also point toward rail being suitable even for shorter distances. What is important to consider then are a number of aspects such as lead time, volumes, complexity, and costs, which are supported by Thorén (2022), who states:

"Since lead time is very time-sensitive, intermodal routes could mean wasting time unloading and losing trains/trucks. Total time of handling goods is hence important to keep in mind" (Thorén, 2022, Interview, 280222).

A statement supported by Lundh (2022) argues that since there will be more fixed costs operating intermodal, volume plays a major role for shorter distances, in order to generate economic sustainability. Additionally, Thorén (2022) and Lundh (2022) state that economic sustainability could be generated on shorter distances if fuel prices continue to increase.

Although longer distances are argued to be more suitable for intermodal rail-road freight setups, what is important to note is that longer distances often involve additional border crossings, which means that it is necessarily not always more beneficial for intermodal setups. Iuonas (2022) and Leijgraaff (2022) argue that if there is a need to cross borders by train, it is vital to acknowledge the need for locomotive availability for the different countries. Literature highlights the importance of ensuring locomotive capability when operating across borders in order to ensure efficiency (Verdicchio et al., 2019). Furthermore, drivers need to have language knowledge as well as operating licenses in all countries covered by a selected route, increasing complexity (Engström, 2016; Iuonas, 2022). Iuonas (2022) states;

"Generally, the longer the distance, the more border crossings you have. And if operating on several railway systems/electrification systems, you increase the complexity of transportation" (Iuonas, 2022, Interview, 080322).

On the contrary, Daams (2022) argues that there are no problems with regard to electrification systems or cultural differences when crossing borders, however, he notes that all paperwork must be in place for such a route to work seamlessly. Which is supported by Fredriksson and Sjöberg (2022) and Wettemark (2022), arguing that border crossing within Europe has not been a problem for Volvo Cars.

4.1.2 Evaluation Method

As a result of the thematic analysis presented in section 4.1.1, different themes were established. Each of these themes consists of a number of parameters that will be included in the evaluation method generated from the findings above. For some of the parameters included, there are attributes representing aspects taken into consideration when evaluating each parameter. The colors visually represented in Table 1 below, represent the weight of each parameter. The weight has been decided through empirical findings, where interviewees have elaborated on whether the parameters are *critical (red), major (yellow),* or *preferable (green)*. The numbering of each parameter is color-based, for the pie radar chart diagram to be easily interpreted.

Route X						
Theme	Parameter	Attribute	Fraction	Score 0-2	Total/attr	Total/par
Freight Volume	7. Volvo Cars Volume	Volume Stability	1,5		0	**0**
		Total Volume	1,5		0	
	1. Clustering Volume	Inbound	1,5		0	**0**
		Outbound	1,5		0	
Infrastructure and Terminal Availability	2. Infrastructure	Infrastructure Availability	1,5		0	**0**
		Conditions	1,5		0	
	3. Terminal	Terminal Availability	1		0	**0**
		Equipment	1		0	
		Storage	1		0	
Strategic Planning	4. Risk Management	External Factors	1,5		0	**0**
		Contingency Plan	1,5		0	
	5.Delivery Accuracy		3		0	**0**
	6.Lead Time		3		0	**0**
Sustainability	8. Economic Sustainability	Startup Cost	1,5		0	**0**
		Cost Efficiency	1,5		0	
	10. Environmental Sustainability		3		0	**0**
	11. Social Sustainability		3		0	**0**
Freight Distance	12. Distance		3		0	**0**
	9. Border Simplicity		3		0	**0**
					Max Score:	**72**
					Actual Score:	0
					Percentage	0%

Table 1. Empirical findings: Themes, Parameters, and Attributes

In order to present the parameters generated and the weight of each parameter, a pie radar chart diagram is made. The parameters are presented in color-coordinated order as opposed to thematic order, where the colors represent how important each specific parameter is considered when implementing a rail-road intermodal setup at Volvo Cars.

As illustrated in Figure 3, there are a total of 12 parameters included in the evaluation method in Table 1, each of which will be given a total score for each specific route evaluated. As mentioned in section 3.3.1.1, each parameter can obtain an overall score of 0-6 where a score of less than 3 indicates that the specific parameter does *not fulfill* Volvo Cars' requirements, a score of 3 indicates that the parameter is *fulfilled*, and a score of more than 3 means it is *fulfilled with distinction*. The score will be visually illustrated in the diagram using more saturated shades of each color. If half a score is obtained, this will be visually illustrated by making a column checkered.

As seen in Table 1, some parameters consist of a number of attributes that will form the basis of a parameter's overall score, as described in section 3.3.1.2. Each attribute can be given a score of 0-2 where 0 equals *not fulfilled,* 1 equals *fulfilled,* and 2 equals *fulfilled with distinction.* Depending on the number of attributes each parameter consists of, that attribute will be multiplied by the fraction it represents, giving a maximum overall score of 6 for all parameters in the evaluation method. As seen in Table 1, parameters consist of either 0, 2, or 3 attributes. If a parameter consists of 0 attributes, the score given will be multiplied by a fraction of 3 giving the possibility of a maximum overall score of 6 for the associated parameter. See section 4.3.1.2. The total maximum score for each parameter will be 6, where the critical level of whether or not a parameter lives up to Volvo Cars' expectations is illustrated by a circle at a score of 3, *fulfilled*. The area covered in saturated color will represent the attractiveness of implementing a specific intermodal setup at Volvo Cars in the future. What is important to note, on the other hand, is that it is especially important that red and yellow parameters cover larger areas as opposed to green ones for the route to be feasible.

Figure 3. Pie Radar Chart Diagram

4.1.3 Implemented Route - The Czech Republic to Sweden

When applying the evaluation tool to the already existing rail-road intermodal transportation flow that Volvo Cars implemented between the Czech Republic and Sweden in 2020, the researchers have scored and analyzed attributes together with employees at Volvo Cars (Majdandzic and Lundh, 2022b). As previously mentioned, each parameter can either be scored as is, or consist of a number of attributes, each scored separately, contributing to the overall score for that parameter. This is visually illustrated in the pie radar chart diagram that will exhibit the overall score of the route. The area fulfilled within the pie radar chart diagram (Figure 4) will later also illustrate if the route is considered satisfactory or not.

Volvo Cars Volume

The first parameter is Volvo Cars Volume, which consists of two attributes, 'Volume Stability' and 'Total Volume'. When analyzing Volvo Cars' volume stability on the selected route, the score given is 1, *fulfilled*. Here, internal data, combined with analysis and evaluation made by employees and the researchers, indicate that volume from many suppliers in the nearby area is large enough to outweigh the negative effects caused by volume fluctuations. It is argued that, since volumes are large enough, fluctuations do not negatively affect the company to the same extent as they would if volume levels were lower. However, a score of *2, fulfilled with distinction,* is not reached as volume is in fact fluctuating quite a bit, which means the attribute has not exceeded Volvo Cars' expectations. When looking at the second attribute, total volume generated from Volvo Cars and their suppliers, a score of 2, *fulfilled with distinction* is given. A score of 2 is given since Volvo Cars' volumes in the nearby area are large enough to obtain a majority of the volume on a train, enabling the initiation and setup of the route. For this specific route, Volvo Cars implemented the route together with a freight forwarding company, which meant that large enough volumes needed to be obtained for the route to be established at all. Volumes are also large enough that trains can depart often enough for the route to operate smoothly, not negatively affecting lead time. The overall score for the Volvo Cars Volume parameter is hence 4.5, exceeding the critical level of 3. See Figure 4 and Table 2.

Clustering Volume

When looking at the parameter clustering volume, there are two attributes to take into consideration contributing to the overall score. These two attributes are 'Inbound' clustering volume and 'Outbound' clustering volume. These attributes are important to consider as total inbound and outbound volumes, to and from hub areas, need to be large enough to fill entire trains. These volumes do also need to be frequent enough for the route to be feasible, as many companies, including Volvo Cars, try to obtain low stock levels. As previously mentioned, this specific route was initiated by Volvo Cars together with a freight forwarding company. This meant that a completely new route was set up, as opposed to Volvo Cars only being offered a number of spots on an already established rail-road route. When analyzing inbound and outbound volumes and scoring them, inbound clustering volume received a score of 2, *fulfilled with distinction* for the chosen route, since there are many suppliers not included in Volvo Cars' supply chain that do also ship to and from the same areas. When looking at the outbound clustering volume, on the other hand, volumes do not seem to be equally as large, contributing to a score of 1, *fulfilled*. The overall score for the clustering volume parameter, therefore, equals 4.5. See Figure 4 and Table 2.

Infrastructure

The third parameter considered in the evaluation method is the infrastructure which consists of 'Infrastructure Availability' and 'Infrastructure Conditions'. When analyzing the chosen route, both attributes are given a score of 1, *fulfilled.* This score is given since both availability and conditions of infrastructure enabled the feasibility of the route, fulfilling Volvo Cars' criteria. However, neither availability nor conditions are considered optimal. The overall score for the parameter infrastructure is therefore 3, which indicates that infrastructure availability and conditions could become considerably better. See Figure 4 and Table 2.

Terminal

When looking at the terminal parameter, there are three attributes considered to contribute to the overall score. The attributes are 'Terminal Availability', 'Equipment', and 'Storage'. When analyzing the Czech Republic - Sweden route, it is argued that all three attributes are to receive a score of 2, *fulfilled with distinction*. It is argued that one of the terminals was moved from the Czech Republic to Germany due to these very reasons. According to employees at Volvo Cars, the terminals included in the route have more than enough storage space and the right equipment to operate efficiently and effectively. The overall score for the terminal parameters is therefore 6. See Figure 4 and Table 2.

Risk Management

As gathered from theory, risk management is a vital parameter to consider for an intermodal setup to become successful. When breaking down risk management, two attributes were established, 'External Factors' and 'Contingency Plan'. When analyzing the Czech Republic - Sweden route there are many external factors to take into consideration. However, as argued by the employees at Volvo Cars, external factors such as weather conditions or accidents are taken into consideration. There are still other factors that are not as easily predictable that can negatively affect the effectiveness of the route. The specific route is therefore somewhat prone to be exposed to negative effects of external factors, a score of 1, *fulfilled,* is therefore given.

When analyzing the second attribute, contingency plan, it is argued to receive a score of 2, *fulfilled with distinction.* According to selected employees participating in the analysis, the contingency plan for the chosen setup has worked exceptionally well. Arguably, the contingency plan has been developed in accordance with the freight forwarding company and has since been developed to work better than anticipated. What is important to note is also that if and when a contingency plan is set up appropriately, there will be alternative ways to operate efficiently when unexpected events occur. Something which has been evident for the selected route. The overall score for the Risk Management parameter is 4.5. See Figure 4 and Table 2.

Delivery Accuracy

The delivery accuracy parameter does not consist of any attributes. Delivery accuracy is therefore scored as is, based on the delivery punctuality of the specific route. When analyzing and measuring delivery accuracy together with employees at Volvo Cars, the overall score given is 2, *fulfilled with distinction*. It is argued that the punctuality exceeds Volvo Cars' expectations. The overall score for the delivery accuracy parameter, therefore, equals 6. See Figure 4 and Table 2.

Lead Time

Similar to delivery accuracy, lead time neither consists of any attributes. In this specific evaluation method, lead time is measured as a comparison to road-based previous setups and will therefore gain a score of 1, if the lead time is not negatively affected by the modal shift. Since lead time was not negatively affected by the implementation of the intermodal setup between the Czech Republic and Sweden, it is given a score of 1, *fulfilled*, since it meets Volvo Cars' expectations and requirements. The overall score of the lead time parameter is hence 3. See Figure 4 and Table 2.

Economic Sustainability

When looking at economic sustainability, there are two attributes that need to be taken into consideration. The first one is 'Startup Cost' and the second one is 'Cost Efficiency' as a comparison between the new implementation and previous road-based transport solutions.

The startup cost refers to the upfront cost of implementing the intermodal transportation flow, whilst the cost efficiency refers to the long-run operational costs and economic sustainability. When analyzing the startup cost attribute, a score of 2 was given because limited to no startup costs were allowed when implementing the Czech Republic - Sweden setup. Similarly, when looking at the cost efficiency attribute, a score of 2, *fulfilled with distinction,* is given. As argued during the analysis, costs decreased compared to operating singularly on road. The overall score for economic sustainability is hence 6. See Figure 4 and Table 2.

Environmental Sustainability

Similar to some of the other parameters, environmental sustainability does not consist of any attributes. It is measured in kg CO_2 saved as a comparison to operating singularly on the road. When analyzing Volvo Cars' internal data as well as making calculations, a score of 1, *fulfilled, is given*, since enough CO_2 is saved when operating intermodal for it to be considered one of the important factors as to why it is beneficial to continue running the route. For a score of 2, *fulfilled with distinction,* the rail-operated part of the route would need to be considerably longer due to environmental differences in operating via rail as opposed to the road. It was also argued that the electric power source in Germany, where this specific train operates, is quite dependent on coal power, making environmental sustainability not exceed expectations. However, the overall score for the environmental sustainability parameter is 3, which aligns with Volvo Cars' requirements. See Figure 4 and Table 2.

Social Sustainability

As gathered from the empirical findings, social responsibility is an important factor to consider, not only for operating intermodal but for Volvo Cars in general. Therefore the next parameter considered is Social Sustainability, which mainly regards working conditions for drivers. As argued by employees contributing to the analysis, the intermodal setup has enabled drivers to work in closer proximity to their homes due to shorter distances, and rail covering much of the route. Since the rail distance is also relatively short, this also allows for rail drivers to gain the same privileges as truck drivers driving shorter distances. Therefore social sustainability is given a score of 2, *fulfilled with distinction,* as working conditions are considerably better when compared to operating singularly on roads between the same locations. The overall score for social sustainability, therefore, equals 6. See Figure 4 and Table 2.

Distance

The penultimate parameter is distance. Distance does, similar to some of the other parameters, not consist of any attributes. Distance is measured in km where a route is given a score of 0 if rail distance is less than 300 km, a score of 1 if the rail distance is between 300 and 600 km, and a score of 2 if rail distance exceeds 600 km. These intervals were established from a combination of empirical and theoretical findings. Although it has been argued that forwarding freight on rail could be feasible also for shorter distances, this would require other parameters exceeding Volvo Cars' expectations. Therefore the intervals were established in the chosen way. The Czech Republic - Sweden route is approximately 950 km in total, whereas it only operates on the rail for around 400 km, giving a score of 1, *fulfilled*. Since there are no attributes to consider, the overall score for the distance parameter will hence be 3. See Figure 4 and Table 2.

Border Simplicity

The last parameter considered in this evaluation tool is border simplicity. Border simplicity regards the selected route operating across different borders, contributing to difficulties with regards to operating permits, differences in electrification systems, language barriers, etc. For the already implemented route, there are some border crossings to take into consideration, however, the train only operates within Germany, making the border crossing simple. Therefore, as analyzed together with employees at Volvo Cars, border simplicity for the selected route is given a score of 2, *fulfilled with distinction*. The overall score of the border simplicity parameter is therefore 6. See Figure 4 and Table 2.

To conclude, the total score for the Czech Republic - Sweden route is presented in Table 2 and is visually illustrated in Figure 4 below.

Czech Republic - Sweden						
Theme	Parameter	Attribute	Fraction	Score 0-2	Total/attr	Total/par
Freight Volume	7. Volvo Cars Volume	Volume Stability	1,5	1	1,5	4,5
		Total Volume	1,5	2	3	
	1. Clustering Volume	Inbound	1,5	2	3	4,5
		Outbound	1,5	1	1,5	
Infrastructure and Terminal Availability	2. Infrastructure	Infrastructure Availability	1,5	1	1,5	3
		Conditions	1,5	1	1,5	
	3. Terminal	Terminal Availability	1	2	2	6
		Equipment	1	2	2	
		Storage	1	2	2	
Strategic Planning	4. Risk Management	External Factors	1,5	1	1,5	4,5
		Contingency Plan	1,5	2	3	
	5.Delivery Accuracy		3	2	6	6
	6.Lead Time		3	1	3	3
Sustainability	8. Economic Sustainability	Startup Cost	1,5	2	3	6
		Cost Efficiency	1,5	2	3	
	10. Environmental Sustainability		3	1	3	3
	11. Social Sustainability		3	2	6	6
Freight Distance	12. Distance		3	1	3	3
	9. Border Simplicity		3	2	6	6
					Max Score:	72
					Actual Score:	55,5
					Percentage	77%

Table 2. Route Score Czech Republic - Sweden

Percentage fulfilled for each weight		
75%	92%	67%

Figure 4. Route Score Czech Republic - Sweden

As seen in Figure 4, the critical level of 3 was reached for all parameters. Table 2 indicates that 77 % of the area covered in Figure 4 is covered by saturated shades of each color. What is important to note on the other hand is each percentage covered per color. As presented in Figure 4, 75 % of the area is filled for *critical* parameters and as much as 92 % is filled for *major* parameters. Although this route has already been established and proved successful, this could act as a future guide to what levels of fulfillment can be met for Volvo Cars to be satisfied with or content with a setup. Although, one can also see that the area of *preferable* parameters is only filled by 67%. As determined by selected employees, *preferable* parameters need to meet Volvo Cars' requirement levels of 3, *fulfilled,* for a route to be evaluated and considered to be implemented. However, these are not as important once the fulfillment level is attained, then *critical* and *major* parameters are considered far more important for a route to be practically successful. Simply it could be argued that social sustainability and environmental sustainability act as basic functions that need to meet Volvo Cars' improvement expectations. If they are, the evaluation method can be applied to a thought after route to see if a modal shift is to consider. If these parameters are met, then the weight of *preferable, major,* and *critical* parameters are established for the evaluation method once an evaluation is to be performed.

4.1.4 Potential Route - Italy to Belgium

When discussing future possible implementation opportunities, a route setup between Italy and Belgium was one of the main contenders discussed with selected employees at Volvo Cars (Majdandzic and Lundh, 2022b). Since it had been established that improvement expectations for social and environmental sustainability could be reached. Therefore, the evaluation method was applied to the thought after setup. During this evaluation and analysis process, internal data in combination with initial thoughts and reactions from the employees participating in the evaluation process act as the base of the overall score of the potential future route (Majdandzic and Lundh, 2022b). Evidently, for future implementation, the evaluation will be done more thoroughly, suggestively in a project group completing an investigative technical evaluation process.

Volvo Cars Volume

When analyzing the implementation of a potential route between Italy and Belgium, volume stability is argued to meet expectations. Therefore a score of 1, *fulfilled,* is given. Similarly, when looking at the total volume between the chosen locations, data show that Volvo Cars cannot obtain enough volumes to fill the majority of a train. A potential setup between the thought after hubs would then, different from the already established route between the Czech Republic and Sweden, mean Volvo Cars collaborating with a freight forwarding company to establish a contract for a few spots on a train. This would also mean that overall clustering volumes in the area would become even more important for a route setup to be feasible. When looking at the overall total volume in the area, enabling an intermodal setup, Volvo Cars' volumes are said to be large enough for a score of 1, *fulfilled,* to be obtained. The overall score for Volvo Cars' volumes will therefore be 3. See Figure 5 and Table 3.

Clustering Volume

When looking at the inbound clustering volume attribute, Volvo Cars' employees participating in the evaluation process argue that large volumes from Italy's automotive centers can be obtained. This will hence allow for the possibility of implementing a feasible intermodal rail-road setup between Italy and Belgium. The inbound attribute would therefore be given a score of 2, *fulfilled with distinction.* Similarly, when analyzing the outbound clustering volume, volumes are argued to be large enough to gain a score of 2, also for returning volumes. As mentioned in the previous section, this is essential for a setup to be feasible, as Volvo Cars' own volumes are not large enough for a completely new setup to be considered. When clustering volumes from the nearby areas together, on the other hand, volumes are believed to be large enough for a route to become considerably better than Volvo Cars' minimum requirements, enabling an overall score of 6 for the clustering volume parameter. See Figure 5 and Table 3.

Infrastructure

When analyzing infrastructure availability and infrastructure conditions, the overall score given is 1, *fulfilled,* for both attributes. When analyzing publicly available data together with selected employees, as well as when discussing the possibility of implementing the thought after setup with different freight operators, it is evident that infrastructure is available. Additionally, conditions are good enough for already established routes to operate today between the chosen hubs. Therefore it would be feasible for Volvo to contract a number of spots on an already established route. However, it is also important to note that, to be sure that the criteria are in fact fulfilled, more in-depth research needs to be done. Since a score of

1, *fulfilled*, is given for both attributes in this evaluation process, the overall score for the infrastructure parameter for the potential route will be 3. See Figure 5 and Table 3.

Terminal

When discussing the terminal parameter, it is argued that terminal availability will receive a score of 2, *fulfilled with distinction*, since much freight is already forwarded between the thought after hubs, meaning that supply has met demand. Similar to infrastructure, there are also available terminals along the route enabling an intermodal implementation for Volvo Cars. Similarly, relevant and well functioning equipment is available, giving a score of 2, *fulfilled with distinction*. When discussing storage, on the other hand, it is argued to be a little less optimal for the chosen route, giving a core of 1, *fulfilled*. The overall score for the terminal parameter will through these various attributes equal to 5. See Figure 5 and Table 3.

Risk Management

Analyzing risk management and associated attributes, both external factors and contingency plan is given a score of 1, *fulfilled*, giving the risk management parameter an overall score of 3. See Figure 5 and Table 3. What is important to note is that Volvo Cars need to put much emphasis on investigating what external factors need to be considered, and what freight forwarding company to collaborate with to operate an intermodal route between Italy and Belgium. This would also very much affect the functionality, construction, and conditions of the contingency plan. On the other hand, a score of 1 is given since it is expected that Volvo Cars will enable a good enough contingency plan to cope with different risks. The score given is, at this point, only an indication of what it can become, as there are many decisions that need to be made before and after a more thorough evaluation is performed.

Delivery Accuracy

Similar to risk management, delivery accuracy can only be evaluated based on previous experience, therefore delivery accuracy is also given a score of 1, *fulfilled*, as it is believed that delivery accuracy will not be negatively affected when making a modal shift. The overall score of the delivery accuracy parameter is therefore 3. See Figure 5 and Table 3.

Lead Time

When analyzing lead time for a possible route between Italy and Belgium it is argued that lead time will most likely meet expectations, hence not exceeding today's lead time when operating unimodally. Therefore a score of 1, *fulfilled,* is given as it is believed that lead time will remain similar to what it is today, also when making a modal shift. The lead time parameter will therefore be given an overall score of 3 for the potential route. See Figure 5 and Table 3.

Economic Sustainability

When analyzing startup costs it is argued that limited to no startup costs will be necessary for the chosen route, as there are already many setups established on the chosen trail. Startup costs will therefore be given a score of 2, *fulfilled with distinction*. When discussing cost efficiency on the other hand it is believed to remain similar to today's unimodal setups at Volvo Cars, leaving a score of 1, *fulfilled*. The overall score of the economic sustainability parameter is therefore 4.5. See Figure 5 and Table 3.

Environmental Sustainability

When operating mainly via rail from Italy to Belgium, internal data and calculations show that much kg CO_2 can be saved instead of forwarding freight singularly on the road. Environmental sustainability is therefore given a score of 2, *fulfilled with distinction*, leaving an overall score of 6. See Figure 5 and Table 3.

Social Sustainability

Similar to the already established route, distances covered by road will be much shorter if a modal shift toward operating mainly on rail between the chosen destinations occurs. Therefore, social sustainability will be given a score of 2, *fulfilled with distinction,* as it is believed that the new route will contribute to far better working conditions for drivers. This, similar to the already established route, will allow for drivers to operate closer to home, attracting new drivers to the industry. The overall score for social sustainability will therefore be 6. See Figure 5 and Table 3.

Distance

When operating mainly on rail between Italy and Belgium, the distance covered will be measured at around 1000 km. As mentioned both in previous studies and empirical findings, there are many benefits to covering longer distances with rail. Therefore, this specific route will be given a score of 2, *fulfilled with distinction*. This hence means an overall score for the distance parameter of 6. See Figure 5 and Table 3.

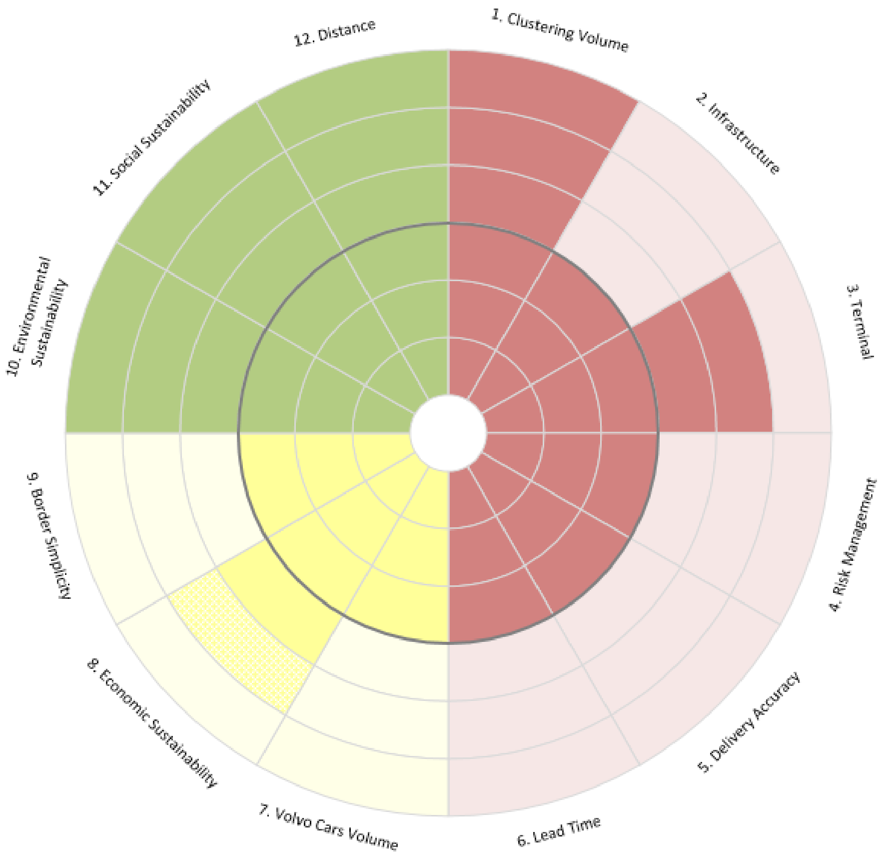
Border Simplicity

When transporting goods between Italy and Belgium, there are many aspects to take into consideration with regards to border crossing such as language barriers, contracts and conflicts of interests to recognize. The border simplicity parameter is hence given a score of 1, *fulfilled*. Evidently, when looking at similar intermodal setups, operating such a route is feasible. However, when considering the border simplicity parameter, the thought after route does in fact entail a few border crossings, as opposed to the already existing route, meaning that it could be much more seamless. The overall score for the border simplicity parameter will therefore be 3. See Figure 5 and Table 3.

To conclude, the score for the Italy - Belgium route is presented in Table 3 and Figure 5 below.

Italy - Belgium						
Theme	Parameter	Attribute	Fraction	Score 0-2	Total/attr	Total/par
Freight Volume	7. Volvo Cars Volume	Volume Stability	1,5	1	1,5	**3**
		Total Volume	1,5	1	1,5	
	1. Clustering Volume	Inbound	1,5	2	3	**6**
		Outbound	1,5	2	3	
Infrastructure and Terminal Availability	2. Infrastructure	Infrastructure Availability	1,5	1	1,5	**3**
		Conditions	1,5	1	1,5	
	3. Terminal	Terminal Availability	1	2	2	**5**
		Equipment	1	2	2	
		Storage	1	1	1	
Strategic Planning	4. Risk Management	External Factors	1,5	1	1,5	**3**
		Contingency Plan	1,5	1	1,5	
	5.Delivery Accuracy		3	1	3	**3**
	6.Lead Time		3	1	3	**3**
Sustainability	8. Economic Sustainability	Startup Cost	1,5	2	3	**4,5**
		Cost Efficiency	1,5	1	1,5	
	10. Environmental Sustainability		3	2	6	**6**
	11. Social Sustainability		3	2	6	**6**
Freight Distance	12. Distance		3	2	6	**6**
	9. Border Simplicity		3	1	3	**3**
					Max Score:	**72**
					Actual Score:	51,5
					Percentage	72%

Table 3. Route Score Italy - Belgium



Percentage fulfilled for each weight		
64%	58%	100%

Figure 5. Route Score Italy - Belgium

As seen in Figure 5, the critical level of 3, *fulfilled, is reached* for all parameters. Furthermore, Table 3 shows that the total percentage of area in the diagram covered is 72 %. The *preferable* parameters score of 100 %, yet again pinpoints Volvo Cars' incentives in initiating the route due to great environmental and social sustainability improvements. This means that implementing the thought after route would be beneficial, meeting Volvo Cars' improvement criteria in terms of these aspects, and therefore, the evaluation tool can be fully applied. What is important to note, on the other hand, is that when using the evaluation tool, social and environmental sustainability, in particular, does not need to exceed the critical level of 3. Once the benefits of environmental and social sustainability have been detected, the evaluation method can be fully applied to a potential intermodal setup, enabling a technical evaluation. At this point, the weights of *preferable, major,* and *critical* are added to each parameter. One can see that *preferable* parameters have reached a score of 100 % whereas *major* and *critical* have only received 58 % and 62 % respectively. This highlights that the route would be feasible to implement, however as previously said, one must note that thorough research and investigation need to be applied when making a proper technical evaluation in the future.

4.2 Discussion

As generated from previous studies and empirical findings, there are a number of themes to consider when implementing an intermodal rail-road setup. As presented in the result section, each theme consists of two or three parameters that, through various attributes, can be evaluated using the generated evaluation method. What is important to note, is that for a complete technical evaluation to be made using the evaluation method, Volvo Cars first need to establish if environmental and social sustainability are assumed to reach Volvo Cars' improvement criteria. If such improvement criteria are not met when making a modal shift, Volvo Cars will have no incentive to initiate an intermodal setup between the thought after locations. On the other hand, if such improvement criteria are assumed to be met, Volvo Cars will have incentives to use the evaluation method to make a proper technical evaluation. The evaluation method can then be a useful tool in determining how attractive such an establishment would be for the company, enabling them to make well-founded decisions.

When establishing the generally applicable evaluation method, the researchers, together with selected employees at Volvo Cars, divided parameters into categories depending on how important they are assumed to be when making a modal shift. As illustrated by color in the evaluation method, generated parameters are weighted differently depending on importance. What is important to note is that, when deciding the weight of each parameter, opinions differed between those who participated, meaning that the chosen weight is based on majority consensus. This also means that the weight of each parameter might be different in the future, depending on the opinions, knowledge, and profession of the project group investigating the attractiveness of a future potential setup. It could also depend on different stakeholder priorities within the organization as a whole.

Notably, no matter the weight of each parameter, most parameters identified are connected in one way or another. When discussing the volume theme, for example, the importance of Volvo Cars' volume is heavily reliant on the clustering volume in the area. Initially, during the empirical study, Volvo Cars' volume seemed to be the most important parameter to acknowledge when considering the implementation of a potential intermodal setup. However, throughout the process, especially when interviewing freight forwarding companies, it was found that obtaining large volumes, singularly from Volvo Cars, is not optimal from a risk management perspective, therefore Volvo Cars' volume parameter is only considered *major*. More importantly, obtaining enough volume in the area was found *critical*, minimizing the effects of volume fluctuations as well as merely highly valued goods getting stuck. It was also found that returning volumes are an essential factor to consider. As argued by some of the interviewees working for freight forwarding companies, there would be no interest in setting up a rail route from a location where returning volumes are not large enough. This, since it would mean immensely greater costs for Volvo Cars being responsible for making it economically feasible, negatively affecting economic sustainability.

From these gatherings, it was found that Volvo Cars' volume is not considered a critical parameter if enough volumes can be obtained in the near area, also highlighting the possibility of Volvo operating intermodal even on routes where internal volumes are relatively scarce. This would then mean that Volvo might be required to reconsider its demands and requirements when setting up a new intermodal route. Instead of presenting potential contracts including specific requirements in terms of costs, lead time, flexibility, etc. to a forwarding company, Volvo Cars might need to start compromising. A suggestion would be to discuss potential setups with various freight forwarders to see if there are other companies willing to collaborate on an already established route, with Volvo Cars only purchasing a few spots on a train, or establishing a completely new intermodal setup. The freight forwarder might then be knowledgeable of the demand of forwarding freight to and from nearby areas, enabling an intermodal setup with enough volumes, not necessarily obtained by Volvo Cars. If other companies are also forwarding freight to and from the nearby area and are willing to collaborate, the inconvenience of fluctuating volumes might decrease as a result of differences in lead time, operating standards, and delivery accuracy requirements between the collaborating partners. One example would be to collaborate with a company not operating with as strict lead times or sensitive stock holdings as Volvo Cars. This is a challenge that could then act as an opportunity rather than a risk, not only for Volvo Cars but also for collaborating partners as well as freight forwarders. Additionally, there would be an opportunity for Volvo Cars to reduce the potential costs of running empty wagons when freight volumes are fluctuating since collaborating companies can complement volumes in order to fill up a train. Moreover, if Volvo Cars' volumes are smaller, the fluctuations might not affect the freight forwarding company negatively to the same extent, making it easier for other companies to collaborate on a thought after route.

Infrastructure and terminal availability were other themes identified from the empirical findings. Similar to clustering volumes, both terminal and infrastructure are considered *critical* parameters in the evaluation tool. As argued by many of the interviewees, if there is no available infrastructure enabling an intermodal setup between two locations, the route will be extremely difficult to implement. Furthermore, it is vital to acknowledge the conditions of already existing infrastructure. Although infrastructure might be available on a particular transportation flow, conditions might not meet expectations. This could for instance mean a limited number of tracks, bad conditions, or construction work on available tracks or roads posing operational challenges. If unexpected events occur on track and no other tracks are available, this could potentially also negatively affect the strategic planning theme. If no alternative transportation options are available, the risk management parameter is affected negatively, also decreasing the score of the *critical* parameters delivery accuracy and lead time. Therefore, infrastructure availability and conditions could mean extensive risks if not fulfilled.

Similar to infrastructure, the terminal parameter, consisting of the attributes of terminal availability, equipment capacity, and storage opportunities, also affects other parameters in the evaluation method. Terminals are considered a *critical* parameter since location and terminal capacity heavily affects the efficiency of operating a rail-road intermodal route. When considering the implementation of a new transportation setup, available terminals need to be located, and it must also be ensured there is enough storage space and that handling equipment possess the required capacity for handling trailers. If such requirements are not met, terminals can become critical bottlenecks, reducing route efficiency and effectiveness, and possibly negatively affecting lead time and delivery accuracy. It is also important to note that lack of capacity could entail increased startup costs, decreasing the economic sustainability score. This is since companies, like Volvo Cars, implementing a potential route, might need to invest in handling equipment making the terminal more efficient. This might also negatively affect the possibilities of implementing a specific intermodal setup, as the cost factor can be considered a deal-breaker.

As generated from the empirical findings, strategic planning is another vital aspect to consider when implementing an intermodal setup. Throughout the research, it was found that strategic planning includes the parameters of risk management, delivery accuracy, and lead time.

As briefly mentioned when discussing infrastructure and terminal availability, lack of available or appropriate infrastructure or terminals, might negatively affect risk management and hence delivery accuracy and lead time. However, there are many other factors that do also need to be considered. In the generated evaluation tool, the *critical* parameter risk management consists of two attributes, external factors and contingency plan, both crucial to consider for intermodal rail-road setups. As previously discussed, external factors affecting rail tracks or road conditions need to be taken into consideration when operating intermodal. Other factors such as weather conditions or accidents are also important to recognize. Although weather conditions can be relatively predictable, enabling proactive solutions, there are other external factors that are not as easy to predict. Additionally, to cope with unexpected events occurring on tracks or roads, increasing safety stock might be needed, which in turn increases the cost of inventory management. If such occurrences do in fact cause delays, production can be negatively affected and if delays do in fact cause production holds, this can be very costly for the organization. Therefore delivery time is considered a vital parameter in the evaluation method. When strategically planning and optimizing an intermodal setup, it is also essential to set up a contingency plan as part of the risk management. This is oftentimes done in accordance with the freight forwarder, where stakeholders agree on a number of issues to enable alternative solutions to original setups. Parts of the contingency plan could for example be to cope with fluctuating volumes by using road transportation as a supplement to forwarding only on the rail. A smaller fraction of total volumes could then be forwarded on road, making sure lead time is met, at least for parts of the anticipated volume. The contingency plan acts as a tool for risk management that is also correlated to the lead time parameter. As found during the empirical investigation, lead time is an immensely important factor for Volvo Cars to consider to maintain operational quality excellence. Therefore, all parameters included in the strategic planning theme are classified as *critical*. When discussing lead time specifically, it was evident that there is limited to no willingness in Volvo Cars to increase lead-time only to enable intermodal setups. Therefore, it is required that future intermodal solutions do not compromise today's road-based lead time. However, it was also argued that if other parameters, for example, all sustainability aspects prove great improvements, lead time might be considered adjustable. Though, this would be very difficult to promote as there are so many aspects of the company's operations that need to work accordingly if such a change is made.

Sustainability was another theme generated from empirical findings, consisting of the parameters of economic-, environmental- and social sustainability. As mentioned when discussing infrastructure and terminal availability as well as strategic planning, economic sustainability can be affected in many ways. Since the economic sustainability parameter regard startup cost and cost efficiency, one can argue that startup costs are dependent on Volvo Cars' initial investment requirements related to infrastructure and terminal availability. If there, for instance, is a need for investing in new infrastructure or equipment for a setup to operate smoothly, startup costs will increase. This, in turn, will negatively affect economic sustainability, making that particular intermodal setup less attractive to implement. These increased costs will also negatively affect commercial benefits, which means Volvo Cars reaching a potential break-even point at a later stage. As found both in theory and during the empirical case, economic sustainability can be considered an opportunity for intermodal setups. This is due to the fact that intermodal operational costs are oftentimes lower than for unimodal road transportation. Cost differences will most likely continue increasing due to driver shortages, associated labor costs and continuously increasing fuel prices. This might also result in economic sustainability becoming one of the main motivating factors as to why a company would evaluate a potential intermodal implementation setup in the future. Because of the aforementioned aspects, economic sustainability is today considered a *major* parameter.

Moreover, intermodal operations are generally considered better in terms of environmental and social sustainability. Increased use of rail transportation oftentimes means electrically driven trains, but could also allow for the usage of trucks being fueled by either renewable fuel alternatives or electricity. The reason for this is that road transportation for rail-road intermodal routes covers much shorter distances since road freight is only operated between the rail terminal and the end location. This allows for decreased environmental footprint, less CO_2 emitted and better working conditions for drivers. The environmental and social sustainability parameters, on the other hand, are today only considered *preferable* in the evaluation method. This is because the method is applied once Volvo Cars have established that these aspects are to meet improvement criteria set by the organization and do not affect the technical feasibility of the implementation. Social and environmental sustainability are therefore considered prerequisites for the evaluation method to be applied. Then, when applying the method, they are only seen as beneficial for the organization.

Although Volvo Cars have taken actions to meet a number of environmental and social sustainability goals set by the organization, operating intermodal is still seen as somewhat complex. Therefore operational complexity is still considered more important than environmental or social sustainability for a modal shift to occur. Additionally, as stated in nearly all interviews held, both with employees at Volvo Cars, the Swedish Transport Administration, and freight forwarding companies, environmental and social sustainability has just become a significant topic. Therefore, it is not yet seen as a *critical* or *major* parameter. This also aligns with the theory of environmental sustainability and costs being paradoxical.

The last theme generated from the empirical findings was that of freight distance. Here, the parameters border simplicity and distance are captured. In this evaluation method, distance is considered a *preferable* parameter that receives a score of 2, *fulfilled with distinction,* if rail distance exceeds 600 km, figures established as a result of both empirical and theoretical findings. What is important to note is that the distance parameter is heavily connected to both environmental- and economic sustainability. From the empirical findings, it was gathered that the longer the distance is, specifically operating on the rail, the better environmental sustainability is assumed to be. Additionally, the longer the distance is, the greater the economic sustainability, due to decreased operational costs connected to driver salaries, goods handling and fuel prices, etc. On the other hand, generally, the longer the distance is, one can assume that border crossings become less simple. Longer distances oftentimes mean that trains operate across borders, requiring operational permits, language or interest barriers, and increased risk of handling multiple electrification systems. However, this depiction is not always correct. Operating within Sweden for example could allow for long distances without difficulties crossing borders, therefore distance is considered a *preferable* parameter, whereas the border simplicity parameter is considered *major*. On the other hand, empirical findings also indicate that border crossings are not considered *critical* since practical evidence disproves its difficulties and complexities.

As gathered from the empirical findings, most parameters classified as *critical* or *major* can be considered challenges for an intermodal implementation. However, although economic sustainability is today considered *major*, it can still be seen as an opportunity in terms of potential cost reductions related to the modal shift. Similarly, environmental and social sustainability are seen as opportunities in improving company performance. One could argue that taking environmental and social sustainability into consideration could possibly make Volvo Cars into a sustainability pioneer, positively affecting marketing. What is important to note on the other hand is that these weights and priorities can change over time. If for example additional environmental or social sustainability requirements are introduced, these parameters could potentially also possess challenges for the organization in the future, making them *critical* or *major* as a result. Therefore, for future implementation of intermodal rail-road setups at Volvo Cars, the evaluation method might need further revision. Additionally, important to mention for the future, is that even if the critical level of 3, *fulfilled*, is not met for some parameters, one parameter might outweigh another. One could assume that if the lead time, for example, is negatively affected, not meeting requirements, resulting in increased stock levels, this might be outweighed by improved sustainability aspects gained from such implementations. Additionally, if stock levels increase as a result of a modal shift, this would also increase handling costs, however, this cost increase could be assumed to be outweighed by reduced transportation costs.

When comparing the assessments of the two selected routes it is important to note that the Czech Republic - Sweden route is evaluated based on performance. Since the route was implemented already in 2020, the evaluation is based on whether or not certain aspects have met Volvo Cars' expectations. Therefore, a score given can be seen as somewhat of a guideline to what score a well-functioning, successful route would receive. When evaluating and assessing different attributes and parameters for the Italy - Belgium route, on the other hand, each score given is simply based on an overall score given by employees at Volvo Cars. This score is based on their initial thoughts on how the route would be scored, also in relation to the already existing route, and can hence not be considered a final evaluation. For a final evaluation to be made, a project group would need to complete thorough research and investigation to make a full technical evaluation. The route could hence receive different scores than the ones given to this date. The score given in this research is therefore only an indication of how attractive this specific route could be for a potential future intermodal implementation.

5. Conclusion

This section concludes the aim of the report, answers the two research questions, and summarizes the results generated from the theoretical and empirical findings. It also highlights the thesis' contribution to research within the selected topic and features a section that regards future research and limitations.

Volvo Cars have stated its aim in improving sustainability, mainly environmental aspects through various measures, one of which involves further implementation of intermodal freight transportation solutions. Resultantly, by making a modal shift, the company can accelerate its possibility of reaching such goals, which also highlights the importance of Volvo Cars being open-minded to new intermodal implementations and how such setups can be developed.

Results from empirical findings, previous studies, and theory generated a number of themes and parameters that needed to be taken into consideration when implementing a rail-road intermodal transportation setup. The evaluation method generated from the results gathered will help Volvo Cars ease the evaluation and assessment process for future potential implementations. This, with the organizational goal of increasing sustainability benefits.

To answer the first research question, "*What are the main parameters needed to consider when implementing and evaluating intermodal rail-road transportation flows?",* Table 4 is presented below. The table represents all parameters gathered from the thematic analysis. All of which need to be considered when implementing and evaluating intermodal rail-road transportation setups.

THEME	PARAMETER
Freight Volume	Volvo Cars Volume
	Clustering Volume
Infrastructure and Terminal Availability	Infrastructure
	Terminal
Strategic Planning	Risk Management
	Delivery Accuracy
	Lead Time
Sustainability	Economic Sustainability
	Environmental Sustainability
	Social Sustainability
Freight Distance	Distance
	Border Simplicity

Table 4. Themes and parameters gathered

To answer the second research question, "*How would a method for evaluating and assessing the attractiveness of potential solutions for future implementation of intermodal freight transport at Volvo Cars be constructed?",* Figure 6 is presented below. The figure represents the method generated for evaluating and assessing the attractiveness of potential implementations at Volvo Cars. Figure 4 also represents how results are visually illustrated using a pie radar chart diagram.

Route X						
Theme	Parameter	Attribute	Fraction	Score 0-2	Total/attr	Total/par
Freight Volume	7. Volvo Cars Volume	Volume Stability	1,5		0	0
		Total Volume	1,5		0	
	1. Clustering Volume	Inbound	1,5		0	0
		Outbound	1,5		0	
Infrastructure and Terminal Availability	2. Infrastructure	Infrastructure Availability	1,5		0	0
		Conditions	1,5		0	
	3. Terminal	Terminal Availability	1		0	0
		Equipment	1		0	
		Storage	1		0	
Strategic Planning	4. Risk Management	External Factors	1,5		0	0
		Contingency Plan	1,5		0	
	5.Delivery Accuracy		3		0	0
	6.Lead Time		3		0	0
Sustainability	8. Economic Sustainability	Startup Cost	1,5		0	0
		Cost Efficiency	1,5		0	
	10. Environmental Sustainability		3		0	0
	11. Social Sustainability		3		0	0
Freight Distance	12. Distance		3		0	0
	9. Border Simplicity		3		0	0
					Max Score:	72
					Actual Score:	0
					Percentage	0%

Figure 6. Evaluation Method

As presented in the result section, the evaluation method allows for a potential route to be given an overall score for each of the parameters evaluated. What is important to note, is that all parameters need to be given a score of 3, *fulfilled,* illustrated by the circle in the diagram, for a route to be considered for future implementation. Although, before the evaluation method is applied to a tough after route, social and environmental sustainability need to reach Volvo Cars' improvement criteria, otherwise, there is no incentive in making such a modal shift. The purpose of the study was to generate a simple, easily interpretable evaluation and assessment method for Volvo Cars to use when considering the implementation of a future intermodal rail-road setup. The method generated will enable such assessments and evaluation processes but could be further revised and developed for deeper analysis and technical evaluation processes to be made. A revised model could also enable other actors within the automotive industry to use the methodology to perform similar processes. Lastly, the evaluation method generated will also help reduce the gap between theory and real-world practices as the inclusion of a combination of theory, previous studies, and empirical findings has enabled a method consisting of all such aspects.

5.1 Future Research and Limitations

Throughout the research, there are different limitations that need to be taken into consideration and discussed in order to fully understand and criticize the results and evaluation method generated. For future implementation, if a technical evaluation is made, the method will benefit from Volvo Cars performing more precise calculations given in how various parameters are connected to one another. Although this evaluation tool has already presented some differences between theoretical and practical aspects that are essential to consider, future revision might also mean deduction or inclusion of some important parameters not yet added to the evaluation method.

Additional parameters could be found if more interviews were held and/or if supplementary previous studies were added. Similarly, since intermodal transportation setup implementation is a fairly new operational activity at Volvo Cars, parameters used and generated from employees might not be optimal for a generally applicable evaluation method used by *any* company. Although the method is used for Volvo Cars, to cope with this issue, the parameters gathered are supported by a combination of theoretical and empirical findings gathered from previous studies, external authorities, and freight forwarding companies. On the other hand, the inclusion of additional organizations within the automotive industry could potentially have generated additional parameters and attributes making results more general, and positively affecting the validity and quality of the evaluation method. The generally applicable evaluation method generated for Volvo Cars could then be applicable for additional companies within the automotive industry.

Another limitation generated from this specific study is whether a parameter is considered preferable, major, or critical. For this specific research, the weight of each parameter was established by the researchers together with selected employees at Volvo Cars. What is important to note, is that if other/additional employees participated, the weight given for each parameter could potentially have generated different outcomes. Similarly, as previously mentioned, weights might be considered different in the future. Furthermore, additional weights levels/colors could be added to further differentiate the importance of each parameter. Because of the aforementioned reasons, it is highly important for Volvo Cars to revise the method in the future to ensure the reliability and validity of the generated method.

In the evaluation method, parameters can be given a score either based solely on the parameter itself or on attribute level. Vital to mention is that all attributes within each parameter are equally weighted, giving a fraction depending on how many attributes that parameter consists of. In this evaluation method, this means that all attributes are equally important to the score of that parameter which might not align with reality. For example, for the economic sustainability parameter, the attributes cost efficiency and startup costs are both given a fraction of 1.5, each contributing to 50 % of the overall score for economic sustainability. In reality, startup costs might be weighted lower than cost efficiency as it might not impact economic sustainability to the same extent in the long run, which is not captured in the generated model. Furthermore, depending on what route is evaluated and who is to do the evaluation, these percentages might differ. This would require extensive research and better knowledge within the field of study. Therefore, the method generated in this research is considered a simplified, easily visualized generally applicable evaluation method for Volvo Cars to use and revise.

Lastly, it would be interesting to perform similar research in the future to see how parameters are weighted in a couple of years and to enable a comparison of how various parameters are weighted in another organization within the automotive industry. Can *preferable* parameters become *major* or *critical* or vice versa? It would also be interesting to see the differences between evaluation methods generated for other industries or companies as well as other transportation modes to compare such challenges and opportunities.

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7. Appendix

Time Plan																
	Week 5	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**	**Week 13**	**Week 14**	**Week 15**	**Week 16**	**Week 17**	**Week 18**	**Week 19**	**Week 20**
Background																
Problem description/problem analysis							M									F
Purpose/Limitations							I									I
Theoretical Framework							D									N
Literature Review							W									A
Methods/contact relevant people at Volvo							A									L
Expected results/hypothesis (?)							Y									
Introduction/Timeplan for remaining work																S
Deadline Midway Report						**Wed. March 9 at 12.00**	S									E
							E									M
Data collection/Interviews							M									I
Results							I									N
Analysis							N									A
Conclusion and contributors							A									R
Final Submission to Volvo/Rickard/Mark							R									S
Final revision							14-18th of March									16-29th of May
FINAL SUBMISSION															**Wed. 11th of May**	

Appendix 1. Gantt Chart of Time Plan