# A COMPARISON OF RAIL AND SEA FREIGHT FROM EUROPE TO ASIA

LUND UNIVERSITY
FACULTY OF ENGINEERING
DEPARTMENT OF INDUSTRIAL MANAGEMENT AND LOGISTICS

Spring 2021

AUTHORS:
Jackie Berg
Louise Pettersson

SUPERVISORS:
Jan Olhager, Faculty of Engineering
Malin Gejde, Tetra Pak

EXAMINER:
Joakim Kembro

# Acknowledgements

This master thesis has been conducted during the spring of 2021 as a final step of a Master of Science in Industrial Engineering and Management at Lunds Tekniska Högskola, LTH, in cooperation with the company Tetra Pak AB. A lot of people have taken their time to contribute to this thesis and we would like to thank them all.

Especially, we would like to thank our supervisor at LTH, Jan Olhager, for your comments and insightful remarks which have been valuable and improved the thesis. Further, we would like to thank our supervisor at Tetra Pak, Malin Gejde, for her valuable support and help with relevant information and contacts. We would also like to thank the shipping team at Tetra Pak as well as other employees we have been in contact with for their time and knowledge. Additionally, we would like to express our gratitude towards the Freight Forwarder at 3PL A and the Project Manager at 3PL B who have contributed with their knowledge which has been extremely important for this thesis.

Lastly, a big thank you to our families and friends for their support during our five years of studying at LTH.

Lund, June 2021

Jackie Berg

Louise Pettersson

# Abstract

| | |
|---|---|
| **Title** | A comparison of rail and sea freight from Europe to Asia |
| **Authors** | Jackie Berg & Louise Pettersson |
| **Supervisors** | Jan Olhager, Department of Industrial Management and Logistics, Faculty of Engineering, Lund University<br><br>Malin Gejde, Shipping Manager, Tetra Pak AB |
| **Background** | Transportation mode selection has become a more strategic part of a well-functioning supply chain as globalization, environmental concerns, and security requirements have become more important. Currently, sea freight is the most used transportation mode for Tetra Pak when transporting goods between Europe and Asia. However, rail transport between Europe and Asia has grown a lot over the past years as a result of the Belt and Road Initiative (BRI) and therefore Tetra Pak would like to explore rail freight to Asia and compare the performance to the current sea freight. |
| **Purpose** | The purpose of this thesis is to evaluate the performance of rail freight compared to sea freight for Tetra Pak's packaging machines from Europe to Asia. |
| **Research questions** | **RQ1.** How does sea freight from Europe to Asia perform?<br><br>**RQ2.** How does rail freight from Europe to Asia perform?<br><br>**RQ3.** How do the transportation modes perform compared to each other? |
| **Methodology** | In order to answer the research questions and fulfil the purpose of this thesis a case study with an abductive approach has been used. The phenomenon that was explored in the case study is transportation from Europe to Asia. Data were collected through a literature review, archival records as well as interviews and was further analyzed through a cross-case analysis to reach the purpose of the thesis. |
| **Conclusions** | The analysis comparing rail and sea freight in the three aspects, service, economic and environmental, concluded that rail freight has shorter transit time and generally lower environmental impact. The costs are rather similar for the two modes, but the results vary depending on the country. It was therefore found that rail transport can be preferential to certain countries in Asia. |
| **Keywords** | Sea freight, Rail freight, Transportation mode selection, Asia, Transportation |

# Table of Content

# List of Figures

# List of Tables

# List of Abbreviations

| | |
|---|---|
| **3PL** | Third Party Logistics |
| **Americas** | North, South and Central America |
| **APAC** | Asia Pacific |
| **BRI** | Belt and Road Initiative |
| **DAP** | Delivered at Place |
| **ETA** | Estimated Time of Arrival |
| **E&CA** | Europe and Central Asia |
| **GHG** | Greenhouse Gases |
| **GME&A** | Greater Middle East and Africa |
| **HC** | High Cube |
| **ICC** | International Chamber of Commerce |
| **IOA** | Input-output Analysis |
| **IO-LCA** | Hybrid between input-output analysis and lifecycle assessment |
| **LCA** | Lifecycle Assessment |
| **MC** | Market Company |
| **NELB** | The New Eurasian Land Bridge |
| **TSR** | Trans-Siberian Railway |

# 1. Introduction

*This chapter sets out to provide an introduction to the thesis and present the problem that the thesis is built upon. Furthermore, the case company for this study, the purpose and research questions as well as delimitations are introduced. The chapter concludes with an overview of the structure of the thesis.*

## 1.1 Background

A well-functioning supply chain makes organizations more competitive in the global marketplace. Globalization has elevated transportation and transportation mode selection to a strategic role in many organization's supply chains (Novack et al., 2019). Globalization has also, together with environmental concerns and security requirements, added complexity to the transportation decision due to requirements of more advanced information systems and transportation between continents (Meixell & Norbis, 2008). When selecting transportation mode several factors such as cost, flexibility and delivery performance are considered in order to select the most suitable mode (Bozarth & Handfield, 2019).

Currently, sea freight is the most used transportation mode when transporting goods between Europe and Asia (Rodemann & Templar, 2014). However, rail transportation between the two continents has grown substantially over the past years as a result of the Belt and Road Initiative (BRI), and forecasts predicts that it will grow even more during the coming years (Jakóbowski et al., 2018). BRI is a project initiated by China to develop a network of ports, railways, roads, pipelines and utility grids connecting China with Central Asia, West Asia, parts of South Asia, Europe and Africa. The aim of BRI is to promote trade between the Asian, European and African continents as well as increase cooperation and partnerships of the countries connected to the routes (Zhang & Schramm, 2018). The recent increasing possibilities of transportation between Europe and Asia by rail are important for companies to examine in order to find potential benefits to their supply chain strategy. Tetra Pak is one of the companies which transport goods between Europe and Asia and could therefore benefit from evaluating their transport between these locations.

## 1.2 Company Description

Tetra Pak is a world leading food processing and packaging solution company founded in Sweden by Dr Ruben Rausing in 1943. The net sales of Tetra Pak in 2020 were 10.8 billion Euros, where the Asia Pacific market accounts for the largest part of the total sales with 35 %. Tetra Pak's main site is located in Lund, however the company has sales in more than 160 countries and has more than 25 000 employees around the world. The production is mainly located in Lund, Sweden, or in Modena, Italy, but Tetra Pak has Market Companies (MC) in the majority of the countries where they operate. The MC is the party that has direct contact with the customers in their region, for example receives the orders and discusses appropriate transportation mode with the customer.

Tetra Pak offers three main solutions which also represents the business areas in the organization, which are processing, packaging and service. The areas are presented further below:

**Processing:** This business area offers the customers processing applications and equipment for dairy, cheese, ice cream, beverage and prepared food. The aim of this business area is to help customers increase processing efficiency through a holistic approach.

**Packaging:** The core of this business area is to offer the customer a packaging solution for their foods and beverages that preserves the nutritional value and the taste of the product. User convenience, easy opening, optimal shelf life and the ability for customers to use the packages as brand exposure are aspects that Tetra Pak offers through their packaging solutions. This was the first business area that Rausing established when he founded Tetra Pak and developed the first tetrahedron-shaped cartons for milk.

**Service:** The aim of this business area is not to help customer fix something that already is broken but instead prevent breakdowns to improve the customer's performance, optimize costs and ensure food safety. This area includes for instance maintenance service, spare parts, consumables, upgrades, employee training, automation services and installation services.

By combining these three areas Tetra Pak offers an end-to-end solution that provides a seamless integration of processing, packaging, automation and technical services. This results in more a convenient production for the customers as well as increased efficiency, quality and reliability. Tetra Pak's promise, "Protects what's good", refers to protecting food, people and the planet and therefore the company has a strong sustainability focus. Strategic goals such as achieving a sustainable value chain, creates a high pressure for the distribution and transportation since Tetra Pak operates worldwide.

(Tetra Pak, 2021a)

## 1.3 Problem Formulation

Currently Tetra Pak uses sea freight, air freight and truck as transportation modes for their packaging machines, with sea freight being the main option for intercontinental transportation. Air freight is generally only used in emergency situations or for small parts. Rail freight is currently not one of the mainly used transportation modes since Tetra Pak ten years ago experienced damaged machines when using rail freight. Since then, there has been concerns that vibrations and temperature changes connected to rail transportation would negatively affect the quality of the machines they sell. In addition to this, Tetra Pak's customers have been resistant to transporting goods by rail.

According to Bozarth & Handfield (2019) rail freight has several benefits compared to sea freight, such as shorter transit time leading to lower tied up capital cost, and higher reliability, which are two main aspects for Tetra Pak when deciding transportation mode. Additionally, BRI has opened up for further possibilities to transport goods from Europe to Asia by rail. Due to the mentioned reasons, Tetra Pak has started to investigate the possibility of rail transportation and conducted six pilot shipments by rail from Lund and Modena to Shanghai and Xi'an in China during 2020 under the project "Rail to Asia". Based on the six test shipments it could be seen that vibrations and temperature changes did not affect the machines and their quality. It could also be seen that the shipments had a higher reliability and shorter transit times compared to the regular shipments with sea freight.

After completing the test shipments Tetra Pak has received increasing requests from the Chinese market to continue to ship by rail as well as interest in rail transportation from other countries in Asia. Before expanding the initiative, it is important for Tetra Pak to examine whether it would be a feasible option as well as preferential to transport goods to other parts of Asia by train compared to the current sea freight. Transportation mode selection involves several trade offs between for example service, cost and quality (Novack et al., 2019). It is therefore important to make a holistic comparison where aspects such as economic and environmental efficiency, customer service and constraints as well as possibilities connected to the infrastructure are evaluated.

## 1.4 Purpose and Research Questions

The purpose of this thesis is to evaluate the performance of rail freight compared to sea freight for Tetra Pak's packaging machines from Europe to Asia. The performance is in this thesis defined as the service, economic and environmental aspects of the transportation mode.

The thesis aims to answer the following research questions:

**RQ1.** *How does sea freight from Europe to Asia perform?*

The goal of this question is to get an overview of how the current shipping process for Tetra Pak's packaging machines from Europe to Asia operates and its performance. The current transportation mode and process are important to understand to make an equitable comparison to rail freight.

**RQ2.** *How does rail freight from Europe to Asia perform?*

The aim of this research question is to evaluate how the performance would be when using rail freight to investigate if it is a viable transportation mode for Tetra Pak.

**RQ3.** *How do the transportation modes perform compared to each other?*

The aim of this research question is to compare the performance of the two transportation modes against each other to understand when it can be profitable for Tetra Pak to use rail freight instead of sea freight.

## 1.5 Delimitations

The focus of this master thesis is to evaluate the transportation option: rail freight for Tetra Pak's packaging machines in comparison to sea freight. The thesis is delimited to only examining shipments from Lund and Modena in Europe to three countries in Asia: China, Japan and Vietnam. This since the time frame hinders the possibility of examining every country in Asia that Tetra Pak does business with. The countries were chosen due to their importance to Tetra Pak as well as their different geographical locations, in order to provide a comprehensive result that can be generalized to other countries in Asia.

Furthermore, the thesis is restricted to Tetra Pak's packaging machines. Tetra Pak offers both newly produced packaging machines and renovated machines. The renovated machines and the processing machines do not have a standardized packaging and therefore they are not included in the scope of this research. The study will only compare rail freight to sea freight, since sea freight is the main transportation mode for packaging machines transported to Asia from Europe as of today. Another delimitation for this thesis is that only rail routes offered by the third party logistics (3PL) company B, who Tetra Pak works with for rail freight, will be investigated. Lastly, the thesis will also only focus on sea shipments that were delivered between November 2019 and March 2021 due to the fact that Tetra Pak began to use a new transportation system in November 2019 as well as due to time restrictions.

## 1.6 Thesis Structure

Table 1.1 provides the structure of this thesis and a brief overview of the chapters included.

Table 1.1. Overview and structure of the thesis.

| Chapter | Description |
|---|---|
| **1. Introduction** | This chapter sets out to provide an introduction to the thesis and present the problem that the thesis is built upon. Furthermore, the case company for this study, the purpose and research questions as well as delimitations are introduced. The chapter concludes with an overview of the structure of the thesis. |
| **2. Methodology** | This chapter aims to present the execution of this thesis. The reader will be introduced to different research methodologies and strategies to provide an understanding and after that the selected methodology and strategy for this thesis will be presented and motivated. Further, the data collection methods applied are included as well as a discussion regarding the data analysis as well as research quality and credibility. |
| **3. Literature Review** | This chapter aims to provide the reader with the theoretical background relevant to this thesis. Firstly, the concept of logistics management is introduced followed by the topic of distribution and its significance. Transportation and different transportation modes, their advantages and disadvantages are presented. After that the reader will be given insight into the |

| | |
|---|---|
| | possibilities of rail freight between Europe and Asia and the three aspects to evaluate the performance of transportation are presented: service, economic and environmental. Lastly, the chapter ends with a conceptual model to provide the reader with an overview of the chapter and its connection to the thesis. |
| **4. Empirical Findings** | In this chapter the empirical data gathered will be presented. Firstly, the chapter introduces the reader to definitions of terms and concepts used later in the chapter in order to provide an understanding for the empirical findings and their meaning. Thereafter, the current sea freight situation at Tetra Pak is presented, followed by the future possibilities of rail freight to Asia. Finally, the chapter concludes with presenting the performance for sea and rail freight to three countries: China, Japan and Vietnam. |
| **5. Analysis** | In the analysis chapter the empirical data gathered for the two transportation modes are compared and evaluated against each other. Firstly, the three aspects, service, economic and environmental will be evaluated individually for each country. Thereafter all three aspects will be taken into account simultaneously. Lastly, Tetra Pak's ranking of the three aspects will be taken into consideration in order to determine which transportation mode is most suitable for each destination. |
| **6. Discussion** | The discussion begins with presenting the reader with the risks associated with the different transportation options. The risks are thereafter assessed and categorized as high, medium or low based on their likelihood and impact. A discussion about the risks and potential mitigation strategies follows. Finally, the chapter ends with a discussion about possible future developments as well as the effects of the covid-19 pandemic. |
| **7. Conclusions & Recommendations** | The last chapter of the thesis begins with answering the research questions it set out to answer to fulfil the purpose of the thesis. Thereafter, recommendations to Tetra Pak are presented for each of the three countries evaluated. Finally, the contribution to research for this thesis and areas for future research are suggested. |

# 2. Methodology

*This chapter aims to present the execution of this thesis. The reader will be introduced to different research methodologies and strategies to provide an understanding and after that the selected methodology and strategy for this thesis will be presented and motivated. Further, the data collection methods applied are included as well as a discussion regarding the data analysis as well as research quality and credibility.*

## 2.1 Research Strategy

There exist several research strategies that can be used when conducting research. Four of the most common strategies are survey, experiment, action research and case study (Höst et al., 2006; Yin, 2014). These research strategies are presented in Table 2.1.

Table 2.1. Research strategies (Source: Höst et al., 2006; Yin, 2014; Forza, 2002; Fisher, 2007; Coughland & Coghlan, 2002 & Leonard-Barton, 1990).

| | **Description** | **Typical Research Questions** | **Purpose** |
|---|---|---|---|
| **Survey** | Collection of information from a predefined group of individuals | Who, what, where, how many, how much? | Expositive |
| **Experiment** | Simulations to explain different depending variables | How, why? | Explanatory |
| **Action Research** | Interactive method where members in the studied system are participants in the study | How, why? | Problem Solving |
| **Case Study** | A strategy for creating a deep understanding of a problem and the factors affecting it | How, why? | Exploration |

### 2.1.1 Selection of Strategy

The strategy most suitable for a research depends on the purpose of the research, the research questions and the design of the research. Aspects to consider is if the research should be theoretical or empirical as well as if the study should consist of quantitative, qualitative or mixed data. The phenomenon that should be investigated has also a significant role in determining the most suitable strategy (Höst et al., 2006; Yin, 2014). Different frameworks have been developed to facilitate the decision of the most suitable strategy. One of these frameworks is by Fisher (2007) and is shown in Figure 2.1.

**Goal of the research**

| Interaction with the world | Prescriprive | Descriptive |
| --- | --- | --- |
| **Highly structured: Data and algorithms** | **Engineering**<br>Learning through implementation | **Operations management econometrics**<br>Uses data analysis tools to support different hypotheses. |
| **Less Structured: Interviews and observations** | **Principles**<br>Uses either numeric and detailed data or more qualitative principles to provide general guidance | **Case studies**<br>Uses interview and observe managers |

Figure 2.1. Empirical research in operations management (Source: Fisher, 2007).

Fisher (2007) describes that the most suitable research strategy can be determined based on two criteria. The first criterion is the goal of the research, which can be either prescriptive or descriptive. Prescriptive means that that the goal is to determine a recommended course of action based on empirical observations and the descriptive goal is to describe the phenomenon. The second criterion is how structured and formal the integration is with the world, it can be highly structured or less structured. The purpose of this thesis is to describe and analyze the actual transportation of goods from Europe to Asia. According to Fisher's (2007) model the goal of the research is therefore descriptive. The thesis will utilize quantitative data from internal systems to make the comparison. However, this information will not be sufficient in order to understand the phenomenon of this thesis which is transportation from Europe to Asia. Therefore, most of the interaction with the world will be through interviews which is a less structured approach. Based on Fisher's (2007) matrix it is concluded that case study is an appropriate research strategy.

Ellram (1996) presents another framework, shown in Figure 2.2, which classifies research strategies based on the type of data used and the type of analysis performed on the data. The types of analysis are divided into primarily quantitative or primarily qualitative. Furthermore, the data can either be gathered from the real world, empirical, or be modeled which means it is either hypothetical or real word data artificially manipulated by a model.

**Type of Analysis**

| Type of Data | | Primarily Quantitative | Primarily Qualitative |
|---|---|---|---|
| | **Empirical** | Survey data, secondary data, in conjunction with statistical analysis such as:<br>Factor analysis<br>Cluster analysis<br>Discriminant analysis | Case studies, participant observation, enthography.<br>Characterized by:<br>Limited statistical analysis often non-parametic |
| | **Modelling** | Simulations<br>Linear programming<br>Mathematical programming<br>Decision analysis | Simulation<br>Role playing |

Figure 2.2. Basic research design (Source: Ellram, 1996).

As stated previously in section 2.1.2, this study will be of both quantitative and qualitative character. The data used for this study will not be sufficient enough to create a model and for that reason the data type is empirical. Therefore, case study is the most suitable research strategy according to Ellram's (1996) model.

In addition, the aim of this thesis is to create an understanding for the transportation between Europe and Asia and the research questions are formulated with the aim of answering "how". The research strategy that is the most suitable when the research questions answer how a phenomenon occurs is case study according to Yin (2014), Ellram (1996) and Meredith (1998). Yin (2014) defines a case study as:

*"A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real world context, especially when the boundaries between phenomenon and context may not be clearly evident."*

Hence, based on the arguments presented above from Fisher (2007), Ellram (1996), Yin (2014) and Meredith (1998), case study is the ideal research strategy to use when wanting to create an understanding for a phenomenon and is therefore the selected strategy for this thesis.

### 2.1.2 Case Study Approach

The chosen strategy, case study, can be used for different purposes. These are exploration, theory building, theory testing and theory extension (Voss et al., 2002). The four different approaches are described and connected to several types of research structures in Table 2.2.

Table 2.2 Case research approaches (Source: Voss et al., 2002).

| Type | Description | Research Structure |
|---|---|---|
| **Exploration** | Used in an early stage of research. Exploration is needed in order to develop research ideas and questions. | In-depth case studies<br>Unfocused, longitudinal field studies |
| **Theory building** | Used to describe variables, linkage and why linkage between variables exists. | Few focused case studies<br>In depth field studies<br>Multi-site case studies<br>Best-in-class case studies |
| **Theory testing** | Used to test complicated findings from earlier theories as well as using different methods to study the same phenomenon to avoid sharing the same weaknesses. | Experiment<br>Quasi-experiment<br>Multiple case studies<br>Large-scale sample of population |
| **Theory extension** | Used as a follow-up to earlier research in order to examine more deeply and validate previous results. | Experiment<br>Quasi-experiment<br>Case studies<br>Large-scale sample of population |

Tetra Pak has during 2020 conducted six pilot shipments of packaging machines with rail freight from Europe to China. As the aim of this thesis is to investigate the possibility of expanding this to the rest of Asia, it shows that a theory extension approach is a suitable research structure for this thesis.

Moreover, a case study can either have a single case or multiple cases in the research. A single case study gives a bigger depth of the research however it also limits the generalizability of the conclusions. A multiple case study will on the other hand contribute to augmented external validity and have a more efficient observer bias. However, it is not possible to get as deep in the research as with a single case study and more resources are needed since more cases are being studied (Voss, et al., 2002). This thesis consists of three main cases, the three countries, where each main case is built up out of two cases each, the two transportation modes. The performance for the two transportation modes is for each country investigated separately and thereafter compared to each other through a cross-case analysis, which is further explained in section 2.3, in order to answer the research questions separately for each country. However, the three main cases are kept separately and will not be compared to each other. The phenomenon and the cases studied in this thesis are visualized in Figure 2.3.

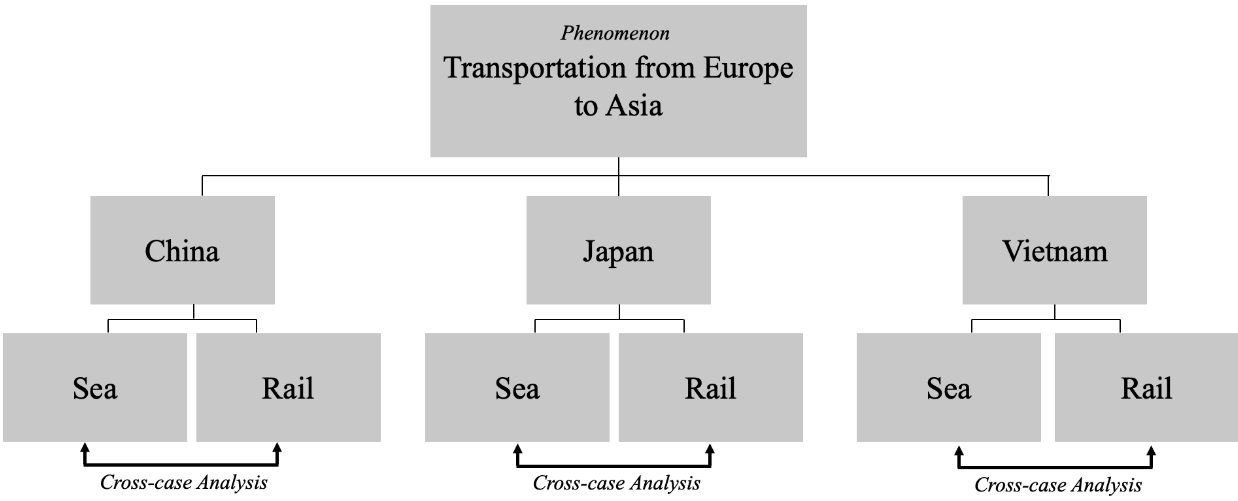


Figure 2.3. Phenomenon and cases in this study.

### 2.1.3 Advantages and Challenges with Case Study

Case study is the most common research strategy in operations management and as mentioned above generally answers research questions formulated with how, which are common in operations. In most instances a case study contributes to new and creative insights (Meredith, 1998). However, case studies have both advantages and challenges, which are presented in Table 2.3.

Table 2.3. Advantages and challenges with case studies (Source: Höst et al., 2006; Meredith, 1998; Voss et al., 2002 & Yin, 2014).

| Advantages | Challenges |
|---|---|
| The phenomenon can be studied in its natural setting | Time consuming |
| Relies on multiple sources of evidence (triangulation) | Requires skilled interviewers |
| Results in a deeper understanding of the phenomenon being studied | Hard to generalize, risk of misjudging a single event |
| Potential for testing hypothesis in well-described, specific situations | Not rigorous enough |

It is of high importance to be aware of the challenges that can arise when conducting a case study and try to mitigate them. Case studies are time consuming due to the considerable amount of available data. To manage this challenge a structured plan including time limits for the data gathering phase have been used in this project. Furthermore, a big part of the data has been gathered through interviews and good interview skills have therefore been necessary. The interviewers have developed these skills by experience from earlier interviews as well as reading articles about interviewing. To mitigate the problem regarding difficulties to generalize, a detailed description of the context of the phenomenon has been developed, which makes it easier to see where results are applicable. Further, triangulation has been used to make sure that the study is rigorous enough.

## 2.2 Data Collection

When conducting a case study, the data can be gathered through several different sources and methods. Some of the most common sources of evidence are interviews, archival records and observations (Höst et al., 2006; Stuart et al., 2002; Yin, 2014). Primary data in this thesis were collected through interviews and archival records. Secondary data were gathered through a literature review in order to support the findings from the primary data. There exist two main methods regarding data gathering: quantitative and qualitative, which both are used in this thesis (Höst et al., 2006).

### 2.2.1 Quantitative and Qualitative data

Quantitative analysis is used to quantify an issue through numerical data which can be processed through statistical analysis (Höst et al., 2006). Qualitative research consists of interpretive practices such as interviews, conversations and observations in order to understand a phenomenon in its natural setting (Denzin & Lincoln, 2011). Höst et al. (2006) argue that a combination of quantitative and qualitative methods and data should be utilized for complex issues to give a deeper understanding of the phenomenon. Therefore, it is concluded that this thesis will use both quantitative and qualitative methods for data collection, which will be explained in the following sections.

### 2.2.2 Literature Review

Performing a literature review in a study is important in order to understand the current knowledge on the subject and make sure that the study contributes with new learnings (Höst et al., 2006). A reliable literature review needs to be performed in a systematic manner, otherwise the researcher might interpret the literature in the wrong way and therefore build the research on flawed assumptions (Snyder, 2019). Höst et al. (2006) proposes to initially perform a broad literature review in order to gain understanding and knowledge of the general topic. A more in-depth literature search can thereafter be conducted to provide more focused information on certain topics and issues (Höst et al., 2006).

In this research books relevant to the research topic and peer-reviewed articles from scientific journals acts as the base of the literature review. To obtain the articles a structured keyword search was performed on the following databases: Web of Science, EBSCO Host, JSTOR, Elsevier and Emerald. The keywords used in the search are presented in Table 2.4. Searches were also performed through different combinations of the keywords.

Table 2.4. Search terms in the literature review.

| | |
|---|---|
| Supply chain | Rail freight |
| Distribution | Belt and Road Initiative |
| Transportation mode | Sustainable distribution |
| Sea freight | Infrastructure development |
| Transportation cost | Transportation performance |
| Logistics | Distribution strategy |

Among the articles found in the keyword search the most relevant were identified and their references were studied in order to find further relevant articles through a snowball approach. This method facilitated the search for relevant articles and helped to extend the base of the literature review. To complement the initial literature review and get a more holistic view of the topic, websites, organizational reports and business articles were used.

### 2.2.3 Interviews

Interviews are used to collect mainly qualitative but also quantitative data and give a deep contextual understanding of the phenomenon as well as participant's experiences and interpretations (Doody & Noonan, 2012). Interviews can be divided into three categories: structured, semi-structured and unstructured (Höst et al., 2006). The biggest challenge with using interviews as a data collection method is that the data gathered can be biased. In order to mitigate this issue several people with high knowledge and different perspectives should be interviewed. The different perspectives could be based on different hierarchical levels, functional areas, organizations or geographies (Eisenhardt & Graebner, 2007).

A structured interview follows a predetermined protocol strictly and can be compared to an oral survey (Höst et al., 2006). The benefits with structured interviews include that they are time efficient, limits bias and the interviewer can control the topics and formats. However, a structured interview leaves no room for elaboration (Doody & Noonan, 2012). Semi-structured interviews have predetermined questions but allows the researcher to seek clarification or explore other topics and issues. Unstructured interviews are based on broad open questions and allows the interviewee to lead the direction and the topics of the interview (Höst et al., 2006). A drawback for semi-structured as well as unstructured interviews is that they can be challenging to conduct for an unexperienced interviewer (Doody & Noonan, 2012).

In this study several interviews have been held with various employees with different positions in order to avoid bias and understand the research object from several perspectives. All of the interviews have been executed with a semi-structured approach in order to assure information gathering on certain topics and concurrently opening up for topics and aspects not thought of previous to the interview. In Table 2.5 all the interviews conducted can be found. An interview guide can be found in Appendix A.

Table 2.5. Conducted interviews.

| Interviewee | Position | Purpose |
|---|---|---|
| **1** | Project Manager at Tetra Pak | Understand the purpose and motivations for rail freight to Asia as well as getting information about the pilot shipments by rail to China. |
| **2** | Shipping Coordinator at Tetra Pak | Develop an understanding for the current transportation processes at Tetra Pak. |
| **3** | Shipping Coordinator at Tetra Pak | Get insight to the operational aspects and processes of rail shipments. |
| **4** | Shipping Coordinator at Tetra Pak | Get insight to the operational aspects and processes of rail shipments. |
| **5** | Shipping Manager at Tetra Pak | Get an overview of important aspects regarding selection of transportation modes for Tetra Pak. |
| **6** | Global Category Managers at Tetra Pak | Understand the contracts and agreements between Tetra Pak and their third-party logisticians. |
| **7** | Product Manager at 3PL B | Get information about the rail freight possibilities offered by 3PL B. |
| **8** | Freight Forwarder at 3PL A | Understand the current sea freight situation and get an overview of rail freight to Asia. |
| **9** | Service Manager Recycling at Tetra Pak | Understand the environmental aspects connected to this thesis. |

### 2.2.4 Archival Records

Archive analysis implicates going through documentation that has been produced for reasons other than the current study. When conducting archive analysis, it is therefore important to have the original purpose of the material in mind to fully understand and interpret the information correctly (Höst et al., 2006; Yin, 2014).

The data that have been collected from archival records in this thesis comes from internal databases at Tetra Pak as well as from logistics companies that have a close collaboration with Tetra Pak. The data are primarily quantitative and used to analyze and compare costs, transit times and delivery reliability between sea and rail freight. However, the data that have been gathered has a larger sample size of sea shipments compared to rail shipments resulting in a more stable average value for the sea shipments than the rail shipments. Therefore, the comparison is not completely fair between the two transport modes but gives an indication of performance of the modes.

### 2.2.5 Triangulation

Patton (2015) describes that each of the data collection methods have their limitations and that multiple methods usually are needed to reach a credible research. The concept of using several types of data is called triangulation and strengthens a study. Other types of triangulation also exist, such as:

**Methodology triangulation**: Usage of multiple methods to study a single problem or program.

**Theory triangulation**: The use of multiple sources of theory to get a wider perspective.

**Investigator triangulation**: Having several researchers and evaluators of the collected data to get a comprehensive analysis.

(Patton, 2015)
In this thesis triangulation will be used by including both quantitative and qualitative data, several data collection methods such as literature review, interviews and archival records and interviewing people with different perspectives.

## 2.3 Data Analysis

Yin (2014) states that having a clear analytic strategy for a case study is an essential aspect in order to link the collected data to concepts of interest. The purpose with this case study is to make a comparison between the two transportation modes, rail freight and sea freight, for Tetra Pak's packaging machines in the route from Europe to Asia. Based on the purpose, a cross-case synthesis has been used as the analytical technique in order to find similarities and contrasts between the transportation modes. Cross-case analysis treats each individual case as a separate study to be able to examine and compare them in terms of themes, similarities and differences (Yin, 2014). Prior to the cross-case analysis, a with-in case analysis must be performed on the individual cases, according to Eisenhardt (1989). The argument for this is that it allows the researcher to become familiar with and explore the unique patterns of each case. This in its turn accelerates the cross-case comparison as well as facilitates generalization (Eisenhardt, 1989).

For this study the performance of the two transportation modes to each country were firstly studied separately to get a deep understanding of the two transportation modes. The three aspects of the performance, service, economic and environmental were quantified for each transportation mode to facilitate a cross-case analysis between sea and rail freight to each country. Thereafter, a cross-case analysis was made individually for the three aspects of each transportation mode in order to gain knowledge and insight for the aspects separately. Finally, all the aspects were analyzed together to get a comprehensive view of the performance and draw conclusions regarding the optimal transportation mode to each destination. An overview of this analysis is visualized in Figure 2.4.

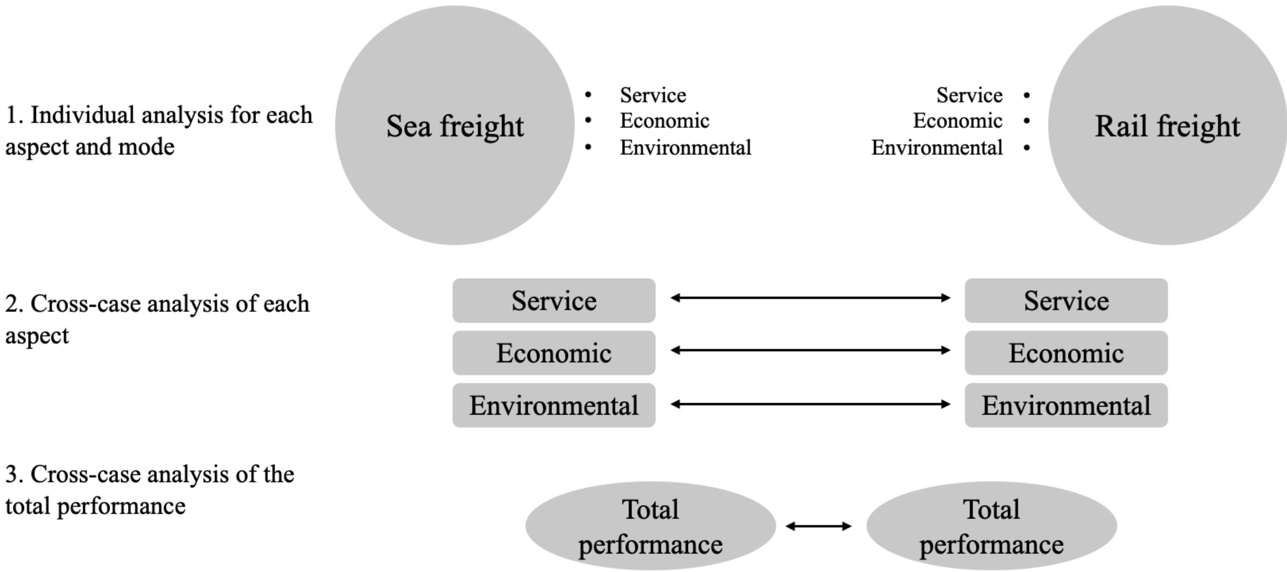


Figure 2.4. Overview of the analysis for this thesis.

## 2.4 Research Quality

In the design of the research an important factor is to judge the quality and credibility of the study. According to Yin (2014) there are four tests that are commonly used in case research to ensure credibility. These are construct validity, internal validity, external validity and reliability.

**Construct validity**: The extent to which proper operational measures are established for the concept being studied (Yin, 2014). To ensure construct validity, multiple sources of evidence and triangulation should be used, and a chain of evidence should be established (Stuart et al., 2002; Voss et al., 2002).

**Internal validity**: Regards how certain conditions can be related and derived from each other and is only applicable for explanatory case studies and will therefore not be considered in this thesis. However, performing pattern matching, explanation building, or time-series analysis are tactics that can be used to ensure internal validity (Yin, 2014).

**External validity**: The extent to which the study's findings can be generalized (Yin, 2014). Ensuring external validity is one of the major challenges when conducting a case study since the sample of cases are often too small to allow for generalization (Stuart et al., 2002). Replication logic can be used in multiple-case studies and the use of theory can ensure external validity in single-case studies (Yin, 2014).

**Reliability**: The extent to which the operations of a study can be repeated with the same results. Methods that are used to ensure reliability are to use a case study protocol as well as developing a case study data base (Stuart et al., 2002; Yin, 2014).

The four tests are summarized in Table 2.6.

Table 2.6. The four tests of credibility (Source: Yin, 2014).

| Test | Case Study Tactic | Phase of research |
|---|---|---|
| **Construct validity** | Use multiple sources of evidence<br>Establish chain of evidence<br>Have key informants review draft case study report | Data collection<br>Data collection<br>Composition |
| **Internal validity** | Pattern matching, explanation building or time-series analysis | Data analysis |
| **External validity** | Use replication logic in multiple case studies<br>Use theory in single case studies | Research design |
| **Reliability** | Use case study protocol<br>Develop case study database | Data collection |

In order to guarantee validity and reliability for the results in this thesis, several of the tactics mentioned above have been implemented. Multiple sources of evidence have been used to gather empirical data. These include interviews with several different people that have different views on the matter, data from archives at Tetra Pak but also from external logistics companies. To ensure external validity a substantial literature review was carried out to act as a theoretical base in accordance with Yin (2014). During the interviews the information gathered has been verified several times in order to assure that it is correct. Clarifying questions have been asked in case of any uncertainty. Finally, the report has been reviewed by knowledgeable and experienced persons in the area the thesis concerns.

# 3. Literature review

*This chapter aims to provide the reader with the theoretical background relevant to this thesis. Firstly, the concept of logistics management is introduced followed by the topic of distribution and its significance. Transportation and different transportation modes, their advantages and disadvantages are presented. After that the reader will be given insight into the possibilities of rail freight between Europe and Asia and the three aspects to evaluate the performance of transportation are presented: service, economic and environmental. Lastly, the chapter ends with a conceptual model to provide the reader with an overview of the chapter and its connection to the thesis.*

## 3.1 Logistics Management

Bozarth & Handfield (2019) define logistics management as:

*"That part of the supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements."*

Logistics management mainly focuses on moving goods and materials among the supply chain partners and managing the information flows necessary to carry out these tasks. Business activities included in logistics management are for instance transportation, warehousing, material handling, packaging and logistics information systems. The correlation between these activities is complex and many resources are put into logistics management to improve costs, flexibility and delivery performance. Due to trends such as globalization and sustainability logistics management faces many challenges, for example pressure to decrease lead times and at the same time provide reliability to create high customer satisfaction (Bozarth & Handfield, 2019).

As supply chains become even more complex due to the growth of global outsourcing, companies assign activities that are not a part of their core competence to third parties which are experts in the topic. This is also the case for logistics activities (Novack et al., 2019). Third-party logistics (3PL) are companies that perform logistics activities, such as transportation, warehousing or information technology, that could be performed by the firm itself (Chopra & Meindl, 2013). It is important to make a well-based decision when choosing a 3PL in order to secure quality and service (Novack et al., 2019).

Novack et al. (2019) classifies 3PLs into two different categories. These are asset-based providers and nonasset-based providers. The asset-based providers own the assets and resources that are necessary in order to carry out the activities, such as truck fleets, terminals and material handling equipment. Nonasset-based providers do not own any assets. Benefits with asset-based providers include that they have high capacity and expertise. However, they often have high fixed costs. It is the opposite for nonasset-based providers where they often have capacity limitations but lower costs. It is also possible to classify 3PLs based on the activities they perform. This classification includes for example transport-based, distribution-based and information-based 3PLs (Novack et al., 2019).

## 3.2 Distribution

Distribution is related to all the activities that occur after a product is produced. Chopra & Meindl (2013) define distribution as follows:

*"The steps taken to move and store a product from the supplier stage to a customer stage in the supply chain."*

Designing a distribution network is based on two broad phases. Firstly, the broad structure of the supply chain network is visualized which includes decisions such as whether the product will be sold directly or go through an intermediary. The second phase takes this broad structure and converts it into specific locations and their capability, capacity and demand allocation. The design of the distribution network can be used to achieve a variety of supply chain objectives, for instance low costs or high responsiveness. Depending on which objectives that are set out to be achieved, companies in the same industry often select different designs of their distribution networks (Chopra, 2003). Factors that must be considered when evaluating the performance of the distribution network design are the customer needs that are met and the cost of meeting these needs. Some of the key customer needs that should be considered are shown in Table 3.1.

Table 3.1. Key customer needs for distribution (Source: Chopra, 2003).

| Key Customer Needs | Description |
|---|---|
| Response time | The time it takes for a customer to receive an order. |
| Product variety | The number of different products/configurations offered by the distribution network. |
| Product availability | The probability of having a product in stock when a customer order arrives. |
| Customer experience | The ease with which the customers can place and receives orders. |
| Time to market | The time it takes to bring a new product to the market. |
| Order visibility | The ability of customers to track their orders from placement to delivery. |
| Returnability | The ease with which a customer can return unsatisfactory merchandise and the ability of the network to handle such returns. |

It can be thought that a customer wants the highest performance in all the dimensions, however this is not the case. For example, if a company offers a wide range of products, the customer might be willing to accept a longer response time. Companies with these types of customer requirements only need a few warehouses which can be located far from the customers. On the other hand, companies with customers who value short response time need facilities located close to the customers. Furthermore, fulfilling the customer needs involves several costs such as inventories, facilities, handling costs and information costs. Depending on which needs that are the most important for the customer the costs will vary (Chopra & Meindl, 2013).

The optimal choice of distribution network design depends on several variables such as the industry the firm operates in and the product characteristics (Olavson et al., 2010). For packaging machines at Tetra Pak a manufacturing storage with direct shipping distribution network is used. This means that the product is shipped directly from the manufacturer to the end customer. This network design is favorable for high product variety and results in high product availability, short time to market, low inventory cost as well as low facility and handling cost. Weaknesses are order visibility and returnability (Chopra & Meindl, 2013).

## 3.3 Transportation

Transportation refers to the movement of products from one location to another. Transportation is an important part of the supply chain since products are rarely produced and consumed in the same location, a product can travel around the world before it reaches the final user. The importance of transportation has increased due to the trend of globalization. Transportation can affect all three levels of a supply chain (Chopra & Meindl, 2013).

### 3.3.1 Parties in Transportation

The shipper is the party that requires the movement of a product between two points in the supply chain while the carrier is the party that moves or transports the product. These two parties together with the owners and operators of the transportation infrastructure such as roads, ports, railroads and airports, and the bodies that set transportation policies worldwide are the four parties that influence the effectiveness of transportation. To understand the transportation in a supply chain it is important to understand the incentives for these four parties which are shown in Table 3.2 (Chopra & Meindl, 2013). In this thesis Tetra Pak has the role of the shipper and the 3PLs they work with are the carriers.

Table 3.2. The four parties in transportation and their incentives (Source: Chopra & Meindl, 2013).

| Party | Incentives |
|---|---|
| **Shipper** | Uses transportation to minimize total costs (transportation, inventory, information, sourcing and facility) while providing an appropriate level of responsiveness to the customers. |
| **Carrier** | Makes investment decisions regarding equipment (locomotives, trucks, airplanes, etc.) and in some cases infrastructure (railroad) and then makes operating decisions to try to maximize the return from these investments. |
| **Owner and operators of transportation infrastructures** | Transportation infrastructure is generally owned and managed as a public good, in order to create an effective industry structure with no congestion and same conditions for all operators. |
| **Bodies that set transportation policies** | Aims to prevent abuse of monopoly power, promote fair competition and balance environmental, energy and social concerns in transportation. |

### 3.3.2 Incoterms 2020

Incoterms are a set of harmonized selling terms established by the International Chamber of Commerce (ICC) in order to facilitate international trade (Novack et al., 2019). Incoterms declare the obligations, who bears the risk and the costs of transportation, insurance, documents and formalities of the buyer and the seller and therefore helps to avoid misunderstandings (Malfliet, 2011; Novack et al., 2019). Every contract should include an Incoterm according to Malfliet (2011) and it is critical to choose an Incoterm that is suitable for the specific situation. The choice of trade term depends on the nature of the goods, the means of transport as well as the conditions of payment and the documentary requirements imposed by these conditions (Malfliet, 2011). Incoterms 2020 can be divided into four different categories which are E-terms, F-terms, C-terms and D-terms (DHL, 2020). They are described as follows:

**E-terms**: The buyer has full responsibility of the transportation and the sole obligation for the seller is to make the shipment available for pick-up.

**F-terms**: Obligates the seller to deliver the shipment cleared for export to a carrier chosen by the buyer and carry the costs associated to this. After that the responsibility as well as the incurred costs transfers to the buyer.
**C-terms**: Implies that the buyer bears the risk of the shipment, however the seller is responsible for the costs of the shipment.

**D-terms**: The seller is fully responsible for the shipment and bears all the risk and costs up to a delivery point in the country of destination.

(DHL, 2020; Malfliet, 2011; Novack et al., 2019)

Tetra Pak uses the Incoterm Delivered at Place (DAP) which is part of the category D-terms. The trade term means the seller pays for the shipment as well as bears the risk up to the agreed destination called Incoterm location. However, the buyer is responsible for import clearance, formalities and any further in-country carriage from the Incoterm location (Malfliet, 2011; Novack et al., 2019).

### 3.3.3 Intermodal Transportation

Intermodal transportation means that the goods is transported by multiple modes of transport. This is a common practice in intercontinental distribution where goods often are transported by truck to a terminal and there reloaded to railway, sea freight or air freight (Lumsden, 2012). Advantages with intermodal transportation include that it allows the shipper to find the most efficient way of transporting the goods as well as it can reduce costs and environmental impact (Novack et al., 2019). However, since the concept relies on several modes of transportation the reliability decreases since the possibility of any link in the chain breaking increases (Kubánová et al., 2020). Another aspect is a higher risk of damage on goods due to increased goods handling when switching modes (Lumsden, 2012).

In order to facilitate intermodal transportation standardized load carriers are used so that it is possible to easily transport the goods by different transportation modes. A standardized load carrier also limits the need of several different types of equipment at the terminals in order to handle different types of load carriers (Kubánová et al., 2020; Lumsden, 2012). Two of the most frequently used standardized load carriers are 20 foot containers and 40 foot containers (Novack et al., 2019).

## 3.4 Transportation Modes

There are four different transportation modes that are the most common when transporting products. These are sea, air, truck, and rail. Which type of mode that is the most suitable to use depends on equipment investments, operating decisions, available infrastructure and transportation policies (Novack et al., 2019).

### 3.4.1 Characteristics of Transportation Modes

Each transportation mode provides certain benefits compared to the others, however these benefits entail trade-offs (Fulzele et al., 2019). The different modes are described in Table 3.3.

Table 3.3. Evaluation of the most common transportation modes (Source: Bozarth & Handfield, 2019; Chopra & Meindl, 2013; Novack et al., 2019).

| Mode | Strengths | Weaknesses | Typical Freight Goods Characteristics |
|---|---|---|---|
| **Sea** | • High capacity<br>• Low cost | • Long transit time<br>• Low reliability | • Low value bulk shipments |
| **Air** | • High speed<br>• Flexibility | • High cost<br>• Low capacity | • Small high value goods<br>• Time sensitive emergency shipments |
| **Truck** | • Door-to-door delivery<br>• Flexibility | • Limited capacity<br>• High cost | • High value and small shipments |
| **Rail** | • High capability<br>• Low cost | • Low frequency<br>• Limited routes | • Low value raw materials<br>• Containerized finished goods |

### 3.4.2 Selection of Transportation Modes

Selection of transportation mode is a complex decision since it depends on multiple variables, which in some cases are dependent and not easily quantified. The important variables to consider differs from industry to industry. Additionally, the decision has become more complex due to increasing concerns regarding environment, security and new technology. On average transportation represents 20 % of the total production costs and about 50 % of the logistics cost of a product. Moreover, transportation is more than a cost, the performance of the transportation may influence the entire logistics function and result in competitive advantages (Meixell & Norbis, 2008). An appropriate selection of transportation mode can also be a big part of enhancing sustainability (Fuzele et al., 2019). Different studies describe different aspects necessary to consider when deciding transportation mode, aspects from five different studies are shown in Table 3.4.

Table 3.4. Aspects to consider when selecting transportation mode (Source: Dotoli & Epicoco, 2020; Meixell & Norbis, 2008; McGinnis, 1989; Novack et al., 2019; Punakivi & Hinkka, 2005).

| **McGinnis, 1989** | **Punakivi & Hinkka, 2005** | **Meixell & Norbis, 2008** | **Novack et al., 2019** | **Dotoli & Epicoco, 2020** |
|---|---|---|---|---|
| • Freight rate<br>• Reliability<br>• Transit time<br>• Damages<br>• Shipper market conditions<br>• Carrier considerations<br>• Product characteristics | • Freight rate<br>• Speed<br>• Reliability<br>• Accuracy<br>• Scheduling<br>• Convenience<br>• Safety | • Freight rates<br>• Reliability<br>• Transit time<br>• Loss/damage/ claims<br>• Processing/ tracing<br>• Shipper market considerations<br>• Carrier consideration | • Accessibility<br>• Capacity<br>• Transit time<br>• Reliability<br>• Safety<br>• Cost<br>• Product | • Economic impact<br>• Congestion issues<br>• Environmental considerations<br>• Safety considerations<br>• Efficiency<br>• Reliability<br>• Speed |

Several of the aspects which are important to consider are mentioned in multiple studies. For instance, all research papers identified service aspects such as reliability, transit time and safety as important considerations, as well as financial aspects. Another concern that has grown in recent years is the environmental impact of the transportation mode. The transportation sector contributes to air pollution, acid rain, maritime water quality problems, noises as well as carbon emissions which is important to measure and decrease (Meixell & Norbis, 2008). All transportation modes have both strengths and weaknesses and deciding which mode to use will generally generate conflicting goals. In order to make the optimal selection of transportation mode it is therefore important to prioritize which aspects that are important for the customers and the shipper (Dotoli & Epicoco, 2020).

## 3.5 Rail Freight from Europe to Asia

Currently there are two main routes for rail transport between Europe and Asia, The Trans-Siberian Railway (TSR) and The New Eurasian Land Bridge (NELB). TSR has been the main bridge between Asia and Europe from the late 1960s. NELB is one of the main routes that has been developed through BRI and connects China and Europe through Kazakhstan and Russia (Schramm & Zhang, 2018).

### 3.5.1 The Trans-Siberian Railway

The TSR is the largest railway in the world which connects the Far East to European countries through mainly Russia. The construction started in 1891 in order to provide a reliable connection between Russia and Siberia. In recent years the TSR has been of interest due to its potential of transporting containers between Europe and the Far East (Liliopoulou et al., 2005). In the east end of the railway, in Vladivostok, goods can be transported to countries such as China, South Korea and Japan through sea freight connections (Schramm & Zhang, 2018).

The TSR connects Europe to Asia, specifically China, through three possible routes, the Kazakh route, the Mongolian route or the Manchurian route (Islam et al., 2013). The routes of the TSR have good infrastructure and all rail routes, expect a section of 253 km on the Mongolian route and a section of 853 km in Kazakhstan, are electrified and have double track (Jakóbowski et al., 2018). The routes of the TSR are illustrated in Figure 3.1.

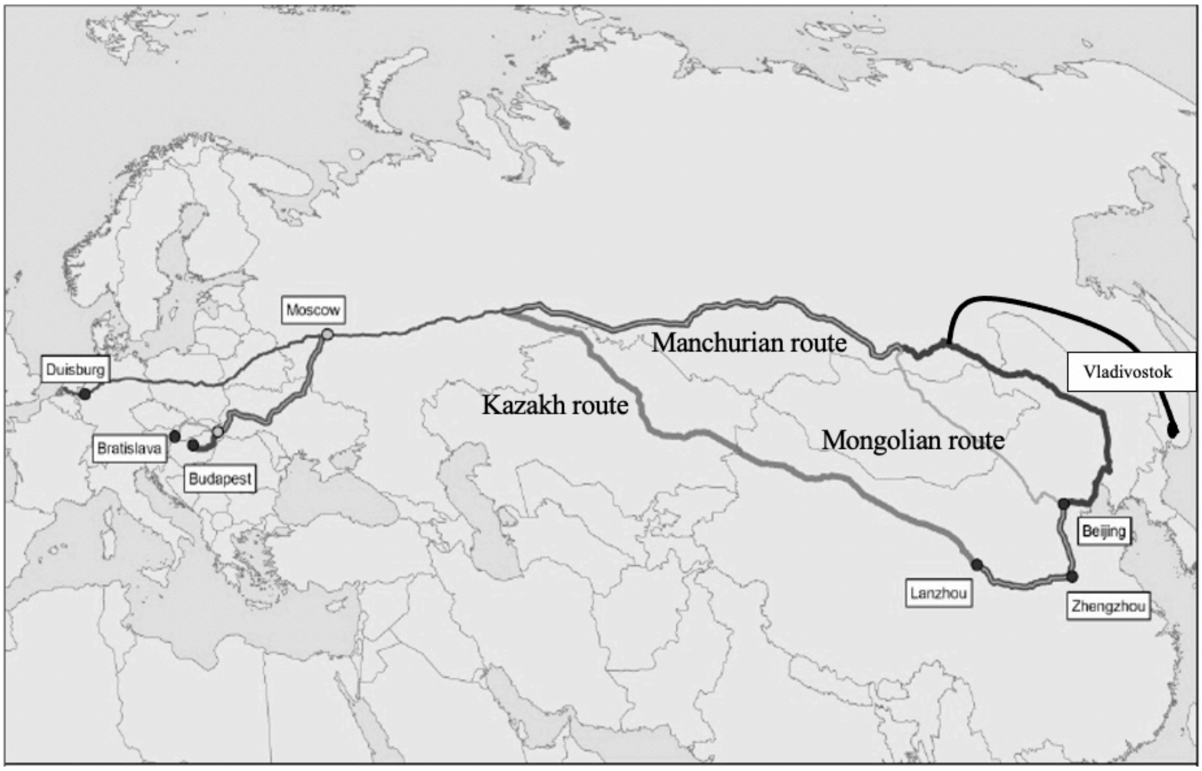


Figure 3.1. Routes of the Trans-Siberian Railway (Source: Islam et al., 2013).

### 3.5.2 Belt and Road Initiative and The New Eurasian Land Bridge

BRI is an initiative launched by the Chinese government in 2013 with the aim to build up and expand infrastructure between continents in order to improve economic connectivity between economies in the different continents. The initiative consists of a vast network of ports, railways, pipelines and maritime roads to facilitate trade and connectivity between different regions (Schramm & Zhang, 2019). As of January 2021, 140 countries spread across all continents have joined BRI and the development costs amount to approximately US $800 billion (Alon et al., 2018; Nedopil, 2021).

According to Rodemann & Templar (2014) a vast majority of the intercontinental transport volume is carried by sea freight, with air freight being the second most common transportation mode. Rail freight accounts for a negligible share of the volume transported between continents. However, the railway routes connected to BRI could change this. Forecasts predict that rail transports between Europe and Asia could represent 20 % of the total trade value between the two regions in the future (Jakóbowski et al., 2018). BRI is intended to cover six economic corridors. An economic corridor is an integrated network of infrastructure within a geographical area designed to stimulate economic development (Brunner, 2013). The six economic corridors are illustrated in Figure 3.2 and are as follows:

1. China, Pakistan Economic Corridor
2. New Eurasian Land Bridge
3. China, Mongolia, Russia Economic Corridor
4. China, Indochina, Peninsula Economic Corridor
5. China, Bangladesh, India, Myanmar Economic Corridor
6. China, Central Asia, West Asia Economic Corridor

(OECD, 2018)

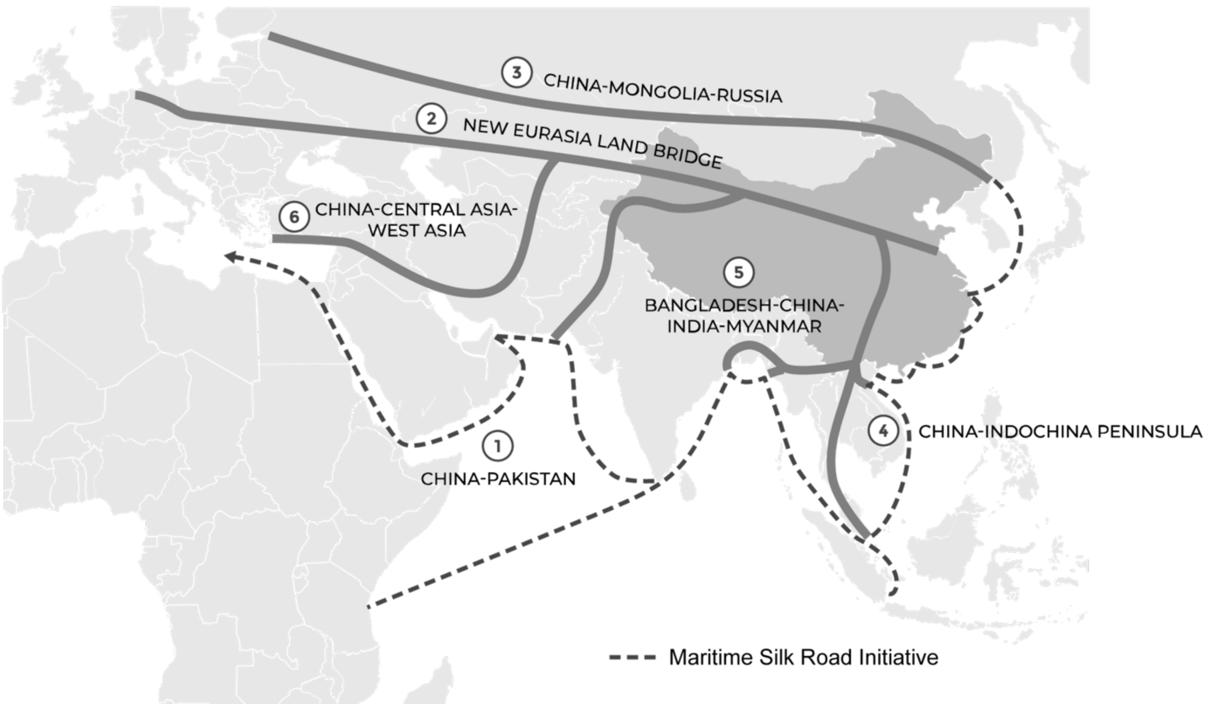


Figure 3.2. The economic corridors of BRI (Source: Standard Chartered, 2019).

NELB is one of the economic corridors of BRI presented above and the main route in BRI concerning rail transport between Europe and Asia. NELB, shown in Figure 3.3, provides a route that connects Asia to Europe through Kazakhstan (Schramm & Zhang, 2019). Compared to TSR, NELB is less electrified and the railway also consist of more single track (Rodemann & Templar, 2014).

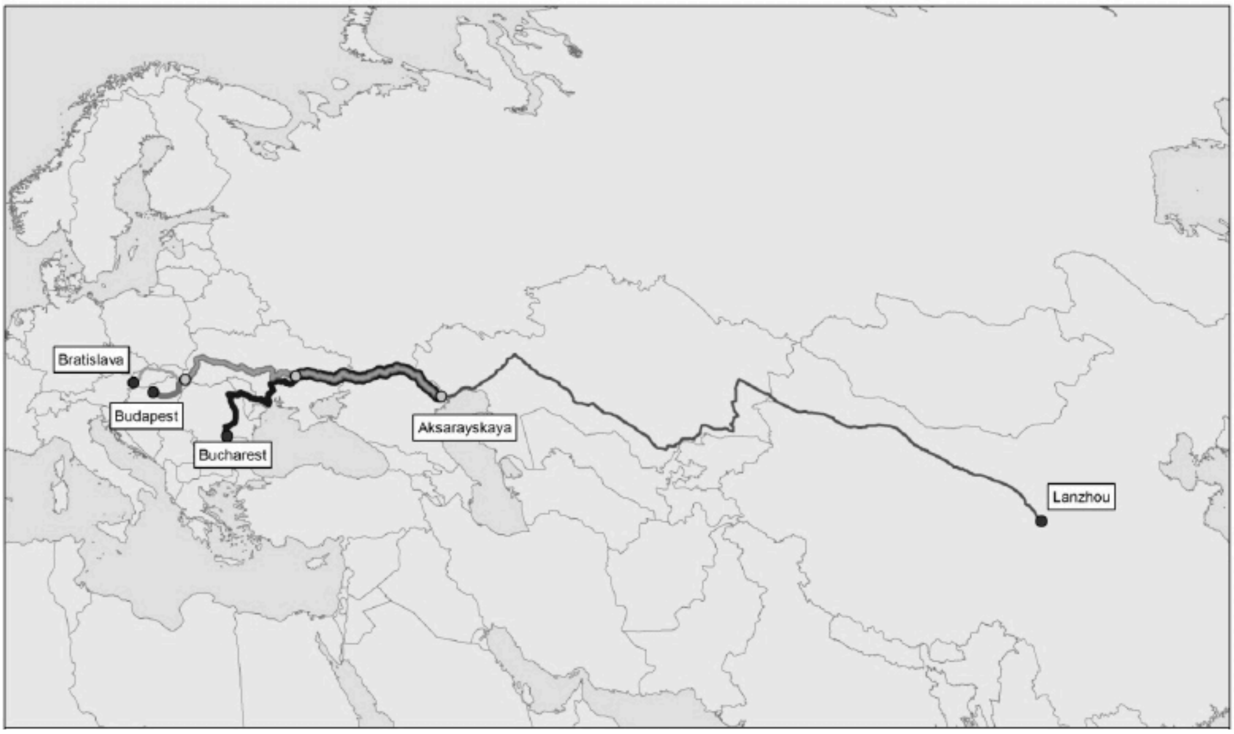


Figure 3.3. The routes of The New Eurasian Land Bridge (Source: Islam et al., 2013).

### 3.5.3 Opportunities with Rail Freight from Europe to Asia

The two most used transportation modes between Europe and Asia, sea and air, are two opposite extremes regarding transit time and cost. With sea freight being the transportation mode that has the longest transit time and lowest cost and air freight having the shortest transit time and highest cost (Novack et al., 2019). The characteristics of the two modes do not fit all types of products and for these cases rail freight can be used as an intermediate solution, with both cost and transit time placed between those of sea and air. Rail can be particularly preferential for high-value, time-sensitive goods with large dimensions. These types of goods require a short transit time in order to reduce tied up capital costs and are often too big to fly at a reasonable cost (Jakóbowski et al., 2018; Rodemann & Templar, 2014; Schramm & Zhang, 2018). The goods that currently are the most transported on rail between Europe and Asia include household appliances, machinery, automotive vehicles and electrical products (Schramm & Zhang, 2018).

### 3.5.4 Challenges with Rail Freight from Europe to Asia

The railway routes from Europe to China go through multiple countries and the railway is managed by the local government in the different countries. The railway is therefore influenced by various political and legal differences and there exists no coherent initiative and thus low cooperation between the different countries (Schramm & Zhang, 2018). Therefore, there also exists a lack of standardized technology across the countries, such as differences in gauges, voltages and safety systems (Rodemann & Templar, 2014). Furthermore, the many countries the train passes through and their legal differences result in that the goods transported need to undergo several customs checks which can possibly slow down the transit time (Galushko, 2016; Jakóbowski et al., 2018).

A crucial part of the financing of the development of rail freight between Europe and Asia comes from subsidies from the Chinese government. It is not known how long rail transport will continue to be subsidized which might discourage certain potential investors from investing in the infrastructure as well as challenges actors to find new solutions to reduce costs after the subsidies are discontinued (Jakóbowski et al., 2018; Wagener et al., 2020).

## 3.6 Service Aspects of Transportation

Meixell & Nobis (2008) state that customers rather value high service of transportation compared to low cost. This is because a late delivery might indirectly imply higher costs than the transportation price, especially if the goods are of high importance for a customer in order for them to run their business. Novack et al. (2019) define service components as transit time, reliability, accessibility, capability and security which are described in Table 3.5.

Table 3.5. Service components for transportation (Source: Novack et al., 2019).

| Service Component | Description |
|---|---|
| **Transit time** | Time for a shipment to be delivered. |
| **Reliability** | Consistency of transit time. How the actual transport meets the pickup and delivery schedule. |
| **Accessibility** | The ability of transportation providers to move freight between a specific origin and destination. |
| **Capability** | The ability of the transport provider to provide special physical and marketing characteristics of the freight. |
| **Security** | How safe the goods are in transit. Ensuring that nothing gets damaged. |

The total quality of service is characterized by the customer's perceptions of service, and service quality can therefore be defined as the difference between customer expectations of service and perceived service (Schramm & Zhang, 2018). It is therefore important to understand the customers' expectations in order to provide great service quality. Additionally, being transparent with information about transportation is also important to create the correct expectations from the customers. From the service components presented in Table 3.6., transit time and reliability are the most important aspects for distribution between Europe and Asia according to Schramm & Zhang (2018).

## 3.7 Economic Aspects of Transportation

With increasingly longer and more complex supply chains, transportation costs are becoming a bigger part of companies' total costs and a more pressing issue. It is not only the direct price from the carrier that needs to be taken into account but also indirect costs such as tied up capital cost and costs that occur if goods do not arrive on schedule (Stalk, 2009). Sheffi et al. (1988) define the total logistics cost as:

*"It is the sum of transportation cost, inventory carrying cost and any other cost of doing business with a particular mode or carrier."*

### 3.7.1 Transportation Cost

The transportation cost, also mentioned as shipping cost, is the cost of a shipment. According to Lumsden (2012) there are three main pricing methods for transportation:

**The contract method:** In the contract method the seller and buyer make a single agreement about price which is valid for a single shipment or a number of shipments over a specified period of time. This method is often used for transportations with specific circumstances such as large volumes or items and when the load is rare or unusual.

**The rate method:** The rate method, which is the most common one, consists of a standard agreement with fixed prices between the buyer and the seller. The prices are calculated dependent on the weight of the goods, the distance of the shipment as well as the value of the goods.

**The agreed rate method**: The agreed rate method is a combination of the two previously mentioned methods mainly used to provide special rates for large customers and their specific situation.

(Lumsden, 2012)

The main factor that affects the transportation cost is the chosen transportation mode where air is the most expensive, followed by road, rail and lastly sea (Chopra & Meindl, 2013). When comparing rail and sea freight from Europe to Asia, come studies show that rail freight is approximately twice as expensive as sea freight. However, when examining destinations that are far from seaports, there is less of a price difference between the two transportation modes and in certain situations can rail even have the most preferential price (Jakóbowski et al., 2018; Rodemann & Templar, 2014).

### 3.7.2 Tied Up Capital Cost

Inventory carrying costs consists of all costs related to holding or storing unsold goods (Sheffi et al., 1988). However, as Tetra Pak transports their machines directly to the customer, tied up capital in transit during the transportation is the sole cost in this category. The cost related to tied up capital is defined as:

$$C = v * T * h$$

Where,
$v$ = value of goods transported
$T$ = transit time
$h$ = holding cost rate per time unit

Equation 3.1. Tied up capital cost (Source: Sheffi et al., 1988).

It can be concluded from Equation 3.1 that the tied up capital cost increases based on the transit time, meaning that a slower mode of transportation would result in more tied up capital compared to a faster mode. Schramm & Zhang (2018) state that rail from Europe to Asia takes approximately half of the time as sea freight. This would imply half of the costs related to tied up capital for rail freight when comparing it to sea freight. For high-value goods this implies that even though sea is cheaper than rail, when also including tied up capital cost, rail can be the cheaper option (Schramm & Zhang, 2018).

## 3.8 Environmental Aspects of Transportation

Transportation is a considerable liability on the environment through emissions, pollution and exploiting natural resources. The greenhouse gas (GHG) concentration in the atmosphere has increased during the last decades and transportation emissions are one of the main sources of GHG emissions, accounting for 27 % in 2015. The most common GHG are carbon dioxide, methane, nitrous oxide and fluorinated gases (Notte et al., 2017; Novack et al., 2019).

In recent years consumers have become more aware, and assess products and services based on their environmental impact and legislations have been passed to improve the environmental performance. It is therefore important for companies to work towards green logistics in order to remain profitable (Montoya-Torres et al., 2015). Besides being beneficial for the environment, reducing emissions can lead to lower production costs, increased market share, better public image and improved logistics performance (Chin et al., 2015; Khan et al., 2020; Montoya-Torres et al., 2015). Aronsson & Huge Brodin (2006) state that there are three main options in order to reduce the emissions of transportation. These are switching the transportation mode, reducing the demand for transportation or reducing the environmental impact by for example improving the utilization.

### 3.8.1 Measuring the Environmental Impact

In order to reduce the environmental impact of transportation, measuring the GHG emissions is important. However, there is no international standard of measuring the environmental impact of transportation. $CO_2$ is the most commonly produced GHG and it is therefore common to measure the environmental impact as a carbon footprint (Montoya-Torres et al., 2015; Novack et al., 2019). Wiedmann & Minx (2008) define carbon footprint as:

*"The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of the product."*

Whereas Novack et al. (2019) defines carbon footprint as:

"*The total set of greenhouse gas emissions caused by an organization, event or product, often expressed as an amount of carbon dioxide."*

Other common GHGs, such as methane and nitrous, are often converted to $CO_2$ equivalents to make them comparable to each other and to $CO_2$ emissions (IPCC, 2014). According to Gao et al. (2014) and Peters (2010) there are three main methods for calculating the carbon footprint: input-output analysis (IOA), life cycle assessment (LCA) and hybrid methods (IO-LCA). IOA is a top down model able to take in account transactions between activities measured in monetary units and extended them at the environmental level in terms of GHG emissions. LCA is instead a method that assesses all GHG emissions associated with every stages of a product's, or service's life time (Caro, 2019). IO-LCA is a combination of the previous two. The selected method depends on the functional unit that should be analyzed, where LCA is better suited for small scale analysis and IOA is preferred for a larger scale and is therefore the favored method regarding transportation emissions (Gao et al., 2014; Peters, 2010). The methods are illustrated in Figure 3.4.

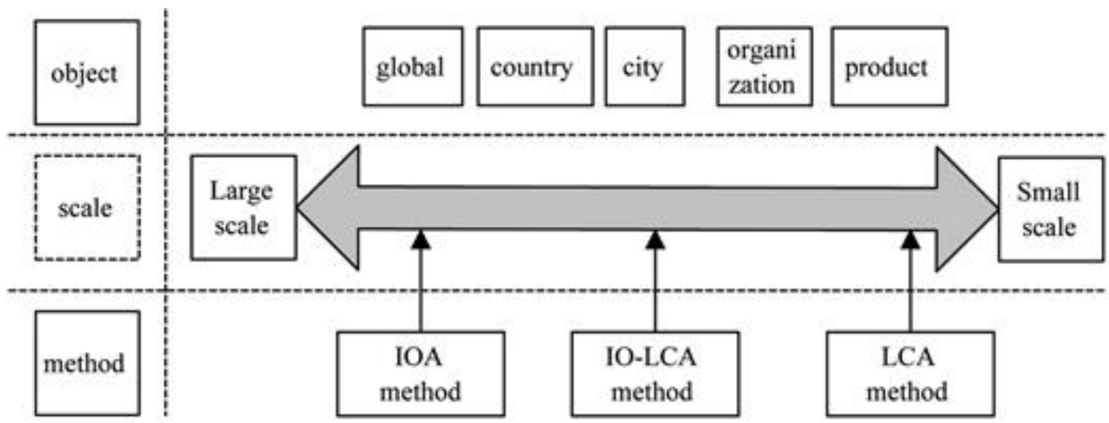


Figure 3.4. Three main methods for calculating the carbon footprint (Source: Gao et al., 2014).

### 3.8.2 Comparison of Environmental Impact Between Transportation Modes

In IPCC's (2014) fifth Assessment Report (AR5), the total GHG emissions from the transport sector are visualized, for both freight and passenger transport. The emissions have increased with 250 % from 1970 to 2010. Direct emissions for each transportation mode are illustrated in Figure 3.5.

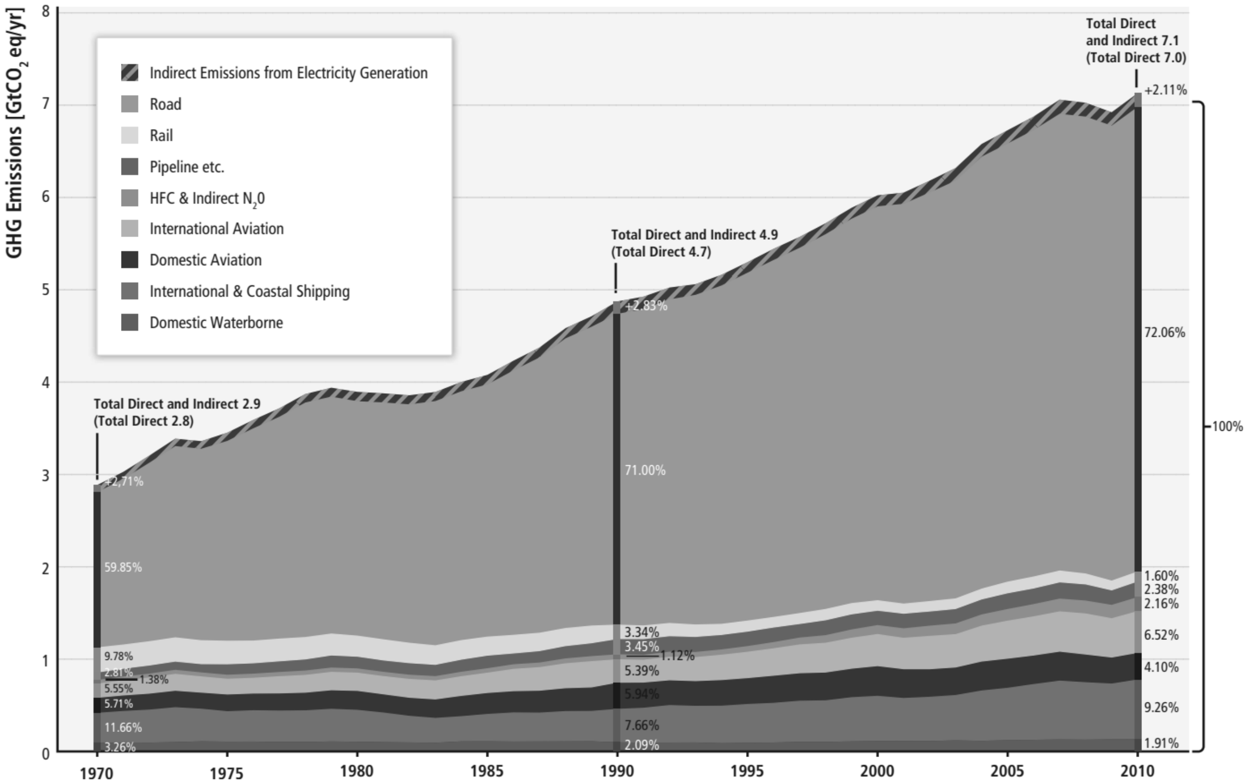


Figure 3.5. Direct GHG emissions of both the passenger and freight transport sector specified for each transportation mode (Source: IPCC, 2014).

Direct GHG emissions are released during the transportation whereas the indirect GHG emissions includes emissions for the construction of infrastructure, manufacturing of vehicles and provision of fuel. Passenger transportation accounts for a large part of the road transportation which is a reason for the high emissions for this mode (IPCC, 2014).

Kohn (2008) explains that emissions for rail depend on the energy source, either electricity or diesel, and the amount of emissions vary greatly depending on the electric mix. Electricity produced in Sweden comes mainly from hydropower which will result in less emissions than electricity produced by for instance coal (Kohn, 2008).

# 3.9 Conceptual model

In this chapter concepts and topic relevant to the purpose and research questions have been presented. Figure 3.6 presents a conceptual model in order to allow the reader to understand how the topics presented relates to this study. The model includes qualitive aspects important to consider when selecting transportation mode for example the characteristics of the transportation modes and the infrastructural constrains and possibilities, as well as how the three performance aspects will be quantified and evaluated in this thesis based on the knowledge gained in this chapter.

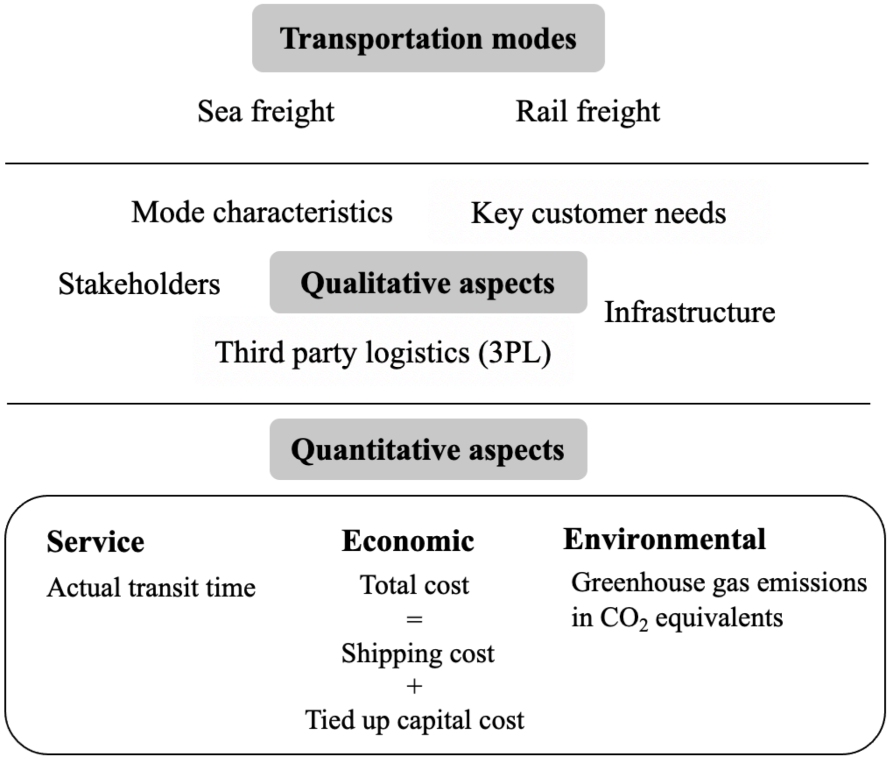


Figure 3.6. Conceptual framework.

# 4. Empirical Findings

*In this chapter the empirical data gathered will be presented. Firstly, the chapter introduces the reader to definitions of terms and concepts used later in the chapter in order to provide an understanding for the empirical findings and their meaning. Thereafter, the current sea freight situation at Tetra Pak is presented, followed by the future possibilities of rail freight to Asia. Finally, the chapter concludes with presenting the performance for sea and rail freight to three countries: China, Japan and Vietnam.*

## 4.1 Definitions of Used Terms and Concepts

**Transit time:** In this thesis transit time is defined as the time from loading the goods at the production site, either in Lund or Modena, until unloading of the goods at the Incoterm location. The reason for this is that Tetra Pak is only responsible for the transportation to this point according to the Incoterms used and not the entire way to the final customer. The transit time for sea shipments is obtained from Tetra Pak's internal transportation system. For the rail shipments the estimated transit time comes from the 3PLs A and B and the average delay for the shipments from "Rail to Asia" is added to account for delays.

**Delayed shipment:** A shipment is seen as delayed if it arrives over two days after the estimated time of arrival (ETA). If the shipment arrives one or two days after ETA it is seen as "late within grace" according to Tetra Pak. Therefore, a shipment is approved if it arrives with less than two days delayed. Shipments that have been delivered before expected delivery date have been counted as delivered in time.

**Shipping cost:** The cost for the shipment is quoted based on the number of containers in the shipment for both rail and sea freight. In this thesis the shipping cost will be presented as the cost per 40 ft high cube (HC) container in order to be able to compare the costs of sea and rail, since a 40 ft HC container is the only container that is used for rail freight. The shipping cost for sea is obtained from Tetra Pak's internal transportation system and from the 3PL B for rail.

**Tied up capital cost:** The cost connected to tied up capital will be calculated according to Equation 3.1 presented in section 3.8.2. The value in the calculations is the average value for one container to each country and the holding rate used is Tetra Pak's global holding rate. The average actual transit time is used in the equation for the sea shipments and for rail shipments the estimated transit time is used where the average delay for the shipments from "Rail to Asia" is added to account for delays.

**Total cost:** The total cost is the average shipping cost per container added to the tied up capital cost per container. The total cost therefore gives a result of the cost for one container. All of the costs have been scaled.

**Environmental impact:** The environmental impact is declared in tons of GHG emissions in $CO_2$ equivalents. The amount of emissions for each route is obtained by a calculation tool called EcoTransIT (EcoTransIT, 2021). The tool is used by Tetra Pak's 3PL B in order for them to calculate their emissions. The GHG emissions calculated from the tool are based on the mode of transportation, the origin and the destination for the different distances the route consist of as well as the number of containers. The emissions presented in this thesis are for one 40 ft HC container. Full calculations for the environmental impact can be found in Appendix B.

## 4.2 Tetra Pak

Manufacturing of processing and packing machines are as mentioned two of the three main areas at Tetra Pak. Orders of processing machines are generally customized where Tetra Pak together with the customer designs the machine, whereas packaging machines often are standardized. Packaging machines are generally large machines which implies large volumes, weights and a large investment for the customers. The packaging machines are shipped worldwide to both small dairies as well as huge soft drink manufactures. The sale could be reiterative or just a one-time deal depending on the customers (Tetra Pak, 2021a).

### 4.2.1 Clusters and Markets

Tetra Pak is a cluster organization meaning that the company is grouped into four geographic cluster to enable efficient management. The four clusters Europe and Central Asia (E&CA), Asia Pacific (APAC), Greater Middle East and Africa (GME&A) and North, Central and South America (Americas) are shown in Figure 4.1.

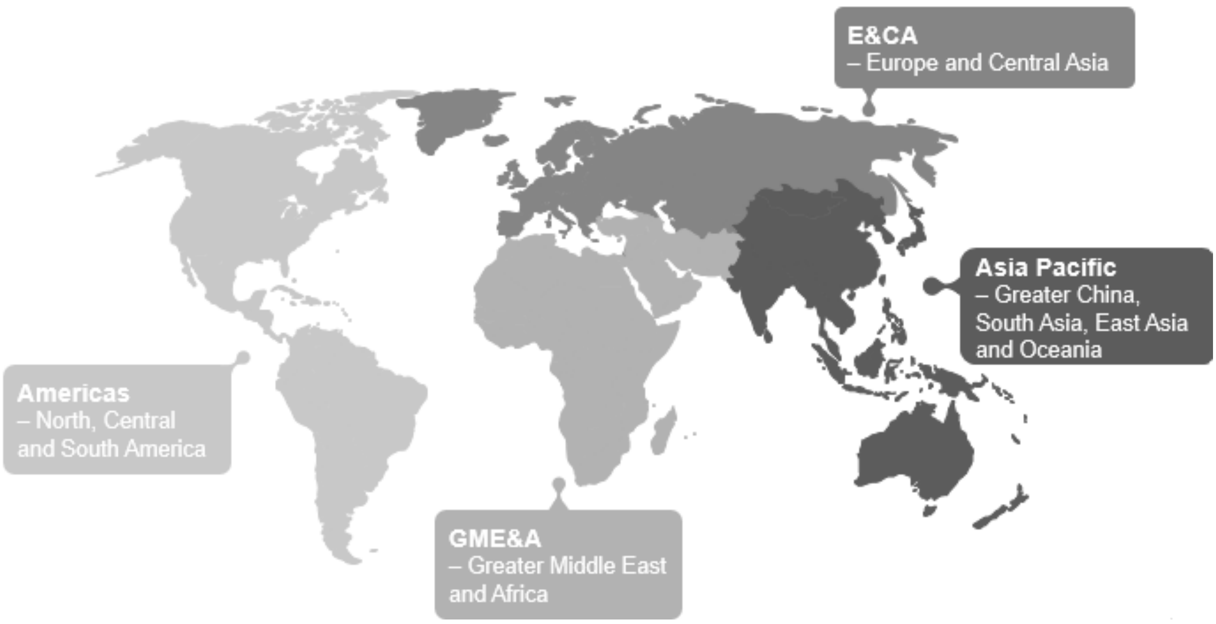


Figure 4.1. Tetra Pak divided into the clusters: Americas, APAC, E&CA and GM&A (Source: Tetra Pak, 2021a).

The APAC cluster represents the largest part of the total worldwide sales accounting for 35 % of it. The APAC cluster is made up of seven markets:

1. Greater China
2. Japan & Korea
3. Malaysia, Singapore, Philippines & Indonesia
4. Oceania
5. South Asia Markets
6. Thailand
7. Vietnam

In the seven markets 24 different countries are included. Each of these markets have their own MC, which for instance handles the contact with the final customers and is responsible for the shipment after Tetra Pak has delivered it to the Incoterm location. It is also the MC that defines where the Incoterm location should be as well as decide the mode of transportation. In the scope of this thesis 476 shipments of packaging machines have been carried out from Europe to APAC, where about ten of these shipments were shipped outside Asia, meaning that most shipments to APAC are within Asia (Tetra Pak, 2021a).

### 4.2.2 Packaging Machines

Tetra Pak offers a complete packaging portfolio which comprises of different types of packaging machines that together contribute to an end-to-end solution for packaging of food products such as dairy products, beverages and cheese. The product portfolio is constantly changing, products are added and removed throughout the year. As of today, Tetra Pak offers eleven different types of packages as well as different types of packaging materials, painting methods, opening, closures and straws. The packaging machines that produce the different packages for the customers are grouped into several categories, which are described below.

**Filling machines:** Machines that fills the packages with the customers' food products. The type of filling machine depends on which type of package the customer requires.

**Line controllers:** The heart of the packaging network that ensures optimal line performance. The product handles the configuration of the packaging line and controls the line during production, handles conveyor speed settings as well as deals with starting, stopping and bypassing.

**Accumulators:** These machines collect and store the packages between the different machines. Consequently, it reduces filling machine stops, raises up-time and avoids eventual damage to packages queuing on the product line.

**External applicators:** A wide range of closures are available for Tetra Pak's packages, cap applicators for each one of these closures are included in this category. Additionally, machines that apply straws to the packages are included in this category.

**Sales unit wrappers:** Machines that wrap the carton packages with film which gives a cost-effective product grouping and protection as well as speeds up shelf replenishment for the retailer.

**Distribution unit packers:** Machines that manage the production of distribution units and the packing of the primary packages into these.

As mention in the introduction, most of the manufacturing of the Tetra Pak packaging machines takes place in Lund or Modena in Europe. An exception from production in Europe is the product group Accumulators, which are produced in the U.S. as well as some types of machines in the other categories where production takes place in China.

(Tetra Pak, 2021b)

The machines are packed in crates at Tetra Pak sites and thereafter loaded in containers. All machines are possible to ship by sea, however the volume and the weight limits the possibilities of loading the machines in containers for shipping by air and rail. For rail transportation a 40 ft HC container is used which has the internal dimensions of 12032 x 2352 x 2698 mm (Maersk, 2021). This delimitation means that 20 % of the packaging machines in the range are not physical possible to ship with rail due to them being too high to fit into this type of container. However, according to Interviewee 2 and Internal Systems at Tetra Pak the types of machines that are too high are rather uncommon and not the ones most frequently sold.

## 4.3 Sea Freight

Tetra Pak has completed 476 shipments of packaging machines to APAC that originated from Europe. An overview of the shipments is displayed in Table 4.1.

Table 4.1. Shipments from Europe to APAC (Source: Internal Transportation System, 2021).

| Transportation Mode | Number of Shipments (%) | Weight (%) |
|---|---|---|
| **Sea** | 58 % | 92 % |
| **Air** | 42 % | 8 % |

Based on the data presented in Table 4.1 it can be confirmed that sea freight is the most used transportation mode. This is the case for the number of shipments sent but especially true for the total weight that is transported with each transportation mode, as sea freight accounts for a vast majority, 92 %, of the total weight transported to APAC from Europe.

### 4.3.1 Shipping Process

Based on information from Interviewee 2 and Interviewee 8 the shipping process for sea freight is as follow. The goods are collected at the two production sites in Europe by truck and are thereafter transported to a nearby port, most commonly Helsingborg when the machines originate from Lund and Genova when the machines originate from Modena. The goods are stuffed in containers either at site when picked up in Lund or at the port. This depends on the resource capacity at the site in Lund when the goods should be picked up. Stuffing the container at the site rather than at the port is preferential as it decreases the shipment cost for Tetra Pak. However, the possibility for this does not exists in Modena and therefore the goods are always stuffed in containers at the port in these cases. From the port in Europe the goods are shipped through the Suez Canal to reach Asia.

Tetra Pak has a collaboration with the logistics company 3PL A for sea shipments. The shipping department at Tetra Pak provides 3PL A with all information necessary. 3PL A is in charge of the coordination and the continuous contact with the shipping company during the transportation. 3PL A has employees working with manually tracking the shipments through the shipping companies tracking systems. The shipping companies have predetermined routes with several stops in ports in both Europe and Asia. The goods are shipped to a port in Asia decided by the MC and offered by the 3PL. Generally, the vessel stops during the route in order to change vessel since the final port often does not have the capacity to handle larger vessels and therefore goods need to be transferred to smaller ships. Singapore is one common port for transshipments. Once the goods are unloaded at the port the responsibility for the shipment is transferred from Tetra Pak to the MC in the region since the goods are shipped according to Incoterms 2020 DAP. The shipment process is illustrated in Figure 4.2 and the route can be seen in Figure 4.3.


Figure 4.2. Shipping process for sea freight.

Figure 4.3. Route for sea freight from Lund and Modena to Asia.

### 4.3.2 Advantages and Challenges with Sea Freight

Based on the interviews with employees working in the shipping team at Tetra Pak in Lund as well as interviews with employees at 3PLs A and B advantages and challenges with sea transportation has been derived.

Sea freight is generally less expensive than other transportation modes and provides an opportunity to transport goods that are both large and heavy which are the conditions of Tetra Pak's packaging machines. Furthermore, sea shipments do not require a specific infrastructure and it is a common transportation mode that has been used for thousands of years which has resulted in many available ports globally. Tetra Pak has worked with 3PL A for sea transportation for several years. This relation is seen as a great advantage since 3PL A has a lot of knowledge about Tetra Pak's products and a well-established partnership makes the shipping process smoother.

However, transportation by sea also implies challenges. Firstly, transportation by vessel has longer transit time than other transportation modes and is especially dependent on the weather conditions. Sea transportation is not flexible since a missed departure might result in a delay of weeks to the end location due to few sea departures. Furthermore, the shipping companies are often inflexible regarding routes and it is not possible to deviate from the routes. Another challenge is the current tracking system for sea transportation, it is not as well functioning as desired. 3PL A are supposed to get information from the shipping company when a delay occurs and send this information manually to Tetra Pak. The manual process makes it hard to notice all delays in a structured way and shipping companies do not always report delays to

3PL A. However, an integration of Tetra Pak's and 3PL A's systems is under investigation which might be a solution for mitigating this challenge.

Furthermore, the global outbreak of the covid-19 pandemic in 2020 has had and still has a huge effect on ocean freight. Well established sea routes between Europe and Asia have been redirected due to restrictions and reduced manpower in ports. For instance, large congestions have occurred in Port Singapore, the port where a large majority of the goods transported from Europe to Asia is transshipped. This has resulted in longer transit times than usually as well as longer delays. Another challenges for the ocean freight due to covid-19 is container shortage. Congestions in ports have led to vessels queuing to get unloaded and making containers unavailable. Further, available containers in Europe shipped empty to Asia in order to enable the export from Asia has therefore occurred. This results in issues of finding space on vessels for containers with goods since it is considered to take longer time to transport containers loaded with goods compared to empty containers.

The advantages and challenges with sea freight are summarized in Table 4.2.

Table 4.2. Advantages and challenges with sea freight.

| **Advantages** | **Challenges** |
|---|---|
| Low shipping costs | Long transit time |
| Well established infrastructure | Fixed sea routes |
| Long term partnership with 3PL | Inconvenient and manual tracking process |
| | The covid-19 pandemic |

## 4.4 Rail Freight

During 2020 Tetra Pak sent six test shipments by rail to China in the project "Rail to Asia", which will be further described in section 4.5.1. After the project's close, around 20 shipments are planned to be transported by rail to China so far in 2021 according to Interviewee 3 and 4. Additionally, the demand for rail transportations has increased from different MCs in Asia. As the project has been closed, it is now the Shipping team in Lund who is responsible for the rail shipments. Tetra Pak has chosen to continue to work with 3PL B, the 3PL for the project, for further rail shipments therefore the thesis will only evaluate the rail freight options that 3PL B can offer. 3PL B offers two separate routings for rail shipments from Europe to Asia called AE18 and AE19.

### 4.4.1 Shipping Process

The shipping process described below is based on the interview with Interviewee 7. AE18 is mentioned as the "traditional" rail route from rail hubs in Europe to rail hubs in China. For this route goods can be transported from the production site in Lund to Helsingborg by truck and thereafter loaded on a vessel to Hamburg. It can also be transported from Lund to Karlshamn by truck and then by vessel to Mukran. From there the goods are shipped by sea to Kaliningrad.

From these points, Hamburg and Kaliningrad, the goods are loaded on trains and transported to China.

The shipments from Modena can be transported by truck to Milan and from there by rail to Hamburg. From Hamburg the goods are transported by rail to China. There is another possible route from Modena, by truck from Modena to Milan and from there directly transport by rail to China through Malaszewicze without passing Hamburg. This option has not been used for the rail shipments Tetra Pak have carried out since Tetra Pak has requested to use Hamburg as a consolidation point for goods from Lund and Modena. The different possible rail routes in Europe are visualized in Figure 4.4.

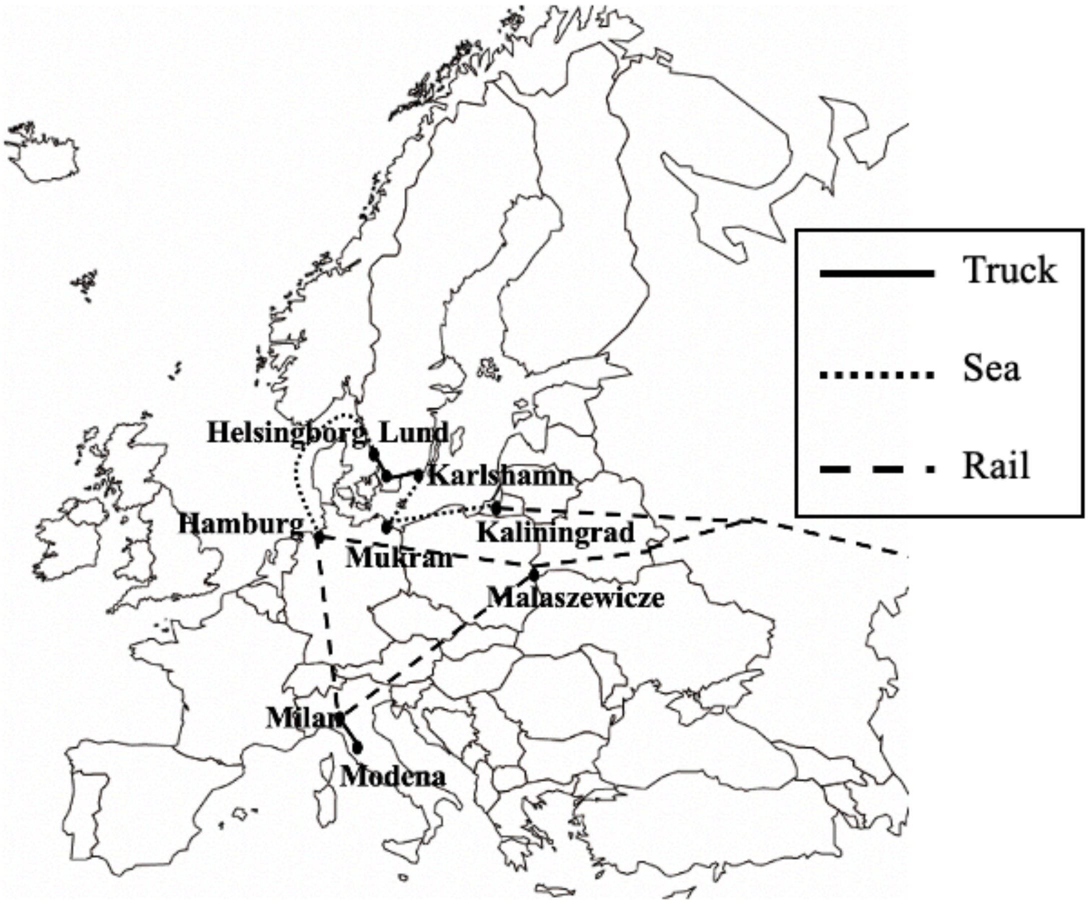


Figure 4.4. AE18 routes in Europe.

The most common border crossing station into China for the AE18 route is Alashankou. An alternative would be to cross the border at Manzhouli. Three common rail hubs in China are Xi'an, Wuhan and Chengdu. From these hubs the goods can be further transported to other locations in China by truck as well as to other countries, for instance countries in South East Asia. When the goods are further transported to countries in South East Asia they are taken by train to Chengdu, which is the most southern rail hub that 3PL B offers rail transportation to. Transporting the goods by truck to the coast will make it possible to transport the goods by sea to for instance Japan, South Korea and Taiwan. The part of the route that is in Asia is visible in Figure 4.5.


Figure 4.5. AE18 routes in Asia.

For AE19, the goods are transported by truck form Lund to Helsingborg and thereafter by vessel to St Petersburg. From the site in Modena the goods are transported by truck to Verona where they are shipped by rail to Hamburg. Thereafter, the goods are transported by truck to Bremerhaven and from there shipped by sea to St Petersburg. In St Petersburg, the goods are transferred to train and transported along the TSR to Vostochny. In Vostochny the shipment is transferred to sea and carried to the final port. The AE19 route is suitable for final destinations such as Northern China, South Korea and Japan. The AE19 route is illustrated in Figure 4.6 and Figure 4.7.

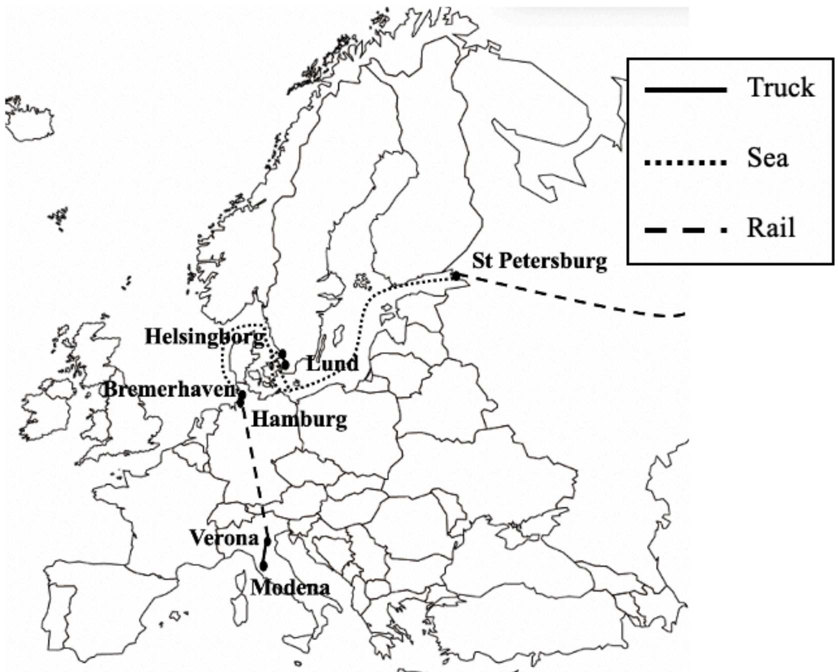


Figure 4.6. AE19 route in Europe.

Figure 4.7. AE19 route in Asia.

### 4.4.2 Advantages and Challenges with Rail Freight

Based on the interviews with employees working in the shipping team at Tetra Pak in Lund as well as interviews with employees at the logistics companies 3PL A and B advantages and challenges with rail transportation have been identified.

For rail freight, it is a possible to have a better established tracking system than for sea freight, since the shipment can be tracked continuously from point of origin to the final destination. This is not the case as of today for sea freight, where the shipment is only tracked at certain key points. Tracking a shipment continuously facilitates to notice and act if anything unexpected happens during the shipment and therefore risks are decreased. This is especially important for high value goods. Further, rail freight has a shorter transit time than sea freight and there are also more carriers to choose from and therefore there are more options and more available booking slots for railway than for vessel. Rail freight has not been as affected by covid-19 as sea freight has been and therefore delays due to congestion have not increased as has been the case for sea transportation. However, it could be an increasing problem with congestion for rail freight as more companies move towards using railway when they experience issues with sea freight.

The main issue experienced with rail freight is that it has higher and different documentation requirements compared to sea freight. One example of this is that rail freight requires one packing list and invoice per container instead of per machine which is the case for sea transportation. Therefore, Tetra Pak has had to find new processes to meet this demand which has led to a lot of work as well as complications and delays. If the documentation is not right it can lead to stopped goods at the boarder which is costly and can take a lot of time.

Furthermore, it can become a challenge to export the goods out from China further on to other countries due to extensive custom processes in China. There are also restrictions concerning the infrastructure for rail freight since the train can only transport goods where there are tracks and therefore destinations and routes are not flexible. Tetra Pak is collaborating with a new 3PL for rail freight who have not worked with Tetra Pak's machines before, which is seen as a challenge. Lastly, some of the machines are too high to fit into 40 ft HC containers, however these are not the most common machines and are therefore only seen as a minor challenge. Table 4.3 provides a summary of the advantages and challenges identified with rail transportation.

Table 4.3. Advantages and challenges with rail freight compared to sea freight.

| Advantages | Challenges |
|---|---|
| Better established tracking system | Higher documentation requirements |
| Shorter transit time | Export from China |
| Better availability | Limitations regarding routes and destinations |
| Less affected by Covid-19 | New 3PL |
| | Machines are too high for rail containers |

## 4.5 China

China is Tetra Pak's biggest market and is therefore of great importance for Tetra Pak. After the "Rail to Asia" project MCs in China have continued to show interest for using rail as a transportation mode due to the shorter transit time and higher reliability compared to sea freight. It is therefore important for Tetra Pak to make an equitable evaluation of the performance of the two modes for transportation to China.

### 4.5.1 Tetra Pak Project "Rail to Asia"

In 2019 Tetra Pak initiated a project named "Rail to Asia". The project's objective was to enable the use of rail freight to China in order to reduce transit time, enhance operational and planning efficiency and decrease tied up capital costs. The project was also set out to collect and analyze data from different shipments, both sea and rail, measuring vibrations and temperature during transportation, with a tracking device. This was done in order to enable a comparison of vibrations and temperature changes between sea and rail freight to ensure that shipping with rail did not damage the quality of the machines which was the hypothesis previous. Lastly, the project was set out to define standards to plan orders, book and execute transport for rail shipments. The project focused on rail shipments between Lund and Modena in Europe to Shanghai and Xi'an in China. During the project six pilot shipments were conducted, five to Shanghai and one to Xi'an. To be able to carry out these shipments a partnership with the 3PL B was initiated.

Interviewee 1 explains that the project group for "Rail to Asia" made a comparison between sea and rail freight based on the results and the conclusions that could be drawn are shown in Table 4.4.

Table 4.4. Conclusions from the "Rail to Asia" project (Source: Interviewee 1).

| | |
|---|---|
| **Shock forces** | No additional shock forces when using rail compared to other transportation modes. |
| **Transit time** | Ramp-to-ramp transportation offers consistency. Moreover, delays are generally related to transportations before and after the main transportation by rail. |
| **Reliability** | Solid on-time performance reliability. |
| **Tied up capital cost** | Savings in tied up capital cost is direct related to transit time reduction. |
| **Environmental** | Rail produces 8 % less GHG emissions compared to sea. However, the difference is dependent on what fuel or energy sources is used for the transportation modes. |
| **Supplier payment** | The payment terms are 30 days from when the goods have been shipped. When using railway the customer sometimes receives the goods within these 30 days compared to sea and therefore the transport mode better supports the payment terms compared to sea freight. |

### 4.5.2 Shipping Process

The process and the routes for the rail shipments in the project "Rail to Asia" have been identified from interviews with Interviewees 1, 3, 4 and 6. The shipping processes for rail freight from Lund and Modena to Shanghai are illustrated in Figure 4.8 and Figure 4.9 and the shipping routes in Figure 4.10 and Figure 4.11. The route to Xi'an is the same route as for Shanghai without the last distance of truck transportation.

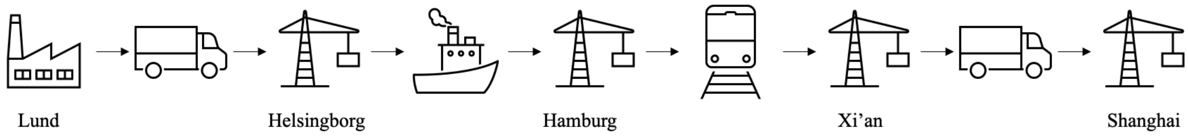


Figure 4.8. Shipping process for rail freight from Lund to Shanghai.

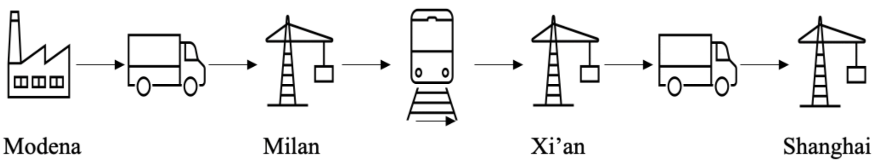


Figure 4.9. Shipping process for rail freight from Modena to Shanghai.


Figure 4.10. The route for rail freight to Shanghai in Europe.


Figure 4.11. The route for rail freight to Shanghai in Asia.

### 4.5.3 Comparison of Sea and Rail Freight

After the project's closure, Tetra Pak has continued with rail shipments to China. In this thesis the five rail shipments to Shanghai from the project as well as the rail shipments carried out to Shanghai after the project, have been compared to sea shipments with the same destination. Shanghai is one of the main destinations in China for Tetra Pak and therefore important to evaluate. In total there are 51 sea shipments from Europe, 24 departing from Lund and 27 departing from Modena. As mentioned in section 2.4.3 the sample sizes of sea and rail shipments are different. Due to the fact that the sample sizes for rail shipments are three and four compared to 24 and 27 for sea, the statistical dispersion for rail is comparatively larger than for sea. Table 4.5 shows the comparison for transit times and delays and Table 4.6 shows the comparison for costs.

Table 4.5. Transit time and delay of sea and rail shipments to China (Source: Internal Transportation System, 2021).

| | | Estimated Transit Time (days) | | Actual Transit Time (days) | | Delay (days) | |
|---|---|---|---|---|---|---|---|
| | | Average | Median | Average | Median | Average | Median |
| **Lund** | Sea | 46 | 46 | 48 | 47 | 2 | 1 |
| | Rail | 26 | 27 | 30 | 34 | 4 | 3 |
| **Modena** | Sea | 46 | 46 | 49 | 47 | 2 | 1 |
| | Rail | 31 | 32 | 32 | 32 | 1 | 1 |

Table 4.6. Costs for one container for sea and rail shipments to China (Source: Internal Transportation System, 2021).

| | | Shipping Cost (SEK) | | Tied up Capital Cost (SEK) | Total Cost (SEK) |
|---|---|---|---|---|---|
| | | Average | Median | | |
| **Lund** | Sea | 102 505 | 97 808 | 359 269 | 461 774 |
| | Rail | 106 201 | 79 721 | 227 038 | 333 239 |
| **Modena** | Sea | 78 550 | 75 574 | 366 755 | 445 305 |
| | Rail | 112 368 | 100 869 | 239 513 | 351 881 |

Table 4.5 shows that rail has a shorter average actual transit time of 18 days for shipments from Lund and 17 days for shipments from Modena than shipments by sea freight. It can be seen that the rail shipments from Lund have the highest average delay. For the sea shipments 33 % originating from Lund and 48 % originating from Modena were delayed, which means that 41 % of the total shipments were delayed. The data presented in Table 4.6 shows that the shipping cost for rail from Lund is approximately 3 % more expensive than sea while the difference is 30 % for shipments from Modena. However, the tied up capital cost is higher for the sea shipments resulting in a lower total cost for the rail shipments.

Table 4.7 displays the GHG emissions from both sea and rail transport to China.

Table 4.7. Environmental impact of one container for sea and rail shipments to China (Source: EcoTransIT, 2021).

| | | GHG Emissions as $CO_2e$ (ton) |
|---|---|---|
| **Lund** | Sea | 2,44 |
| | Rail | 1,87 |
| **Modena** | Sea | 2,15 |
| | Rail | 1,89 |

The environmental impact in form of GHG emissions is lower for both of the rail routes compared to sea.

The rail shipments with Xi'an as destination will not be compared to sea shipments since there exists no sea shipment to this destination. However, the results for the rail shipments are presented in Table 4.8 and Table 4.9.

Table 4.8. Transit time and delay of rail shipments to Xi'an (Source: Internal Transportation System, 2021).

| | Estimated Transit time (days) | | Actual Transit Time (days) | | Delay (days) | |
|---|---|---|---|---|---|---|
| | Average | Median | Average | Median | Average | Median |
| **Lund** | 22 | 22 | 25 | 26 | 3 | 1 |
| **Modena** | 27 | 27 | 27 | 27 | 0 | 0 |

Table 4.9. Costs for one container for rail shipments to Xi'an (Source: Internal Transportation System, 2021).

| | Shipping Cost (SEK) | | Tied up Capital Cost (SEK) | Total Cost (SEK) |
|---|---|---|---|---|
| | Average | Median | | |
| **Lund** | 120 933 | 122 432 | 187 119 | 308 052 |
| **Modena** | 114 510 | 114 510 | 202 090 | 316 600 |

Table 4.8 and Table 4.9 show that the transit time to Xi'an for rail transportation is shorter than the transit time to Shanghai and the total cost is cheaper. This is due to the fact that the distance is shorter from Europe to Xi'an than to Shanghai for rail transportation. A shorter route to Xi'an compared to Shanghai would also lead to lower emissions.

## 4.6 Japan

After the "Rail to Asia" project, Tetra Pak has received several requests from the MC and customers located in Japan to utilize rail transportation for their shipments. As the interest of rail transport from the MC and the customers in Japan is high it is important for Tetra Pak to investigate the possibilities to provide rail freight for this country.

As Japan is an island it will not be possible to transport the goods to the final location by rail the entire way. It will therefore be necessary to switch mode to sea for the final part of the transport. Furthermore, Japan is a country located far east and therefore is one of the countries that has the longest transit times when transporting goods by sea freight from Europe. An overview of the shipments Tetra Pak has carried out to Japan during the time period for this thesis is provided in Table 4.10.

Table 4.10. Overview of shipments from Europe to Japan (Source: Internal Transportation System, 2021).

| Transportation Mode | Number of Shipments (%) | Weight (%) |
|---|---|---|
| **Sea** | 50 % | 87 % |
| **Air** | 50 % | 13 % |

To Japan the number of air shipments are equal to the number of sea shipments, unlike the entire APAC cluster. However, when focusing on the total weight that is shipped with each transportation mode, sea freight transports the majority of the total weight shipped to Japan.

### 4.6.1 Sea Freight

20 sea shipments have been sent to Japan whereof half of them were transported from Modena and half of them from Lund. The ports in Japan the goods have been shipped to are presented in Table 4.11 and their locations are visualized in Figure 4.12.

Table 4.11. Shipment value and number of shipments to the ports in Japan (Source: Internal Transportation System, 2021).

| Port | Shipment Value (%) | Number of Shipments |
|---|---|---|
| **Port Tokyo** | 62 % | 12 |
| **Port Yokohama** | 17 % | 4 |
| **Port Shimizu** | 21 % | 4 |

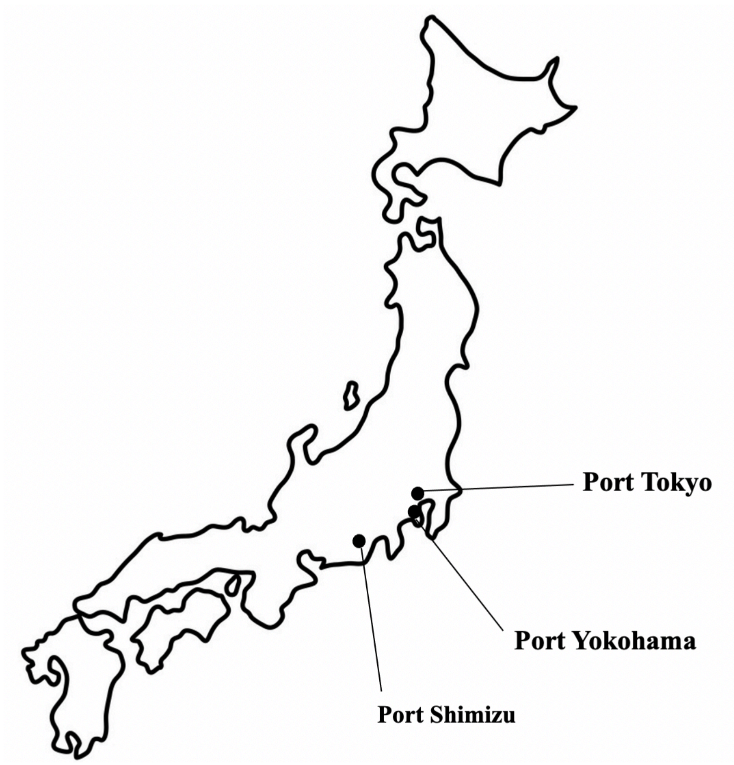


Figure 4.12. Map of ports in Japan.

Three ports were utilized among the 20 shipments, the most used port was Port Tokyo, with 12 shipments sent there, followed by Port Yokohama and Port Shimizu with four shipments each. The shipped value is distributed between the different ports with 62 % to Port Tokyo, 17 % to Port Yokohama and 21 % to Port Shimizu. Since the ports are closely located to each other all of the shipments will be evaluated together since transit times, costs and environmental impact to the different ports can be seen as comparable. Data for rail shipments will be based on Port Tokyo as this is the port with the most shipments and the highest value shipped to it.

The service aspects transit time and delays of the sea shipments to Japan are shown in Table 4.12.

Table 4.12. Transit time and delay of sea shipments to Japan (Source: Internal Transportation System, 2021).

| | Number of Shipments | Estimated Transit Time (days) | | Actual Transit Time (days) | | Delay (days) | | Delayed Shipments (%) |
|---|---|---|---|---|---|---|---|---|
| | | Average | Median | Average | Median | Average | Median | |
| **Lund** | 10 | 51 | 50 | 56 | 55 | 5 | 5 | 60 % |
| **Modena** | 10 | 53 | 57 | 58 | 63 | 5 | 5 | 80 % |

As can be seen in Table 4.12 the average estimated transit times are 51 and 53 days while the average actual transit times are 56 and 58 days, implying that not all shipments were delivered on time. Of the 20 shipments, 14 of them were delay which is 70 % of all the shipments. The shipments from Modena are more common to be delayed than the shipments from Lund. The average delay of the shipments was five days from both sites. The main reason for the delays is congestion in ports accounting for nine of the 14 delayed shipments. Other common reasons are overbooked vessels and weather related problems.

Table 4.13 shows the costs for one container shipped by sea from Lund and Modena to Japan.

Table 4.13. Costs for one container for sea shipments to Japan (Source: Internal Transportation System, 2021).

| | Shipping Cost (SEK) | | Tied Up Capital Cost (SEK) | Total Cost (SEK) |
|---|---|---|---|---|
| | Average | Median | | |
| **Lund** | 73 875 | 75 646 | 293 411 | 367 286 |
| **Modena** | 99 334 | 87 113 | 303 889 | 403 223 |

The shipping cost per container is more expensive from Modena than Lund. As well as the tied up capital cost is higher for shipping from Modena due to a longer average transit time from this production site. It can be identified that the cost for tied up capital is close to three times as high compared to the shipping cost.

The environmental impact for the sea shipments is shown in Table 4.14.

Table 4.14. Environmental impact of one container for sea shipments to Japan (Sourec: EcoTransIT, 2021).

| | GHG Emissions as $CO_2e$ (ton) |
|---|---|
| **Lund** | 2,59 |
| **Modena** | 2,30 |

Table 4.14 shows that the emissions generated from shipments from Lund is slightly higher than the emission generated from shipments from Modena due to a longer distance.

### 4.6.2 Rail Freight

There is an infrastructure possibility to take both AE18 and AE19 to transport goods from Europe to Japan by rail. For AE18 the goods would be transported by rail to the rail hub in Xi'an in China and thereafter taken by truck to Port Shanghai where the goods would be loaded on a vessel and taken to the final port in Japan. For the last transport with sea freight the 3PL B can only offer their own vessel departures, which have a sparse schedule and are therefore not that effective. The goods could also be shipped on AE19 to Vostochny Port and thereafter transported by sea freight to Japan. As of today, 3PL B can only offer the AE19 route to Japan, however AE18 might be an option in the future according to Interviewee 7 and is therefore also evaluated in this thesis. Table 4.15 shows the expected performance for rail freight to Japan obtained from Interviewee 7. The average delay from the rail shipments in "Rail to Asia" has been added to the transit time obtained from Interviewee 7 to account for delays.

Table 4.15. Transit time and cost for one container shipped by rail to Japan (Source: Interviewee 7).

| | | **Estimated Transit Time (days)** | **Shipping Cost (SEK)** | **Tied Up Capital Cost (SEK)** | **Total Cost (SEK)** |
|---|---|---|---|---|---|
| **Lund** | AE18 | 48 | 142 989 | 251 495 | 394 484 |
| | AE19 | 47 | 111 784 | 246 257 | 358 041 |
| **Modena** | AE18 | 48 | 119 571 | 251 495 | 371 066 |
| | AE19 | 46 | 150 014 | 241 017 | 391 031 |

The estimated transit time is nearly the same for all four options and therefore tied up capital cost is also similar for all four routes. Furthermore, the two most expensive options are AE18 from Lund and AE19 from Modena. AE19 from Lund is the cheapest option.

The two different routes to Japan generate different amount of GHG emissions, these are presented in Table 4.16.

Table 4.16. Environmental impact of one container for rail shipments to Japan (Source: EcoTransIT, 2021).

| | | **GHG Emissions as $CO_2e$ (ton)** |
|---|---|---|
| **Lund** | AE18 | 2,21 |
| | AE19 | 0,82 |
| **Modena** | AE18 | 2,23 |
| | AE19 | 1,07 |

Table 4.16 shows that for Lund as a starting point, the AE19 route through St Petersburg and Vostochny generates the least amount of emissions. The environmental impact is higher for both routes from Modena compared to the same routes from Lund. Furthermore, the AE19 route has less environmental impact than the AE18 route from both sites in Europe.

## 4.7 Vietnam

According to Interviewee 5 are several customers in Vietnam seen as strategically important. Moreover, Interviewee 7 explains that there exists a lot of trade between Vietnam and countries in Europe and that there exists infrastructural possibilities to transport goods by railway to Vietnam. Examining the performance of railway to Vietnam is therefore of interest to Tetra Pak. To Vietnam it is possible to take the goods all the way by land transportation. An overview of the shipments to Vietnam during the time period for this thesis is displayed in Table 4.17.

Table 4.17. Overview of shipments from Europe to Vietnam (Source: Internal Transportation System, 2021).

| Transportation Mode | Number of Shipments (%) | Weight (%) |
|---|---|---|
| **Sea** | 66 % | 89 % |
| **Air** | 34 % | 11 % |

In similarity with both APAC and Japan, a vast majority of the shipped weight is transported by sea freight to Vietnam. The number of shipments by sea is also higher than the number of shipments by air, confirming that it is the primary shipping mode.

### 4.7.1 Sea Freight

12 sea shipment have been sent to Vietnam from Europe. Eight out of the total 12 shipments originated from Lund and four originated from Modena. The shipments were delivered to three separate ports in Vietnam, which are summarized in Table 4.18 and their locations can be viewed in Figure 4.13.

Table 4.18. Shipment value and number of shipments to the ports in Vietnam (Source: Internal Transportation System, 2021).

| Port | Shipment Value (%) | Number of Shipments |
|---|---|---|
| **Port Haiphong** | 36 % | 4 |
| **Port Ho Chi Minh City** | 40 % | 6 |
| **Port Cat Lai** | 24 % | 2 |

Figure 4.13. Map of ports in Vietnam.

It can be concluded from Table 4.18 and Figure 4.13 that the shipments are mainly concentrated around the cities Haiphong and Ho Chi Minh City, with 36 % of the shipment value and four shipments being shipped to Port Haiphong in the north and 64 % of the shipment value and eight shipments to Ho Chi Minh City in the south. These two destinations are located approximately 1 600 km apart and will therefore be analyzed separately, since transit times, costs and environmental impact will differ. Shipments to Port Haiphong will further be mentioned as shipment to the north and shipments to Port Ho Chi Minh City and Port Cat Lai will be mentioned as shipments to the south.

Table 4.19 provides an overview of the service performance of the sea shipments to Vietnam.

Table 4.19. Transit time and delay of sea shipments to Vietnam (Source: Internal Transportation System, 2021).

| | | Number of Shipments | Estimated Transit Time (days) | | Actual Transit Time (days) | | Delay (days) | | Delayed shipments (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Average | Median | Average | Median | Average | Median | |
| **Lund** | North | 3 | 45 | 45 | 53 | 53 | 8 | 9 | 100 % |
| | South | 5 | 40 | 41 | 41 | 43 | 2 | 2 | 20 % |
| **Modena** | North | 1 | 34 | 34 | 42 | 42 | 8 | 8 | 100 % |
| | South | 3 | 36 | 36 | 40 | 37 | 4 | 5 | 67 % |

As can be seen in Table 4.19 the longest average estimated transit time is from Lund to the north of Vietnam which is 45 days. The shortest average estimated transit time is from Modena to the south of Vietnam with 34 days. These are also the distances with the highest and lowest average actual transit time, with 53 and 40 days. The difference in the estimated and actual transit time for the four different routes implies that not all shipments were delivered on time. Of the 12 shipments, seven of them were delayed which is approximately 58 % of all shipments.

The average days of delay was eight days from both Lund and Modena to the northern destination while the average delay was two and four days to the south of Vietnam. Approximately 70 % of the delays was caused by congestion and other reasons for the delays are vessel departure delay and overbooking.

Table 4.20 shows the shipping costs and tied up capital cost for one container from Lund and Modena to Vietnam.

Table 4.20. Costs for one container for sea shipments to Vietnam (Source: Internal Transportation System, 2021).

| | | Shipping Cost (SEK) | | Tied up Capital Cost (SEK) | Total cost (SEK) |
|---|---|---|---|---|---|
| | | Average | Median | | |
| **Lund** | North | 101 271 | 88 561 | 191 832 | 293 103 |
| | South | 122 570 | 92 008 | 147 674 | 270 244 |
| **Modena** | North | 79 571 | 79 571 | 152 017 | 231 588 |
| | South | 99 095 | 103 843 | 144 779 | 243 874 |

The shipping cost per container is on average higher from Lund to Vietnam than from Modena, which can be the result of a longer transportation distance from Lund compared Modena. This is in line with both a longer expected and actual transit time from Lund. A longer transit time also results in a higher tied up capital cost.

Table 4.21 shows the environmental impact of one container for the different sea routes to Vietnam.

Table 4.21. Environmental impact of one container for sea shipments to Vietnam (Source: EcoTransIT, 2021).

| | | GHG Emissions as $CO_2e$ (ton) |
|---|---|---|
| **Lund** | North | 2,25 |
| | South | 2,10 |
| **Modena** | North | 1,95 |
| | South | 1,81 |

As can be seen in Table 4.21 the shipments from Modena have a lower environmental impact compared to the shipments from Lund. The shipments to southern Vietnam have less emissions than those to northern Vietnam since the sea route is shorter to that location.

### 4.7.2 Rail Freight

When transporting goods by rail to Vietnam the AE18 route would be used. The goods would be transported to the rail hub in Chengdu which is the most southern rail hub in China that 3PL B offers rail transportation to. There the goods would e unloaded from rail and placed on a truck. The truck would then carry the goods to the final Incoterm location where Tetra Pak no longer is responsible for the goods. As of today, 3PL B does not offer this route, however it might be an option in the future according to Interviewee 7 and is therefore evaluated in this thesis. Table 4.22 shows the expected performance for rail freight to Vietnam obtained from

Interviewee 7. The average delay from the rail shipments in "Rail to Asia" has been added to the transit time obtained from Interviewee 7 to account for delays.

Table 4.22. Transit time and cost for one container shipped by rail to Vietnam (Source: Interviewee 7).

| | | **Estimated Transit Time (days)** | **Shipping Cost (SEK)** | **Tied up Capital Cost (SEK)** | **Total Cost (SEK)** |
|---|---|---|---|---|---|
| **Lund** | North | 31 | 189 138 | 112 205 | 301 343 |
| | South | 33 | 216 613 | 119 442 | 336 055 |
| **Modena** | North | 31 | 202 307 | 112 205 | 314 512 |
| | South | 33 | 229 754 | 119 442 | 349 196 |

The estimated transit time for rail shipments to Vietnam is short and therefore is the tied up capital cost low as well. Further, the shipping cost is high and it is higher from Modena than from Lund.

Table 4.23 displays the environmental impact for the rail freight options to Vietnam.

Table 4.23. Environmental impact of one container for rail shipments to Vietnam (Source: EcoTransIT, 2021).

| | | **GHG Emissions as $CO_2$e (ton)** |
|---|---|---|
| **Lund** | North | 2,03 |
| | South | 3,58 |
| **Modena** | North | 2,05 |
| | South | 3,60 |

Lund has the lowest emissions of the two origin points for rail freight. The northern location has the lowest emissions of the destinations since it the shortest distance from Europe when using freight on land.

# 5. Analysis

*In the analysis chapter the empirical data gathered for the two transportation modes are compared and evaluated against each other. Firstly, the three aspects, service, economic and environmental will be evaluated individually for each country. Thereafter all three aspects will be taken into account simultaneously. Lastly, Tetra Pak's ranking of the three aspects will be taken into consideration in order to determine which transportation mode is most suitable for each destination.*

## 5.1 China

### 5.1.1 Service

Figure 5.1 displays the transit time for sea and rail freight from Lund and Modena to China, specifically Shanghai. The transit time for sea comes from the internal transportation system and the transit time for rail is the average of the shipments performed during "Rail to Asia".

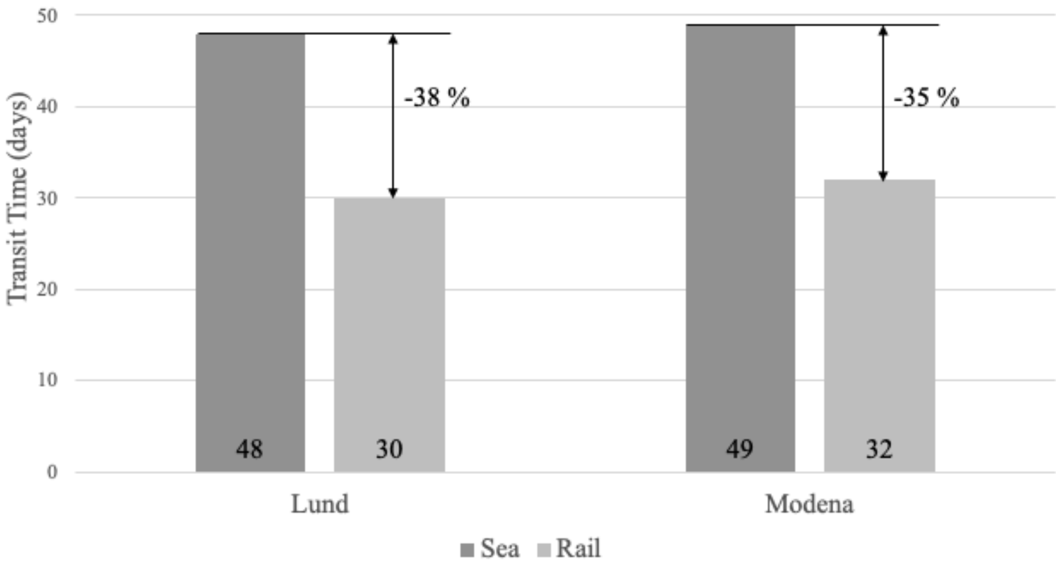


Figure 5.1. Difference in transit time between sea and rail transportation from Lund and Modena to China.

From the interviews with Interviewees 3 and 4 it was stated that several of the early rail shipments to China were delayed due to issues with documentation and internal processes at Tetra Pak. This is less of an issue today since the shipping team have become more accustomed to the new requirements and the issue can potentially even be eliminated in the future. Therefore, the transit time for rail could be even less than what is presented in Figure 5.1.

### 5.1.2 Economic

Figure 5.2 shows the difference in costs for sea and rail transportation from Lund and Modena to Shanghai in China.

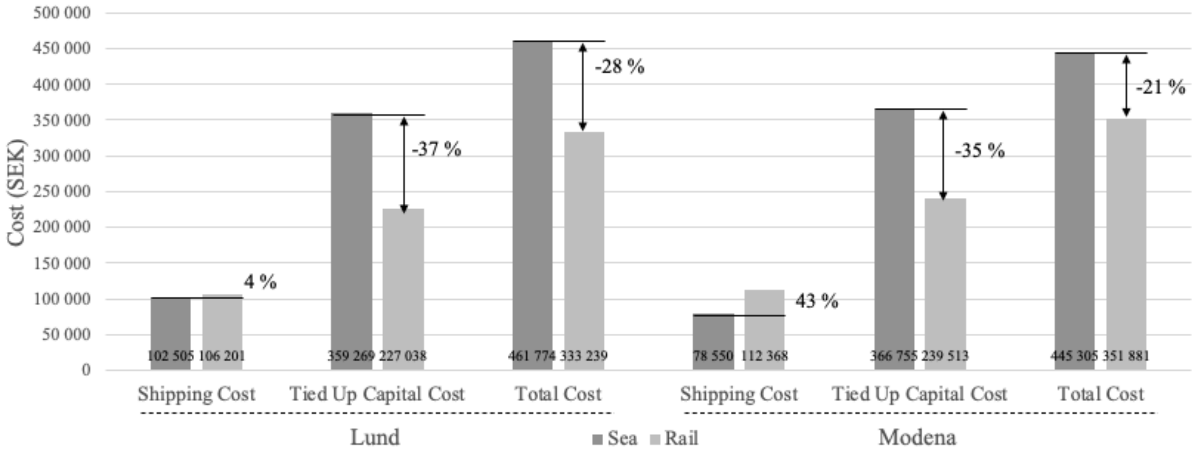


Figure 5.2. Difference in costs between sea and rail transportation from Lund and Modena to China.

For both the origins the shipping cost is higher and the tied up capital cost is lower for rail than for sea. This results in a lower total cost for rail transportation compared to sea freight. The tied up capital cost is direct related to the transit time, and due to a small sample size of rail shipments a sensitivity analysis is performed to examine how long the transit time would need to be, to reach a more expensive total cost for rail than for sea. The result of the sensitivity analysis is shown in Table 5.1.

Table 5.1. Sensitivity analysis of the transit time related to the total cost.

| | **Transit Time (days)** | **Break Even Transit Time (days)** | **Difference (days)** |
|---|---|---|---|
| **Lund** | 30 | 45 | 15 |
| **Modena** | 32 | 46 | 14 |

Table 5.1 shows that rail freight from Lund can be 15 days delayed and still be less expensive than sea. Moreover, the rail transportation from Modena can be up to 14 days delayed. This implies that even though shipments by rail are several days delayed, the total cost will still be cheaper than sea freight. However, if a shipment is subject to a delay it also implies other costs which are not accounted for in this thesis. Examples of this could be warehousing costs if the goods were to be stuck at a border crossing station due to paperwork that does not meet the requirements or in a port due to lack of space on the vessels or a missed departure. Furthermore, there exists costs connected to the customer’s production. If the customer does not get the machine on time their production is stopped resulting in loss of income and Tetra Pak is subject to fees as a consequence of the delay.

### 5.1.3 Environmental

Figure 5.3 shows the difference of GHG emissions between sea and rail freight from Lund and Modena to Shanghai in China.

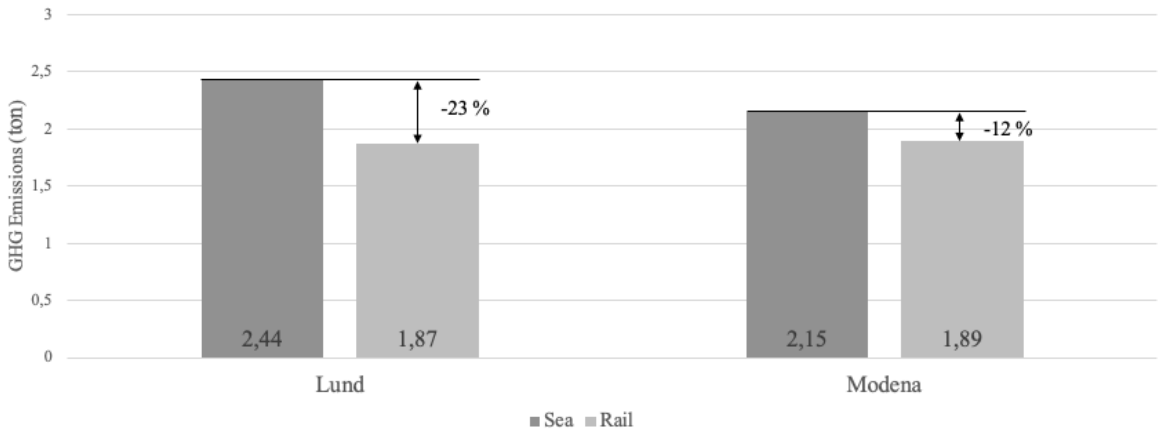


Figure 5.3. Difference in GHG emissions between sea and rail transportation from Lund and Modena to China.

The GHG emissions for rail freight are lower compared to the emissions from sea freight for both the origins. EcoTransIT, the tool used to calculate the emissions, takes whether the railway is electrified or powered by diesel into account when calculating the emissions for a certain distance. However, it does not consider what source the electricity comes from which can affect the results of emissions for rail freight.

### 5.1.4 Total Evaluation

Figure 5.4 and Figure 5.5 illustrates the performance of the two transportation modes compared to each other from Lund and Modena for the three aspects, service, economic and environmental. The transportation mode with the best result for the specific aspect gets a value of one. The other transportation mode gets a value of the best performance divided by its own performance, thereof showing the relative performance compared to the best transportation mode.

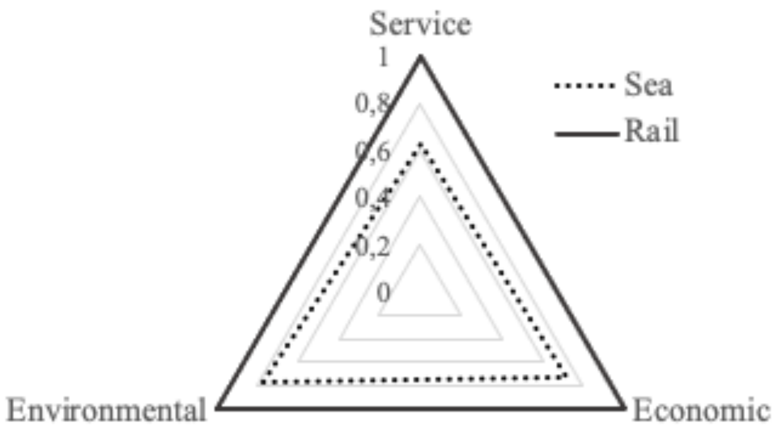


Figure 5.4. Performance of sea and rail freight from Lund to China.

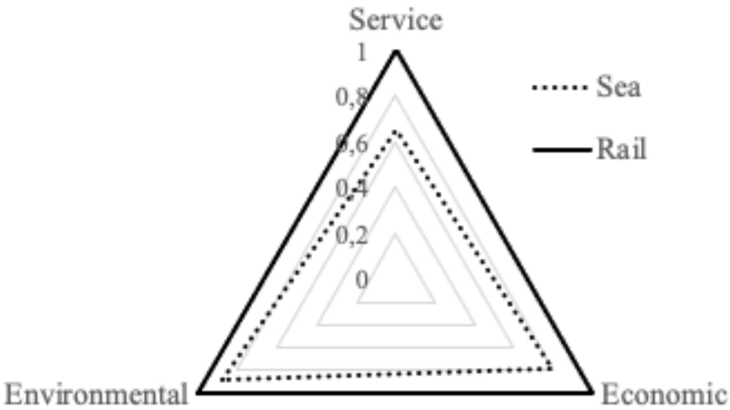

Figure 5.5. Performance of sea and rail freight from Modena to China.

Figure 5.4 and 5.5 show that the rail option is the best performing alternative in all three aspects from both Lund and Modena.

Tetra Pak does not view the three aspects, service, economic and environmental, as equally important. This needs to be taken into consideration when comparing the transportation modes against each other. According to Interviewee 5 Tetra Pak values service highest, closely followed by economic and lastly environmental. The three aspects are therefore given a weight to illustrate their relative importance against each other, which can be found in Table 5.2 and Table 5.3. To attain the total score for the mode, the weight for the aspects is multiplied by the relative performance of the transportation mode in relation to the other mode, which was presented in Figure 5.4 and Figure 5.5. Table 5.2 and Table 5.3 display the score of the transportation modes where 1,00 is the best result.

Table 5.2. The weighted performance of sea and rail freight from Lund to China.

| | | **Sea** | | **Rail** | |
|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score |
| **Service** | 45% | 0,63 | 0,28 | 1,00 | 0,45 |
| **Economic** | 40% | 0,72 | 0,29 | 1,00 | 0,40 |
| **Environmental** | 15% | 0,77 | 0,11 | 1,00 | 0,15 |
| **Total** | 100% | | 0,68 | | **1,00** |

Table 5.3. The weighted performance of sea and rail freight from Modena to China.

| | | **Sea** | | **Rail** | |
|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score |
| **Service** | 45% | 0,65 | 0,29 | 1,00 | 0,45 |
| **Economic** | 40% | 0,79 | 0,32 | 1,00 | 0,40 |
| **Environmental** | 15% | 0,88 | 0,13 | 1,00 | 0,15 |
| **Total** | 100% | | 0,74 | | **1,00** |

The total result from both Lund and Modena is almost equal with a difference of 0,06 in the performance of sea freight. Rail is the best performing alternative in all three categories, since it has the total score of one.

## 5.2 Japan

### 5.2.1 Service

In Figure 5.6 the transit times from Lund and Modena to Japan for sea and rail freight are shown as well as the difference between sea and the two rail alternatives. The transit time for sea freight is the actual transit time that has been presented previously and has been obtained from the internal transportation system at Tetra Pak. The transit time for rail freight is the estimated transit time from the 3PLs added with the average delay of the rail shipments sent during the project "Rail to Asia", which is three days.

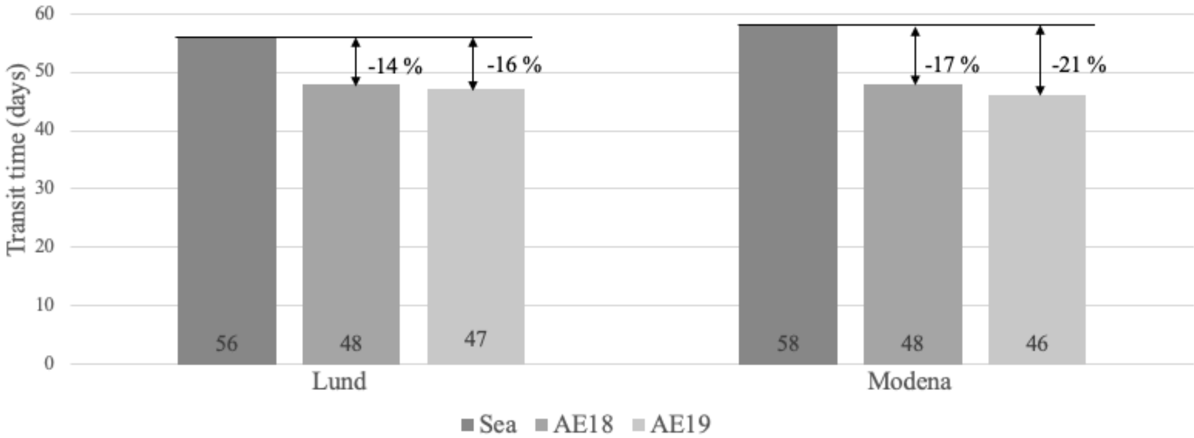


Figure 5.6. Difference in transit time between sea and rail transportation from Lund and Modena to Japan.

The rail routes have shorter transit times than sea freight, with AE19 being the fastest option. The difference for transit time between rail and sea is not as big as it is for China. This is due to the fact that there are more mode changes on the rail routes to Japan as well as the sparse schedule of the boats for the final part of the route. However, the transit time for rail is uncertain since no actual shipments have been sent and the delay added to the estimated transit time is uncertain as discussed in section 5.1.1.

### 5.2.2 Economic

Figure 5.7 and Figure 5.8 display the costs connected to the two transportation modes from Lund and Modena to Japan as well as the differences.

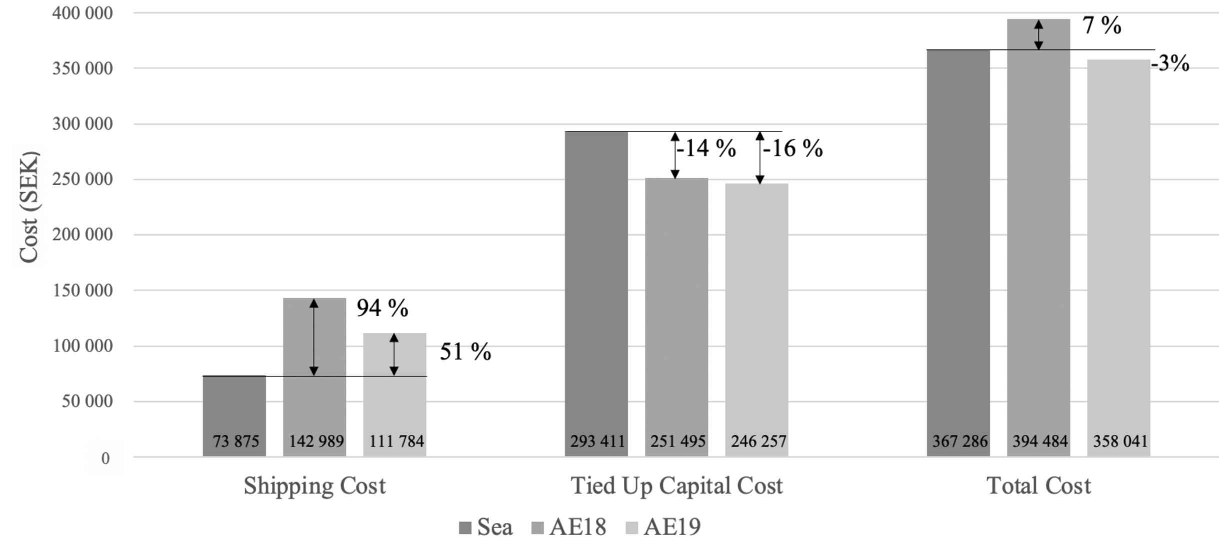


Figure 5.7. Difference in costs between sea and rail transportation from Lund to Japan.

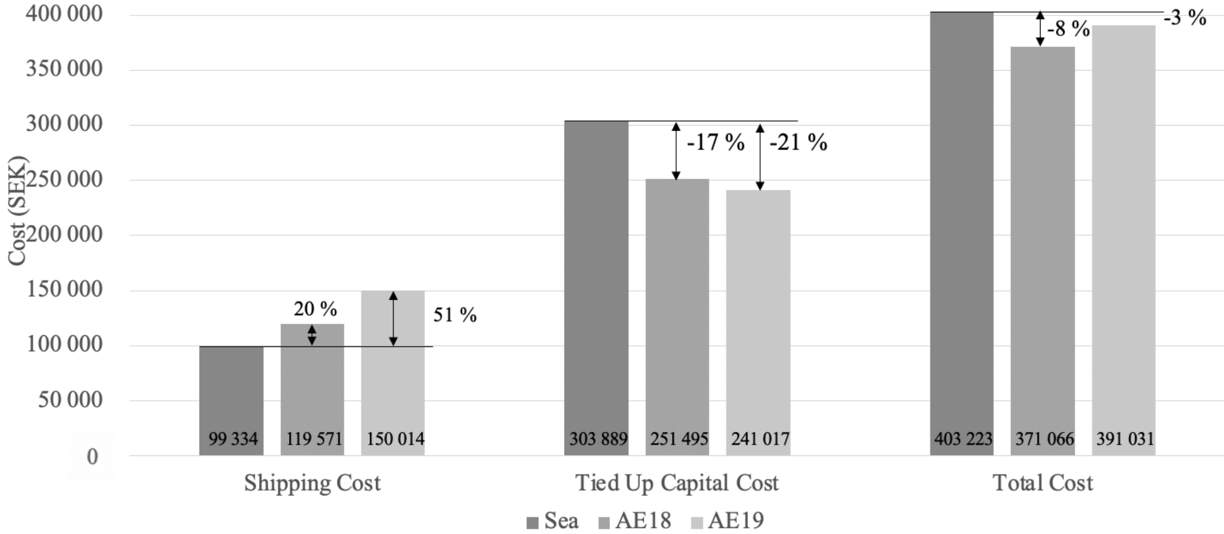


Figure 5.8. Difference in costs between sea and rail transportation from Modena to Japan

The figures show that the two rail freight routes have higher shipping costs but lower total costs due to a lower tied up capital cost compared to the sea freight. However, the tied up capital cost is in direct relation to the transit time and therefore the cost for the rail routes might not be exact since the transit time is uncertain. A sensitivity analysis was performed in order to determine the break even transit time where the total cost for rail freight is equal to the total cost for sea freight. The result of the sensitivity analysis is found in Table 5.4.

Table 5.4. Sensitivity analysis of the transit time related to the total cost.

| | | Transit Time (days) | Break Even Transit Time (days) | Difference (days) |
|---|---|---|---|---|
| **Lund** | AE18 | 48 | 42 | - 6 |
| | AE19 | 47 | 48 | 1 |
| **Modena** | AE18 | 48 | 54 | 6 |
| | AE19 | 46 | 48 | 2 |

The AE18 route from Lund to Japan is the only option that has a higher total cost for rail than for sea. To reach a lower cost than sea the transit time must decrease with six days. Furthermore, the AE19 route from Lund as well as the AE18 and AE19 route from Modena have lower total costs than the sea route. For these routes it is acceptable with one, six and two days delay to still be cheaper than sea.

The shipping cost for the AE18 rail route is uncertain since it is not a route that 3PL B offers as of today and the cost is therefore an estimate by the authors of this thesis. The estimate is based on completed rail transportations to Shanghai from Lund and Modena with an added cost for the sea shipment from Shanghai to Japan, which is calculated by an international freight company, Freightos (Freightos, 2021). This estimation contributes to uncertainties since it is not the cost for using 3PL B's vessels between Shanghai and Japan which is the solution that 3PL B would offer in the future as well as it is not the price for the total solution that will be offered by one 3PL handling the whole shipment from start to finish.

As mentioned in section 5.1.2 there are also other costs that can affect the total cost such as warehousing costs and fees for delays.

### 5.2.3 Environmental

Figure 5.9 shows the difference of GHG emissions between sea and rail freight for Lund and Modena to Japan.

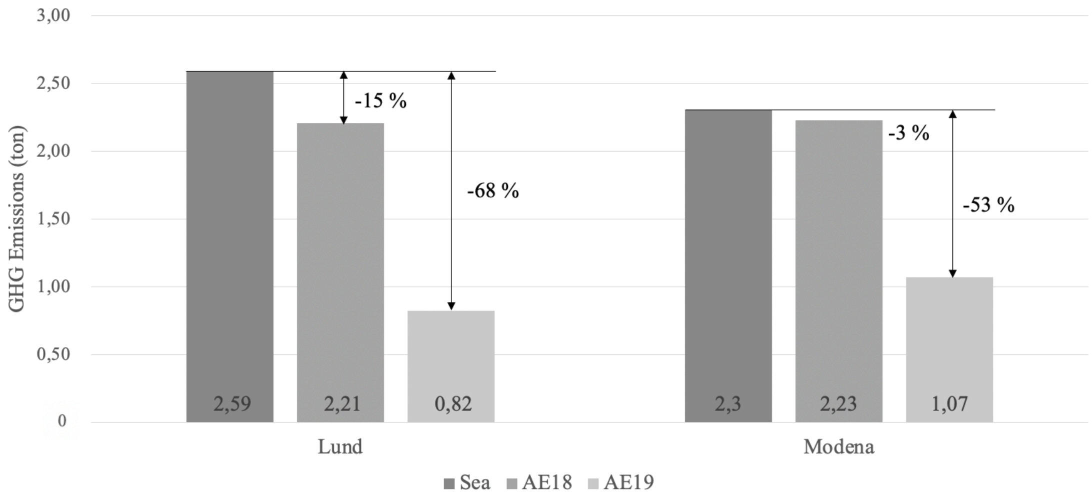


Figure 5.9. Difference in GHG emissions between sea and rail transportation from Lund and Modena to Japan.

The two rail routes have lower GHG emissions compared to the sea route, particularly AE19. This is due to the fact that the AE19 route has less truck transportation compared to AE18, which is a transportation mode with a high environmental impact. Moreover, the calculation tool, EcoTransIT, does not consider what source the electricity for the rail transportation comes from, as mention in section 5.1.3. Since the AE19 route goes through Russia where main sources of energy are coal and gas (EIA, 2017), the emissions could be higher than what has been calculated.

### 5.2.4 Total Evaluation

In Figure 5.10 and Figure 5.11, the performance of sea freight and the two rail freight routes are visualized for the three aspects.

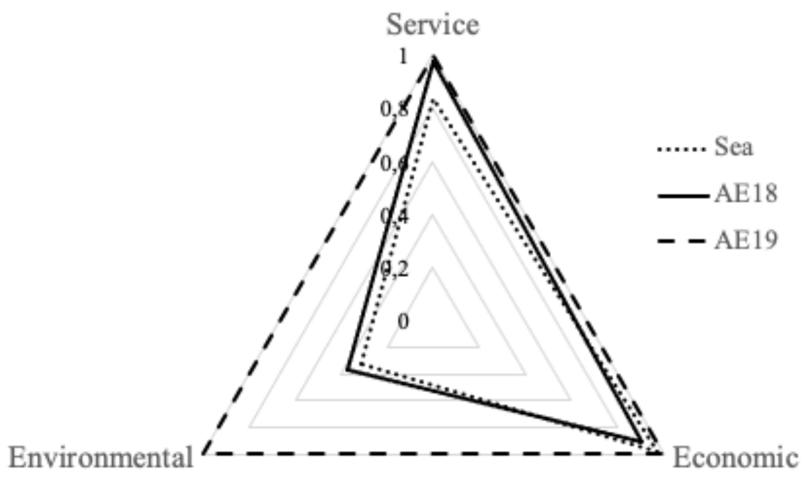


Figure 5.10. Performance of sea and rail freight from Lund to Japan.

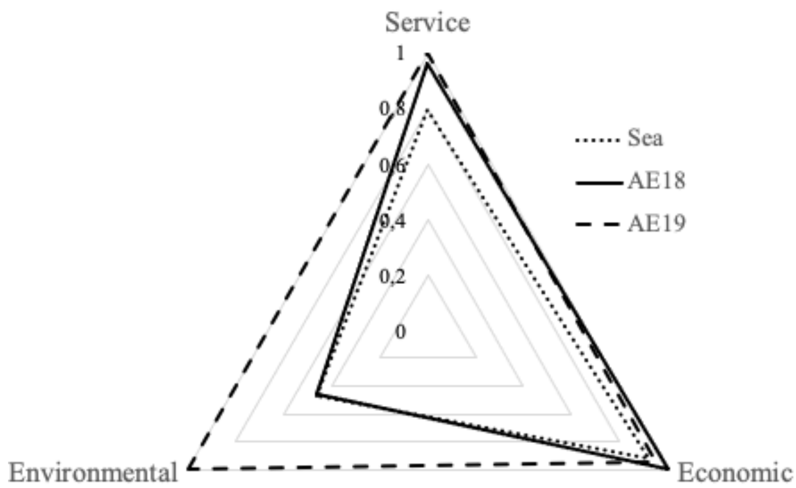


Figure 5.11. Performance of sea and rail freight from Modena to Japan.

The three different transportation options perform quite similar for the service and economic aspects from both Lund and Modena. However, sea is the transportation alternative that has the lowest performance in the service aspect. The largest difference is seen in the environmental aspect where AE19 performs better than both sea and the AE18 route, which have rather similar values. From Lund the AE19 route is the best alternative in all three aspects whereas from Modena the AE18 route has the best economic performance and AE19 is the best option in the other two aspects.

As mentioned in section 5.1.4 Tetra Pak's ranking between the three aspects needs to be considered in order to find the optimal route. The result of this for Lund is displayed Table 5.5 and in Table 5.6 for Modena.

Table 5.5. The weighted performance of sea and rail freight from Lund to Japan.

| | | **Sea** | | **AE18** | | **AE19** | |
|---|---|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score | Performance | Score |
| **Service** | 45 % | 0,84 | 0,38 | 0,98 | 0,44 | 1,00 | 0,45 |
| **Economic** | 40 % | 0,97 | 0,39 | 0,91 | 0,36 | 1,00 | 0,4 |
| **Environmental** | 15 % | 0,32 | 0,05 | 0,37 | 0,06 | 1,00 | 0,15 |
| **Total** | 100 % | | 0,82 | | 0,86 | | **1,00** |

Table 5.6. The weighted performance of sea and rail freight from Modena to Japan.

| | | **Sea** | | **AE18** | | **AE19** | |
|---|---|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score | Performance | Score |
| **Service** | 45 % | 0,79 | 0,36 | 0,96 | 0,43 | 1,00 | 0,45 |
| **Economic** | 40 % | 0,92 | 0,37 | 1,00 | 0,40 | 0,95 | 0,38 |
| **Environmental** | 15 % | 0,47 | 0,07 | 0,46 | 0,07 | 1,00 | 0,15 |
| **Total** | 100 % | | 0,80 | | 0,90 | | **0,98** |

When Tetra Pak's prioritization is considered, rail is the best alternative from both Lund and Modena, where the AE19 route performs better than the AE18 route. Further, the result differs slightly between Lund and Modena, where the AE18 route performs better from Modena than Lund and the opposite result for sea. The reasons for this seems to be lower costs for AE18 from Modena and for sea a combination of better performance in service and economic aspects from Lund compared to Modena.

## 5.3 Vietnam

### 5.3.1 Service

Figure 5.12 shows the transit times from Lund and Modena to northern and southern Vietnam and the difference between the transportation modes. Similar to the transit times presented in section 5.2.1, the transit time for sea is from the internal transportation system and the transit time for rail is the estimated transit time from the 3PLs added with the average delay of the "Rail to Asia" shipments.

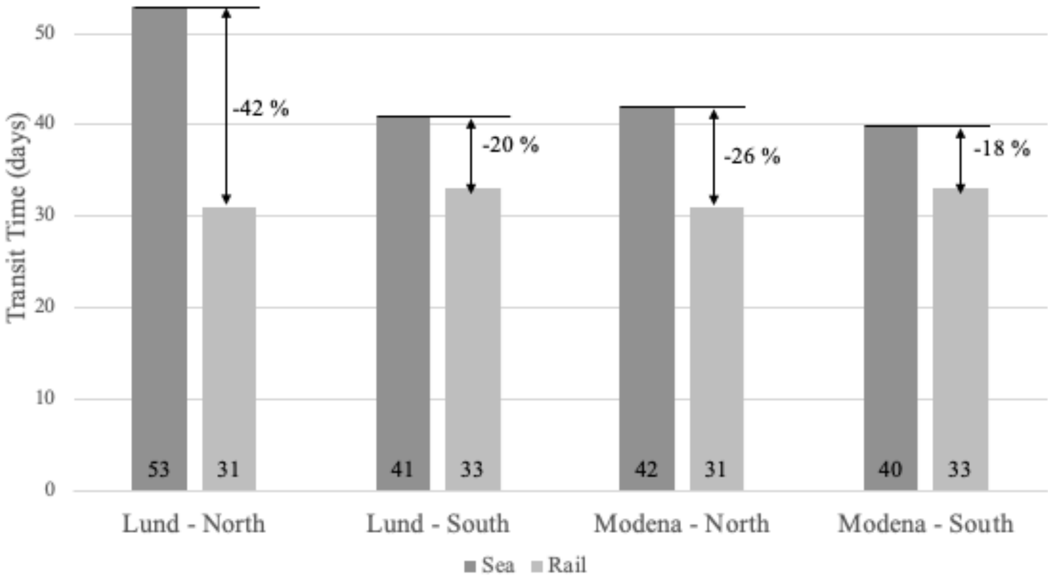


Figure 5.12. Difference in transit time between sea and rail transportation from Lund and Modena to northern and southern Vietnam.

The transit time for rail is shorter for all origins and destinations compared to sea freight. Rail transportation from Lund to northern Vietnam is especially preferential due to the high transit time for sea freight on this route. However, as discussed in section 5.2.1 the transit time for rail freight is uncertain.

### 5.3.2 Economic

Figure 5.13 and Figure 5.14 visualize the costs for sea and rail freight from Lund and Modena to Vietnam as well as the differences between the two transportation modes.

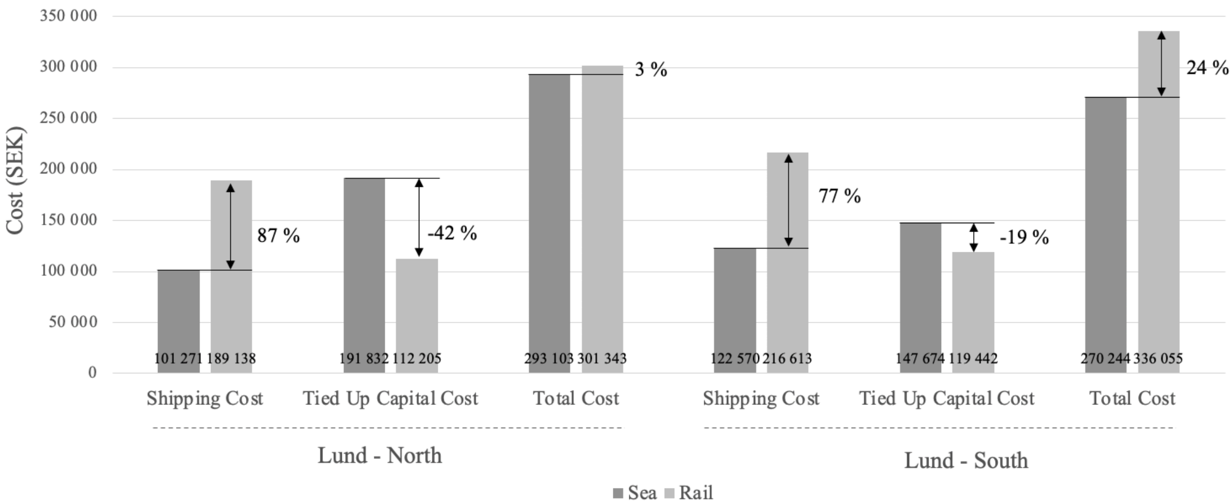


Figure 5.13 Difference in costs between sea and rail transportation from Lund to northern and southern Vietnam.

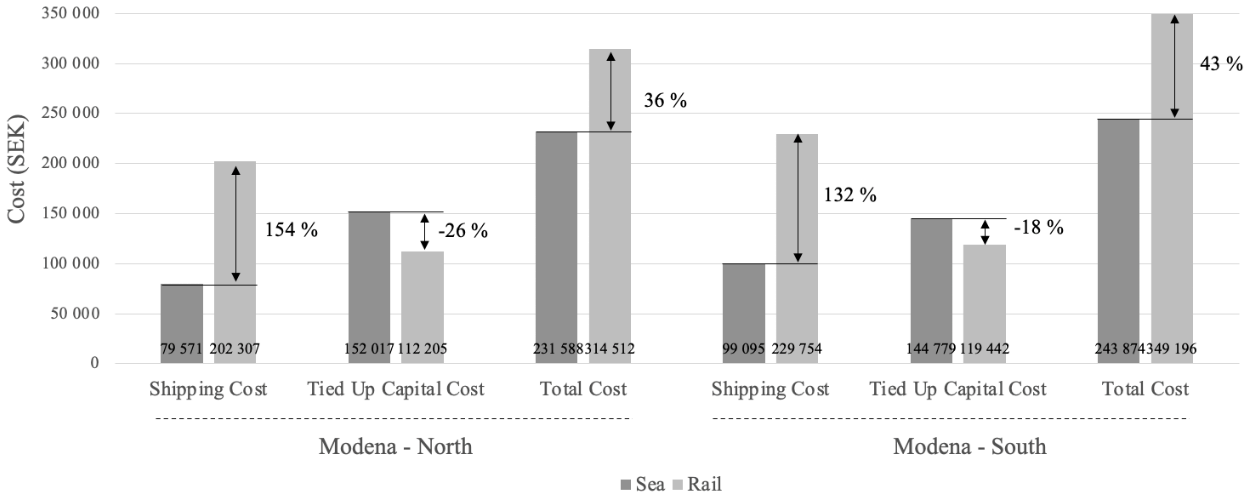


Figure 5.14 Difference in costs between sea and rail transportation from Modena to northern and southern Vietnam.

It can be noted in the results that rail freight is more expensive than sea freight for all of the origins and destinations. Unlike for Japan and China, where the tied up capital cost was the largest cost, the tied up capital cost is lower than the shipping cost for all rail routes to Vietnam. This is mainly due to short transit times leading to low tied up capital cost as well as a high shipping cost. The reason for the expensive shipping costs is that the last distance of the route is a long truck transport from China to Vietnam, which is the second most expensive transportation mode after air freight. As the shipping cost is the largest segment of the total cost Table 5.7 displays how much it would need to go down in order for rail to become an equivalent option to sea freight based on costs.

Table 5.7. Sensitivity analysis of the shipping cost.

| | | **Shipping Cost (SEK)** | **Break Even Shipping Cost (SEK)** | **Difference (%)** |
|---|---|---|---|---|
| **Lund** | North | 189 138 | 180 899 | - 4 % |
| | South | 216 613 | 150 802 | - 30 % |
| **Modena** | North | 202 307 | 119 383 | - 41 % |
| | South | 229 754 | 124 432 | - 46 % |

For all routes expect Lund – North the shipping cost would need to be significantly lower in order to make rail transportation the same price as sea transportation. This indicates that rail freight to Vietnam might not be a viable option in terms of the economic aspect, except Lund to northern Vietnam.

As mentioned in section 5.1.2 there are also other costs that can affect the total cost result such as warehousing costs and fees.

### 5.3.3 Environmental

Figure 5.15 displays the GHG emissions emitted from the transportation options to Vietnam and the difference in percent between them.

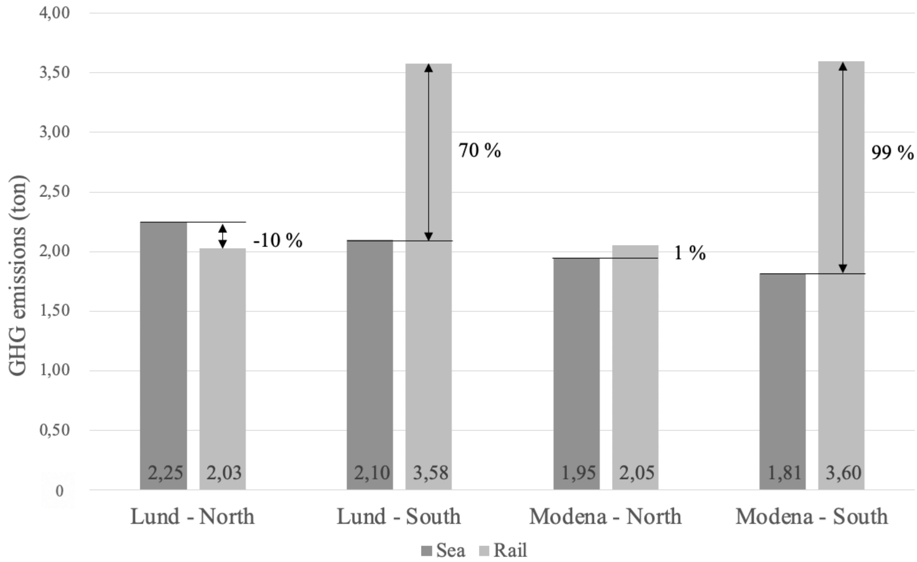


Figure 5.15. Difference in GHG emissions between sea and rail transportation from Lund and Modena to northern and southern Vietnam.

Rail freight has a much higher environmental impact for the routes to the southern destination when comparing it to sea freight. This is due to the fact that the rail routes include a long truck transport from Chengdu in China to Vietnam which is a transportation mode with high environmental impact compared to both rail and sea freight. The northern destination has a lower environmental impact since the truck transport is shorter for this route.

### 5.3.4 Total Evaluation

Figure 5.16 – 5.19 illustrates the performance of the two transportation modes from Lund and Modena to northern and southern Vietnam for the three aspects, service, economic and environmental.

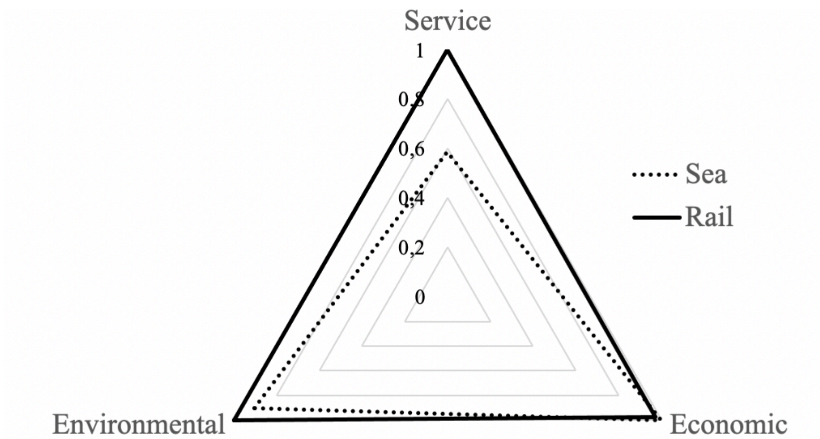


Figure 5.16. Performance of sea and rail freight from Lund to northern Vietnam.

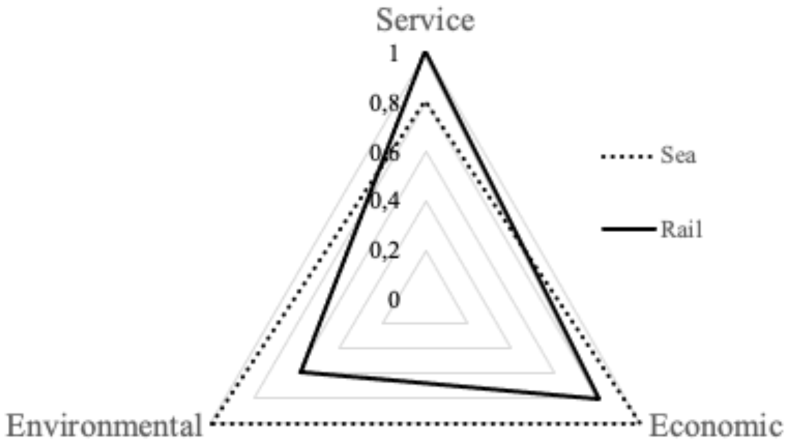

Figure 5.17. Performance of sea and rail freight from Modena to southern Vietnam.

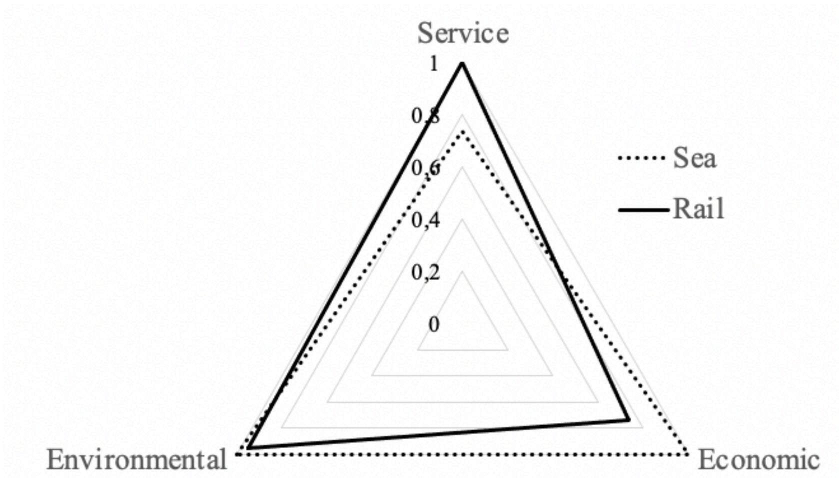

Figure 5.18. Performance of sea and rail freight from Modena to northern Vietnam.

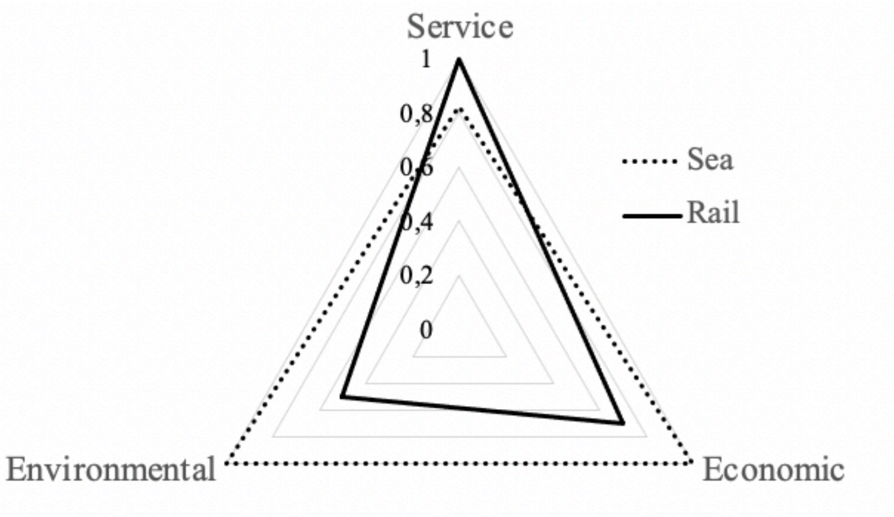

Figure 5.19. Performance of sea and rail freight from Modena to southern Vietnam.

As the figures illustrate rail performs better than sea for the service aspect while sea is the better transportation mode for the economic aspect. Sea also generates less emissions than rail when evaluating the southern destination. However, for the northern destination the environmental impact is similar for the two transportation modes.

As mentioned in section 5.1.4 Tetra Pak's ranking between the three aspects needs to be considered to find the optimal transportation mode. The result of this is displayed in Table 5.8 and Table 5.9 for Lund as well as for Modena in Table 5.10 and 5.11.

Table 5.8. The weighted performance of sea and rail freight from Lund to northern Vietnam.

| | | Sea | | Rail | |
|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score |
| **Service** | 45 % | 0,58 | 0,26 | 1,00 | 0,45 |
| **Economic** | 40 % | 1,00 | 0,40 | 0,97 | 0,39 |
| **Environmental** | 15 % | 0,90 | 0,14 | 1,00 | 0,15 |
| **Total** | 100 % | | 0,80 | | **0,99** |

Table 5.9. The weighted performance of sea and rail freight from Lund to southern Vietnam.

| | | Sea | | Rail | |
|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score |
| **Service** | 45 % | 0,80 | 0,36 | 1,00 | 0,45 |
| **Economic** | 40 % | 1,00 | 0,40 | 0,80 | 0,32 |
| **Environmental** | 15 % | 1,00 | 0,15 | 0,59 | 0,09 |
| **Total** | 100 % | | **0,91** | | 0,86 |

Table 5.10. The weighted performance of sea and rail freight from Modena to northern Vietnam.

| | | Sea | | Rail | |
|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score |
| **Service** | 45 % | 0,74 | 0,33 | 1 | 0,45 |
| **Economic** | 40 % | 1,00 | 0,40 | 0,74 | 0,29 |
| **Environmental** | 15 % | 1,00 | 0,15 | 0,95 | 0,14 |
| **Total** | 100 % | | **0,88** | | **0,88** |

Table 5.11. The weighted performance of sea and rail freight from Modena to southern Vietnam.

| | | Sea | | Rail | |
|---|---|---|---|---|---|
| | Weight | Performance | Score | Performance | Score |
| **Service** | 45 % | 0,83 | 0,37 | 1 | 0,45 |
| **Economic** | 40 % | 1,00 | 0,40 | 0,70 | 0,28 |
| **Environmental** | 15 % | 1,00 | 0,15 | 0,50 | 0,08 |
| **Total** | 100 % | | **0,92** | | 0,80 |

When taking Tetra Pak's prioritization in account, the results shows that sea is the best alternative to southern Vietnam. Rail is the best option from Lund to northern Vietnam whereas the two transportation modes perform equally from Modena to northern Vietnam. It is mainly the economic aspect that makes sea a better option than rail.

## 5.4 Summary

In this section the most important conclusions found for each country will be summarized.

For China it was found that rail freight was the best option for all three aspects evaluated, from both origins. This means that even if the weight of the three aspects would change the result would remain the same. Further, it can be concluded that if the destination in China would be located further inland compared to Shanghai, rail would perform even better compared to sea. This can be seen in section 4.5.4, where the result of rail shipments from Europe to Xi'an are shown and indicate a better performance of rail transportation to Xi'an compared to Shanghai. This since the rail route becomes shorter and thus cheaper with shorter transit time, while the sea route becomes longer and thus more expensive with longer transit time. The environmental impact would also improve for the rail transportation and become worse for the sea transportation.

AE19 is the best option from both Lund and Modena for transportation to Japan. For Lund it is the best performing route for all aspects and therefore the weight of the aspects does not affect the score. For Modena AE18 performs the best in the economic aspect, however AE19 performs much better in the other two aspects that even if the economic aspect would be weighted the highest AE19 would still have the best result. Further, it can be seen in the results that transit times and costs for the two rail routes are closer to the transit time and cost for sea compared to the results of China. This is due to a longer route with more transportation mode changes compare to the route to China. Lastly, the AE19 route has the lowest environmental impact of all the routes evaluated in this thesis.

For Vietnam, rail is only the best performing transportation mode for the route from Lund to northern Vietnam. In the other cases sea is performing either at the same level or better than rail. This is due to high costs and emissions related to rail transportation to Vietnam. However, rail transportation offers shorter transit time so if the service aspect is weighted higher, rail is a better option to northern Vietnam from Modena as well. However, if the economic aspect is weighted higher than service, rail is less preferrable. A high weight on the environmental aspect also results in a lower score for rail due to the high GHG emissions it implies.

# 6. Discussion

*The discussion begins with presenting the reader with the risks associated with the different transportation options. The risks are thereafter assessed and categorized as high, medium or low based on their likelihood and impact. A discussion about the risks and potential mitigation strategies follows. Finally, the chapter ends with a discussion about possible future developments as well as the effects of the covid-19 pandemic.*

## 6.1 Risks

From the interviews conducted in this thesis several risks for the different transportation options have been identified. The risks are presented in Table 6.1 and their impact and likelihood are evaluated in Figure 6.1.

Table 6.1. List of risks associated with the different transportation options.

| | **Risks** |
|---|---|
| **Sea** | |
| S.1 | Shortage of containers reducing the availability for sea freight |
| S.2 | Containers stuck on the route due to for instance stop in the Suez Canal |
| S.3 | Congestion in ports resulting in that goods cannot be unloaded |
| **Rail** | |
| R.1 | New partnership with 3PL B leading to miscommunication |
| R.2 | Higher documentation requirements resulting in delays |
| **AE18** | |
| AE18.1 | AE18 route not being offered by 3PL B within the next few years |
| AE18.2 | Complex export process from China to further countries leading to delays |
| AE18.3 | Missing a departure of the vessels between China and Japan. The sparse schedule of these can lead to delays |
| **AE19** | |
| AE19.1 | Russian government prioritizes coal transports to their coal plants on the route during the winter and regular goods traffic is down prioritized |

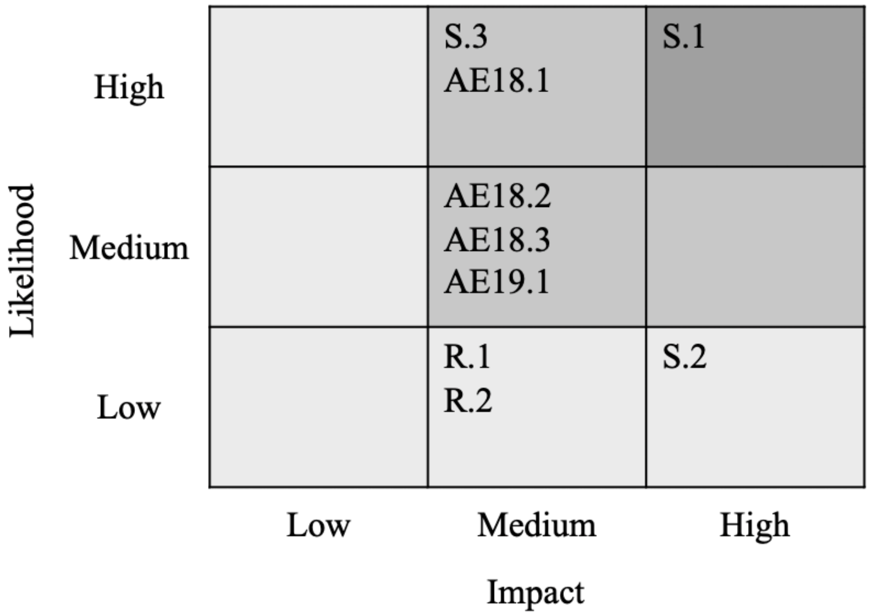


Figure 6.1. Risk matrix for the different risks in Table 6.1.

The highest risk is for sea, shortage of containers reducing the availability has been a significant problem during the covid-19 pandemic and has caused many delays as well as issues regarding realizing shipments due to lack of space on vessels. This risk is outside Tetra Pak's control and therefore hard to mitigate, however a mitigation could be to use more transportation modes from Europe to Asia, such as rail, to be more flexible if sea freight is not functioning properly due to container shortage.

Further, S.3, AE18.1, AE18.2, AE18.3 and AE19.1 are classified as medium risks. S.3, congestion in ports, is a risk with a high likelihood especially due to the covid-19 pandemic where ports have been closed due to disease outbreaks among workers. However, according to Interviewee 5 congestion in ports have commonly occurred before the covid-19 pandemic as well, for instance due to port strikes. The impact of this risk can vary significantly. Tracking and tracing the goods can make this risk easier to handle. The risk that 3PL B will not offer the AE18 route to Japan or Vietnam within the next few years is highly probable since they do not offer test shipments on this route today and it generally takes long time to implement such a complex transportation route. Not being able to use the AE18 route for transportation further in Asia from China will affect the possibilities for Tetra Pak to use rail transportation.

The complex export process from China to further countries and the risk of missing the vessel departure between China and Japan are two risks for the AE18 route which both can lead to large delays. To mitigate the risk with the export process, Tetra Pak needs to be prepared with the right documents and for the vessel departures the planning process together with 3PL B is important in order to make the transportation mode switch as efficient as possible. It could also be an option to use other vessels than the ones that 3PL B owns, to have access to more departures between China and Japan. Further, the risk for the AE19 route is delays due to the Russian government's coal transportations. This is a medium risk due to the fact that this type of delay only occurs during the winter and length of the delay can vary. To mitigate this risk Tetra Pak can send less goods through the AE19 route during the winter as well as be prepared for some days delay.

R.1, R.2 and S.2 are considered as low risks due to their low likelihood. The probability of miscommunication with 3PL B leading to a delay or another substantial issue is seen as low as well as the likelihood of this happening becomes less the longer Tetra Pak works with 3PL B. This risk can be further mitigated through clear and frequent communication between the two parties. The high documentation requirements leading to a delay is seen as a risk with low likelihood since Tetra Pak have become more accustomed to the documentation requirements as they have performed more rail shipments leading to less errors. Further, the containers getting stuck at sea due to for example a ship getting stuck in the Suez Canal is also low since this is a rare occurrence. However, this is a risk that Tetra Pak themselves cannot mitigate and if it were to happen the impact would be high.

AE18 is the transportation option that has the highest number of risks with five in total, followed by both sea and AE19 with three risks each, where one of the risks is specific for AE19 and two are general for rail. It can also be seen that AE18 has high and medium risks, sea has risks at all levels while AE19 only has low and medium risks. Based on this it is concluded that AE18 is the route that is associated with the most risk while AE19 is subject to the least risk.

## 6.2 Future Development

China continues to invest in BRI and expanding the railway network in Asia (Alon et al., 2018; Nedopil, 2021). With this expansion and extended railways new opportunities to transport goods in a more efficient manner to current destinations as well as further destinations will emerge. If for example the railway network is further developed in Vietnam, the distance of the truck transportation from China to Vietnam would be shortened. The transport would therefore become both cheaper and the environmental impact would be reduced, which would make the rail option to Vietnam more attractive. The investments in BRI and the railway network in Asia does not only concern building new tracks but also improving the existing tracks. According to Interviewee 7 this involves for example expanding the electrified parts of the tracks thus reducing the parts where the train is powered by diesel and improving the environmental impact of the rail routes.

The main reason for the long transit time and delays for the AE18 route to Japan is the infrequent time schedule of 3PL B's vessels between China and Japan. If the departures of these vessels would be increased or if it was possible to use other shipping companies' vessels the transit time as well as the reliability of this route would be increased, making it a more viable option. Another possible source for delays is the customs procedures in China when transporting the goods further to another country after entering China. If this procedure would be eased to facilitate and encourage trade between Europe and Asia the transit time and reliability for the AE18 route would be improved.

As many companies have experienced issues with sea freight during the covid-19 pandemic and the opportunities to transport goods to Asia by train has improved, many companies have become interested in using rail freight between Europe and Asia. Currently, there are no issues regarding availability for rail freight but with more companies looking into the opportunity of rail from Europe to Asia this might become an issue in the future thus making transit times longer.

## 6.3 Effects of Covid-19

The covid-19 pandemic is in section 4.3.2 mentioned as one of the main challenges with today's sea freight due to it leading to for instance congestion in ports and long delays. The majority of the sea shipments that have been used to calculate the average transit time and delays for sea frieght in this thesis have been carried out during the pandemic which has resulted in longer transit times than usual. However, Interviewee 5 has explained that even before the pandemic sea freight resulted in many delayed shipments, implying that the transportation mode has low reliability even during normal circumstances. It is hard to estimate the delay without the effect of the pandemic since the data used in this thesis is mainly from the pandemic, however it is presumably lower than the results presented in this thesis.

According to Interviewee 8 it has in some cases been nearly impossible to book a sea transport from Europe to Asia due to container shortage caused by the pandemic. Therefore, even if the cost and the transit time is not the most advantageous for some of the rail routes it can be a good alternative in order to actually transport a machine from Europe to Asia when it is not possible through sea freight. Further, using rail as a third transportation mode, besides sea and air, between Europe and Asia might make Tetra Pak more flexible and mitigate risks if problems occur with the other transportation modes.

The result of this thesis shows that rail generally has shorter transit time than sea and during the covid-19 pandemic has the service aspect increased in importance for Tetra Pak. This since the effects of covid-19 has increased the interest for Tetra Pak to be able to deliver the goods and the cost is playing a less important role. The results of this points to rail being more preferential since it has shorter transit time and higher reliability. During other conditions could this prioritization change and therefore could also the most preferable transportation mode change. It can therefore be a good idea to have the possibility to use different transportation modes and choose the most preferential one based on the currently most important aspect.

# 7. Conclusions & Recommendations

*The last chapter of the thesis begins with answering the research questions it set out to answer to fulfil the purpose of the thesis. Thereafter, recommendations to Tetra Pak are presented for each of the three countries evaluated. Finally, the contribution to research for this thesis and areas for future research are suggested.*

## 7.1 Research Questions Answered

**RQ1.** *How does sea freight from Europe to Asia perform?*

To answer research question one, quantitative data from the internal transportation system at Tetra Pak have been used as well as qualitative data gathered from interviews and a literature review. The reason for this was to get a holistic view of the performance of sea freight with both measurable data as well as deeper insight coming from the interviews. The empirical data gathered during this thesis shows that the transit time for the current sea freight is long and often affected by delays. The long transit time leads to a high tied up capital cost which results in a high total cost even though the shipping cost is low compared to other transportation modes. Regarding the environmental impact sea freight generates a low amount of GHG emissions compared to other transportation modes. The sea shipments consists of only sea freight besides the truck transportation from the production site to the first port. The overall sea freight route therefore has a rather low environmental impact.

Tetra Pak has worked with 3PL A for several years and therefore have established a well-functioning partnership with them. This facilitates the shipping processes and reduces errors that might appear due to miscommunication. Furthermore, sea freight is a well established transportation mode with a long history and broad infrastructure. However, the covid-19 pandemic has greatly affected the sea freight industry leading to longer transit times and delays as well as issues concerning availability on vessels.

**RQ2.** *How does rail freight from Europe to Asia perform?*

In order to investigate the performance of rail freight for packaging machines to Asia, three different countries have been investigated: China, Japan and Vietnam. For rail freight to China, data from the six pilot shipments conducted during a project at Tetra Pak together with five rail shipments after the project have been used. Whereas for Japan and Vietnam information about rail shipments has been obtained from logistics companies and calculation programs. Furthermore, opportunities and challenges with rail freight have been investigated through a literature review as well as interviews. The analysis of the data gathered through this thesis showed short transit time for rail freight to all three countries. The transit time is directly related to the tied up capital cost, which resulted in low tied up capital cost. However, the shipping cost is high. Concerning the environmental impact, the GHG emissions is highly dependent on the distance and the mode of the complementary transportation to and from the railways.

Rail freight to China has the most established infrastructure and is therefore the most efficient option for rail transportation to Asia of the three countries investigated. For Japan, the AE19 rail route is the preferable route out of the two rail routes that exist. It is also the only rail route that 3PL B offers today. Rail freight to Vietnam has a high total cost even though the tied up capital cost is low, due to its high shipping cost. Furthermore, the environmental impact for transportation to Vietnam is high. The reason for the high costs and GHG emissions is the long distances of truck from China to Vietnam, which is an expensive transportation mode that also generates a high amount of emissions.

Rail freight has been less affected by the covid-19 pandemic compared to sea freight and no issues with availability have been experienced. The transportation mode also has higher reliability and less delays. The biggest challenges with rail freight are the new documentation requirements which have forced Tetra Pak to alter their processes as well as the communication and partnership with a new 3PL.

**RQ3.** *How do the transportation modes perform compared to each other?*

When comparing the performance of the two transportation modes it can generally be seen that rail freight has a shorter transit time compared to sea freight. Further, the shipping cost for rail is higher than for sea. However, the shorter transit time for rail leads to a lower tied up capital cost which results in a lower total cost for China, a rather similar total cost for the two transportation modes for Japan and a higher total cost for Vietnam. For Vietnam the total cost for rail freight is higher compared to sea due to a high shipping cost as a result of the truck transportation from China to Vietnam. This is also the case for the environmental impact, it is generally lower for rail freight, however not for Vietnam which is due to the truck transport.

Both transportation modes are related to risks. The main risks for sea freight are connected to the covid-19 pandemic as well as the low reliability of the mode. For rail the risks are associated with it being a relatively new transportation mode between Europe and Asia as well as being a new transportation mode for Tetra Pak's packaging machines.

## 7.2 Recommendations

The empirical data gathered and analyzed indicate that rail transport is the preferential transportation mode to China. Rail freight was proven to perform best in all the aspects evaluated, service, economic and environmental. Furthermore, several rail shipments have been carried out to China during the project "Rail to Asia" as well as after the project's closing with satisfactory results. Only two of the risks mentioned in section 6.1, a new partnership with 3PL B and high documentation requirements, apply to the rail route to China which are considered as low risks. The recommendation to Tetra Pak is therefore to use rail freight to

China as it reduces transit times, the total cost as well as the environmental impact. Further, Tetra Pak is recommended to investigate the possibilities of transporting machines the opposite route, from China to Europe, by rail.

The analysis showed that the best option for transportation to Japan from both Lund and Modena is the AE19 rail route. The AE19 route is the alternative with least risks as well as it is a route that is currently offered by 3PL B. Moreover, the MCs in Japan have expressed an interest in using rail transportation, which is an important part in making this option feasible. Therefore, the recommendation to Tetra Pak is to try the AE19 rail transport by planning pilot shipments together with 3PL B. Furthermore, the AE18 route is not offered by 3PL B today, however this thesis indicates potential benefits, compared to sea, with AE18 and the recommendation is therefore to investigate the route further in the future when 3PL B can offer this option. The results and recommendations of Japan can be generalized to South Korea since this is a country with similar geographical characteristics. A further recommendation to Tetra Pak is therefore to look deeper into transportation on the AE19 route to South Korea.

The results for Vietnam showed that sea is the most preferential transportation mode to the southern part of the country. For the northern part the two transportation modes were performing equally from Modena and rail freight was the best option from Lund. However, the route is not an option as of today since 3PL B does not offer it and further it is associated with many risks. The recommendation to Tetra Pak is therefore to continue with sea freight to Vietnam and to assess the rail route to northern Vietnam again in the future when it is believed that the risks have decreased and the route is offered. The railways should also be expanded in order to make rail to Vietnam a suitable option. If this were to happen the need for truck would be reduced and therefore the high costs and emissions associated with rail to Vietnam would also be reduced. Another possibility could be to consider using another 3PL that offers the route and reviewing their offer. The results and therefore recommendations for Vietnam can be generalized to Cambodia, Laos and Thailand since they have the similar geographical position as Vietnam.

Finally, rail transportation can be used as a complement to sea freight for the destinations where it was not concluded as the most preferential mode. This since there has been many issues with sea freight recently. If rail freight were to be used in instances when issues with the availability of sea are experienced Tetra Pak could become more flexible and reduce lead times by getting the goods shipped sooner. A summary of the recommendations can be found in Table 7.1.

Table 7.1. Summary of recommendation.

| Country | Preferential mode and route | Result can be generalized to |
|---|---|---|
| **China** | Rail: AE18 route | |
| **Japan** | Rail: AE19 route | South Korea |
| **Vietnam** | Sea | Cambodia, Laos and Thailand |

## 7.3 Contribution to Research

Transportation by rail from Europe to Asia is a relatively new phenomenon that has recently received attention due to the BRI. However, there exists little literature that explores transportation to other countries beyond China. This thesis therefore contributes to theory by analyzing two other countries: Japan and Vietnam. Furthermore, there exists several studies on the topic of transportation mode selection. However, the literature rarely focuses on mode selection in situations of intermodal transportation, where several modes are used in one route, but instead studies the different transportation modes separately. This study has not only evaluated the main transports of the routes but also focused on the supporting transportations necessary to complete the shipment, in order to give a comprehensive picture of the transportation. Lastly, this study has contributed with strengthening and adding more information to the previous literature of transportation mode selection, trade offs as well as risks and challenges concerning this, especially regarding transportation between Europe and Asia.

## 7.4 Future Research

For future research, it could be interesting to complement this study by an investigation of rail transportation the opposite way, meaning rail transportation from Asia to Europe. Asia is a region where a great quantity of production takes place and a large volume of the products are shipped to Europe, which should make it interesting to investigate the opportunities and challenges with rail freight from Asia to Europe. Further, in this thesis three different countries have been investigated and based on the results a generalization has been made for countries with similar characteristics. However, it could be interesting to properly investigate other countries in Asia to get insight into rail transportation from Europe to these countries, for example Thailand, Cambodia, Laos and South Korea.

Moreover, this thesis investigates the options that 3PL B, the 3PL that Tetra Pak collaborates with for rail transportation, offers which limits the research. Therefore, a suggestion for future research is to analyze rail freight routes offered by multiple 3PLs to get a deeper understanding of the actual infrastructure possibilities that are currently available on the market. Furthermore, the social aspect when evaluating transportation modes is not included in this thesis. This aspect could be added in a future research of the topic to get a more holistic view.

# References

Alon, I., Zhang, W. & Lattemann, C. (2018). *Chinas Belt and Road Initiative.* Palgrave Studies of Internationalization in Emerging Markets.

Arbnor, I. & Bjerke, B. (1997). *Methodology for creating business knowledge.* 1st ed., SAGE Publications.

Aronsson, H. & Huge Brodin, M. (2006). The environmental impact of changing logistics structure. *The International Journal of Logistics Management,* 17(3), pp. 394-415.

Bozarth, C. & Handfield, R. (2019). *Introduction to Operations and Supply Chain Management*. 5th ed., Pearson.

Brunner, H-P. (2013). What is economic corridor development and what can it achieve in Asia's subregions?. *Asian Development Bank,* 117.

Caro, D. (2019). Carbon footprint. *Encyclopedia of Ecology (Second Edition),* 4, pp. 252-257.

Chin, T. A., Tat, H. H. & Sulaiman, Z. (2015). Green Supply Chain Management, Environmental Collaboration and Sustainability Performance. *Procedia CIRP,* 26, pp. 695-699.

Chopra, S. (2003). Designing a Distribution Network in a Supply Chain. *Transportation Pesearch Part E: Logistics and Transportation Review*, 39(2), pp. 123-140.

Chopra, S. & Meindl, P. (2013). Supply Chain Management: Strategy, Planning, and Operation. $5^{th}$ ed. Harlow: Pearson Education Limited.

Coughlan, P. & Coghlan, D. (2002). Action research for operations management. *International Journal of Operations & Production Management,* 22(2), pp. 220-240.

Denzin, N. K. & Lincoln, Y. S. (2011). *The SAGE Handbook of Qualitative Research.* 4th ed., SAGE Publications.

DHL. (2020). Basic overview of the incoterms 2020 rules. [Online] Available at: https://www.dhl.com/content/dam/dhl/global/dhl-global-forwarding/documents/pdf/glo-dgf-incoterms-2020-brochure.pdf. [Accessed 25 February 2021].

Doody, O. & Noonan, M. (2013). Preparing and conducting interviews to collect data. *Nurse Researcher,* 20(5), pp. 28-32.

Dotoli, M. & Epicoco, N. (2020). Integrated Network Design of Agile Resources-Efficient Supply Chains Under Uncertainty. *IEEE, Transactions on system, man, and cybernetics: systems*, 50(1), pp. 4530-4544.

EcoTransIT. (2021). Calculation. [Online] Available at: https://www.ecotransit.org/calculation.en.html. [Accessed 7 April 2021]

EIA, U.S. Energy Information Administration. (2017). Russia. [Online] Available at: https://www.eia.gov/international/overview/country/RUS. [Accessed 9 April 2021]

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *The Academy of Management Review,* 14(4), pp. 532-550.

Eisenhardt, K. M. & Graebner, M. E. (2007). Theory Building from Cases: Opportunities and Challenges. *The Academy of Management Journal,* 50(1), pp. 25-32.

Ellram, L. M. (1996). The use of the case study method in logistics research. *Journal of Business Logistics,* 17(2), pp. 93-138.

Fisher, M. (2007). Strengthening the Empirical Base of Operations Management. *Manufacturing & Service Operations Management,* 9(4), pp. 368-382.

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

Freightos. (2021). Freight Calculator. [Online] Avaliable at: https://www.freightos.com/freight-tools/freight-rate-calculator-free-tool/. [Accessed 24 April 2021]

Fuzele, V., Shankar, R. & Choudary, D. (2019). A model for selection of transportation modes in the context of sustainable freight transportation. *Industrial Management and Data Systems*, 119(8), pp. 1764-1784.

Galushko, D. (2016). *Study on Corridors.* OTIF.

Gammelgaard, B. (2004). Schools in logistics research?. *International Journal of Physical Distribution & Logistics Management,* 34(6), pp. 479-491.

Gao, T. Liu, Q. & Wang, J. (2014). A comparative study of carbon footprint and assessment standards. *International Journal of Low-Carbon Technologies,* 9(3), pp. 237-243.

Golicic, S. L., Davis, D. F. & McCarthy, T. M. (2005). A Balanced Approach to Research in Supply Chain Management. In: H. Kotzab, S. Seuring, M. Muller and G. Reiner, ed., *Research Methodologies in Supply Chain Management*, 1st ed. Physica-Verlag HD, pp.15-29.

Höst, M., Regnell, B. & Runeson, P. (2006). *Att genomföra examensarbete.* 1st ed., Studentlitteratur AB.

Internal Transportation System, Tetra Pak, 2021-03-02.

IPCC, Intergovernmental Panel on Climat Change. (2014). *Climate Change 2014: Mitigation of Climate Change.* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Islam, D. M. Z., Zunder, T. H., Jackson, R., Nesterova, N. N. & Burgess, A. (2013). The potential of alternative rail freight transport corridors between central Europe and Asia. *Transport Problems,* 8(4), pp. 45-57.

Jakóbowski, J., Poplawski, K. & Kaczmarskiet, M. (2018). *The Silk Railroad: The EU-Chain Rail Connections: Background, Actors, Interests.* Center for Eastern Studies.

Khan, S., Zhang, Y. & Nathaniel, S. (2020). Green supply chain performance and environmental sustainability: A panel study. *Scientific Journal of Logistics,* 16(1), pp. 141-159.

Kohn, C. (2008). *Towards $CO_2$ efficient centralized distribution.* Dissertation. Department of Management and Engineering, Linköping Universitet.

Kovács, G. & Spens, K. M. (2005). Abductive reasoning in logistics research. *International Journal of Physical Distribution & Logistics Management,* 35(2), pp. 132-144.

Kubánová, J., Otáhalová, Z. & Senko, S. (2020) Advantages and Disadvantages of Intermodal Freight Transportation. In: Mikulski J, ed., *Research and the Future of Telematics.* TST 2020. Communications in Computer and Information Science, vol 1289. Springer.

Leonard-Barton, D. (1990). A dual methodology for case studies: synergistic use of a longitudinal single site with replicated multiple sites. *Organization Science,* 1(3), pp. 248-266.

Liliopoulou, A., Roe, M. & Pasukeviciute, I. (2005). Trans Siberian Railway: from inception to transition. *European Transport,* 25, pp. 46-56.

Lumsden, K. (2012). *Logistikens Grunder.* 3rd ed., Studentlitteratur AB.

Malfliet, J. (2011). Incoterms 2010 and the mode of transport: how to choose the right term. *Management challenges in the 21st century: transport ans logistics: opportunity for Slovakia in the era of knowledge economy, Proceedings,* pp. 163-179.
Maersk. (2021). Our fleet – Equipment specifications; Dry containers. [Online] Available at: https://www.maersk.com/industry-sectors/dry-cargo. [Accessed 8 March 2021]

Meixell, M. & Norbis, M. (2008). A Review of Transportation Mode Choice and Carrier Selection Literature. *The International Journal of Logistics Management*, 19(2), pp. 183-211.

Mentzer, J., DeWitt, W., Keebler, J., Min, S., Nix, N., Smith, C. & Zacharia, Z. (2001). Defining Supply Chain Management. *Journal of Business Logistics*, 22(2), pp. 1-25.

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management,* 16(4), pp. 441-454.

Montoya-Torres, J. R., Gutierrez-Franco, E. & Blanco, E. E. (2015). Conceptual framework for measuring carbon footprint in supply chains. *Production Planning & Control,* 26(4), pp. 265-279.

Nedopil, C. (2021). "Countries of the Belt and Road Initiative"; Beijing, IIGF Green BRI Center. Available at: https://green-bri.org/countries-of-the-belt-and-road-initiative-bri/?cookie-state-change=1613574304726. [Accessed 17 February 2021].

Notte, A., Tonin, S. & Lucroni, G. (2017). Assessing direct and indirect greenhouse gases in road transportation, taking into account the role of uncertainty in the emissions inventory. *Environmental Impact Assessment Review.* 69, pp. 82-93.

Novack, R., Gibson, B., Suzuki, Y. & Coyle, J. (2019). *Transportation: A global Supply Chain Perspective.* 9th ed., Cengage Education.

OECD. (2018). The Belt and Road Initiative in the global trade, investment and finance landscape. In: *OECD Business and Finance Outlook 2018.* OECD Publishing.

Olavson, T., Hau, J. & Gavin, D. (2010). A Portfolio Approach to Supply Chain Design, Supply Chain Management Review, (July-August 2010), pp. 20-27.

Patton, M. Q. (2015). *Qualitative Research & Evaluation Methods*. 4th ed., SAGE Publications.

Peters, G. P. (2010). Carbon footprint and embodied carbon at multiple scales. *Current Opinion in Environmental Sustainability,* 2(4), pp. 245-250.

Rodemann, H. & Templar, S. (2014). The enablers and inhibitors of intermodal rail freight between Asia and Europe. *Journal of Rail Transport Planning & Management,* 4(3), pp. 70-86.

Schramm, H-J. & Zhang, X. (2018). Eurasian Rail Freight in the One Belt One Road Era. *Conference: The Nordic Logistics Research Network.*

SeaRates. (2021). Shipping Distances & Time Calculator. [Online] Available at: https://www.searates.com/services/distances-time/. [Accessed 16 March 2021].

Sheffi, Y., Eskandari, B. & Koutsopoulos, H. N. (1988). Transportation mode choice based on total logistics costs. *Journal of Business Logistics,* 9(2), pp. 137-154.

Simatupang, T. & Sridharan, R. (2005). Supply Chain Discontent. *Business Process Management Journal*, 11(4), pp. 349-369.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research,* 104, pp. 333-339.

Stalk, G. Jr. (2009). The Threat of Global Gridlock. *Harvard Business Review,* (July-August 2009), pp. 126-129.

Standard Chartered. (2019). Belt and Road: One masterplan. Six economic corridors of power. [Online] Available at: https://www.sc.com/en/feature/one-masterplan-six-corridors/. [Accessed 11 March 2021].

Stuart, I., McCutcheon, D., Handfield, R., McLachlin, R. & Samson, D. (2002). Effective case research in operations management: a process perspective. *Journal of Operations Management,* 20(5), pp. 419-433.

Tetra Pak. (2021a). About Tetra Pak. [Online] Available at: https://www.tetrapak.com/about-tetra-pak/the-company/facts-figures. [Accessed 11 February 2021].

Tetra Pak. (2021b). Packaging Solutions. [Online] Available at: tetrapak.com/solutions/packaging. [Accessed 9 March 2021].

Voss, C., Tsikriktsis, N. & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management,* 22(2), pp. 195-219.

Wagener, N., Aritua, B. & Zhu, T. (2020). The new silk road: opportunities or global supply chains and challenges for further development. *Scientific Journal of Logistics,* 16(2), pp. 193-207.

Wiedmann, T. & Minx, J. (2008). A Definition of 'Carbon Footprint'. In: C. C. Pertsova, *Ecological Economics Research Trends*: Chapter 1, pp. 1-11, Nova Science Publishers.

Zhao, J. & Zhao, H. (2018). Design of prototype system for multi-agent supply chain information sharing benefit distribution management. *Springer-Verlag GmbH Germany*, pp. 581-602.

Yin, R. K. (2014). *Case Study Research – Design and Methods.* 5th ed., SAGE Publications.

# Appendix A

In Appendix A the interview guide is provided. However, the questions were adapted to the position and knowledge of the interviewee and therefore not all of the questions presented here were asked at all interviews. The interviews were also conducted in a semi-structured fashion and therefore some questions that are not included in the interview guide might have been asked.

1. What is your position and responsibilities at the company?
2. What do you see as important aspects to evaluate regarding Tetra Pak's transportation?
3. What aspects do the customers value the most, on-time delivery, fast delivery, cheap prices etc.?
4. What are the biggest advantages and challenges with sea freight?
5. What are the biggest advantages and challenges with rail freight?
6. How do the current processes and routes for sea freight look like?
7. What routes are possible to take for rail freight to the different destinations?
8. How is the process for rail freight?
9. How does the tracking system work for the two transportation modes?
10. How is the cost calculated for the two transportation modes?
11. How are emissions calculated for the two transportation modes?
12. Have the transportation modes been affected by the covid-19 pandemic?
13. What do you think the future will look like for sea freight?
14. What do you think the future will look like for rail freight?

# Appendix B

In this appendix the emissions for the different routes are presented. The tables show the emissions and transportation mode of the sub routes and thereafter the total emissions for the route. Emissions have been rounded off and therefore some sub routes show a GHG emission of 0 tons.

### GHG Emissions to China

Table A.1. GHG emissions for sea transportation from Lund to Shanghai.

| Route | Lund - Helsingborg | Helsingborg - Shanghai | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,048 | 2,39 | **2,44** |

Table A.2. GHG emissions for rail transportation from Lund to Shanghai.

| Route | Lund-Helsingborg | Helsingborg-Hamburg | Hamburg-Xian | Xian-Shanghai | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Sea | Rail | Truck | |
| **GHG Emissions (ton)** | 0,048 | 0,11250 | 0,16 | 1,55 | **1,87** |

Table A.3. GHG emissions for sea transportation from Modena to Shanghai.

| Route | Modena - Genova | Genova - Shanghai | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,26 | 1,886 | **2,15** |

Table A.4. GHG emissions for rail transportation from Modena to Shanghai.

| Route | Modena-Milano | Milano-Hamburg | Hamburg-Xian | Xian-Shanghai | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Rail | Rail | Truck | |
| **GHG Emissions (ton)** | 0,18 | 0 | 0,16 | 1,55 | **1,89** |

### GHG Emissions to Japan

Table A.5. GHG emissions for sea transportation from Lund to Japan.

| Route | Lund - Helsingborg | Helsingborg - Tokyo | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,05 | 2,54 | **2,59** |

Table A.6. GHG emissions for route AE18 from Lund to Japan.

| Route | Lund – Helsingborg | Helsingborg – Hamburg | Hamburg – Xi'an | Xi'an – Shanghai | Shanghai – Tokyo | Total |
|---|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Sea | Rail | Truck | Sea | |
| **GHG Emissions (ton)** | 0,05 | 0,11 | 0,16 | 1,55 | 0,34 | **2,21** |

Table A.7. GHG emissions for route AE19 from Lund to Japan.

| Route | Lund – Helsingborg | Helsingborg – St Petersburg | St Petersburg – Vostochny | Vostochny – Tokyo | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Sea | Rail | Sea | |
| **GHG Emissions (ton)** | 0,05 | 0,33 | 0,13 | 0,31 | **0,82** |

Table A.8. GHG emissions for sea transportation from Modena to Japan.

| Route | Modena – Genova | Genova – Tokyo | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,26 | 2,04 | **2,30** |

Table A.9. GHG emissions for route AE18 from Modena to Japan.

| Route | Modena – Milano | Milano – Hamburg | Hamburg – Xi'an | Xi'an – Shanghai | Shanghai - Tokyo | Total |
|---|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Rail | Rail | Truck | Sea | |
| **GHG Emissions (ton)** | 0,18 | 0 | 0,16 | 1,55 | 0,34 | **2,23** |

Table A.10. GHG emissions for route AE19 from Modena to Japan.

| Route | Milano – Verona | Verona - Hamburg | Hamburg - Bremerhaven | Bremerhaven– St Petersburg | St Petersburg – Vostochny | Vostochny – Tokyo | Total |
|---|---|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Rail | Truck | Sea | Rail | Sea | |
| **GHG Emissions (ton)** | 0,1 | 0 | 0,14 | 0,39 | 0,13 | 0,31 | **1,07** |

## GHG Emissions to Vietnam

Table A.11. GHG emissions for sea transportation from Lund to northern Vietnam.

| Route | Lund - Helsingborg | Helsingborg - Haiphong | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,048 | 2,20 | **2,25** |

Table A.12 GHG emissions for rail transportation from Lund to northern Vietnam

| Route | Lund - Helsingborg | Helsingborg - Hamburg | Hamburg - Chengdue | Chengdu - Haiphong | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Sea | Rail | Truck | |
| **GHG Emissions (ton)** | 0,05 | 0,11 | 0,16 | 1,71 | **2,03** |

Table A.13. GHG emissions for sea transportation from Lund to southern Vietnam.

| Route | Lund - Helsingborg | Helsingborg - Ho Chi Minh City | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,048 | 2,05 | **2,10** |

Table A.14. GHG emission for rail transportation from Lund to southern Vietnam.

| Route | Lund - Helsingborg | Helsingborg - Hamburg | Hamburg - Chengdu | Chengdue - Ho Chi Minh City | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Sea | Rail | Truck | |
| **GHG Emissions (ton)** | 0,05 | 0,11 | 0,16 | 3,26 | **3,58** |

Table A.15. GHG emissions for sea transportation from Modena to northern Vietnam.

| Route | Modena - Genova | Genova - Haiphong | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,26 | 1,69 | **1,95** |

Table A.16. GHG emission for rail transportation from Modena to northern Vietnam.

| Route | Modena - Milano | Milano - Hamburg | Hamburg - Chengdu | Chengdu - Haiphong | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Rail | Rail | Truck | |
| **GHG Emissions (ton)** | 0,18 | 0 | 0,16 | 1,71 | **2,05** |

Table A.17. GHG emission for sea transportation from Modena to southern Vietnam.

| Route | Modena-Genova | Genova-Ho Chi Minh City | Total |
|---|---|---|---|
| **Transportation Mode** | Truck | Sea | |
| **GHG Emissions (ton)** | 0,26 | 1,55 | **1,81** |

Table A.18. GHG emission for rail transportation from Modena to southern Vietnam.

| Route | Modena-Milano | Milano-Hamburg | Hamburg-Chengdu | Chengdu - Ho Chi Minh City | Total |
|---|---|---|---|---|---|
| **Transportation Mode** | Truck | Rail | Rail | Truck | |
| **GHG Emissions (ton)** | 0,18 | 0 | 0,16 | 3,26 | **3,60** |