A FEASIBILITY STUDY ON RAIL TRANSPORTATION OF PAPERBOARD AT TETRA PAK

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- Murilo Teldeschi and Sanjay Mudaliar.

Abstract

Title: A feasibility study on rail transportation of paperboard at Tetra Pak

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Background: The current global trade scenario has a large infrastructural gap, which limits the possibilities for physical distribution of goods among different countries or continents. The 'Belt and Road Initiative' will be used to close this gap. Tetra Pak being global organisation would like to explore the possibilities of using rail transport in BRI. For this reason, they would like to evaluate the benefits and challenges associated with changing of transport mode from sea to rail.

Purpose of study: The purpose of this thesis is to conduct a feasibility analysis of change in mode of transportation from sea to rail from an economic, environmental and service performance aspects while proposing a better understanding of the advantages and challenges of rail freight.

Research question: **RQ1**: How is the performance of the current sea freight route in terms of economic, environmental and service aspects?
RQ2: How would be the performance of rail freight be in terms of economic, environmental and service aspects?
RQ3: What are the risks and challenges to implement rail freight from Scandinavia to China?

Methodology: In order to fulfil the purpose of the thesis, the authors have used inductive case study approach. This was done by analysing and comparing the as is state to the to be state, using the qualitative and quantitative data coming from interviews and company documents.

Conclusion: The analysis resulted in showcasing the total logistics costs for both modes of transport along with the impact it would have on service and environmental performance. It was found that the rail freight would not be suitable and economical to ship paperboard due the its low unit value.

Keywords: BRI, Mode choice, total logistics cost, service, environment.

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List of Abbreviations

AM	Additional material
APO	Advanced planner and optimiser
BK	BillerudKorsnäs
BM	Base material
BOM	Bill of materials
BRI	Belt and Road Initiative
BSC	Balanced Scorecard
CS	Cycle Stock
GHG	Greenhouse gas
GPS	Global Positioning System
GT&T	Global transport and travel
IS	In-transit stock
ISC	Integrated supply chain
LT	Lead time
MOQ	Minimum order quantity
MRP	Material requirement planning
OTD	Ontime deliveries
OTP	On time performance
PD	Physical distribution
PM	Performance measurements
RFID	Radio frequency identification
SC	Supply chain
SCM	Supply chain management
SCV	Supply chain visibility
SKU	Stock keeping units
SS	Safety stock
TLC	Total logistics costs
TTP	Total transport performance
PM	Packaging material

1. Introduction

This chapter focuses on presenting a brief background of the thesis and describes the problem that the organisation encounters. The background and problem formulation then lead to the purpose of the study and the research questions it aims to answer. The section is then concluded by addressing the delimitations and the structure of the thesis.

1.1 Background

Freight transportation systems play a huge part in the economy of a nation by providing goods and services to the required destination on time (Köfteci, 2015). Suppliers and customers, factories and markets are often parted by a physical distance. Freight transportation often connects them together in an efficient way (Özalp et al., 2010). In order to fulfil customer demands, freight transportation systems integrate numerous complex activities with logistics being one of them (Muerza et al., 2017). Service time to customers is considered as a key factor in freight transportation, which is directly related to the mode of transport used by the shipper (Fulzele et al., 2019). Different modes of transportation have unique characteristics which determine several factors like transportation costs, carbon emissions, safety, etc. (SteadieSeifi et al., 2014).

According to (SteadieSeifi et al., 2014), pre haul (first mile), long haul (door to door transit of containers) and end haul (last mile) are the three segments in a transportation chain; out of which long haul transportation could be implemented using any of the four modes of transportation. In order to choose a particular mode of transport, it is of utmost importance to factor in multiple variables when arriving at decisions (Tuzkaya and Önüt, 2008). One of these factors is the infrastructure in place to support the transportation mode which is important for economic production and trade (ADB, 2017).

The current global trade scenario has a large infrastructural gap, which limits the possibilities for physical distribution of goods among different countries or continents. In order to close this gap, China has commenced a major global effort, by initiating a global development strategy, called the 'Belt and Road Initiative' (BRI) (OECD, 2018). BRI aims to develop infrastructural network of railways, highways and ports across six main economic corridors encompassing China, Mongolia and Russia; Eurasian countries; Central and West Asia; Pakistan; other countries of the Indian subcontinent; and Indochina (OECD, 2018 and Clarke, 2017).

The goal of the BRI is to lay down new infrastructure and mechanisms across the three continents that will lead to global economic growth (Chan et al., 2019). There are around 72 countries participating in BRI. The main motivations for BRI are the connectivity in terms of industrial cooperation and development, openness to embrace the outside world and promote liberalisation. Furthermore, it pursues innovation-based development and ensure sustainable development in terms of peace, environment and ecology, water conservation and civil society to name a few. To conclude, BRI will affect global trade and investments in significant ways and hence, it is important to analyse how firms can use this initiative to improve their supply chains. (OECD, 2018)

1.2 Problem formulation

Tetra Pak is a global leading company for complete solutions related to food processing, packaging and distribution. The company was founded in 1951 by Ruben Rausing in Lund, Sweden. Currently, the company employs over 25 thousand people worldwide, has a net sale of over 11 billion Euro and sells their products and services in more than 160 countries over the globe (About Tetra Pak - processing and packaging solutions for food, 2020). Having quality and sustainability as its core values, Tetra Pak aims to be efficient in the usage of resources as consumption of energy and raw material, while delivering high quality solutions to its end customers. Having the continuous improvement mindset, the company currently looks at the BRI as an opportunity to optimize their supply chain, not only from an economic perspective but also from a service performance and environmental perspective.

Tetra Pak's packaging materials are made from three base components: paperboard, polymer and aluminium foil. These base components are called base material goods. Currently, Tetra Pak ships base materials from Scandinavia to China via sea freight. The main driver for this decision is the lower transportation costs due to the possibility of taking advantage of the economies of scale. Although sea freight has its advantages, it involves higher lead times, that leads to higher uncertainties, which in turn demands higher safety stock and inventory level in general (Bozarth and Handfield, 2016). Furthermore, it has a lower on time performance (OTP) compared to rail transportation. Another factor that is important to consider is the environmental impact of such transportation modes, as it is currently one of the major concerns of organizations and society in general.

Due to the BRI, an improved railroad infrastructure is available for shipments between Europe and Asia. For that reason, Tetra Pak can now consider shipping orders on rail instead of sea. This change not only has the potential to reduce lead times and increase on time performance but could also be advantageous in terms of transport cost. Due to the unbalanced trade relationship between Scandinavia and China on rail transportation, there are more goods being shipped from China to Europe rather than Europe to China. This setup generates relatively low transportation costs for rail shipments going from Europe to China.

Quality and environmental practices are at the forefront of Tetra Pak's strategy across different business functions. For that reason, it is of utmost importance to analyse the performance of rail shipments from Scandinavia to China and compare it to the current sea transportation from an economic, environmental and service perspectives.

1.3 Purpose of the study and research questions

The purpose of this thesis is to conduct a feasibility analysis of change in mode of transportation from sea to rail from an economic, environmental and service performance aspects while proposing a better understanding of the advantages and challenges of rail freight for paperboard material going from Scandinavia to China at Tetra Pak. In order to fulfil this purpose, the following three research questions need to be addressed.

RQ1: *How is the performance of the current sea freight route in terms of economic, environmental and service aspects?*

It will be important at first to have a solid grasp of the current supply chain for the route from Scandinavia to China. Once an understanding of this process is established, it will be essential to consider the different factors like lead time and costs related to transportation and inventory in the overall supply chain. Since the scope of this thesis includes environmental factors, it will be essential to calculate the carbon emissions for sea transport, if Tetra Pak does not determine currently. Service performance will also be evaluated in this thesis.

RQ2: *How would the performance of rail freight be in terms of economic, environmental and service aspects?*

Since Tetra Pak plans to use the New Eurasian Land Bridge economic corridor to transport goods from Scandinavia to China and vice versa, the first step would be to calculate the total logistics costs. This approach will include calculating/ assessing the size of shipment, transportation cost, lead time, inventory holding costs and finally the carbon emissions. Then, the authors will evaluate the environmental impacts, looking at carbon footprint emissions and the impacts on service, looking at on-time deliveries. The three performance indicators will be analysed, comparing each defined rail freight scenario to the current sea freight reality.

RQ3: *What are the risks and challenges to implement rail freight from Scandinavia to China?*

Before deciding to make changes in the current transportation setup, it is important to understand the risks and challenges related to rail shipments that will be involved in its possible implementation. The authors will perform risk and sensitivity analysis in order to better understand internal and external risks, as well as changes in the global physical distribution reality that could impact the decision of implementing rail freight to ship goods from Scandinavia to China. Based on these analyses, the authors aim to recommend to Tetra Pak the mode choice leading to the best overall performance, when looking to cost, emissions and service levels.

1.4 Delimitation

To properly define the scope and the boundaries of the thesis, delimitations must be defined. This is a single company study, focused on the Supply Chain Operations department of Tetra Pak AB. The thesis is restricted to assessing the feasibility of changing the means of transport for paperboard from Scandinavia to China, in terms of total logistics cost, as well as environmental and service impacts. The thesis will evaluate the material flow from one paperboard supplier located in Gävle, Sweden to the three Tetra Pak factories in China. The focus is to understand the overall effect that a potential change in transportation mode would have on Tetra Pak's paperboard supply chain. Therefore, the authors aim to evaluate the possibility of implementing rail transportation using the Eurasian economic corridor, enabled by the BRI, and to compare it with the currently adopted sea freight. Information regarding other means of transport is not found in this document. Another delimitation of this thesis is the sustainability aspect, as it only addresses the environmental impacts of shipping practices, which are measured by the total carbon footprint of each transportation mode. Social sustainability is not considered in this project.

1.5 Thesis structure

Introduction

The introduction chapter focuses on presenting a brief background of the thesis and describes the problem that the organisation encounters. The background and problem formulation then lead to the purpose of the study and the research questions it aims to answer. The section is then concluded by addressing the delimitations and the structure of the thesis.

Methodology

This chapter focuses on describing and motivating the reason for selecting the research method/ strategy for the thesis. It also illustrates the plan to execute the research process in a way, observable insights could be generated. Furthermore, the research quality is addressed.

Literature review

This thesis is based on the relevant theoretical and mathematical foundation, which is presented in this chapter. Concepts which are helpful for the researchers to fulfil the purpose of the thesis is explained in detail and the software or tools used to address the research questions is recognised.

Approach to Analysis

This chapter summarises the relevant literature that will be relevant to the thesis and provide a foundation for further analysis. It also goes about explaining the relevant performance measurements that will be analysed for the different modes of transportation.

Tetra Pak processes

This section focuses on the empirical data gathered at the focal company. It will start with a brief introduction of the company, considering its products, processes and services. The supply chain operations will be briefly discussed and a detailed supply chain map of the current physical distribution of paperboard from Scandinavia to China will be presented. Detailed data regarding total logistics cost and environmental impact related to the current sea route and the potential rail route will be collected in this chapter.

Analysis

The analysis part aims to use the empirical findings to discover the most appropriate route with respect to cost and environmental impact. The first step is to expose the significant relationship among the related variables, thus creating a formal model that could accurately express the current physical distribution possibilities at Tetra Pak. The next step would be to discuss conclusions and theorems based on the results from the created model, while having the theoretical background as a support for the discussion.

Discussions

The main objective of this section would be to discuss the overall performance for the different parts like the costs, environmental impact and service performance for the two modes of transportation. The discussions in this section will also include the qualitative data which is relevant for Tetra Pak as an organisation while choosing the mode of transportation to ship paperboard.

Conclusion

This chapter discusses the insights deduced from the analysis and responds to the research questions posed in the initial sections of the thesis. Furthermore, an overall summary and the learning from the project is discussed, leading to the final conclusion of this study.

2. Methodology

The methodology chapter aims at illustrating a plan to execute the research after which observable insights regarding the subject could be generated. It also focuses on explaining the research strategy used for this thesis and the motivation behind choosing it. This chapter begins by explaining the relevant research strategy. It then moves on to describe and illustrate the research design or the general steps to be followed for the chosen research strategy. The focus then shifts on the unit of analysis and the topics from the literature that will be relevant for the study. Finally, it also exposes how the relevant data within the organisation will be collected and analysed while also mentioning about the research quality.

2.1 Research strategy

In order to develop a research strategy, it is important to have a methodological approach which guides the researcher throughout the project and makes sure that it leads to attaining the purpose of the project. The available methodological research strategies could be modified depending on the purpose of the thesis (Arbnor and Bjerke, 1997). This is affirmed by Easton (2010), who claims that the research method should be dependent on the research questions and nature of the study. The goal of this thesis is to conduct a feasibility analysis and propose which mode of transportation will be beneficial for Tetra Pak's supply chain. The researchers would be interested to analyse how a global organisation like Tetra Pak implements a change in transport mode. At the same time, the authors would also like to understand why the organisation would move from a well-established mode of transport to rail. Hence, the chosen research strategy is case study.

In order to understand the dynamics, present within the same setting, case research is the appropriate research strategy (Eisenhardt, 1989). The new mode of transportation that is enabled by BRI could be considered as the phenomenon that the researchers are analysing, after which feasibility analysis could help to uncover new areas for further research. There are several interesting characteristics pointed out by researchers related to case research, like different data collection methods could be combined together like interviews, observations which could be qualitative or quantitative and could be used to provide description, test or generate theory (Eisenhardt, 1989; Kidder, 1982; Pinfield, 1986 and Anderson, 1983).

After choosing the research strategy that fits the purpose of the project, it is important to choose the appropriate approach to study the nature of phenomenon and the research question. (Woodruff, 2003) suggests there could be two ways to approach depending on what the researcher wants to study; one is an inductive approach and the other is deductive approach as shown in Figure 2.1.

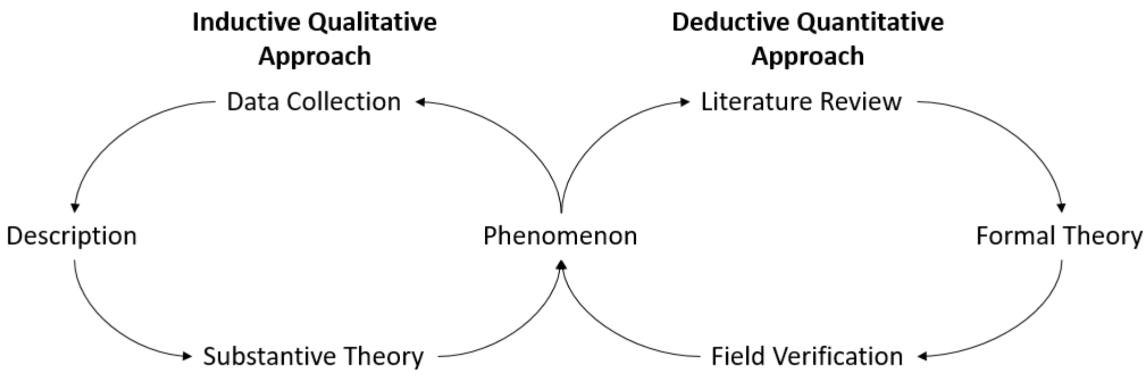

Figure 2.1: Research Approaches (source: Woodruff, 2003)

The research approach, in the same way as the research methodology, also needs to be motivated, according to the phenomenon that is going to be studied. If the researchers aim to describe a process, research questions would often start with 'how' and 'what', which is an indication that a qualitative/ inductive research approach would be the ideal choice (Golicic et al., 2005). The phenomenon in this project is the new mode of transportation that is enabled by BRI. It is a novel subject and there is a void to be filled in the subject's literature, therefore it is also an opportunity to increase the understanding of the phenomenon by collecting and analysing field data (Creswell, 1998). This means that this research would be analysed in the close-up view of the subject. (Golicic et al., 2005), also suggest that researchers who study the subject areas which are familiar in new circumstances are better off having qualitative approach. Hence, the authors of this report have an Inductive/ Qualitative approach for this thesis, which is backed by relevant literature.

In conclusion, the overall purpose of the project is to uncover new areas of research in the subject area of transportation mode choice in the context of BRI. Using an explorative case research methodology with a qualitative approach to analyse the phenomenon in up-close.

2.2 Research design

As discussed in the previous section, it is very important to follow a standard protocol that will cover all the necessary steps to enable the development of a good result. The research design comes into place to fulfil this objective. This paper's approach is inspired by (Stuart et al., 2002) approach of five critical steps in order to conduct a case research, which are depicted in Figure 2.2

Figure 2.2: Steps for case research development (source: Stuart et al., 2002)

In this part, the authors aim to explain in a more detailed level the overall structure of the report, explaining what will be done in each phase of the study. The idea of the research design is to give some guidance to the researchers and readers, so that they can understand the relationship of all the constructs and variables and relate them to the final conclusions. The research design model of this thesis can be seen in Figure 2.3.

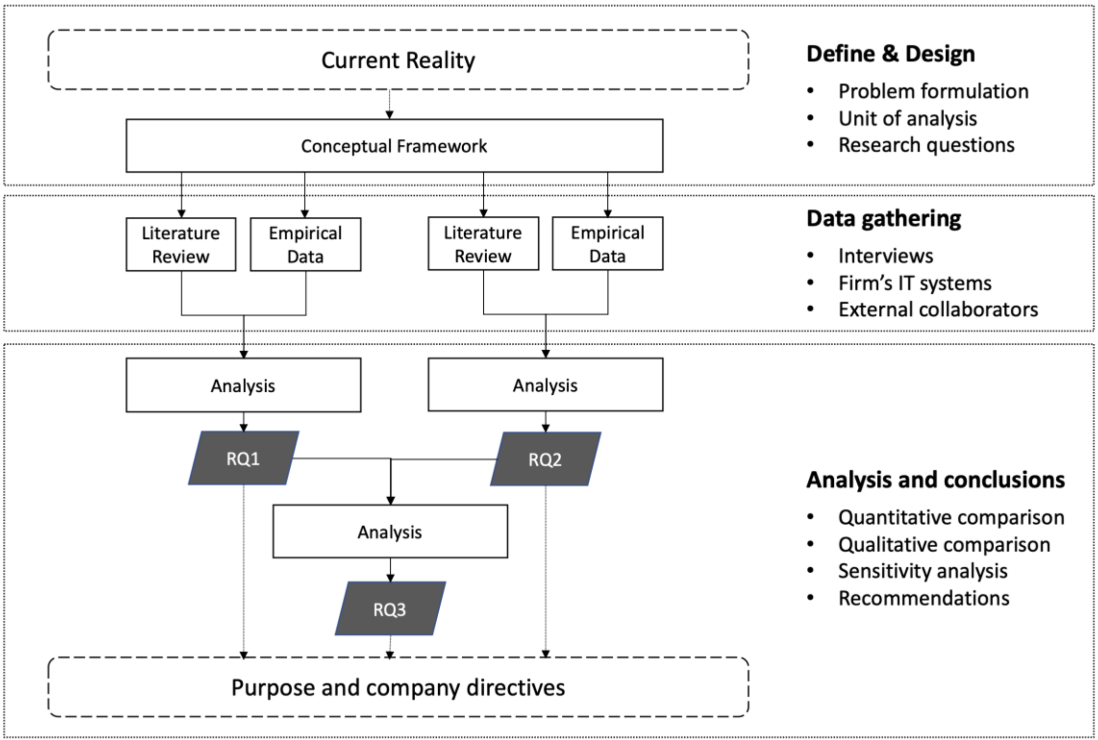

Figure 2.3: Research design (source: authors)

2.2.1 Unit of analysis

Yin (2018), suggests that defining a unit of analysis is one of the most important steps in research. The definition of unit of analysis is the first step in a case research development, and it is related to what the case is about. The unit of analysis can be an individual, an event, an organization, a process, and incident or a sequence of events; and it must be related to the research questions (Verleye, 2019). When it is not possible to conclude if one unit of analysis is more advantageous than another, there might be a need to make changes in the questions so they can be more precise to the problem studied. The goal of this thesis is to study the feasibility of implementing rail freight transportation for the shipment of paperboard from Scandinavia to China at Tetra Pak. Therefore, the unit of analysis can be defined as "the possible means of transportation for the distribution of paperboard between Scandinavia and China".

2.2.2 Forming a theoretical background

After the unit of analysis, the purpose of the study and the research questions are defined, it is important to explain the process of developing the conceptual model. The purpose of this project is the "feasibility analysis of rail shipments for Tetra Pak's paperboard going from Scandinavia to China in comparison with the traditional sea route, from an economic, environmental and performance standpoint". Furthermore, the unit of analysis is "the possible transportation modes for the distribution of paperboard between Scandinavia and China". The context of the study lays within the physical distribution and the new transportation possibilities that were enabled by the BRI. Physical distribution has already been extensively explored in previous literature. But when combined with the BRI, there is not enough literature to explore the potentialities that could emerge from the initiative. So, the first step in the development of the conceptual model is to perform a literature review to summarize all important aspects of physical distribution and BRI that are relevant to this project, including economic, environmental and performance factors, as well as the key variables related to a proper transportation mode choice selection.

In order to have a solid and reliable literature review, it is important to perform the searches in proper data bases. The authors opt to use the Web of Science, IEEE, JSTOR and EBSCO as the main data bases to find relevant literature, which are peer reviewed academic journals, books and articles. As a second source, consultancy and industry reports will be used to cover in-depth all the aspects related to BRI, as it is a novel topic in literature. Furthermore, the company website serves as another source of information. Table 2.1 summarises the topics and subtopics that were covered in the literature review, together with its sources.

Table 2.1: Topics covered under literature review

Topic	Subtopic	Sources
Operations in Physical Distribution	Shipment size, modal choice, total logistics cost, economies of scale	Peer reviewed academic journals, books
Infrastructure in Physical Distribution	Modes of transportation, rail shipment, sea shipment	Peer reviewed academic journals, books
Environmental impact of logistics	Carbon footprint, water pollution, air pollution	Peer reviewed academic journals, industry reports, consultancy reports
The Belt and Road Initiative	The new Eurasia land bridge, trade balance	Peer reviewed academic journals, industry reports, consultancy reports

2.2.3 Data collection

Data collection methods for a case research need not be just a survey in the organization which is the most common method to collect data in case research, it could also include archival documents, qualitative or quantitative observations or a combination of several data gathering techniques (Eisenhardt, 1989 and Voss et al., 2002). Since, this thesis is a single case study, it will provide greater depth on the subject being analysed but a drawback would be of having prejudice and exaggerating the collected data. Therefore, having multiple sources of data collection in order to depict the true scenario is essential which will also, allow the researchers to triangulate the data (McCutcheon and Meredith, 1993). Data gathering methods used in this project are interviews, qualitative and quantitative observations and company documents which could be in the different information systems. These data collections will be considered as the primary sources while industry reports, Tetra Pak's webpages were the secondary source.

Interviews

Interviews are mainly categorised as unstructured, semi structured and structured, as they tend to provide a holistic picture of the subject under analysis (Doody and Noonan, 2013 and Alshenqeeti, 2014). In order to understand the state of affairs, from different points of view, e.g. Business units, functions, etc. the researchers will be conducting semi-structured type of interview. Table 2.2 shows the type of interview along with the areas of study.

Table 2.2: Interviews conducted

Organisation	Interviewee	Interview type	Purpose
Tetra Pak GT&T	Martin Olsson	Semi-structured	To develop understanding of sea freight and the current routes for shipping.
Tetra Pak GT&T	Björn Hellqvist	Semi-structured	
Tetra Pak GT&T	PerX Nilsson	Semi-structured	To develop understanding of rail freight in BRI context.
Maersk	Raghav	Semi-structured	
Tetra Pak Integrated Planning	Taras Shevchenko	Semi-structured	To understand of processes related to planning and inventory of base materials.
Tetra Pak China material planner	Lola Li	Semi-structured	
Geodis	Rebecca Tunlid	Semi-structured	To understand the services provided by Geodis and benefits and challenges associated to rail freight.
Tetra Pak Logistics Manager China	Monica Zhao	Semi-structured	To understand the different costs associated with respect to storage and transport at Chinese factories.
Tetra Pak Integrated Logistics Manager	Vivian Wang	Semi-structured	

Company documents

The purpose of this thesis is to conduct a feasibility analysis which will involve data existing not just in Tetra Pak's data base but also cost parameters and other information available on transport providers webpages. The data collected from this source will be extensively used to analyse different cost and performance parameters later in the project. Since much of the data will be available in the information systems, access to them will be of utmost importance.

Observations

The observed data will be collected and documented during the interviews, by recording the interview and transcribing right after concluding the interview. Observed data could also collected while analysing the different processes, mapping the supply chain and collecting the relevant quantitative data.

Secondary sources

Although industry reports and data from the websites are secondary data sources, the information generated from them will be treated at par with the data collected from the primary sources. It is important to keep in mind that this information will be on a general level. These will be information for BRI since, there is a lack of academic literature about them, but consultancy firms have kept a closer eye on it with updates about the BRI being included in the reports.

Lastly (Yin, 1989 and Voss, et al., 2002), suggest that a case study protocol is essential, in order collect the data in a systematic manner by the researchers at the same time enhancing data reliability and validity. This will increase the readers clarity on the process of data collection and ensure the quality of data collected is not compromised.

2.3 Data Analysis

The primary purpose of this project/ thesis is to examine the economic and environmental feasibility for rail and sea freight, as well as its service performance. This will be done by collecting relevant data and analysing them with the appropriate tools. Considering that this project is being performed at Tetra Pak, it will be essential to understand the method and different variables studied by the organisation and incorporate it during the analysis stage.

There are three different research questions proposed by the authors. RQ1 and RQ2 will have the same method for analysis, since both include calculating the performance measures related to logistics and material management.

Firstly, to answer RQ1, the as-is data will be analysed, illustrating the current economic, environmental and service scenarios. There will be quantitative and qualitative data gathered from different sources. On the other hand, to answer RQ2, the data required will be gathered from different internal (Tetra Pak) and external organisations. This data will be further analysed using tools and techniques used within the organisation. Once the results from the analysis are generated, it will be compared to the results from RQ1 which could be identified as comparative analysis. The comparison will be done the economic, environmental and service aspect for the two modes of transport. RQ1 and RQ2 are independent of each other and hence, will be performed simultaneously.

Secondly, it will also be necessary to perform a sensitivity analysis, where it will be important to alter different variables to observe how the economic performance of rail would change. The purpose of sensitivity analysis is to get insights into which variables is sensitive to changes in the economic performance.

Finally, to conduct a comprehensive analysis, RQ3 will be analysed by examining the risks and challenges associated with rail freight under the BRI. This will enhance the quality of the analysis and give additional insights for the future on how to perform transportation modal choice decisions aiming a more efficient operation.

2.4 Research quality

While conducting research, it is important to address the credibility and the overall quality of the research. As discussed in the previous section, a quantitative research approach is being used. Yin (1989) suggests that researchers can use four logical tests namely, internal validity, external validity, construct validity and reliability in order to ensure the quality of the research. Each of the research tests will be explained below.

Construct validity: To ensure the construct validity, Stuart et al. (2002), suggest that researchers should expose the sources of data in order to address how the data is being collected. The authors of this paper mention the various ways in which data is being collected for the relevant information needed to answer the relevant research questions and contribute to the organisation under analysis. A way to go one step further and enhance the construct validity is to have the key informants review the draft of the report (Stuart et al., 2002).

Internal validity: According to Stuart et al. (2002), evidence needs to be recorded for other factors which could provide alternative explanation for the patterns observed by the researchers. The authors of this report make sure to use various sources while forming the related literature which are relevant for the analysis of the study and the organisation. This research test would help the authors to separate the true relationship with the ones which are not (Stuart et al., 2002).

External validity: Usually, the results of a case-based research cannot be generalized due to the limited number of cases under analysis (Stuart et al., 2002). In order to prevent the lack of generalization, the authors use references which are peer reviewed, relevant in today's times which is used to develop the related theory for the subject under analysis.

Reliability: Reliability can be explained as the extent to which findings or results could be repeated over a period to obtain similar results (Stuart et al., 2002). The authors enhance the reliability of this project by ensuring the use of a case study protocol and maintaining a case study data base as suggested by Stuart et al. (2002). This will not only provide the researchers with the required focus for the research but also allow other researchers to follow the same procedure to analyze the raw data.

2.5 Summary of research methodology

As mentioned in the beginning of this section, it is important to approach the study in a methodological manner, in order to fulfil the purpose of the thesis and answer the relevant research questions. Summary of the research methodology can be seen in the Table 2.3 below.

Table 2.3: Research methodology summary

Research Strategy	Case study
Research approach	Inductive/Qualitative approach
Unit of Analysis	Means of transportation for the distribution of paperboard between Scandinavia and China
Research execution	Literature review- Academic journals, books, reports, and websites Empirical data- Interviews and company documents
Analysis	Comparative Analysis - Comparing costs, CO_2 emissions & service Sensitivity Analysis - Altering variables and observing its effects on costs Risk Analysis - Potential challenges arising due to the use of rail
Validity	Multiple and credible sources, peer reviewed sources
Reliability	Use of case study protocol and database

3. Literature review

The proposed thesis will be based on the relevant theoretical and mathematical foundation presented in this chapter. Concepts and tools which are helpful for the researchers to fulfil the purpose of the thesis are explained. This section will start by giving an overview of supply chain management and logistics practices. Basic concepts related to physical distribution and transportation modes will be covered. Then, the authors will introduce relevant aspects regarding manufacturing inventory management. The upcoming part will explain what the belt and road initiative is, and how it is changing the possibilities for the transportation of goods between continents. Furthermore, the authors will touch upon the environmental impacts connected to logistics practices. After that, basic concepts of performance measures will be covered, followed by the chosen performance measurements that will be the basis for the problem evaluation. Lastly, the literature review will be concluded with the conceptual model depicting the studied reality.

3.1 Supply chain management

Supply chain management (SCM) can be defined as the integrated planning and management of all the processes and relationships within an organization and between different players of a supply chain network (Mentzer et al., 2001). It is responsible for the management of the upstream and downstream flow of goods and services, information, and finances between three or more organizations (Ballou, 2007), according to Figure 3.1.

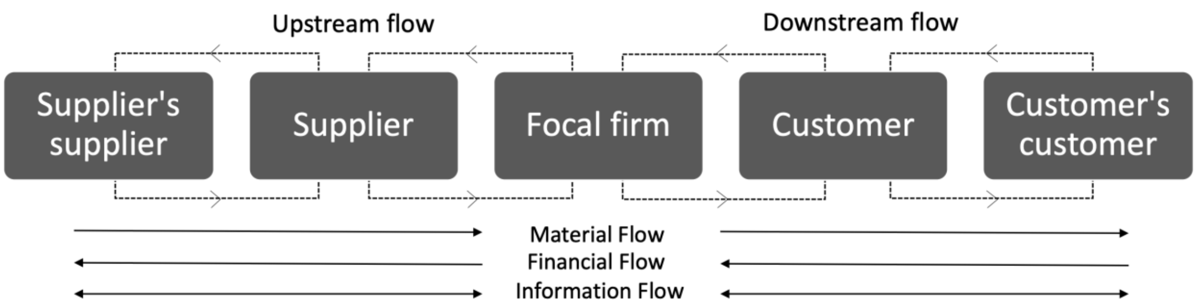

Figure 3.1: Supply chain representation.

The management of the different flows in a SC network happen in three different levels: strategic, tactical and operational. Furthermore, it involves functions like product development, marketing and sales, operation, distribution and service (Chopra and Meindl, 2013). The systems approach of SCM aims to view the supply chain as a whole, instead of treating its members separately. The idea is to avoid fragmented goals and suboptimal overall performance. Therefore, SCM follows a system thinking philosophy focus on collaborative efforts and on the development of a common shared goal among the different members of a supply chain (Mentzer et al., 2001). SCM ultimate goal is to develop efficient processes, minimizing non value-adding costs and activities while enhancing customers satisfaction (Stock, 2009).

The term SCM was first used in the end of the 20th century, as a product of the increasing demand for integration of business processes within a network of activities. Around 1960s, activities within a supply chain used to be treated separately. This mentality led to a very fragmented scenario in relation to the management of logistics activities. Organizations were still lacking coordination within their boundaries, as well as long-term collaboration and among different SC partners (Hou et al., 2015). Companies were increasingly thinking on how to approach organizational activities so that they could improve operational efficiency and effectiveness, at the same time maintain high levels of customer satisfaction (Bozarth and Handfield, 2016). Integration and alignment started to be noticed as key factors for the success of a business. As a result, in the middle of the 1990s the concept of SCM arose with the aim of fully integrating all activities within a supply chain, considering the different levels, functions and partners (Ballou, 2007).

Hou et al. (2015) claims that the evolution SCM was a product of the constant growth in the number of activities and cross-functional integration of the different processes within supply chain network. Figure 3.2 depicts this evolution, exposing the connections among the different fields of logistics and SCM.

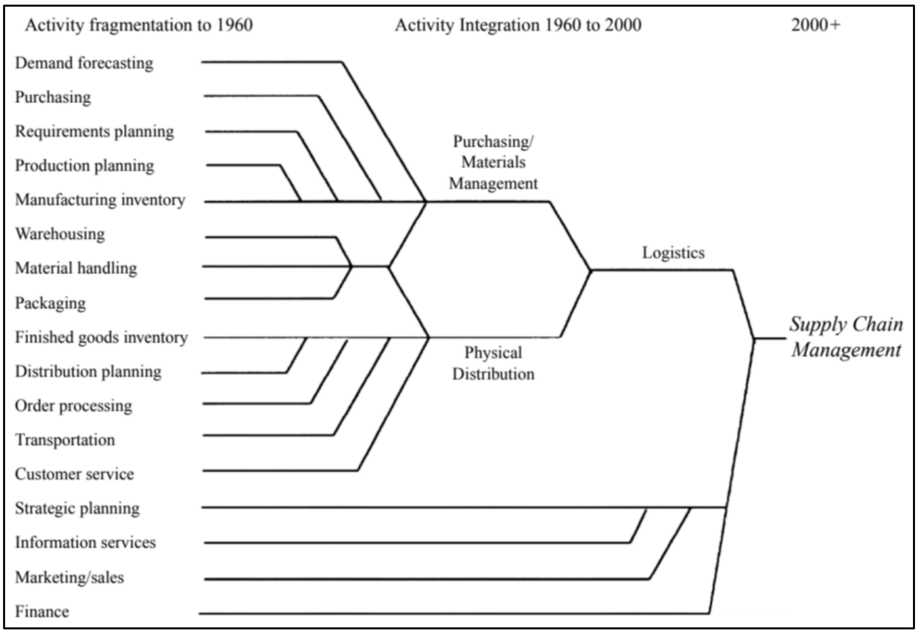

Figure 3.2: Evolution of logistics and supply chain management activities. Source: (Ballou, 2007)

3.2 Logistics

According to the Council of Supply Chain Management Professionals (CSCMP, 2020), logistics can be defined as:

> *"Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses 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."*

The term logistics emerged on the beginning of the 20th century connected to military practices. It encompassed all the activities related to the procurement, maintenance and transportation of people, materials and facilities (Ballou, 2007). As it can be seen from Figure 3.2, in the middle of the 20th century, organizations started to pay attention to the fact that logistics cost represented a big chunk on average business's expenses. For e.g., Heskett et al. (1973), reveals that it reflects15% of the gross national product in the USA. Bozarth and Handfield (2016) also highlight that logistics activities in the USA represents 5% to 35% of total sales costs.

The awareness of the cost impact of logistics activities in a firm's results, led companies to give proper attention to them. Companies started to consider the trade-offs between transportation and inventory costs as an important way to measure financial performance (Hou et al., 2015), which led to the concept of total landed costs. According to Bozarth and Handfield (2016), the landed costs of a product encompass its unit cost, together with all the related logistics cost. Common logistics costs are related to transportation, handling and warehousing activities.

Besides the cost impact, logistics activities also have an important role in other performance measures like delivery, reliability and speed. When making logistics decisions, it is quintessential to understand customers need to avoid making bad investments, such as investing in shortened lead times when customers would prefer reduced prices (Bozarth and Handfield, 2016). Alignment and integration are being seen by logistics practitioners as an essential approach when managing supply chains. The technological advancements are widening the possibilities for integrated system that could improve process visibility and decision making within an organization. By the end of the 20th century, companies are increasingly investing in information systems aiming to improve the efficiency and effectiveness of their processes (Shou et al., 2020).

3.3 Physical distribution

Physical distribution (PD) is the part of logistics that is responsible for the movement and distribution of goods at every step of the supply chain, from the supply of raw materials to the distribution of finished goods to final customers. It also encompasses the development of systems related to these activities (Anderson, 1961). In the beginning of its adoption in the early 1900s, the term was related only to the physical supply of goods to the marketplace, also known as outbound PD. Later, around the 1960s, the activities related to the inbound movement of material, from suppliers to factories were also gradually included in the PD scope (Hou et al., 2015).

The origin of the term PD dates back to the early twentieth century, when nations were trying to solve the issue among the storage and movement of agricultural goods and commodities in general (Hou et al., 2015). For the first time in history, the supply was higher than the demand as a direct reflex of the advancements from the industrialization and the consequent improvement on the efficiency and effectiveness of production and distribution processes (Shaw, 1912). Until the middle of the 19th century, companies did not give much attention to PD, considering it as part of cost accountancy. The priority was the focus on inventory management and stock cost reductions (Ballou, 2007). Only around the 1960s, with the fast-growing US economy, the term started to be recognised as an important factor to consider when managing a certain firm's operations. PD got the proper attention from companies since logistics costs were quite high all over the globe. Researchers started to highlight the importance of viewing PD from a total cost perspective, instead of just considering transportation costs (Lewis et al., 1957). From that point on, the term came to fruition as an important factor for sustainable business success, while its importance spread globally, becoming a priority for companies worldwide (Hou et al., 2015).

PD activities can be divided in three different areas, according to Figure 3.3. Infrastructure activities refers to all technical aspects of PD systems like transportation modes, performance objectives, terminals and cargo handling facilities, including multimodal options. Markets functions are related to the supply and demand of PD, focusing on activities like sourcing, buying behaviour and pricing related matters, as well as the structure and characteristics of PD. Finally, operations deal with the strategic, tactical and operational decision-making activities. It regards to the design and planning of networks, including decisions regarding shipment size and mode selection. For an efficient management of PD activities, it is essential to link them to proper performance objectives. Furthermore, it is important to take into consideration aspects regarding security and risk, sustainability and international trade matters.

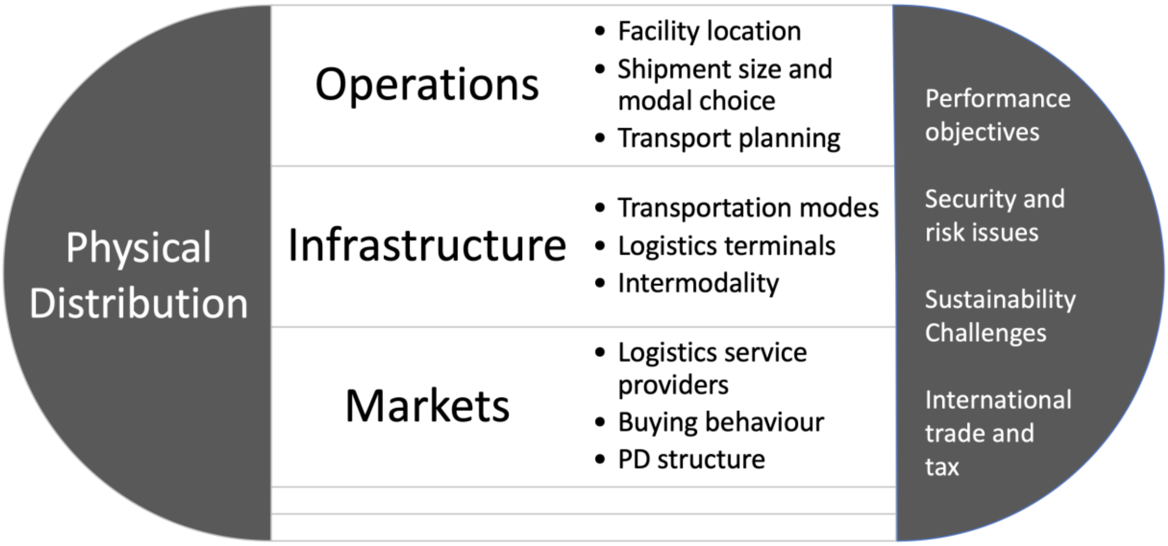

Figure 3.3:Areas of physical distribution. Source: Lund University

3.3.1 Transportation modes

To achieve mobility over long distances, different transportation modes like roadways, railways, maritime transportation and air transportation are used (Rodrigue, 2020). Different modes of transportation have their own benefits and challenges. As mentioned by Ivanov et al. (2019), rail transportation is suitable to carry heavy loads like coal, ore, etc. in a reliable manner over long distances which costs lower than air but higher than sea. Whereas, road transport systems are generally used for short distances to ship a variety of products in limited quantities (less than one ton) in a cost-efficient manner (Lumsden, 2007). On the other hand, maritime transportation is the most economical mode to ship products over long distances but have the lowest speed compared to other modes of transportation (Lumsden, 2007). Furthermore, air transportation is typically used to ensure fast and safe transportation for high value products. As it can be seen, all modes of transportation have several characteristics which make them suitable to be used in certain situations. Figure 3.4 summarises the typical usage, advantages and disadvantages of the four most common transportation models.

Mode of transport	Typical usage	Advantages	Disadvantages
Road	Door-to-door Ideal for mixed cargo. Typically used for first and final leg	Most flexible for door-to-door, cheap	Limited to continental transport Urban congestion Damage to roads
Rail	For domestic, continental and inter-continental transport	Ideal for heavy goods and long distances Environmental-friendly	Connection to rail system required. Complete trains require large volumes (thus low frequency), otherwise handling in yards (low transport speed)
Air	To ensure fast transport	Fast and safe	Expensive Limits for size and weight Typically as part of multi-modal transport
Sea	bulk shipments, where long lead time is ok	Ideal for bulky and heavy goods Highly standardized sea containers worldwide Less costly than air for inter-continental transports	inflexible routes Long lead time Inflexible timetables (ship will not wait for missing container)

Figure 3.4: Transportation modes comparison (source: Ivanov et al., 2019)

3.3.2 Trade-offs in modal choice decisions

An important consideration that must be done in order to efficiently manage operational costs in transportation related decisions, is to evaluate the trade-offs when shipping goods from one point (origin) to another (destination) in a supply chain. Decision regarding which transportation mode to choose is dependent on a variety of quantitative and qualitative factors such as cost, speed, networking, security, availability, reliability, etc. Organizations prioritize them in different ways. (Liberatore and Miller, 1995)

When selecting a mode of transportation, inventory costs must be accounted. A common approach is done by evaluating the trade-offs between the costs of using a particular transport mode with the inventory carrying costs associated with the performance of the selected mode. Transportation modes have different freight rates depending on their service reliability, shipment capacity, transit time and delivery frequency availability. In addition to that, it is important to consider the commodity price, as this will directly influence the tied-up capital of a logistics system, as well as the possibility to reduce costs through the economies of scale (Silberston, 1972). These factors express the trade-offs between transportation and inventory costs when considering different transportation modes. Slower and less reliable services tend to increase inventory levels and its associated costs, while reducing transportation costs, whereas a mode with higher transportation costs can be justified if it results in significantly lower inventory costs. The optimal choice will be the one that delivers the lowest total logistics cost while meeting customer service needs. (McGinnis, 1989)

In addition to the concern with lowering total logistics cost, the evaluation of service quality, or customer responsiveness is also relevant in decision regarding transportation modal choice. (Matear and Gray, 1993) evaluated the inherent foundation of service choice decisions for shippers when selecting between different transport modes. He noticed that frequency, reliability (i.e. on-time deliveries) and capacity (i.e. space availability) are the most important criteria. Furthermore, Rodemann and Templar (2014) as well as Seo et al. (2017) also highlight that transport cost, transit time and transit time reliability are the most important decision criteria when it comes to transportation modal choice for shipments of goods between China and Europe.

This section shows that there are several trade-offs that must be taken into account when choosing a single or a combination of transportation modes for distribution activities in order to optimise logistics operations and avoid unnecessary costs.

3.4 Material Management

Material management is a major supply chain responsibility and encompasses activities related to planning and execution functions. According to the Association for Supply Chain Management (APICS, 2020, p. 34) material management can be defined as:

> *"The grouping of management functions supporting the complete cycle of material flow, from the purchase and internal control of production materials to the planning and control of work in process to the warehousing, shipping, and distribution of the finished product."*

The main goal of material management is to allow a smooth flow of components for production to ensure that goods are available on time to customers. Maintaining a consistent flow of materials to production is a constant challenge. Many factors can be responsible for inventory inaccuracies, which in turn can result in production shortages. It is important to approach material, management efficiently to avoid negative impact on service levels and unnecessary costs for the system (Florén et al., 2018).

The main areas related to material management are demand forecasting, purchasing, requirement planning, production planning and inventory management (Ballou, 2007). This thesis is mainly focused on production planning and inventory management. First the authors will briefly explain some aspects of demand and forecasting, due to their importance to the studied subject. Then, concepts regarding production and inventory management will be discussed.

3.4.1 Demand and environmental uncertainties

According to O'Sullivan and Sheffrin (2007, p. 79), demand can be defined as "*the quantity of a good that consumers are willing and able to purchase at various prices during a given period of time*". Demand can be classified in two distinct groups: deterministic and stochastic. Deterministic demand means that future values are known and can be constant or vary with time (where in this case the variations are known). Deterministic demand is less common in practice. Stochastic demand is more common in real life scenarios and means that demand in not certain, varying with time in a non-certain way. It can be stationary or non-stationary. The stationary type can be defined by probability distributions that are known or derived from historical data. The non-stationary type changes over time, behaving randomly (Ziukov, 2015).

Businesses, in current times face challenges like high customer expectations due to competitive market conditions leading to high demand volatility (Gupta and Maranas, 2003). There are different reasons for uncertainty, like supply shortages, lead times, forecasting practices, order quantity and fluctuations on price (Lee et al., 1997). Failing to address the issue of demand uncertainty, companies could either incur high inventory holding costs or would diminish customer satisfaction (Petkov and Maranas, 1997). According to Subrahmanyam et al. (1994), uncertainties could be categorised based on the timeframe, namely, short-term uncertainties which would arise due to cancelled order, equipment failures and long-term uncertainties like seasonal demand variations. Small demand uncertainties downstream in the supply chain generally tend to amplify when it passes through the different actors, leading to the phenomenon called bullwhip effect (Giard and Sali, 2013), which is illustrated in Figure 3.4. Although bullwhip effect is commonly attributed to lack of information sharing, uncertainty in demand can be the primary cause of it (Dai et al., 2017).

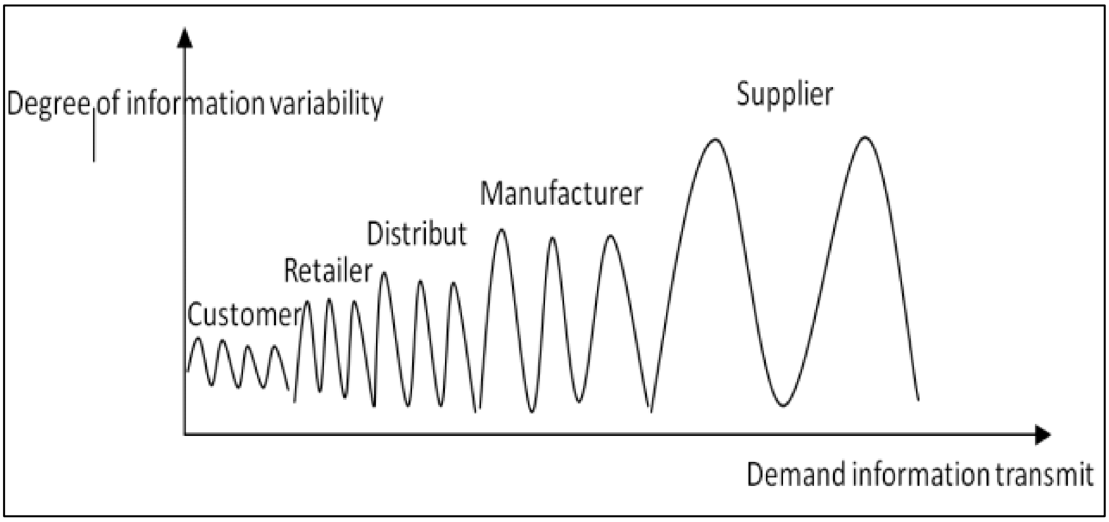

Figure 3.5: Bullwhip effect (source: Dai et al., 2017)

3.4.2 Forecasting

Forecasting is the first step in all production planning systems (Hopp and Spearman, 2012). Its major function is to predetermine the demand coming from a customer during a time period and ensure there exists enough resources to support future demand (Eni et al., 2016). It is important to understand that forecasts do not consider uncertainties in the demand. Hence, it is also important to calculate the forecasts errors, which are represented by standard deviation (Axsäter, 2006). Forecasts uncertainties have a direct impact on the safety stocks, which are to be used up during crisis (Axsäter, 2006).

Hopp and Spearman (2012), indicates forecasting could be approached by either using a qualitative forecasting approach or a quantitative forecasting approach. As the name suggests, qualitative forecasting would develop scenarios based on the expertise of employees whereas a quantitative approach would make use of mathematical model and numerical measures from the past data (Hopp and Spearman, 2012).

3.4.3 Master scheduling

Master scheduling can be regarded as a planning method to track the production output and compare it to the actual production orders. This allows companies to compare the actual demand and production numbers. Master scheduling planning is done once the planning team assigns the overall production and workforce capacities for a large period. Once that is established, master scheduling helps in determining, when will an order specific to the customer be manufactured and take into consideration the available production capacities to fulfill new demand. It is quite possible that the numbers from the overall production and material planning do not match actual capacity and demand. Under such circumstances, companies use up their safety stocks or run the production facilities overtime to cover for the rise in demand. Master scheduling is a tool which allows planning at a high level. Once a high-level plan is established, it is important to go into detailed planning for products which is addressed by Material requirement planning followed below (Bozarth and Handfield, 2016). According to Axsäter (2006), master scheduling for products must include the period between the ordering the raw materials and delivering the products to customer.

3.4.4 Material Requirement Planning (MRP)

Material requirement planning is a detailed planning tool which breaks down master scheduling of orders into the components required to produce the finished product. MRP is used in situations when the inventory is demand dependent or linked to the production of other materials. A basic example to understand the concept of MRP is a regular wooden chair. A wooden chair comprises of five basic items namely, Legs, side rails, seat, crossbars and back slats as shown in Figure 3.6 below. (Bozarth and Handfield, 2016)

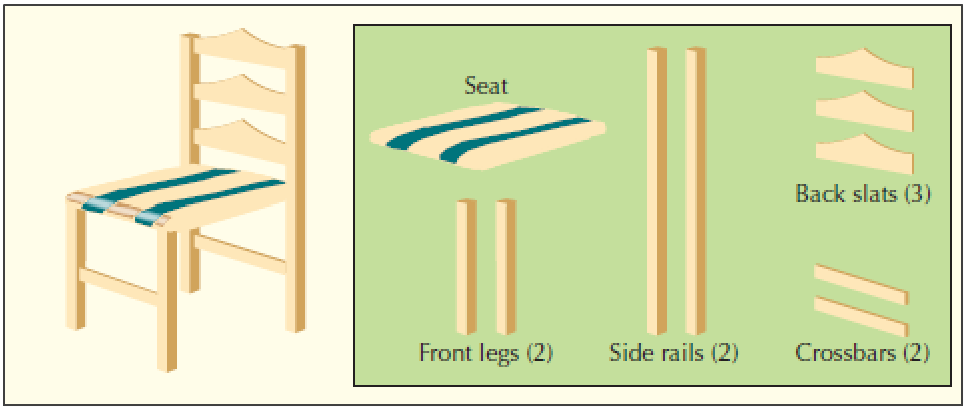

Figure 3.6: Basic components of a chair (source: Bozarth and Handfield, 2016)

In this example the demand for components that are required to manufacture a chair is completely dependent on the demand for chairs. In situations of dependent demand, MRP is an ideal tool for detailed planning (Bozarth and Handfield, 2016).

According to Axsäter (2006), MRP is based on the following data coming from Master scheduling, external demands, bill of materials, inventory status of items, constant lead times and safety stock rules followed. Bill of materials (BOM) is a list of subassemblies or parts along with the number needed to make the finished product (Bozarth and Handfield, 2016). The definition given by the Association of Supply Chain Management (ASCM) says that *"the bill of material (BOM) is the document that specifies the components needed to produce a good or service. It lists the parts, raw materials, sub-assemblies, and intermediates required by a parent assembly. A BOM specifies the quantity required to make one item, specifies units of measure, and quantifies phase-in and phase-out dating."* (APICS, 2020)

Bozarth and Handfield (2016), suggest that an advantage of MRP is that it has a direct relation to the master production schedule which specifies the quantity of the raw materials and the time when it is required. This reduces the speculation while managing demand dependent inventory at the same time lowers the inventory levels. While planning using the MRP method, the lot sizes or the order quantity are generally fixed which is also known as the minimum order quantity (MOQ). MOQ as the name suggests is lowest number of units that a supplier would ship to its customers in order to achieve economies of scale. The MOQ is generally fixed by the supplier and depending on the inventory levels, customer can order an integer multiple of the MOQ. (Bozarth and Handfield, 2016)

3.5 Inventory management

According to the ASCM, inventory can be defined as *"those stocks or items used to support production (raw materials and work-in-process items), supporting activities (maintenance, repair, and operating supplies) and customer service (finished goods and spare parts)."* (APICS, 2020). Certain types of business have conditions that force firms to hold inventories (Bozarth and Handfield, 2016).

Inventory management is related to decisions regarding how often a firm should check their inventory levels, at which inventory level the replenishment order should be made and how much to order on replenishment (Silver, 2008). These decisions are influenced by factors like costs, demand pattern, transportation modes and delivery methods. Furthermore, some constraints should be considered like service levels, budget restrictions and vendor limitations (Axsäter, 2006).

3.5.1 Periodic review system

A periodic review system is an approach to inventory management characterized by having regular time periods to check inventory levels. The pictorial representation of the system is shown in Figure 3.7. With this system, replenishment orders are made within every replenishment period of which the stock levels reach a certain pre-determined reorder point. Orders are based on multiples of the MOQ, aiming to reach stock levels close to the restocking level. (Bozarth and Handfield, 2016)

$$Q = R - I \tag{3.1}$$

Where:

Q The quantity that will be ordered (n times MOQ)

R The desired replenishment level

I Inventory on hand

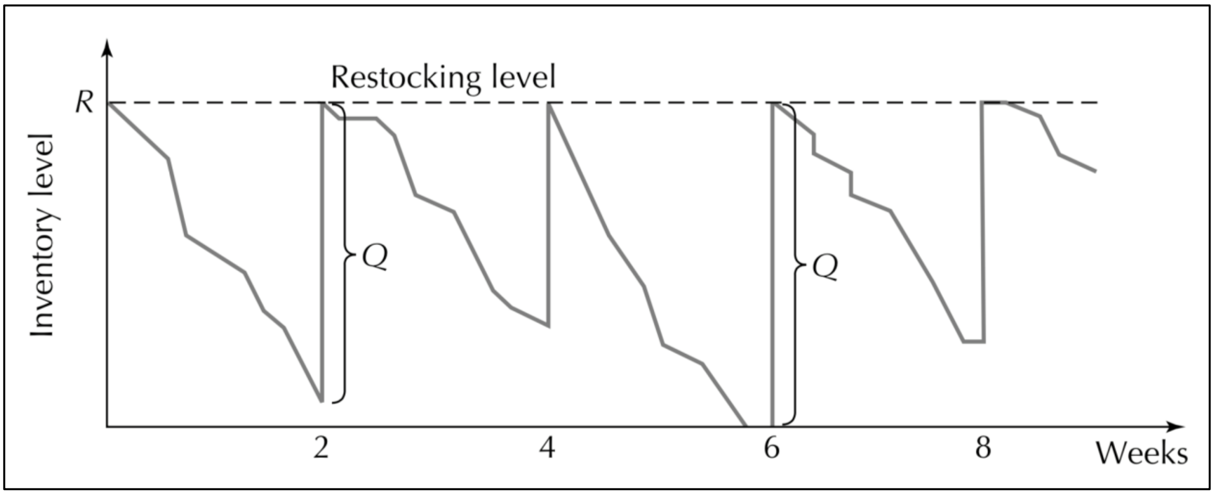

Figure 3.7: Periodic review system (source: Bozarth and Handfield, 2016)

3.5.2 The function and types of inventory

In the context of manufacturing systems, inventory is defined as goods and materials that organizations holds in order to satisfy customers' needs in the most efficient way. The main reason for holding inventories is to make sure that production processes function efficiently without disruptions due to shortages of materials. Customer relationship and cost are the main factors in decisions regarding how much inventory to hold. It is essential to not overstock products and materials because it can cause unnecessary cost of capital or need of space. Furthermore, excessive inventory has the potential to hide problems within an organization production processes. Japanese manufacturing companies created a philosophy aiming to minimize inventory levels in order to visualize hidden problems. It is called "the Japanese Sea" and is depicted in Figure 3.8. (Lumsden, 2007)

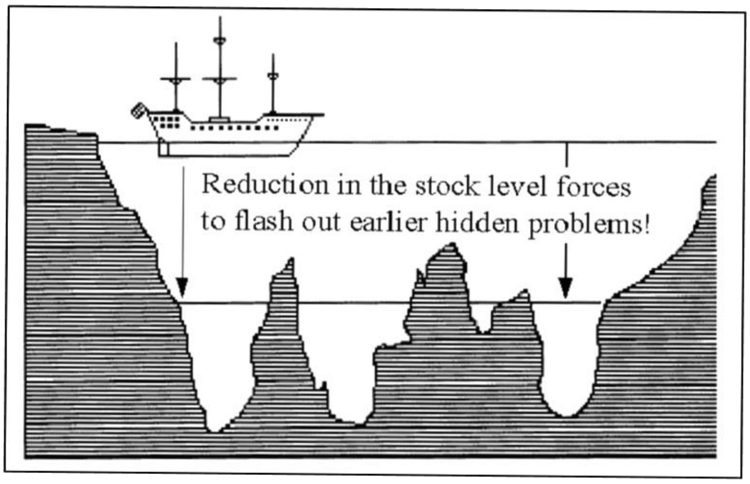

Figure 3.8: The Japanese Sea (source: Lumsden, 2007)

Inventory can be classified in different ways. Inventories can be classified according to processes, functions or flows (Lumsden, 2007). The different classifications of inventory within each different standpoint are presented in Table 3.1. The process standpoint looks at inventories aiming to secure manufacturing processes, without the emergence of disruptions. The functions classification evaluates the different functions of inventories, regarding internal conditions that a firm can control as well as uncontrollable environmental factors. When looking at flows, firms approach inventories according to the different flows of material, considering the flows before, within and after manufacturing processes. (Lumsden, 2007)

Table 3.1: Different inventory classifications (source: Lumsden, 2007)

Inventory management standpoint	Inventory classifications
Processes	Storages, component inventory, consumption material, work in progress
Functions	Cycle stock, safety stock, process stock, smoothing stock, market stock, speculation stock, coordination stock
Flows	Buffer, process, transportation

Bozarth and Handfield (2016), stresses that the most common types of inventory are cycle stock and safety stock. Figure 3.9 depicts a basic inventory system composed of replenishment cycles and a safety stock. The sawtooth pattern is a result of demand being consumed gradually and the inventory being replenished when the stock levels reach the safety stock, which should be used just in case of uncertainties. (Bozarth and Handfield, 2016)

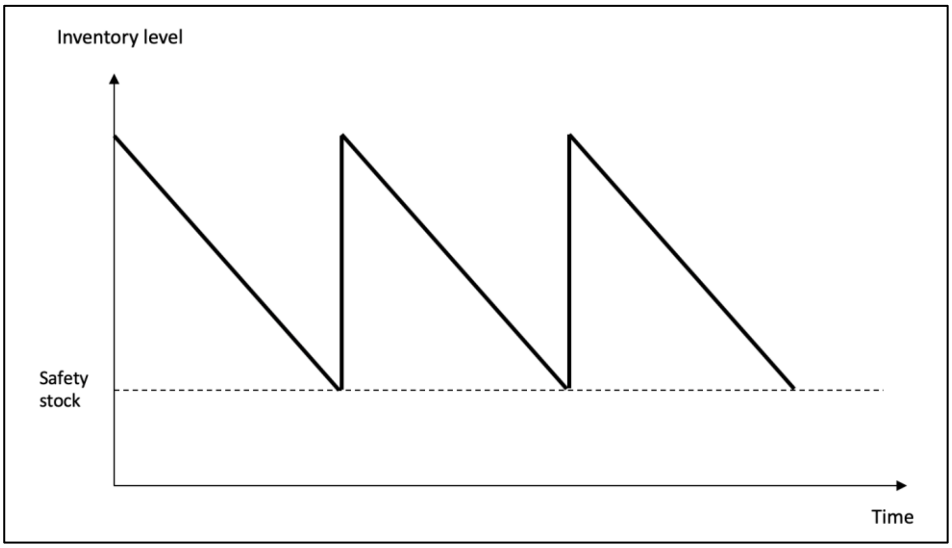

Figure 3.9: Inventory system with safety stock (source: Bozarth and Handfield, 2016)

Another inventory type that must be addressed in case of long physical distances and transportation times is the in-transit stock. It can be defined as the amount of materials or products that are moving from one point in a supply chain network to another. Goods "in transit" can represent considerable amount of tied-up capital, which can restrict other investment possibilities. (Bozarth and Handfield, 2016)

Cycle stock

Cycle stock relates to goods that are received in batches by a downstream partner. These goods are consumed gradually until the inventory level reaches certain point where another batch must be ordered to replenish the stock and avoid stockouts (Bozarth and Handfield, 2016). It varies as a function of the demand rate and is replenished during replenishment cycles when the inventory level reaches a certain pre-determined reorder point. It is normally assumed that the average cycle stock is half of the demand during replenishment intervals. For that to be accurate, demand rate should be constant (Bozarth and Handfield, 2016). In general cases, the average stock on hand in a time period can be represented as the area under the stock level curve over time. A more generic approach can be taken by dividing the total demand for the number of orders during a time period, which gives the average order size. The average cycle stock is half of the average order size and can be expressed as:

$$Average\ cycle\ stock = \frac{1}{2} * \frac{d}{r} \tag{3.2}$$

Where,

d demand per unit and time unit
r frequency of orders per time unit

Service level and safety stock

Service level is a measurement used to specify the desired amount of demand that will be satisfied in situations with environmental uncertainties (Bozarth and Handfield, 2016). The service level can be defined in different ways and is normally the measure used for the definition of reorder points and safety stocks (Axsäter, 2006). In this thesis, the authors are going to consider the definition of service level defined by the focused company, which is the probability of no stockouts during an order cycle.

Safety stock (SS) refers to a level of extra inventory that is needed in order to mitigate risk of stockouts that are normally caused by uncertainties in supply and demand. According to Bozarth and Handfield (2016), the uncertainties force organizations to keep more inventory than what is needed to cover the demand during the lead-time. It increases the inventory level where companies usually place orders, in order to secure that new order will arrive before the stock runs out of items. Adequate SS levels allow business operations to work according to their plans (Bozarth and Handfield, 2016). For normal distributed demand, SS calculation can be expressed as:

$$SS = Z * \sqrt{LT * \sigma_d^2 + FC^2 * \sigma_{LT}^2} \tag{3.3}$$

Where,

Z safety factor connected to the desired service level
LT supply lead-time
d demand per time unit
σ_d standard deviation of demand
σ_{LT} standard deviation of lead-time
FC Forecast of demand

In-transit stock

As discussed previously, in-transit stock represents the amount of time items are held in transportation when a supplier ships goods to a customer. In cases where the transit time is long, the goods in transit can represent a substantial amount of tied up capital (Bozarth and Handfield, 2016). The smaller the time goods stay in transit, smaller is the tied-up capital reserved to hold goods while in transit. Less tied up capital represents better cash flow and opportunities for other investments (Bozarth and Handfield, 2016). The calculation is done by multiplying the total demand per time unit by the fraction of time the demand stays in transit, as expressed bellow:

$$In\ transit\ stock\ cost = d * t \tag{3.4}$$

Where:

d demand per unit and time unit
t time units in transit

3.6 Belt and road initiative

The trend of economic globalization and liberalization has been growing rapidly over the past decades. Within this reality, China has turned out to be the largest producer and trade entity of the world (Sun and Xie, 2019). This was the result of a country with the potential to support global demand, opening its border to the world. With China's recent interest to emerge as an economic leader, it plans to go one step further with the proposal of Belt and Road Initiative (BRI) to make trade between countries and continents viable. According to (OECD, 2018) report, there is a huge infrastructural void, for global trade to be benefited and BRI has the potential to fill this gap. This initiative would also develop economic cooperation while flourishing the Euro - Asia region and its markets (Clarke, 2017 and Huang, 2016).

3.6.1 Routes in BRI

China plans to invest heavily in order to support the project while enhancing connectivity and integrating between the countries under the region at the same time sustain its own economic growth (Huang, 2016). Reports suggest that investments of US $ 1 trillion and over would be put aside by China to construct roads, railway lines, ports and pipelines to develop the infrastructure required to ensure connectivity (Molavi, 2018). According to ADB (2017), approximately one third of the investment would be used to develop transportation infrastructure only in Asia as shown in Figure 3.10. This indicates the lack of infrastructure which hinders physical distribution of goods across international borders. BRI plans to link China with Europe through Asia, particularly central and west Asian countries while the other would connect China and Southeast Asian countries Africa and Europe (Rolland, 2017).

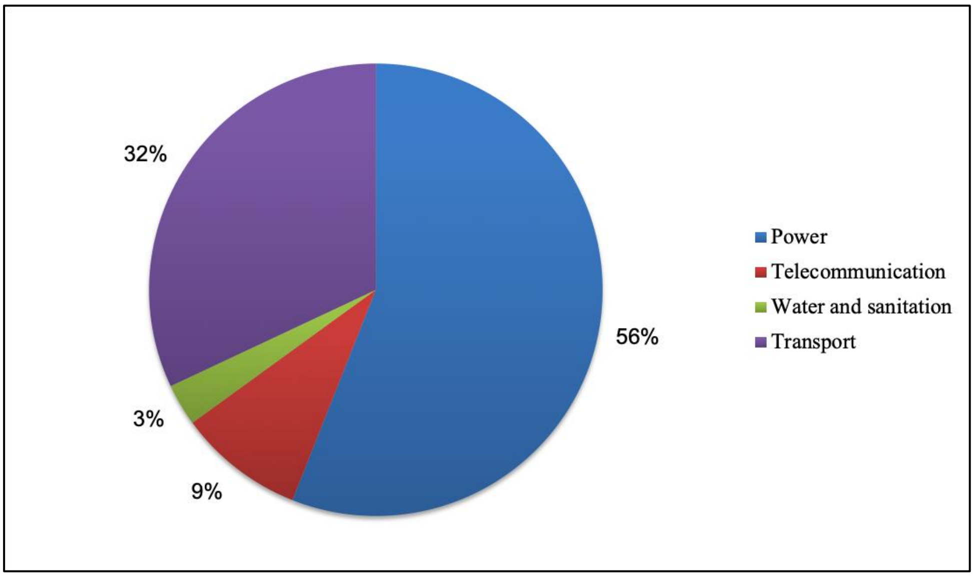

Figure 3.10: Infrastructure investment needs in Asia by sector (source: ADB, 2017)

Initially, 64 economies were to be a part of the program but since then the numbers have increased with major emerging economies being a part of the initiative, increasing the number to 72 (OECD, 2018). These 72 economies have been grouped into different regions which have been termed as economic corridors. Each economic corridor consists of the countries that will be linked to each other. Since this initiative originates from China, it will be linked to all six economic corridors. The six economic corridors are:

- New Eurasia Land Bridge
- China, Russia, Mongolia economic corridor
- China, Central Asia, West Asia economic corridor
- China Indochina Peninsula economic corridor
- China Pakistan economic corridor
- China, Bangladesh, India, Myanmar economic corridor

Table 3.3 below shows the countries included in each of the economic corridor.

Table 3.2: Economic corridors and the countries included (source: OECD, 2018)

Economic Corridor	Countries included
New Eurasia Land Bridge	Czech Republic, Hungary, Slovak Republic, Slovenia, Poland, Kazakhstan, Ukraine

China-Russia-Mongolia	Belarus, Estonia, Latvia, Lithuania, Mongolia, Russian Federation
Bangladesh-China-India-Myanmar	Bangladesh, Myanmar, India, Sri Lanka, Nepal, Bhutan
China-Pakistan	Afghanistan, Pakistan, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen
China-Indochina Peninsula	Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Malaysia, Philippines, Singapore, Thailand, Timor-Leste, Vietnam
China-Central West Asia	Albania, Armenia, Azerbaijan. Bosnia and Herzegovina, Bulgaria, Croatia, Georgia, Islamic Republic of Iran, Iraq, Israel, Jordan, Kyrgyzstan, Lebanon, Former Yugoslav Republic of Macedonia, Republic of Moldova, Montenegro, Palestinian Authority or West Bank and Gaza Strip, Romania, Serbia, Syrian Arab Republic, Tajikistan, Turkey, Turkmenistan, Uzbekistan.

From the six economic corridors, this project will focus on only the New Eurasia Land Bridge as mentioned in the delimitation section in the introduction.

3.6.2 New Eurasian Land Bridge

The Land Bridge was in existence since ancient times (Pomfret, 2019). In order to utilize this route to the fullest, shippers, national rail companies, freight forwarders, service providers played a major role which led to reduced costs, generating additional customers and making service innovations possible (Pomfret, 2019). Figure 3.11 below represents the route for the New Eurasian Land Bridge.

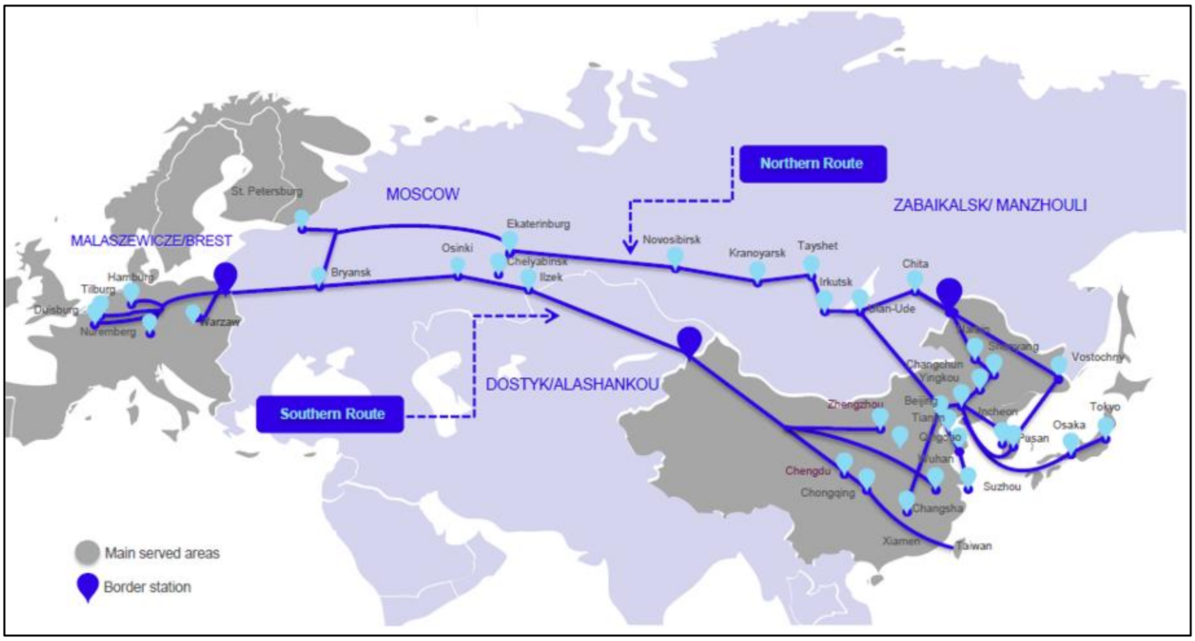

Figure 3.11: New Eurasian Land Bridge corridor (source: Geodis)

An economic concept that is important to consider while analysing shipping from Scandinavia to China is the trade balance. According to FocusEconomics (2020) "*Trade balance is the net sum of country's exports and imports of goods without taking into account all financial transfers, investments and other financial components.*" If the exports of a nation are less than the imports there exists a trade deficit and if the exports are more than the imports it leads to a trade surplus (Piana, 2006). China being the largest producer of goods in the world, recorded a surplus of USD 47.2 billion in December 2019 (China Trade Balance [1981 - 2020] [Data & Charts], 2020). Trade balance is generally broken down by product and by country.

In 2017, 71.8 billion SEK worth of goods and services was imported by Sweden to China and only 2.61 billion SEK was exported to China (Sweden Aborad, 2017). This shows that there exists a trade imbalance between the two countries.

3.6.3 Challenges

For numerous countries in the world, railways are an important part of the economic system, allowing the growth of trade and commerce (Kandel Catalano et al., 2018). In the year 2012, the rail sector contributed 1.1% to the European Union's economy (Molemaker and Pauer, 2014). Rail transportation is economically feasible while transporting goods which are low in value but high in volume over long distances (Lumsden, 2007). Freight transport through rail can be a valid substitute for road transport due to better features like capacity, safety standards and carbon footprint (Kandel Catalano et al., 2018). As it can be seen from Figure 3.12, rail freight per annum (p.a.), has shown a swift growth along the ancient silk road for trains going from China to Europe or west bound (WB) and from Europe to China or east bound (EB).

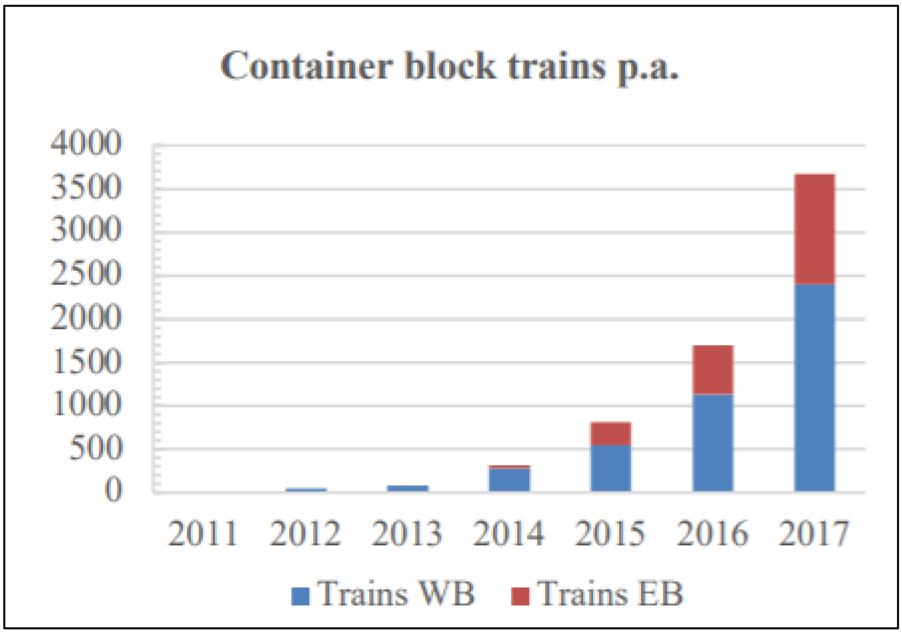

Figure 3.12: China-Europe rail freight per annum (source: CRCT, 2018)

When compared to air freight, rail freight tends to have lower cost and when compared to ocean freight, rail reduces the transport times by half (Kuester, 2017; Seo et al., 2017 and Davies, 2017). Rail freight is being considered as a feasible option by companies due to its speed and cost advantages. On the other hand, rail freight faces several challenges (Zhang and Schramm, 2018). Challenges could include technical limitations, complex legal environment, capacity limitations and political issues as shown in Table 3.3 (Islam et al., 2013).

Table 3.3: Challenges in Eurasian rail

Challenges	
Complex Legal environment	Different countries have different custom laws and border crossing procedures leading to higher transit times. (Zhang and Schramm, 2018)
Technical limitations	Countries involved in Eurasian rail freight do not have a standard railway technology like

	the broad-gauge or standard-gauge systems. (Zhang and Schramm, 2018)
Physical constraints	Trains in China ship 55 to 75 containers on a single train whereas that number decreases to 44 containers in Europe. Extreme weather conditions in some countries could be a challenge while transporting temperature sensitive products. (Zhang and Schramm, 2018)
Imbalanced cargo volume	The volume of trains going from China to Europe is three times higher than volume from Europe to China which results in shipping empty wagons for east bound trains. (Jakóbowski et al., 2018)

For goods which are time sensitive and have low cargo value, the use of rail freight for long haul transportation is an ideal alternative to air freight (Zhang and Schramm, 2018). Rail transportation cannot be viewed as a competitor in terms of the cost or the speed but as a substitute which provides a balance between them (Davies, 2017). While selecting a mode for shipping goods, transit time is given a higher weightage than costs (Matear and Gray, 1993). This is because longer lead times would incur higher inventory holding and depreciation costs leading to an increase in the total logistics, but Eurasian rail freight can help in optimising cost, efficiency and responsiveness to serve customers (Zhang and Schramm, 2018).

3.7 Environmental impact of logistics

The past decade has seen a rise in sustainable practises not only due to the legislative reasons but also due to the rising demand by customers for it (Govindan et al., 2013). The increase in awareness is because, there has been a rapid depletion of natural resources and the ever-increasing gap of wealth which cannot be overlooked (Govindan et al., 2013). The increase in the consumption habits by the customers has led to companies producing and shipping more products. This is another reason which has led to an increase in carbon emissions which is released during the distribution activities like logistics which has a significant impact on the environment (Chin et al., 2015; Gruner and Power, 2017 and Khan et al., 2020). Organisations especially the ones, which have global supply chains, have included sustainability practices in their strategic goals (Ageron et al., 2011). This motivates them to implement solutions that will support environmental conservation and social prosperity (Shokri Kahi et al., 2017).

The different modes of transportation use fossil-based fuels which are not only non-renewable source of energy but emit greenhouse gases like CO_2, CH_4, etc, which causes global warming (Abukhader and Jönson, 2004). A report by the World Economic Forum in 2016 claimed that 13% of the world's carbon emission was produced due to the logistics activities. These logistics activities included the carbon emissions generated from the different modes of transportations and the infrastructure like terminals and ports required to support them (Onghena et al., 2014). Currently there does not exist any globally accepted standard to calculate carbon footprint (Kellner and Schneiderbauer, 2018). For logistics, environmental sustainability is generally measured based on the carbon footprint (Montoya-Torres et al., 2014).

Wiedmann and Minx (2008, p. 4), suggest a definition for carbon footprint as "*The carbon footprint is the measure of the exclusive total amount of carbon dioxide emissions that is directly or indirectly caused by an activity or is accumulated over a life stages of a product*." To calculate carbon footprint, academic literature suggests three methods: Input Output analysis, Life cycle assessment and hybrid, which combine input output and life cycle assessment (Ruzevicius and Dapkus, 2018). As shown in Figure 3.13 the method to analyse the carbon footprint will be dependent on the object which could be a single product, an organisation or a global supply chain.

Object	Global	Country	City	Organisation	Consumer	Products
Scope	Large Scale	⟷				Small Scale
Method	Input Output			Hybrid		Life Cycle Analysis

Figure 3.13: Objects and methods to analyse carbon footprint (source: Gao et al., 2013; Peters, 2010)

As the proposed study focuses on the transportation mode between two countries, which can be considered a large-scale scope, it would be ideal to use Input and Output analysis for calculating carbon footprint for different modes of transportation.

There exist several input output calculation tools for companies to calculate the carbon footprint based on their needs (Montoya-Torres et al., 2014). One such tool is the 'GHG Emissions from Transport or mobile sources' developed by the Greenhouse Gas Protocol.

Greenhouse gas (GHG) Protocol is an organisation that develops comprehensive global standard framework to measure and manage greenhouse gas emissions from public or private sector and value chains (Ghgprotocol.org, 2020). It also offers standard tools built on the GHG protocol to calculate carbon footprint which are used by companies in various industries and countries like India, Brazil and Mexico to name a few (Ghgprotocol.org, 2020). The tools developed by GHG protocol could be country specific, sector specific and cross sector tools. The GHG emissions from transport or mobile sources tool is used to calculate indirect sources of carbon emissions (Ghgprotocol.org, 2020).

3.8 Supply chain visibility

According to Goh et al. (2009, p. 2549), can be defined as "*Supply chain visibility is the capability of a supply chain player to have access to or to provide the required timely information/ knowledge about entities involved in the supply chain partners from/ to relevant supply chain partners for better decision support*". Supply chain visibility (SCV) is an important aspect in today's time, especially when companies tend to have suppliers and customers located globally. In order to serve their customers better and be responsive to market demands, SCV is of key importance. The subsections below, explain about the reasons and enablers of SCV and further go on to mentioning the challenges of the available technologies currently used.

3.8.1 Reasons

For global supply chains to run their operations efficiently, accessibility of relevant information is important (Papert et al., 2016). This information should be mutually beneficial to majority of the actors in the supply chain (Barratt and Oke, 2007). Accurate information of the supply chain such as customer demands and shipment location help to improve the operations. Some examples are performance of delivery, forecasts accuracy, production planning for the different actors in the supply chain (Somapa et al., 2018). According to Papert et al., (2016), supply chain visibility can aid firms in establishing an overview of material flow, especially when they have a global supply chain. Furthermore, having end to end visibility, which refers to the information sharing from the first-tier supplier to the end consumers, results in improved customer service. This is done by being responsive and at the same time reducing potential disruptions occurring within the supply chain (Wei and Wang, 2010 and KPMG, 2016).

Another reason to address SCV is the prevention of bullwhip effect occurring in the supply chain, which is attributed to lack of information sharing between the actors (Dai et al., 2017). Also, in recent times, outsourcing, emergence of production facilities in low cost countries and the presence of customers in multiple countries has made supply chains more complex than ever (Yan et al., 2012). Supply chain visibility in such cases can be of high importance to evaluate the performance and develop valuable knowledge of the suppliers (Swift et al., 2019). This shows that visibility of information between different actors in a supply chain offers various advantages to a firm. SCV in this study will be focusing more on the shipment tracking. For that reason, the enablers for tracking shipments and the challenges associated to it are explained below.

3.8.2 Enablers

As discussed above, information sharing is critical to ensuring SCV. To share information across supply chain, the use of identification technologies and information technologies is essential (Kärkkäinen et al., 2003). At the same time, the information systems used in companies need to be compatible with the information system that will allow electronic data interchange. Hence, these systems can be viewed as enablers of SCV which collect and share information. According to Lempert and Pflaum (2011), the function of identification technologies depending on their capabilities could include:

1. Identification of shipments
2. Locating shipments
3. Sensors
4. Communication
5. Data storage
6. Logic

Another enabler of ensuring SCV is the costs associated to develop and implement the software systems used to monitor shipment visibility (Roos et al., 2005). These tracking systems require significant investments that transfer information quickly and accurately which improve the process flows and provide visibility throughout supply chains (Coronado Mondragon et al., 2012). Therefore, cost and technological requirements/ capabilities are the enablers identified by research.

3.8.3 Current Tracking Technologies

According to Kandel et al. (2011), tracking solution provided by logistics service providers can be classified into two categories, known as discrete tracking and continuous tracking. In order to track shipments using the discrete tracking systems, it is important that the supply chain infrastructure is equipped with devices that can detect and read information. Examples of discrete tracking systems are Radio frequency identification (RFID) and barcodes. Both these technologies need devices that can scan the barcode or RFID and provide information regarding the freight at the point where it is scanned. Whereas, continuous tracking technologies can provide shipment information at any point in time by identifying its current position without the use of any device. A common technology used in continuous tracking system is the use of Global Positioning System (GPS). With the use of GPS, the exact position of the shipment can be identified continuously by transmitting the GPS signals. GPS requires connection to a minimum of four satellites in order to determine the exact location which sometimes is a challenge where network connectivity is an issue (He et al., 2009). Figure 3.14 below shows the categorization of tracking solutions available.

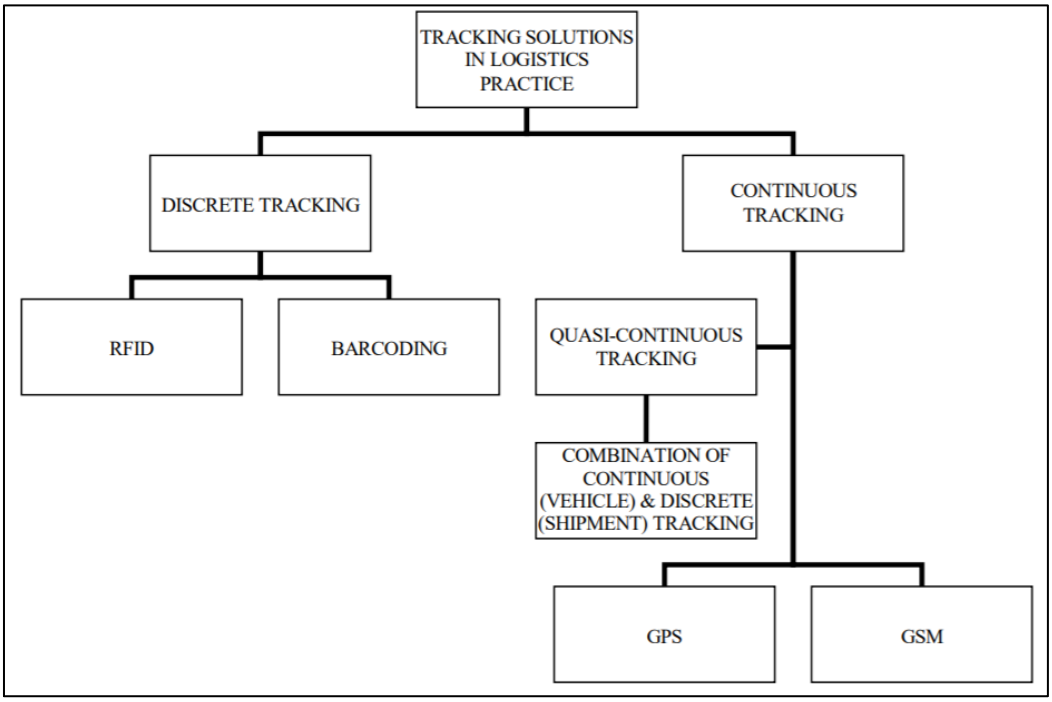

Figure 3.14: Categorization of tracking solutions (source: Kandel et al., 2011)

This study would be based on continuous tracking system, provided by the freight forwarders and hence, the challenges related to it are addressed below.

3.8.4 Challenges

The tracking systems are like a double-edged sword which offer several benefits but also come with some challenges. Challenges could include the requirement of hardware devices to update the status of the shipment in case of discrete tracking systems or increased cost of shipping while equipping containers with GPS (Kandel et al., 2011). Another difficulty related to GPS systems is the requirement of having clear view of the skies to function. Hence, if the GPS devices are placed on outer walls of the containers and stacked with other containers on a ship it would be difficult to send out signals, especially which are placed between containers (Ray, 2018). This is a huge disadvantage considering the investments that will be put into the implementation of GPS tracking systems. Furthermore, operating a GPS based tracking device, needs a power source like battery which has the potential to consume the energy within days if used continuously (Ray, 2018 and Kandel, et al., 2011). Another criticism that GPS faces is the lack of accuracy in instances when the GPS is not connected to four or more satellites which affects the real time visibility of shipments (Kandel et al., 2011). These points will be considered during the analysis phase, while choosing a transportation mode considering SCV is an important aspect at Tetra Pak.

3.9 Supply chain and logistics performance

The current business reality is characterized by a dynamic, fast changing environment, which is a direct product of the exponential growth of technological advancements and the crescent globalization. This increased competition is changing customers behaviour, which are becoming more demanding. Customers are asking for customised products and are not willing to wait for it. Furthermore, they are becoming more aware of environmental impacts caused by the business industry, which also must be taken into consideration when drawing the strategies of a certain business. Therefore, it is essential that organizations maintain their competitive advantages to keep differentiating themselves from the competition (Ballou, 2007). In order to allow that, it is important to keep track of an organization's performance against itself and their competitors, which is done using performance measurements. This topic will be discussed in the upcoming section.

3.9.1 Performance measurements

Performance measurements (PMS) can be defined as the action of analysing information to compare a firm's current performance to a desired outcome. It is an essential part of business as they are directly related to the so important planning and control activities. Neely (1999, p. 205) stresses that there are seven main reasons for the utilization of PMS namely "*the changing nature of work; increasing competition; specific improvement initiatives; national and international quality awards; changing organizational roles; changing external demands; and the power of information technology*". Undoubtedly, the use of PMS allows a company to make internal and external comparison to check if they are on the right track or if changes need to be made (Neely, 1999).

Traditionally, companies adopted only financial measurements, considering that they are the main drivers to reduce costs and increase profit. Many authors consider this as a limited and problematic approach. (Eccles, 1991) highlights that financial focus often leads to avoidance on investments in innovation due to the short-term vision of keeping all costs low. Banks and Wheelwright (1979), argues that this mindset stimulates firefighting actions focus on the short term instead on solid long-term measures. Kaplan and Norton (1992), criticise it because it does not focus on customers' needs and it lacks the ability to make comparisons with competitors. Goldratt and Cox (1986) argues that focusing only on financial measures refrain companies to reach the best possible performance due to their focus on local optimisations. Finally, information regarding quality, flexibility and responsiveness are not taken into consideration with financial measurements, which directly compromise a proper strategic focus (Skinner, 1974).

By the end of the twenty first century, a major shift in the way companies develop their competitive advantages start to emerge. Kaplan and Norton (1992), highlights that it became more advantageous for companies to focus on the intangible assets as the main source of achieving competitive advantage. Eccles (1991), expresses the importance of embracing a broader set of measures related to quality, market share, service, flexibility and responsiveness as equally important to a sustainable success of an organization. The author says it is fundamental to encompass internal process and quality measures as well as external measures focus on the customers and business environment in general. This is especially important on the present moment, considering that the 21st century is being characterized by a highly dynamic environment with intense competition. Companies are fighting for resources and being pressured to find new ways to maintain competitive advantage (Shou et al., 2020).

3.9.2 Balanced Scorecard

Kaplan and Norton (1992) introduced the idea of Balanced Scorecard (BSC) to overcome the mentality of focusing only on financial measures. The authors attempt was to highlight the importance of linking PM to a firm's strategy. The approach involves measures from four different perspectives: financial, customer service, internal business and innovation/ learning. The author stresses that even non-financial measurements seldomly provide immediate impact on revenue or profit, they can have a long-term impact through a chain of cause and effect relationships. The integration of the different perspectives allows an organization to look ahead, promoting long term value creation. Below, the authors briefly highlight some aspects of the four dimensions on the BSC:

- **Financial**: It is responsible for the connection between the company and its shareholders. They evaluate the long and short-term performance of tangible assets like the investment on inventory, equipment, property, etc. Financial measures can be found in balance sheets and income statements, which exposes revenues, assets, expenses and profit. It can be used to measure the performance of previous investments and organizational strategies.
- **Customer service**: It focuses on how customers perceive the company. It is directly related to the customers' perception derived from reaching the strategic goals of the operations. It is possible to measure the number of customers, satisfaction and loyalty, as well as market share.

- **Internal business**: looks internally to what processes a company should prioritize and excel on, in order to reach financial and customer service goals. All internal activities can be analysed in order to define critical factors for business success.
- **Innovation/ learning:** It aims to develop a proper environment that can support changes, growth and innovation. It is also related to the improvement of employees' life quality in the organization. With the adequate attention and investment, employees can feel motivated and learn. Therefore, leading to contribution to the continuous improvements and value creation inside a firm.

Kaplan and Norton (1992) argue that this approach changes the way companies perform actions. It allows firms to shift from a behavioural control approach towards focusing on strategic measuring, aligning people with the overall vision of the company. Lu et al. (2016) also highlights the flexibility gained by the company when integrating different measures, which in turn, tends to increase the overall competitiveness of certain firm. Table 3.4 shows some examples of performance indicator for each different dimension in the BSC.

Table 3.4: Performance indicators for different dimensions

Dimension	Focus	Performance indicator
Financial	Sales growth	% increase on goods sales
	Cost reduction	% reduction of unit cost of goods
Customer service	Customer satisfaction	% points increase in satisfaction surveys
	Increase # of customers	# rate of new customer over existing ones
Internal business	Quality improvement	% decrease on number of defected goods
	Process productivity	% decrease in production time for a product
Innovation/ learning	Employee satisfaction	% points increase in employee satisfaction
	Increase skills of employees	training hours per employee

3.10 Conceptual model

Using the above concepts which are relevant to the research questions and purpose of the thesis, the authors have developed a conceptual model shown in Figure 3.15 below. This is done to help the readers visually understand the relevant logistics topics related to the proposed study, as well as the context which is BRI under which the performance measures are being analysed. The figure below shows the variables like product value, delivery speed and cost of transportation to name a few that will be considered for analysing the different performance measures of economic, customer service and environment. It also presents the flow of paperboard from the supplier in Sweden to China and the mode of transport it will use to ship them.

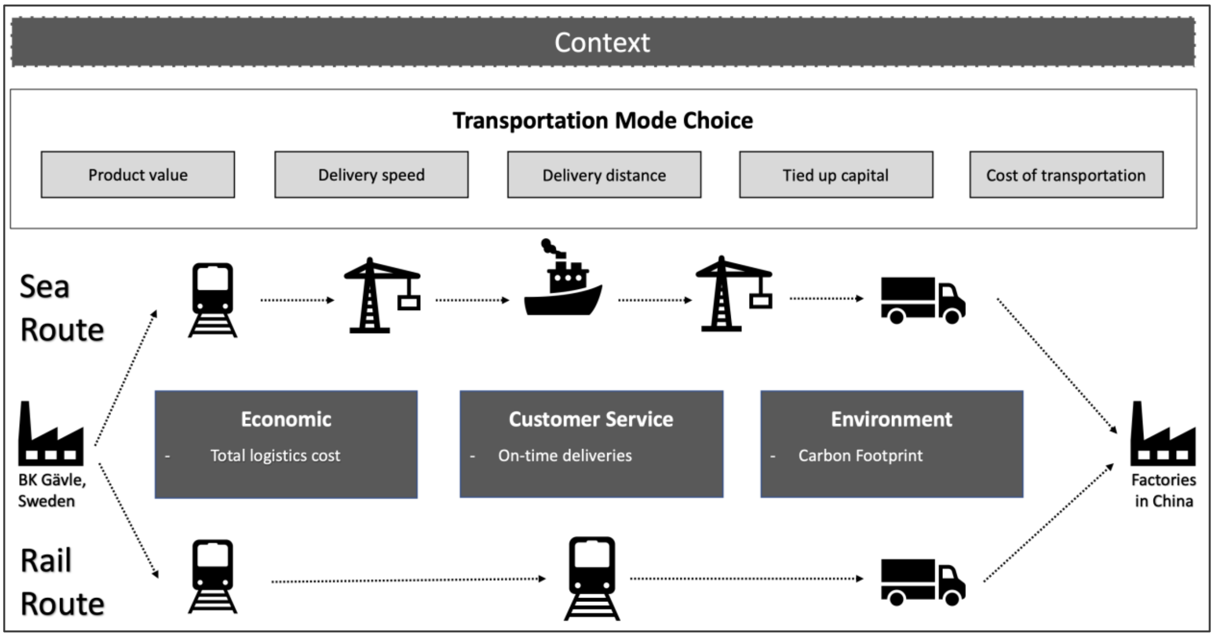

Figure 3.15: Conceptual model

4. Approach to analysis

In this section, the authors aim to explain the chosen performance measurements that are going to be the basis for the evaluation of the problem at hand. Firstly, it will explain how they arrive on their decision and provide a brief introduction of the chosen performance measurements. Secondly, each measurement will be explained and how the calculations are going to be performed.

4.1 Chosen performance measures

The BSC approach highlights the importance of focusing on a broad range of measures to develop a complete analysis of the overall performance of a firm (Kaplan and Norton, 1992). The authors of this thesis agree with this approach and therefore decided to be based on the BSC to define the performance measures that are going to be evaluated in this study.

The nature of the problem lies within the logistics field of study, where the trade-offs between mode of transportation and tied-up capital are going to be analysed. The goal of the project is to compare rail and sea transportation when shipping paperboard materials from Europe to China. The focus will be on the economic, environmental and service impacts of each transportation mode. Taking those points into consideration while being inspired by the BSC, it is possible to prioritize certain performance measurements that are proper to logistics related matters.

4.2 Total logistics costs (TLC)

Financial measures are the traditional way that companies measure performance, being the starting point for the evaluation of performance. They are good to evaluate tangible assets connected to profitability, growth and risk from the shareholders point of view (Kaplan and Norton, 1992). Total logistics cost is a financial measurement widely used in supply chain organizations. It is defined by Sheffi et al. (1988, p. 138), as "*the sum of transportation cost, inventory carrying cost and any other cost of doing business with a particular mode or carrier"*. Inventory carry cost is composed of three parts: running stock, safety stock and in-transit inventory. TLC is going to be used in this thesis to compare the two possible transportation modes in terms of cost. In the upcoming section the authors will explain how to calculate each cost member of TLC.

$$TLC = transportation\ costs + inventory\ carrying\ costs \quad (4.1)$$

4.2.1. Transportation cost

The transportation cost of base materials in Tetra Pak have a fixed rate per container. This cost derived from the negotiations between Tetra Pak and its suppliers based on the forecasted annual demand of each SKU. Order quantities do not influence the rates per container. Therefore, shipping more containers per shipments do not decrease the shipment cost per unit. The factories placing the order must respect the minimum order quantity established by the suppliers. In this case, the total transportation cost is a product of the numbers of containers shipped in a year multiplied by the cost per container.

$$Trasportation\ cost = d * c \quad (4.2)$$

Where:

d demand per unit and time unit
c cost per unit of freight

4.2.2. Inventory carrying costs

Inventory carrying costs are costs related to keeping materials and products in stock, such as opportunity cost, handling charges, storage costs and risk related costs (Sheffi et al., 1988). In this study, the total cost of carrying inventory are connected to three different inventory types: in-transit, cycle and safety stock. They were covered in the literature review section of this paper. Base materials at Tetra Pak have their ordering process and inventory managed by the use of MRP. Planners look ahead when future forecasted demand reaches the safety stock level and make a replenishment order, always respecting the minimum order quantity defined by the suppliers.

The calculation of the **cycle stock (CS)** in this thesis is going to be based on the number of orders placed in 2019. The total demand on each factory is going to be divided by the number of orders, giving an average order quantity. The authors will consider the average cycle stock to be the average order quantity divided by two. When it comes to **safety stock (SS)**, Tetra Pak uses it to cover variations both on the demand and on the replenishment lead time. The company adopts the service measure that calculate the probability of no stock outs per order cycle, which does not take the replenishment quantity in consideration. In addition, demand is assumed to be normal distributed. As mentioned before, the **in-transit stock (IS)** is basically the fraction of time that the demand in a time period is hold during transportation.

Therefore, the total inventory carrying cost will be the sum of the three distinct inventories multiplied by the inventory carrying cost per unit and time.

$$Inventory\ carrying\ cost = (CS + SS + IS) * (v * i) \tag{4.3}$$

Where,

v unit value of item
i inventory carrying charge percentage per time unit

Typically, these costs are expresses as the product of the product value and an inventory carrying charge (Sheffi et al., 1988). They are costs related to keeping goods in inventory. These costs can be divided in 4 distinct categories (Berling, 2019):

- **Capital cost**: possible loss of interest due to investing in inventory instead of other types of investments.
- **Service cost**: tax, insurance, etc.
- **Storage space cost**: electricity, staff, rent, etc.
- **Risk cost**: theft, compensation for depreciation, etc.

Table 4.1 expose the estimated percentual share of each cost type.

Table 4.1:Inventory carrying charge per cost type (source: Berling, 2019)

Capital cost	Interest	6,00%
Inventory service cost	Insurance	0,25%
	Taxes	0,50%
Storage space cost	Storage facilities	0,25%
	Transportation	0,50%
	Handling and distribution	2,50%
Inventory risk cost	Depreciation	5,00%
	Obsolescence	10,00%
Total		**25,00%**

Therefore, for this study, the authors are considering a carrying charge of 25%.

4.3 On-time deliveries (OTD)

OTD measures the percentage of orders that are delivered on the correct time defined by the customer (Irfani et al., 2019). It is a measure of service reliability because it is related to sending the right products, at the right time, in the proper conditions, with the right documentations to the correct customer (Lu et al., 2016). This measure is directly linked with lead-time variability. The higher the variability, the higher is the impact on OTD performance. The measure reflects the ratio of on-time deliveries in relation to the total number of deliveries. It is connected to the degree of uncertainty of the lead time from supplier to customers, which can also directly affect inventory levels (besides the impact on customer service).

$$OTD\ (\%) = no.of\ deliveries\ OTD\ \div total\ no.of\ deliveries \times 100\ \ldots(4.4)$$

4.4 Carbon footprint

The environmental impact is a topic by itself and it was discussed thoroughly in the environmental impact of logistics section of this paper. To calculate the carbon footprint of the different transportation mode scenarios, the authors use the tool developed by EcoTransitIT. The tool is used as-is, without any modification to the model. In order to calculate the total GHG emissions, the input parameters required are:

- Mode of transport
- Origin
- Destination
- Total weight of freight
- Units of measurement

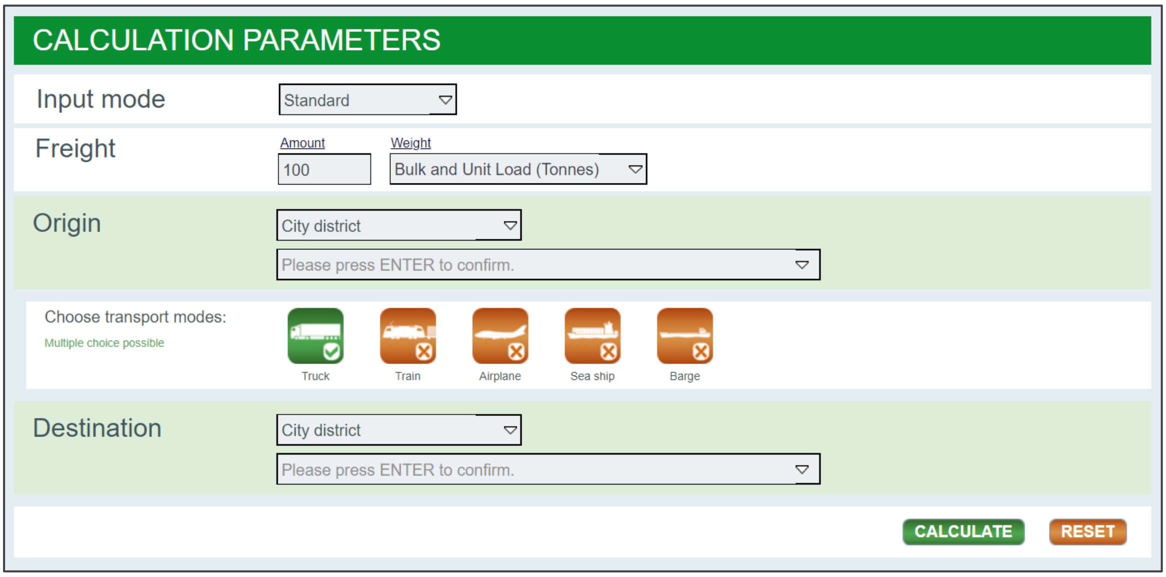

Figure 4.1: Emissions calculator interface provided by Eco Transit

This project involves the change in mode of transportation hence, factors like distance travelled, total weight of freight and the unit's consumption will be essential for calculating the emissions.

In conclusion, the above performance measurements will be used to analyse and compare the different performance measurements and would form the basis of recommendations. The economic measure should be connected to the total costs involved with the storage and transportation of goods as discussed by (Sheffi et al., 1988). The cost drivers in this case are transportation and inventory related costs. The "***total logistics costs***" is a measurement that take these aspects into consideration and was chosen to cover the economic aspects of the analysis. For the environmental impact part of the project, the authors opt for a popular measure among logistics, which measures the total "***carbon footprint***" connected to the transportation of goods from one point to another as presented by (Montoya-Torres et al., 2014). Considering the service measure, it is important to take into consideration the customers' point of view when deciding on which transportation mode to choose as presented by (Kaplan and Norton, 1992). Different modes of transportation have different levels of variation on the lead time, which could directly impact customers' service. For that reason, the authors chose "***on-time deliveries***" as the service performance measurement. Figure 4.2 summarize the set of performance measures that will be used to evaluate the problem at hand.

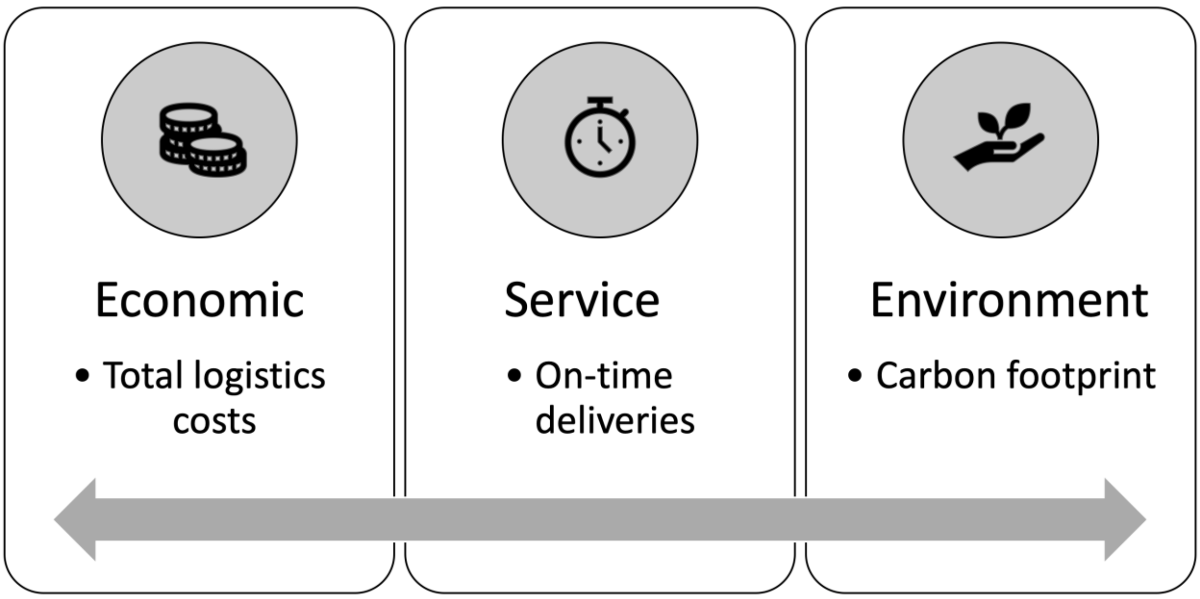

Figure 4.2: Performance measurements evaluated on this thesis

5. Tetra Pak overview

This chapter focuses on presenting an overall background of the organisation under study and the information collected for the study. The chapter begins by sharing some basic information about Tetra Pak and products and services it has to offer to its customers. This is followed by explaining the raw materials used to manufacture the packaging product, with a focus on the specific raw material that is being analysed. The information which follows, describes the flows, processes and functions of the various teams in relation to the product and under the scope of this thesis. Finally, it mentions the specific flow of focus and delimitations of the project.

5.1 Organization

Tetra Pak (TP) is a global organisation, which provides its customers with food processing and packaging solutions. It was founded in the year 1943 by Dr Ruben Rausing. Tera Pak has its customers in more than 160 countries and over 24000 employees worldwide. Tetra Pak specialises in providing end to end solutions for processing, packaging and distribution of foods. Tetra Pak invests heavily in research and development in order to provide better solutions at a reduced rate in order to maintain the competitive edge over other packaging companies. The net sales for Tetra Pak in 2018 was 11.2 billion euros across the different geographical regions.

Tetra Pak as an organisation consists of three business areas, they are:

- **Process solutions**: This business area offers customers with food processing and equipment solutions. The equipment offered can be used to process dairy products like ice cream, cheese, milk and ready-made food. This area aims at increasing processing efficiency by using a holistic approach to reduce waste and energy consumption.

- **Services**: The main function of this business area is to provide customised service solutions to ensure food protection, enhance performance, and optimise costs. They offer maintenance services, training services, automation services and installation services for the equipment sold.

- **Packaging solutions**: Packaging solutions business areas offer packaging products which are innovative and sustainable at the same time. Along with the packaging materials, they also offer packaging equipment like filling machines and distribution equipment. Out of the total net sales of Tetra Pak in 2018, 7.56 billion euros was generated by packaging products.

5.2 Packaging products

Packaging products constitutes a major chunk of the sales for TP, 67% to be precise. Packaging products portfolio is divided into two major parts by TP.

- Packaging materials (PM)
- Additional materials (AM)

Although handled by different entities, PM and AM are sold with each other. PM (carton material) is the primary product which makes up the majority portion of the package while AM (primary package consumables) are the products that complement PM. AM includes products like straws, strips, closures and films. Figure 5.1 below shows the packaging material and additional material in a Tetra Pak product.

Figure 5.1: Packaging and Additional material in a Tetra Pak product (source: Tetra Pak)

PM and AM are manufactured separately by Tetra Pak factories. The raw materials used to manufacture PM and AM are referred to base materials (BM) which is explained in the next section.

5.3 Base material

Base materials (BM) are those materials which are used in the production of PM and AM. BM consists of five different raw materials which are paperboard, polymer, films, inks and aluminium (Al) foil which are known as base materials (BM). The base material used in all the packaging products is paperboard. The main function of paperboard is to provide stiffness to the package and enable printing on the package. Polymers and films are used to offer moisture protection to the package and ensure adhesion and sealing between the other BM. The Al-foil provides barrier against oxygen and light which restricts the lowering of nutritional values of the food inside. Finally, ink is used to print the designs which are unique to its customers. Each of them provides a function to the package and helps in keeping the product safe. Functions for each BM are summarised in Table 5.1 below.

Table 5.1: Functions of base materials

Base Material	Function
Paperboard	Provide stiffness and printability
Polymer	Sealing the package product protection
Films	Moisture protection, adhesion between Al foil and paperboard, flap sealing
Ink	Printing designs
Aluminum foil	Oxygen light and flavor barrier, induction sealing and additional stiffness

Tetra Pak procures BM from all over the world and ships it to the converting where they are combined in the converting factories using sophisticated processes which finally form the PM or AM. This thesis focuses on the paperboard, which is a part of packaging product that Tetra Pak offers its clients. Hence, more information regarding it is given below.

5.4 Paperboard and its suppliers

Paperboard is used in Tetra Pak products to provide stiffness and enable printability. Paperboard is purchased in the form of a reel or a blank feed. Since, the requirement for paperboard is quite high, Tetra Pak uses multiple suppliers for paperboard which are located mainly in Scandinavia, US and Brazil apart from the few local suppliers in the respective countries.

In Brazil, the largest supplier of paperboard comes from the company Klabin, while the US has five suppliers which are MWV, Clearwater, IP Augusta, Weyerhaueser and Evergreen

Packaging. The two companies that supply paperboard from Scandinavia are BillerudKorsnäs (BK) and StoraEnso. BK and StoraEnso have papermills located in Sweden and Finland. BK has papermills in Gävle, Frövi and Gruvön located in Sweden which deliver to TP, whereas the paperboard from StoraEnso comes from the board mill in Skoghall, Sweden and Imarta in Finland. Table 5.2 shows the Scandinavian suppliers of paperboard in Scandinavia.

Table 5.2: Scandinavian Paperboard suppliers to Tetra Pak

Country	Company	Location of Paperboard mills
Sweden	BillerudKorsnäs	Gävle, Frövi and Gruvön
	StoraEnso	Skoghall
Finland	StoraEnso	Imarta

Although, these are the two suppliers of paperboard in Scandinavia to TP, the information collected and the analysis conducted is for the paperboard coming in from BK in Gävle, Sweden.

5.5 Integrated Supply Chain

The integrated supply chain (ISC) organisation at Tetra Pak, works together and focus on optimising the entire supply chain operations at TP. It focuses on securing reliable and cost-efficient fulfilment of customer demand. ISC organisation consists of four main function, namely, Integrated Planning, Process Performance, Integrated Logistics and Customer Service and Design. Apart from the main functions, it has separate entities for Integrated logistics and demand and supply management in the different clusters or regions. All these business units work cross functionally and ensure the supply chain operates in an efficient manner. The ISC organisation at Tetra Pak is represented in the form of a chart in Figure 5.2 below.

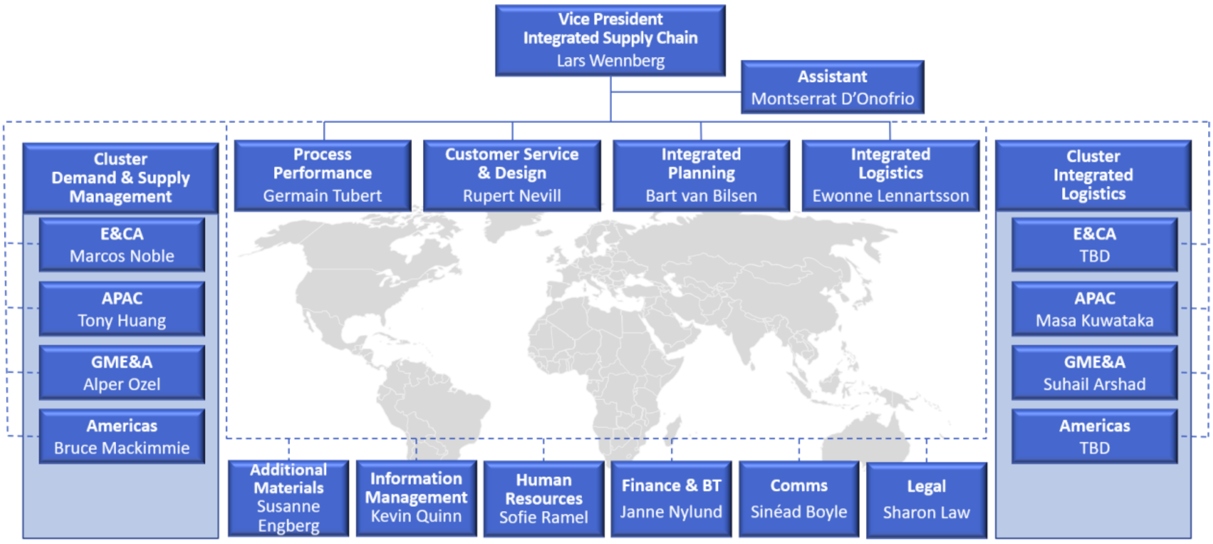

Figure 5.2: ISC organisation (source: Tetra Pak)

According to the purpose and scope of the thesis, the authors will collaborate majorly with the two business functions integrated planning and integrated logistics. Also, the analysis will not affect the operations of the other business units, hence, more information about them is given below.

5.5.1 Integrated Logistics

Integrated logistics team focuses on the physical distribution activities in the supply chain. These include all activities including arranging transportation for the year depending on the demand as well as warehousing activities across the different markets. Figure 5.3 shows the overall setup of integrated logistics along with the organisations involved.

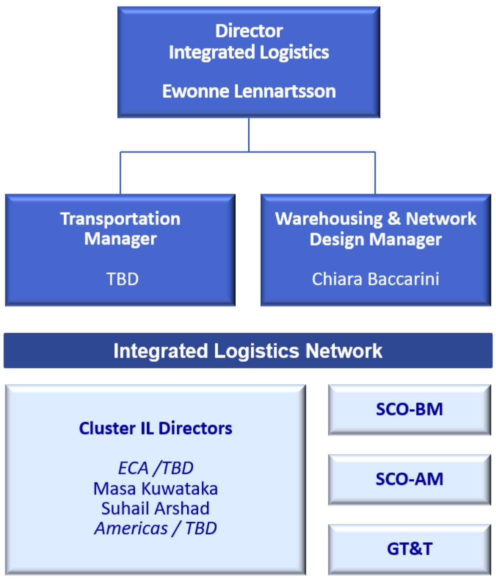

Figure 5.3: Integrated logistics organisational structure (source: Tetra Pak)

The primary objectives of Integrated Logistics are to:

- Drive excellence in integrated logistics across PM/AM/BM
- Secure shipments on time with quality
- Reduction in logistics cost
- Enable operational flexibility
- Develop logistics capabilities and enable critical business needs

The researchers will also be working closely with the Global transport and travel (GT&T) team. The main function of GT&T is to arrange transportation. Each year or every second year GT&T invites freight forwarders and nominates multiple freight forwarders for road, sea or rail freight. These companies are then assigned volumes for shipping products from Europe for the entire year.

The purpose of this thesis is to conduct a feasibility analysis considering the total logistics cost for the different modes of transport. This change in mode of transport, if more feasible than sea freight, would directly affect the two objectives of integrated logistics which is the reduction in logistics cost and on time shipments.

5.6 Integrated planning

The integrated planning team ensure that the Tetra Pak factories run in an efficient manner to provide the best service to its customers in a cost-efficient way. This team aims to maintain a balance between inventory and production to reduce wastage of raw materials. The planning done by this team is done with the planning managers responsible for each cluster. Figure 5.4 shows the overall setup of integrated planning along with the organisations involved.

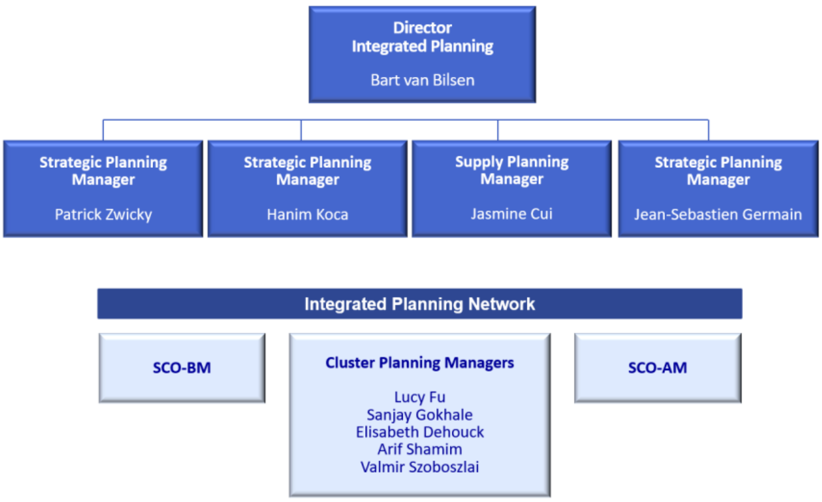

Figure 5.4: Integrated planning organisational structure (source: Tetra Pak)

The primary objectives of Integrated planning are:

- Balance service, cost & capabilities
- Develop cluster/global S&OP and integrated planning of PM/AM/BM
- Coordinate industrialization of NPIs
- Plan investments and divestments
- Manage risk and secure continuity

The data relevant for analysing the total logistics cost will be retrieved from the integrated planning team located in Lund and the material planners in the Chinese factories. The analysis will also show the changes in inventory costs and safety stock, which is one of the objectives of the integrated planning team.

5.7 Tetra Pak Factories

Tetra Pak categorises its markets and factories in four geographical regions which are also known as clusters to enable efficient management. They are Americas, Europe & Central Asia (ECA), Greater Middle East & Africa (GMEA) and Asia Pacific (APAC). Each cluster consists of serveral countries in which Tetra Pak has its own converting factories. Currently, ECA cluster has the 16 factories, followed by the Americas cluster consisting of 10 factories while APAC and GMEA have 9 and 5 factories respectively. Figure 5.5 represents the four clusters in order to have an efficent control.

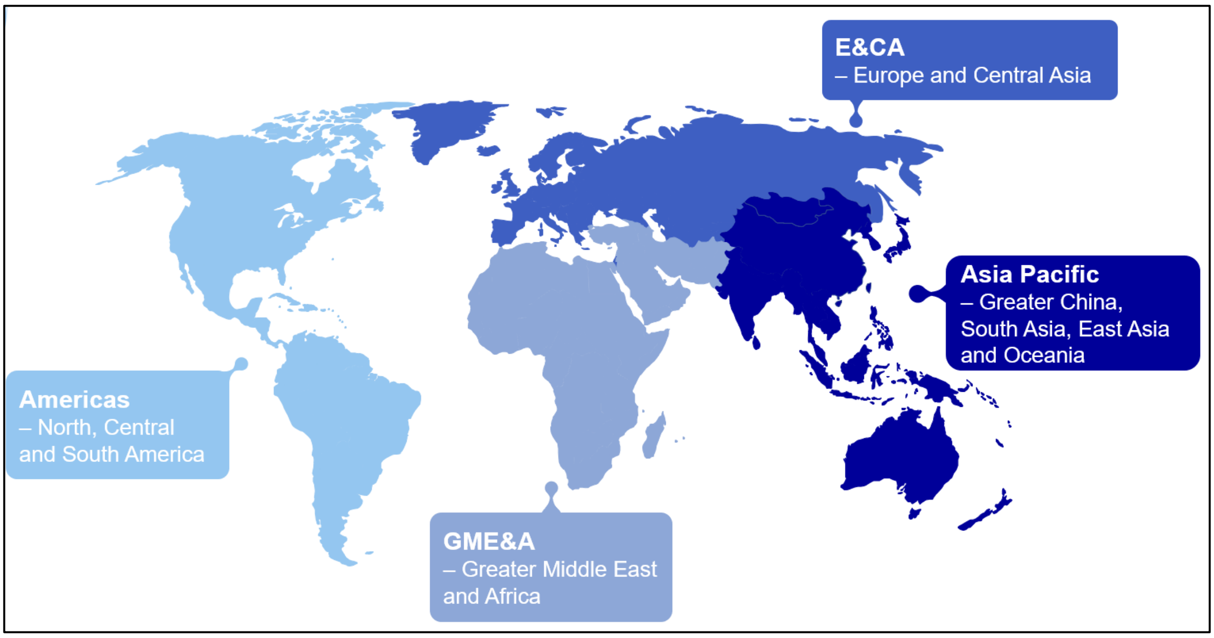

Figure 5.5: Tetra Pak clusters

Tetra Pak production sites for packaging products are located all across the globe. The converting factories for PM and AM, could have individual factories or are manufactured in the same facility. These factories convert the BM into finsished goods to be distributed to their customers located in each of their respective markets.

This study limits its analysis to the three converting factories in China located in Hohhot, Beijing and Kunshan. Apart from these factories in the APAC region, the other countries having operations in the region are India, Japan, Taiwan, Singapore and Vietnam. The converting factories in these countries produce either PM product or PM and AM together. Table 5.3 shows the location of PM and AM manufacturing factories in the APAC region.

Table 5.3: PM and AM factories in APAC cluster

Cluster	Country	Packaging material factory sites	Additional material factory sites
APAC	China	Beijing	
		Kunshan	
		Hohhot	
	Taiwan		Taipei
	India		Chakan
	Japan	Gotemba	
	Singapore	Jurong	
	Vietnam	Binh Duong	

5.8 Flow of focus

To answer the research questions, it is important to narrow down the scope of the thesis. This section aims to address the processes that are of specific interest to the authors. The flow that is under analysis is the paperboard originating from the BK paperboard mills in Gävle to the three converting factories in Hohhot, Beijing and Kunshan, according to Figure 5.6.

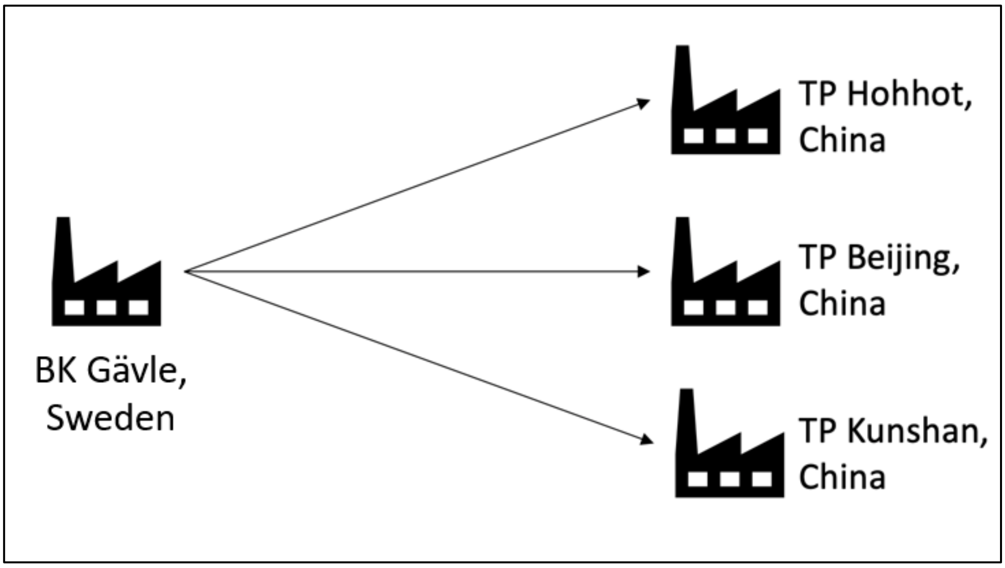

Figure 5.6: Flow of focus

It will also be interesting to analyse how the change in mode of long-haul transportation affect the inventories at the converting factories, transport costs, environmental impact and service levels. The change in transportation will affect the capacity of shipments and lead-times. Furthermore, other challenges specific to the mode of transportation will be studied as well. In order to analyse them, the study of each business units involved will also be of great significance. More about them will follow in subsections below. In order to protect sensitive data of Tetra Pak, all demand data and costs are masked and are not actual but the change in costs are actual.

5.8.1 Demand of paperboard

Different types of paperboard are used for different packaging systems. The different SKUs are differentiated based on its stiffness and the width of the paper roll. Apart from these two parameters, paperboard could also be distinguished on the type of surface it has. The unit of measure used by Tetra Pak and its suppliers is m^2 and all the values for paperboard mentioned further will have the same unit, unless stated otherwise.

In order to compare the different scenarios, it is important to have a common basis of comparison. Hence, the analysis will be performed on the 2019 demand data of the paperboard. There are a total of 17 SKUs managed by the Chinese factories, 4 of them being considered to be critical by Tetra Pak. According to the planner interviewed, Tetra Pak classify the paperboard SKUs essentially according to its volumes. The critical SKUs are the ones with the highest volumes. The reason for this was that any stockouts of these SKUs would have a drastic impact on the production lines, that would have to stop due to the lack of materials. Table 5.4 shows the 2019 demand and standard deviation of each paperboard SKU in each Chinese factory. The ones highlighted in bold red are the ones classified by the planners in each factory as critical SKUs.

Table 5.4: 2019 demand of paperboard in China

Factory name	Product Number	Annual Demand In containers	Average monthly demand In containers	Sigma of monthly demand In containers
Beijing	**A**	186	15,48	7,06
	B	109	9,07	3,76
	C	105	8,67	1,49
	D	35	2,86	2,02
	E	45	3,67	1,05
	F	8	0,60	0,86
	G	6	0,44	0,19
	H	4	0,27	0,21
	I	3	0,22	0,46
	J	1	0,04	0,13
	K	1	0,01	0,04
Kunshan	**A**	121	10,05	5,49
	B	62	5,11	2,42
	L	58	4,78	2,04
	M	8	0,63	0,39
	N	7	0,52	0,23
	O	8	0,67	0,22
	P	2	0,15	0,16
	Q	1	0,07	0,05
Hohhot	**B**	199	16,53	4,09
	O	36	2,96	0,48
	C	13	1,02	0,84

5.8.2 Material management

The material management process at Tetra Pak is done using the MRP system in SAP APO (Advanced Planner and Optimiser). The system depends on the forecast of finished goods, which is the independent demand. The process of forecasting the demand for paperboard and other BM is done by actively involving the customers. Tetra Pak's customers are required to share their sales forecasts for the products that they offer. The sales forecast is then converted into the production forecast, which also takes the lead-times into consideration. The system converts the production forecast of finished goods into the components forecast via the bill of materials. This process driven by the MRP which helps Tetra Pak to get an idea of the quantity of raw materials that would be required for each factory to produce packaging products.

MRP assists the demand planners by recommending procurement proposals based on the inventory levels. The demand planning team analyses the values and recommendation and plan the demand for BM accordingly. The system exposes the expected inventory levels for the future based on the forecast. When inventory levels reach the safety stocks, planners schedule a future order, taking the lead-time into consideration, making sure they have enough stock to support future demand from customers.

Orders are placed based on the replenishment cycle defined by Tetra Pak, also respecting the MOQ defined by the suppliers. For paperboard materials, the MOQ is set to be one container of the material. For sea freight, Tetra Pak has as a standard replenishment cycle, which is the period of 7 days, which means one order per week with a total of 52 order a year. This is valid for SKUs where the demand per time unit is bigger than the MOQ. In cases where the demand per time unit is inferior than the MOQ, planners make orders within longer replenishment cycles, in order to respect the MOQ. Table 5.5 exposes the unit cost per SKU of paperboard and Table 5.6 shows actual number of orders made by each Chinese factory in 2019.

Table 5.5: Unit cost per paperboard SKU

Product Number	**Unit cost Per container (US$)**
A	$2 384,87
B	$2 455,03
C	$2 432,84
D	$2 897,60
E	$2 134,75
F	$2 417,41
G	$2 145,47
H	$2 324,23
I	$2 365,07
J	$2 357,11
K	$2 149,49
L	$2 110,19
M	$2 499,35
N	$2 614,28
O	$2 342,11
P	$2 613,31
Q	$3 163,15

Table 5.6: number of paperboard SKUs purchase orders per Chinese factory in 2019

SKU	Beijing	Kunshan	Hohhot
A	73	30	-
B	55	51	107
C	52	-	18
D	45	-	-
E	55	-	-
F	22	-	-
G	24	-	-
H	1	-	-
I	2	-	-
J	1	-	-
K	2	-	-
L	-	48	-
M	-	25	-
N	-	30	-
O	-	33	56
P	-	12	-
Q	-	8	-

The cycle stock level evolves according to the order quantities that occur during the replenishment cycles. The dynamic of demand being consumed and replenished from time to time generates the saw tooth patterns well known when looking to inventory levels evolution.

When it comes to safety stock levels, as presented previously on this report, they are based on the service measure that calculate the probability of no stock outs per order cycle. This calculation does not take the order quantity in consideration. The service levels set by Tetra Pak to calculate the safety stock levels for paperboard materials is set to be 95%. This means that Tetra Pak aims to satisfy 95% of the customers' orders with the stock on hand. Considering that the demand for paperboard is said to be normal distributed, a service level of 95% gives a safety factor of 1,64 which is going to be used on the safety stock formula used by Tetra Pak.

5.8.3 Physical distribution

Distribution and the processes in it, is another aspect that is relevant to this study. This section will shed light on issues such as capacity, containers, transport routes and lead times which is essential to the analysis. Also, entities which manage some parts of physical distribution for TP, will also be mentioned.

Containers used to ship paperboard

Paperboard is shipped in containers from the supplier located in Gävle to the factories in China. The capacity of containers required to ship paperboard is allocated, when the GT&T team receives the forecasts data for the coming year. Once the demand for a year is known, GT&T team invites multiple freight forwarders to bid for transporting the containers from the supplier to the converting factories. Freight forwarders are then required to provide relevant information like the cost of each container with the breakup of costs for each leg of transportation, route that it would follow, transit time, frequency of departures, number of transshipments and customs clearance cost at each port. Once the bids from all forwarders are received, GT&T analyses each of them keeping in mind the important factors like the transit times, costs and the setup. The companies which provide the best setup and cost are awarded the contract for a year or two. Containers used to ship paperboard are generally 40 feet containers, as it can accommodate maximum of 9 pallets at a time.

Shipment Booking

Shipments are booked once the factories place an order with the supplier. Tetra Pak gives the responsibility of booking of shipments to Geodis. Geodis is a logistics service provider, that provides expertise in freight forwarding, contract logistics, distribution, road transport and supply chain optimization. Geodis books the shipments and chooses among the different freight forwarders, according to the demand allocated to each freight forwarder by TP. In order to track information related to shipments from door to port, Geodis has developed IRIS (Intelligent Real Time Information System) portal which is used by Tetra Pak. Apart from the shipment details, information regarding the number of containers, deviations, route taken, mode of transportation and carbon emissions are recorded. Shipments booked by Geodis is from door to port which means they are responsible for shipments from the supplier in Gävle to the Chinese ports. This includes the pre-carriage (supplier to port of origin) and main carriage (port of origin to port of destination).

The responsibility for the final leg of transit, which is also known as the on-carriage, lies with the Chinese factories. The logistics team are responsible for the customs clearance at the Chinese ports and arrange for transport from the Chinese port to factories.

Shipping routes

The route of shipment is dependent on the freight forwarding company. As mentioned above, the route of shipment is categorized into three main parts. They are:

- Pre-carriage: From supplier factory to Port of Origin

- Main carriage: Port of Origin to Port of Destination
- On carriage: Port of destination to converting factory

The current transportation from the paper mills to converting factories in China, takes place using intermodal transportation. This could include a combination of rail and sea or just sea freight. Since Gävle does not have ships going to Chinese ports, the paperboard needs to be shipped via rail or sea to Gothenburg before it moves ahead in the chain. Since it would be difficult to analyse all the combinations of shipment routes, it is important to choose the route which is used in majority of situations. The most common route for sea freight is the one from Gävle to Gothenburg by rail and from Gothenburg to either Xingang or Shanghai by sea. Figure 5.7 below represents the mode of transport for different legs of transportation via sea.

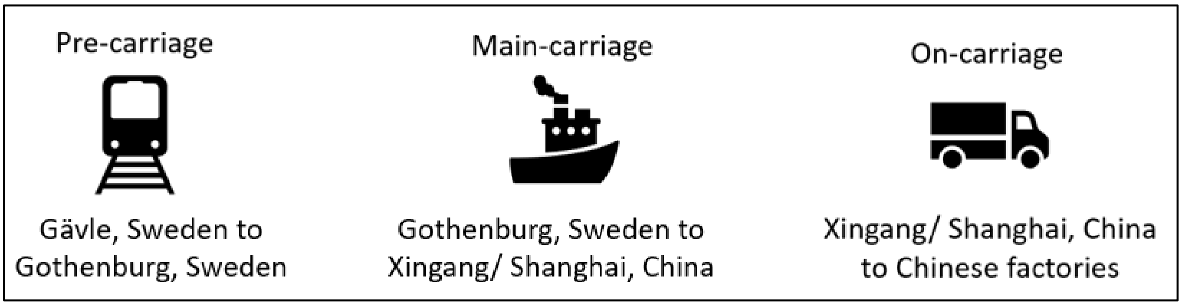

Figure 5.7: Transport mode for different legs via sea

For rail shipments, the route and mode for pre carriage changes, which originates from Gävle, Sweden and is transported to Hamburg, Germany by rail. For trains going east bound (EB) i.e. to China from the route developed in the BRI, Hamburg and Duisburg are the major terminals apart from Nuremberg all located in Germany. Like the sea route, rail solutions offered by freight forwarders have different routes but for this thesis the route from Gävle to Hamburg and Hamburg to Xian is the chosen one as it has the lowest transit times and the available capacity for shipping containers. Figure 5.8 below represents the mode of transport for different legs of transportation via rail.

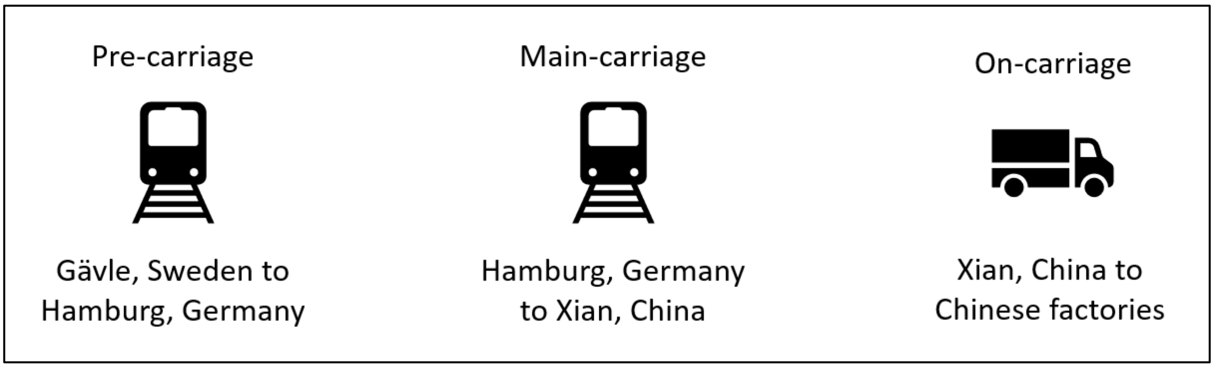

Figure 5.8: Transport mode for different legs via rail

A block train departing from Hamburg in Germany heading to Xian in China travels through Poland, Russia and Kazakhstan. Rail tracks in different region of the world have different sizes or gauges. Similarly, tracks in Hamburg and Poland are of similar gauge, the tracks in Russia and Kazakhstan are of the same gauge while Chinese tracks have different gauges. Due to this particular reason, a single train cannot go from one country to another. In this case, trains originating from Hamburg go up to the Russian border where the containers are unloaded and placed on to a train whose sizes are compatible with the track gauge in Russia and Kazakhstan.

Cost per container

**All the cost information on this study is based on US$.*

The cost of a 40-foot container for the current sea transportation is composed of long haul and short haul costs. The long-haul cost per container for the three Chinese destinations is the same. The information was given by the GT&T team according to the current contracts. When it comes to short-haul costs, the cost is dependent on some factors (for e.g. inspection fee, detention fee, import custom clearance fee, Storage fee, Handling fee, THC, document fee) and is charged by tons. Therefore, it varies according to the demand size in each factory. Below in Table 5.7 is the summary of the transportation cost per container for the current sea freight.

Table 5.7: Transportation cost per container for sea freight

Sea freight average cost per container	**Beijing**	**Kunshan**	**Hohhot**
Long-haul cost	\$156	\$156	\$156
Short-haul cost	\$76	\$26	\$169
Transportation cost	\$232	\$183	\$326

For rail freight, the transportation cost was also given by the GT&T team. It was based on a tender done with the freight forward company Maersk, considering one block train per week. In this case, the cost considered door to door transportation, which means from the supplier to the final destination. Table 5.8 below exposes the summary of the transportation cost per container for rail freight.

Table 5.8: Transportation cost per container for rail freight

Rail freight average cost per container	**Beijing**	**Kunshan**	**Hohhot**
Transportation cost	\$530	\$542	\$542

Lead times

Paperboard are transported from the paperboard mills in Gävle in large volumes. For this reason, it is not possible to have paperboard readily available. Also, since the paperboard would be used to manufacture food packaging, paperboard older than a certain period cannot be used. Hence, the mill begins the manufacturing of paperboard only when the converting factories place an order to the supplier. This leads to an increase in the overall lead time.

The overall lead time (LT) is sum of three different time intervals, namely supplier replenishment time, transit lead time and internal transit time. The supplier lead time is the time from which the converting factory places an order to time when it about to leave the papermill. This time is independent of the transportation mode used to ship paperboard. The supplier replenishment time is decided after the inputs from the supplier, which must always be respected. This time is always fixed, and the supplier needs to make sure that paperboard is ready for dispatch within this time frame. The supplier lead times is also used as an input in the APO tool to manage the inventories. Hence, ensuring the dispatch of material does not cross this period is of great importance for managing inventories at optimal level. The supplier replenishment time set by BK Gävle and Tetra Pak is 42 days.

The next part of the lead time is known as the transit time. This is the time taken for the shipment or container to reach the destination port from the door of the paperboard mill. The responsibility of this leg of transportation lies with the nominated freight forwarders like Maersk or Geodis. This part of transportation is further divided into two parts which are known as pre-carriage and main carriage. Pre-carriage is the time taken by the container to move from the door of the papermill to the port of departure. In case of sea shipment, pre carriage is the point from Gävle to the port of Gothenburg is 3 days, while for rail, it is the time from Gävle to Hamburg is 4 days. Main carriage is the second part of the transit time which is essentially the longest leg of transportation. For sea shipments, main carriage is from the port of Gothenburg to Port of Shanghai and Xingang, which takes approximately 35 and 42 days respectively. While for rail shipments, it takes 17 days for the main carriage route which originates from Hamburg and terminates at Xi’an. The responsibility for this leg of transport also lies with the freight forwarder.

The last leg of transportation from the port of destination to the Chinese factories is called the internal transit time or on-carriage. The transport arrangement along with the customs clearance for this is done by the respective factories. Currently, the lead times from the port to factories takes 4 days, but for rail it takes approximately 3 days. Table 5.9 and Table 5.10 below represents the lead times for sea and rail segregated into supplier replenishment time, Long haul transit time and short haul transit time.

Table 5.9: Door to door lead times for sea

Mode	Origin- Destination	Supplier replenishment time	Long haul lead time	Short haul lead time	Total lead time
Sea	Gävle - Kunshan	42	42	4	88
	Gävle - Hohhot	42	45	5	92
	Gävle - Beijing	42	46	4	92

Table 5.10: Door to door lead times for rail

Mode	Origin - Destination	Supplier replenishment time	Long haul lead time	Short haul lead time	Total lead time
Rail	Gävle - Kunshan	42	17	6	65
	Gävle - Hohhot	42	17	6	65
	Gävle - Beijing	42	17	6	65

The values in the above tables are the lead times for the different modes of transportation. Another important aspect to take into consideration for the analysis of the total logistics cost is the deviation of lead times. The deviation on lead times directly affect the safety stock as can be represented in the formula mentioned in Service level and safety stock section. This deviation on lead times was calculated based on the transit time values gathered in Geodis database. The lead time deviation is different for the three different factories and is represented in Table 5.11 below.

Table 5.11: Lead time deviations for sea

Mode	Route	Lead time deviation
Sea	Gävle - Kunshan	5.7 days
	Gävle - Hohhot	5.5 days
	Gävle - Beijing	9.6 days

5.9 Environmental impact

The environmental impact for transportation is not calculated separately by TP. Geodis, the organisation that is responsible for booking shipments, calculates the carbon and other greenhouses gases emitted by the vessels. The emissions are captured from the port of origin to the port of destination. The reason for this is that the responsibility of the final leg of transportation lies with the Chinese factories and they do not capture this piece of information.

The carbon emissions are based on the calculations by EcotransitIT (ETW). ETW provides a software tool for organisations, to calculate emissions and energy consumptions related to freight. The software is developed in line with GHG protocol and with regulations mentioned in EN 16258. The calculations can be made with respect to mode of transport, weight, origin and destination. The results obtained from this calculator, can be used as benchmarking values to develop strategies for sustainability or determining the CO_2 footprint. The key features of calculator provided by EcotransitIT are:

- Determines energy consumption, greenhouse gases and air pollutants for all modes of transport.
- Consistent calculation for global, intermodal transport chains.
- Scientifically sound methodology developed by neutral scientific institutes (Ifeu, INFRAS, Fraunhofer IML).
- Accredited for the GLEC Framework and compliant with EN 16258 and GHG Protocol (Corporate Standard).
- Flexible and customer-oriented interfaces ready for immediate use.
- Clear license and cost model including updates and method extensions.

The carbon emissions for the sea route is retrieved from the IRIS portal but for rail shipments, it will be calculated using the EcotransitIT emissions calculator.

5.10 Shipment Visibility

Visibility of shipments is another service aspect that is important for Tetra Pak. It is important to track the containers in order to prevent uncertainties in supply chain. Freight forwarders frequently offer this service which comes with an extra cost. This is because the containers are not equipped with infrastructure like Global Positioning System (GPS) required to track and trace shipments. The method of tracking of shipments depends on the freight forwarders. Freight forwarders typically, place the GPS inside the containers to track shipments. An important factor for the GPS to work is the network connectivity from the region that it passes through. Only when there is network connectivity will the device used to track the shipment work. When goods are being transported by sea, network connectivity is an issue that limits the visibility capabilities. On the other hand, rail tracks are generally laid down much closer to civilizations, hence, rail offers a better visibility of containers when it is being shipped from Sweden to China.

6. Analysis

In this section, the authors intend to explain the analysis process. The overall goal is to use the empirical data gathered with the company to calculate and analyse the problem at hand, considering the covered literature and the proposed performance measures.

A sequence of steps was developed and performed in order to allow a structured and complete analysis. Firstly, the authors will calculate the TLC for the as-is sea freight shipments, as well as for the to-be rail freight shipments. The goal is to perform a comparative analyse of the results. The same process will be done for carbon footprint impact and on-time delivery performance. At last, the authors will develop a sensitivity and risk analysis to explore possible future situations that could be favourable to rail, as well as the risks that could impact the modal choice decisions. Figure 6.1 is the pictorial representation of the steps involved in the analysis part of this thesis.

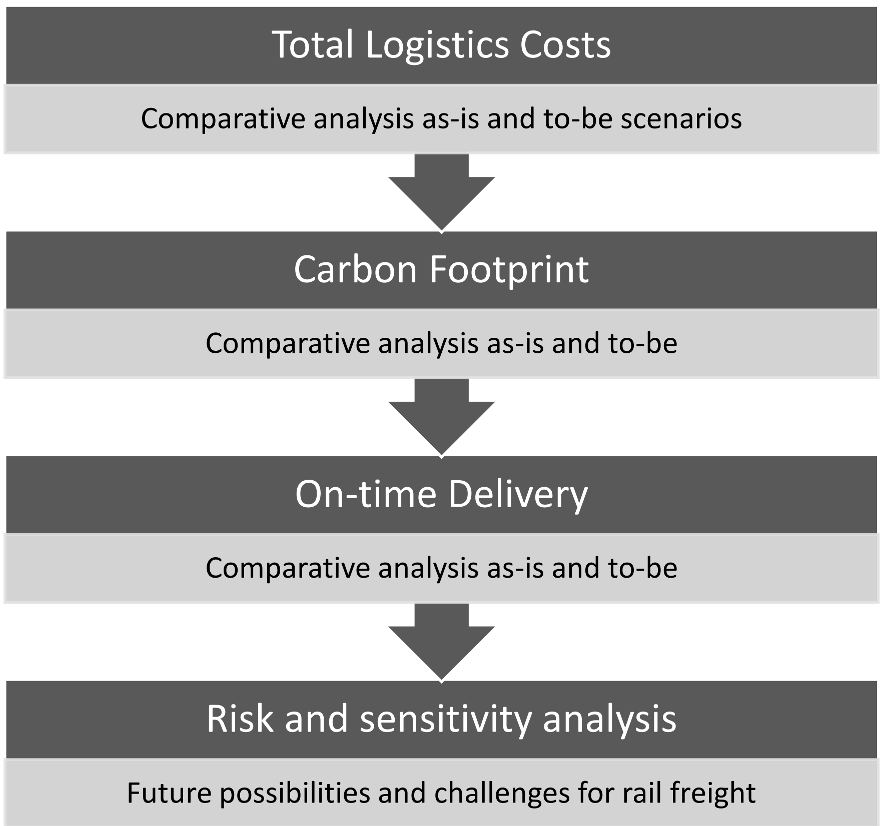

Figure 6.1: Steps involved in the analysis approach

6.1 Total Logistics Costs

In this section, the authors will analyse the TLC for paperboard shipments from BK Gävle in Sweden to the three factories in China. The calculations will be performed for the current sea freights shipments, as well as for the possibility of the full demand being shipped by rail freight. As presented previously in section 5.8.3, the calculation of TLC for rail shipments in this study is based on the shipment of block trains, where each train can transport 41 containers per trip. The results of both scenarios will be further compared in order to assist on the visualization and understanding of the impact of each possibility.

According to Sheffi et al. (1988), TLC is composed of transportation cost and inventory carrying. Inventory carrying costs, in turn, consists of safety stock, cycle stock and in-transit stock costs. Firstly, as covered in section 4.2, the annual transportation cost is calculated by multiplying the cost per container (found in section 5.8.3) with the total number of containers shipped in a year (found in section 5.8.1). The number of containers shipped in a year, in turn, was calculated by dividing the annual demand in m^2 (extracted in the SAP APO system) by the amount of m^2 that one container can hold, which varies for different SKUs.

Secondly, the calculation on inventory carrying costs is shown in section 4.2, stating it as the sum of cycle stock, safety stock and in-transit stock, multiplied by 25% which is the holding cost of the materials. For the calculation of the average cycle stock, it is necessary to find the average order quantity. As discussed by Bozarth and Handfield (2016), the average order quantity was found by dividing the annual demand by the number of purchase orders done in the year. For in-transit stock, the annual demand is multiplied by the time the materials stay in transit, which is the sum of the long and short haul transit time.

At last, safety stock is calculated using the formula presented by Bozarth and Handfield (2016) and the defined service level which is 95%. The sum of these three stock types are then multiplied by 25% of the price of the materials, generating the total inventory carrying cost. The results for as-is (sea freight) and to-be (rail freight) scenarios are presented in the next section.

6.1.1 As-is – Sea freight

Table 6.1 below exhibit the TLC results for the current sea shipments. Figure 6.2 highlights the percentual distribution among the different TLC cost types for the sea shipments.

Table 6.1: TLC for sea freight

Sea freight – As-is		Beijing	Hohhot	Kunshan	Total
Transportation cost		$ 115 584	$ 80 444	$ 47 800	$ 243 829
Inventory carrying cost	**Cycle stock cost**	$5 937	$1 211	$4 286	$11 433
	In-transit Cost	$40 873	$20 650	$19 440	$80 964
	Safety Stock cost	$30 610	$9 649	$18 336	$58 596

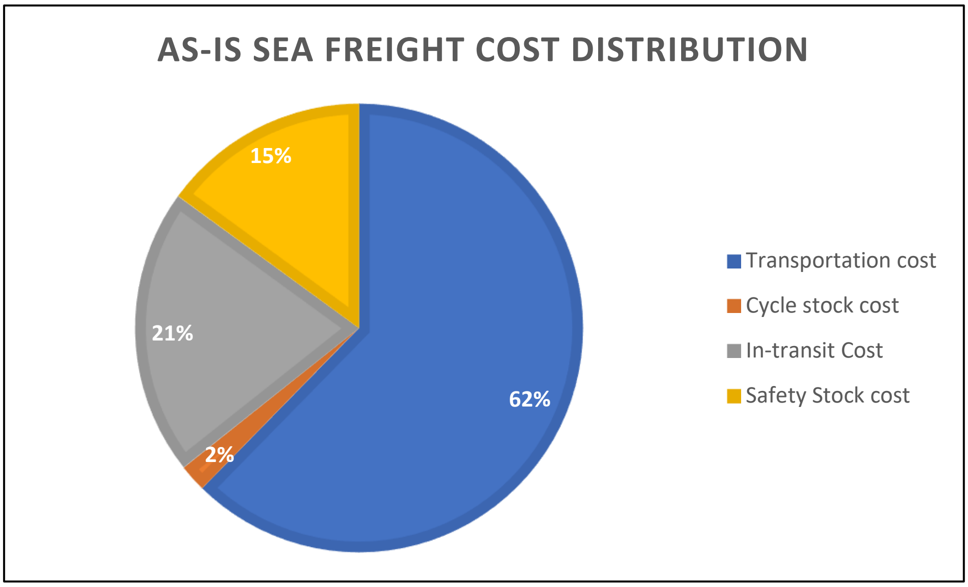

Figure 6.2: Sea freight TLC cost distribution

In Figure 6.2 above, it is possible to see that transportation cost represents the biggest share of costs with 62% of TLC. In-transit costs is responsible for the second biggest cost with 21% of the TLC, followed by safety stock costs with 15% of the costs, while cycle stock costs come at last, being responsible for just 2% of the costs in the current scenario.

6.1.2 To-be – Rail freight

Table 6.2 below exhibit the TLC results for rail shipments. Figure 6.2 highlights the percentual distribution among the different TLC cost types for the possible rail freight.

Table 6.2: TLC for rail freight

Rail freight – To-be		Beijing	Hohhot	Kunshan	Total
Transportation cost		$262 843	$133 684	$142 843	$539 370
Inventory carrying cost	**Cycle stock cost**	$5 443	$1 848	$3 737	$11 028
	In-transit Cost	$19 160	$9 600	$9 902	$38 661
	Safety Stock cost	$25 871	$8 142	$15 953	$49 966

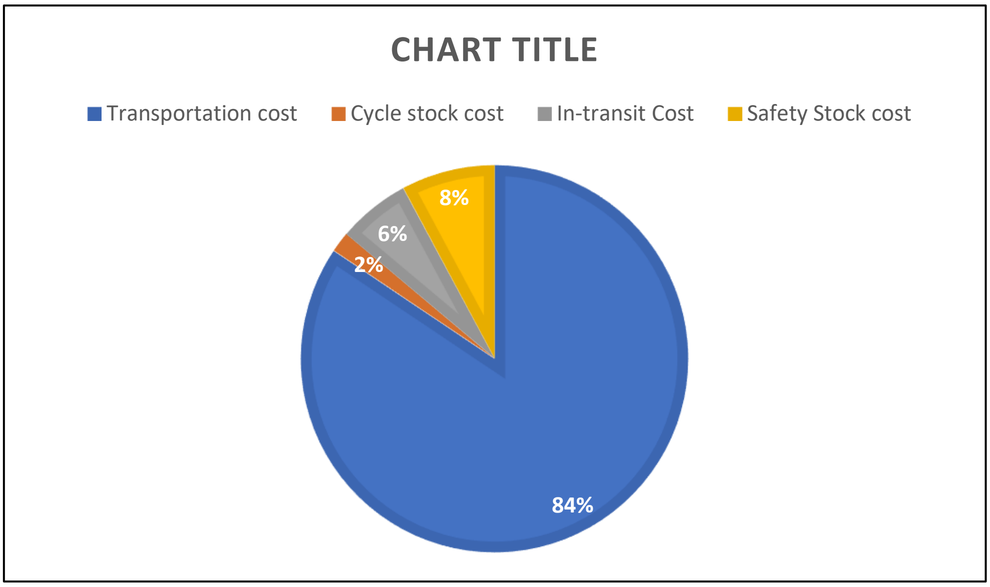

Figure 6.3: Rail freight TLC cost distribution

When changing the transportation mode to rail, it is possible to notice in Figure 6.3 that the percentual share of transportation cost increases to 84%, while there is a reduction in the percentual share of the three other costs, which are part of the inventory carrying cost. This change is related to the increase in transportation cost, together with the reduction in the three types of inventory carrying costs. Next, the authors will put all the values together to perform a comparative analysis of all the results.

6.1.3 Comparative analysis

The goal of the analysis is to compare the TLC of sea and rail freights in order to understand the trade-offs between transportation modal choice and tied-up capital, as covered on section 3.3.2. In another words, the authors aim to evaluate what would be the impact on inventory carrying costs when investing on rail shipments. Shipping goods by rail increase transportation costs but also offer faster and apparently more reliable lead-times, which could potentially reduce inventory carrying costs. Below is the TLC comparison per cost type between the two modes of transportation.

Table 6.3: TLC comparison

	As-is sea freight	Rail full demand	Variation
Transportation cost	$243 829	$539 370	**121%**
Cycle stock cost	$11 433	$11 028	**-4%**
In-transit Cost	$80 964	$38 661	**-52%**
Safety Stock cost	$58 596	$49 966	**-15%**
TLC	**$394 822**	**$639 025**	**62%**

Figure 6.4 and 6.5 below, show the graphical representation and comparison for sea freight and rail freight.

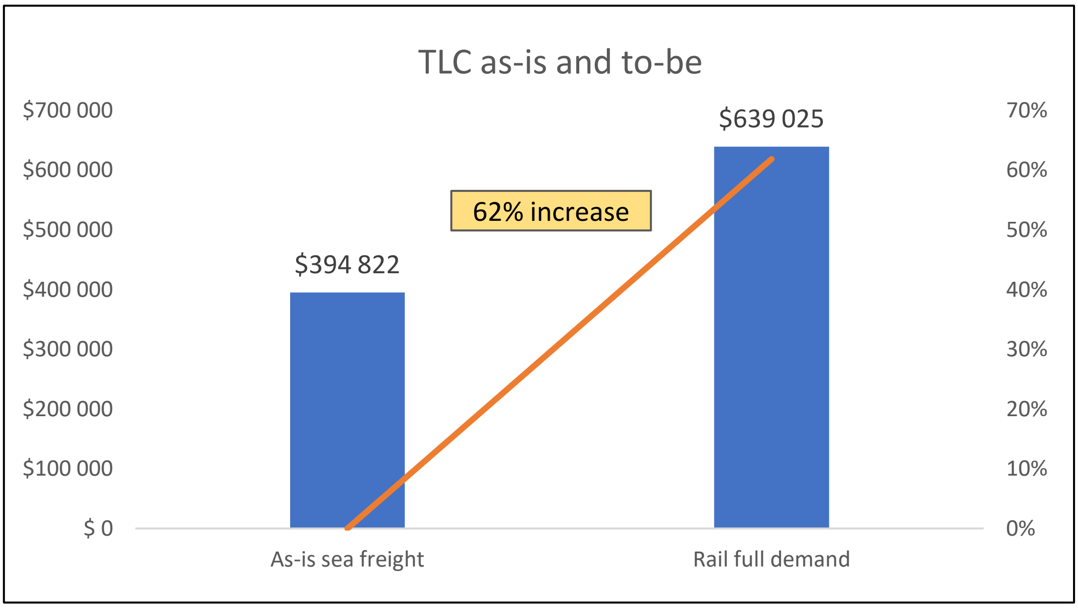

Figure 6.4: TLC graphical comparison

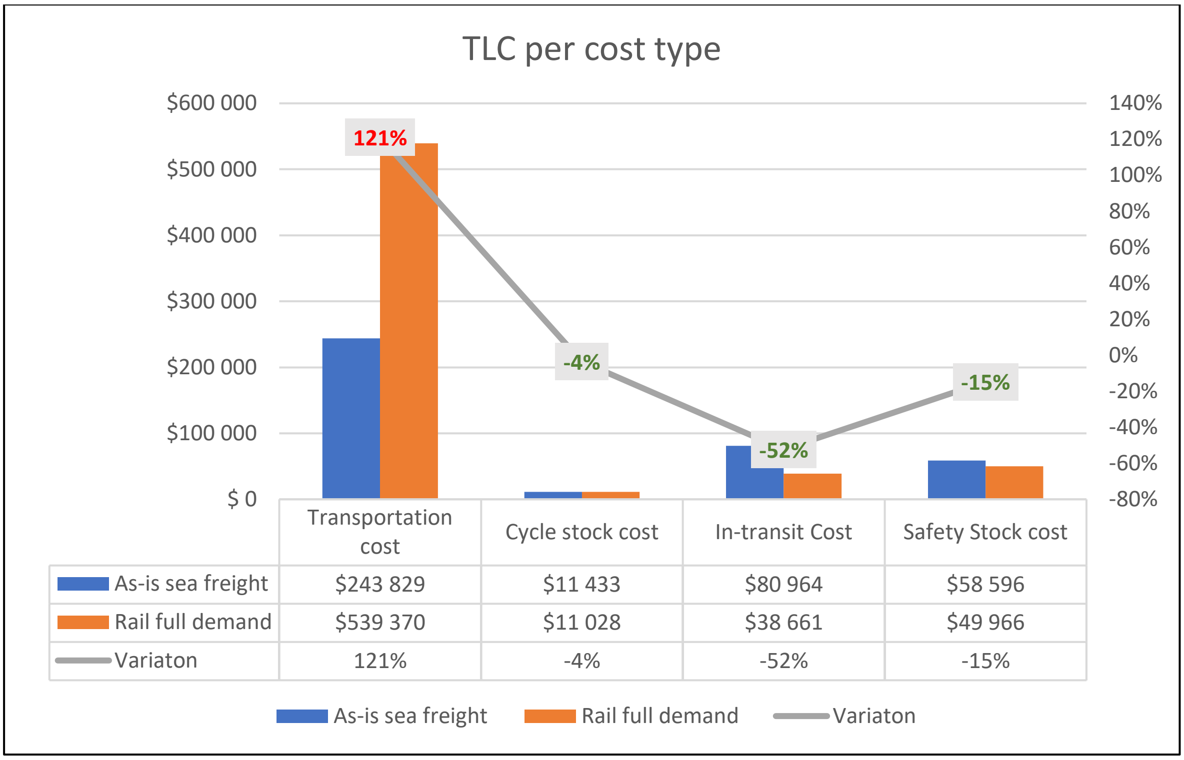

Figure 6.5: TLC per cost type graphical comparison

As is possible to see in Figure 6.4, switching the transportation mode to rail freight for the entire demand generates an increase in TLC by 62%. This is clearly justified by the fact that transportation costs are responsible for the majority of TLC, as shown in Figure 6.5. Therefore, it is possible to conclude that the increase in TLC is related to the fact that the absolute increase in the value of the transportation was higher than the absolute reduction of inventory carrying costs.

The higher transportation cost for rail freight is connected to the lower capacity per train and the higher operational costs related to the operations, as discussed in section 5.8.3. On the other hand, the main reason for the low percentual share of inventory carrying costs could be related to the fact that they are based on a fraction of the price of the material, as presented (Sheffi et al., 1988) and since the material in question is paperboard, which can be considered relatively cheap, the inventory carrying costs ends up being relatively low. Furthermore, the decrease in inventory carrying costs are related to the shorter lead-times and lower lead-time variability. As is possible to see in Figure 6.5, the main reduction in inventory carrying cost is related to in-transit inventory costs. As presented by Bozarth and Handfield (2016), this cost type is related the fraction of time that materials are kept in transit. The reduction of 53% in in-transit cost is directly related to the same percentual reduction of the sum of short and long-haul transit time. Furthermore, it is possible to notice that safety stock and cycle stock costs also suffer a reduction, but in a slightly smaller scale. In case of cycle stock, the reduction is a product of the change in the replenishment cycle for some SKUs that could have been shipped more frequently according to their current volumes. This generates smaller order quantities, which is directly connected to lower levels of average cycle stock. The reduction in safety stock is related to the reduction in lead-time and lead-time uncertainties, as discussed in section 5.8.3 and mentioned by Bozarth and Handfield (2016).

Looking to the results of both transportation modes, it is possible to conclude that the implementation of rail shipments comes with a cost. This substantial rise on transportation cost outweigh the gains from inventory carrying cost reductions, making rail freight in this case is not economically feasible.

6.2 Environmental Aspect

This section aims to give an insight in how the different modes of transportation perform on the environmental aspect of carbon emissions released in the atmosphere. The values for carbon emissions was calculated using the EcotransitIT calculator mentioned in sections 4.4 and 5.9. The emissions are calculated per container for the different legs of transport in order to understand the concept of emissions holistically.

6.2.1 As-is – Sea freight

Tetra Pak uses intermodal transportation to ship containers from the paperboard supplier in Sweden to the Chinese factories. As a result of this, different legs of transportation use different modes of transportation. For sea freight, Tetra Pak uses rail for pre-carriage and road for on-carriage, while major part of transportation is done by sea. Hence, it would be ideal to segment the carbon emissions for different route and add them to calculate the total carbon emission. The carbon emissions will be calculated for a single container, which will make the comparison for the different modes much easier for the readers to understand.

Using the emission calculator available on EcoTransit.org, the authors calculate the carbon dioxide in tonnes for one 40 feet container to the converting factories in Beijing and Hohhot with the results shown in Table 6.4 below.

Table 6.4: CO2 equivalent to Beijing and Hohhot factories via sea for different legs of transport

Transport leg	Mode	Route	Distance (km)	CO2 equivalent (in tonnes/ containers)
Pre-carriage	Rail	Gävle - Gothenburg	538	0.012
Main-carriage	Sea	Gothenburg - Tianjin Xingang Port	21 453	2.84

On-carriage	Road	Tianjin Xingang Port - Beijing	130	0.20
On-carriage	Road	Tianjin Xingang Port - Hohhot	732	1

For the converting factory in Kunshan, the port of arrival is Shanghai and the carbon emission value for the 40 feet container from Gävle is shown in Table 6.5 below.

Table 6.5: CO2 equivalent to Kunshan factories via sea for different legs of transport

Transport leg	Mode	Route	Distance (km)	CO2 equivalent (in tonnes)
Pre-carriage	Rail	Gävle - Gothenburg	538	0.012
Main-carriage	Sea	Gothenburg - Shanghai Port	20 340	2.530
On-carriage	Road	Shanghai Port - Kunshan	62	0.092

The two tables above show the carbon emission for each converting factory located in China. Along with the distances and the transport mode used in each leg of transportation. The following Table 6.6 will depict the total CO_2 equivalent from the paperboard supplier to the Chinese factories.

Table 6.6: Total CO2 equivalent from Sweden to China per 40' container via sea

Origin	Converting factory	CO_2 equivalent ton/ container (door to door)
Gävle	Beijing	3.05
Gävle	Hohhot	3.85
Gävle	Kunshan	2.732

6.2.2 To-be – Rail Freight

The route for shipping paperboard from Sweden to China over rail is slightly different from the one used when shipping via sea. The pre-carriage route originates from Gävle and terminates at Hamburg in Germany. The shipment then proceeds on the main carriage from Hamburg to China on rail which passes through, Poland, Russia, Kazakhstan and finally entering China. The main carriage terminates at the railway station in Xian, China which is then custom cleared and released from the station. The final leg of its journey is covered via roadways from the train station. The CO_2 emissions is for the to the Chinese factories for the different legs of transportation is mentioned below in Table 6.7.

Table 6.7: CO2 equivalent to China via sea for different legs of transport

Transport leg	Mode	Route	Distance (km)	CO2 equivalent (in tonnes)
Pre-carriage	Rail	Gävle - Hamburg	1 272	0,19
Main-carriage	Rail	Hamburg – Xi'an	9 164	5,16
On-carriage	Road	Xi'an - Beijing	1 117	1,66
On-carriage	Road	Xi'an - Hohhot	1 022	1,52
On-carriage	Road	Xi'an - Kunshan	2 000	2,10

Table 6.8: Total CO2 equivalent from Sweden to China per 40' container via rail

Origin	Converting factory	CO_2 equivalent ton/ container (door to door)
Gävle	Beijing	7.01
Gävle	Hohhot	6.87
Gävle	Kunshan	7.45

6.2.3 Comparative analysis

The two figure below, namely 6.6 and 6.7 show represent the difference in emission factor for the two modes of transport.

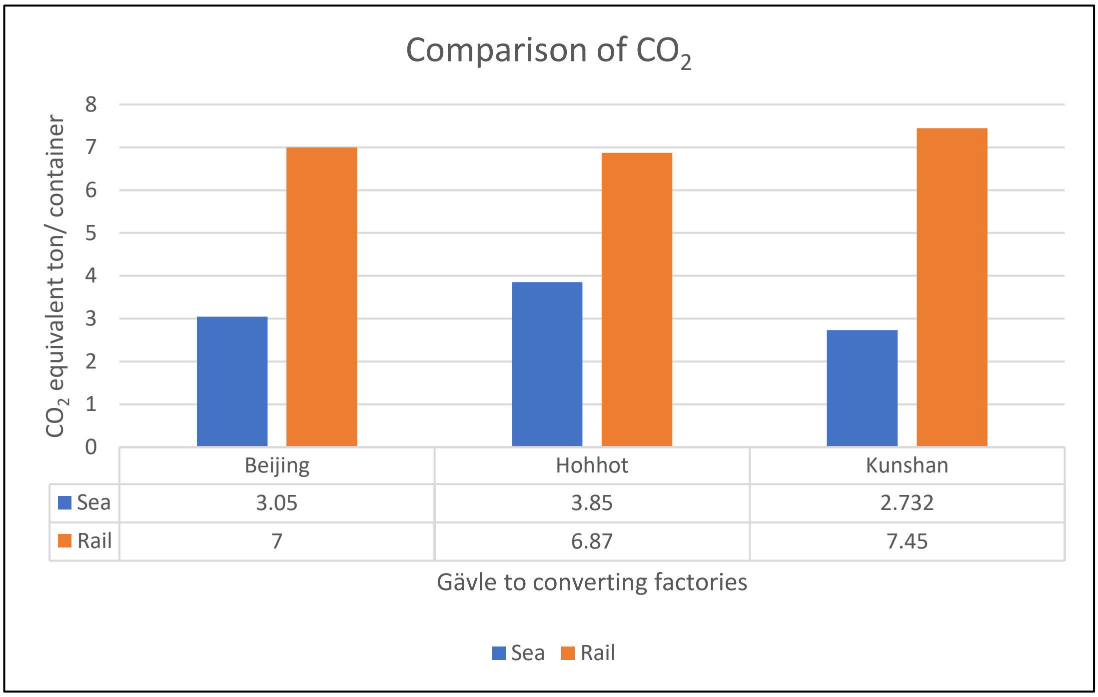

Figure 6.6: Difference in CO2

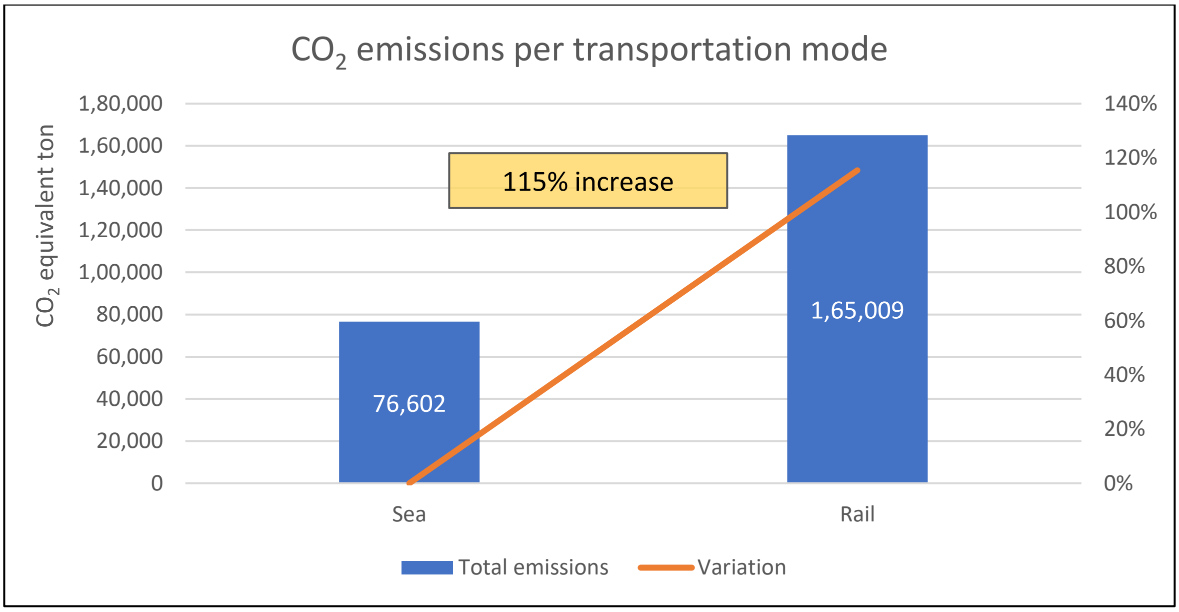

Figure 6.7: Annual CO2 emissions per transportation mode

Figure 6.7 shows that switching the entire demand to be shipped by rail, there is an increase of 115% of carbon emissions. As it can be deduced from the Figure 6.6 above the carbon emissions for rail is much higher when compared to sea. Even though the distance travelled by trains and the fuel consumed is much lower for rail, the emissions for rail freight is much higher than sea freight. This is in line with what Lumsden (2007) suggest regarding the environmental emissions for both modes of transport. Capacity is the main reason attributed to lower emissions for sea freight. This means rail freight will have to perform higher number of journeys to ship the same capacity of containers that sea freight can handle in a single journey as discussed by Ivanov et al. (2019). The higher number of journeys would lead to higher consumption of fuel and in turn generate higher emissions. Considering paperboard is low value high demand raw material, it would be better to ship them in large quantities rather than in small quantities less frequently. This would not only secure availability at a lower cost but also, have a reduced negative impact on the environment.

6.3 On time performance

This section discusses and compares the on-time performance of sea freight which comes from the IRIS portal to rail freight. As the historical data for rail freight on time performance was not available, data from the freight forwarding companies was used to evaluate the criteria.

6.3.1 As-is – Sea freight

The current service performance of on time delivery of shipments at Tetra Pak is referred to as Total Transport Performance (TTP). Tetra Pak compares the Estimated time of arrival to the actual arrival date to check the TTP. Tetra Pak also provides a 2-day grace period for its freight forwarders, meaning if the shipment arrives 2 days later than expected, it is still counted as on time delivery. Any delivery of shipment taking place before the estimated time of arrival is still counted as on-time delivery. In 2019, Tetra Pak sent 981 shipments from Gävle to Chinese factories by sea out of which 824 shipments were on time which translated to 86% on time deliveries. A reason attributed to a low on time performance of sea is due to the higher cost of operating vessels. Freight forwarders for sea, need to consolidate all containers from different customers in order to make shipping viable for their organisation. Hence, vessels are generally docked at the ports until the capacity is not utilized in order to the journey profitable.

6.3.2 To-be – Rail freight

A major advantage of rail freight apart from the lower lead time, is its potential to arrive on time in its destination. Since, Tetra Pak does not use rail for shipping base materials to China via BRI, the data for on time performance was collected by interviewing the freight forwarders. Although the actual percentage of on time performance could not be found, the deviation of lead time was used to compare the service aspect. The on-time performance of rail is much better when compared to sea, with shipment deviations of at the most 2 days. A deviation with more than 2 days for rail, would be due to a disruption in the process. Another reason for the higher on time performance of rail is because, freight forwarders also make use of public trains to ship containers. Unlike sea freight, due to the low volume of containers that rail handles, forwarders do not need to consolidate containers to cover for the higher operating costs. Hence, the lower lead time variation apart from the low lead times itself, enhances the performance of rail when compared to sea.

6.4 Sensitivity Analysis

As discussed in the previous section, with the current costs TLC of rail is 62% higher than TLC of sea. The primary objective of this section is to analyse how a change in one variable such as unit price and transportation cost could affect the TLC in a way both the modes of transport have the same TLC. For this analysis, the authors will consider different values of holding cost charge from 10% to 80%, as this value is an estimation that is the basis for the valuation of inventory carrying costs. The reason for having the holding charge going up to 80% is due to the low material value of paperboard. The analysis was done with the assistance of the "What-if Analysis" tool in Microsoft Excel, that allows one to change the value of a dependent cell to a specified target by changing the value of an independent cell.

6.4.1 Transportation cost per container

As is possible to see in section 6.1, changing the mode of transportation to rail increase the transport in 121%. This increase was one of the drivers that made rail freights economically unfeasible. Therefore, the authors would like to evaluate the reduction in rail freight cost per container that would equalize the TLC in comparison to sea freight. For that, the transportation cost per container will be treated as the average of the costs for the three different routes. As there is not a big different between the routes, the average value will work fine to evaluate the decrease in cost per container needed. The results are presented bellow in Table 6.9.

Table 6.9: Sensitivity analysis focused on rail transportation cost change

Holding charge	New Rail transp. cost	Current Rail transp. cost	% Var	Current Sea transp. cost	% Var
10%	$263,00	$536	-51%	$227	16%
20%	$284,00		-47%		25%
30%	$306,00		-43%		35%
40%	$327,00		-43%		44%
50%	$348,00		-39%		53%
60%	$369,00		-35%		63%
70%	$390,00		-31%		72%
80%	$411,00		-27%		81%

According to Table 6.9, it is possible to see that would be necessary a substantial decrease on rail transportation cost per container in order to enable the TLC for both modes to be balanced. If the reduction in the cost per container is higher that the values specified in the table, rail freight begins to be a more attractive mode of transportation from an economic standpoint.

6.4.2 Unit price per m^2

In section 6.1.3 was mentioned that one the reasons for inventory carrying costs are responsible for a much smaller share of TLC compared to transportation cost is because of the low unit price of paperboard. This low unit price value reflects a low value being transported in each container, which is the unit of analysis being considered in this thesis for inventory carrying cost calculations. For that reason, the authors thought it would be interesting to analyse what increase on unit price would make the TLC for sea and rail freight equal. For the calculations, the authors considered the weighted average of the unit price per square meter of all paperboard SKUs. All paperboard SKUs have similar unit price, so the average value will work fine to evaluate the needed increase in the average cost per square meter. The average unit price was then multiplied by the average square meter per container to also evaluate what minimum value per container would start to make rail shipments economically feasible. Below in Table 6.10 and Table 6.11, the values and calculations are presented.

Table 6.10: Average square meter price for paperboard

Avg M2 price (US$)	Avg M2 per container	Avg value per ctnr (US$)
$0,03	93 300,13	$2 430,00

Table 6.11: Sensitivity analysis focused on square meter price change

Holding charge	Avg M2 price (US$)	Avg value per ctnr (US$)	Increase on price
10%	$0,363	$33 850	1293%
20%	$0,181	$16 925	597%
30%	$0,121	$11 283	364%
40%	$0,091	$8 462	248%
50%	$0,073	$6 770	179%
60%	$0,060	$5 642	132%
70%	$0,052	$4 836	99%
80%	$0,045	$4 231	74%

The results in Table 6.11 show that would be necessary a substantial increase on unit price in order to make rail freight economically feasible. These results just confirm the fact that the rail transportation might not be the ideal transportation mode from an economic standpoint for products with a low unit value. It is also possible to see the value that a container should carry in order to equalize sea and rail TLC in this particular case. With the results it is possible to conclude that rail shipments are not economically feasible for paperboard materials, but they might be good for products that could fill-up one container with more value.

6.5 Risk Analysis

The aim of this section is to shed light on the potential risks identified by the authors during the data collection process. These risks were mentioned by the freight forwarders which would be common for all organisations using rail under the BRI. These potential risks are discussed to provide an overall picture and provide a holistic understanding of rail freight and BRI.

6.5.1. Trade and subsidy issues

As the BRI is a global initiative by the Chinese government, it does have some control over the routes of the system. This can have a huge impact on trade, if there arises a conflict between Sweden and China which could generate a possible trade war, as it currently happens between USA and China. Issues can include increasing import, decisions of lowering non-tariff barriers and impact on intellectual property protection. Furthermore, another risk that is identified is the control on subsidy for rail transportation. In order to motivate companies to use the rail route in BRI, Chinese government initially subsidised the cost of rail. Now since, companies have realised the potential benefits of using rail, Chinese government reduces the subsidy each year by 20% increasing the cost of transportation. Hence, the control on the capacity of containers and the reduction in subsidy each year is a potential risk for the smooth trade between Sweden and China.

6.5.2. Technical Limitations

A technical limitation pointed out by the rail freight forwarders and the theory, is the lack of standard rail gauges in the Eurasian land bridge. This not only causes a slowdown in the chain but also increases the cost. The lack of standardisation is considered as a potential risk because, this involves moving the containers from one train to another which requires manpower and the necessary infrastructure. Furthermore, the fact that the BRI covers a vast heterogenic region can represent some risks due to the different levels of technological advancements among the different regions within the route. Historically limited regions such as the Middle East and Central Asia could represent operational risks in case the technological gaps in these areas are not narrowed. Another technical limitation in the process of using rail is a concept of ‘stuffing’. Stuffing refers to the way in which goods are placed in containers in order to ensure proper load distribution. While shipping containers by rail, shippers need to load containers partially and take pictures of the goods. This although, does not disrupt the process but has the potential to increase the transport time and delay the process.

6.5.3. Capacity Limitations

Currently, the world is facing a global pandemic crisis due to the COVID-19, which is directly impacting demand for different businesses. This decrease in demand has further influenced sea freight forwarders as many of their customers tend to cancel overseas shipments that was to be transported via sea. This situation results in ocean blanking, which is the lack of minimum number of containers that need to be shipped in order to make the journey profitable. Due to this situation, sea freight forwarders are not operating vessels which lead to increase delay. Rail transport has a considerably lower transit time and operating costs when compared to sea transport. This has turned out to be quite a lucrative deal for Tetra Pak in these tough times. Due to this reason, companies have moved from shipping large quantities less frequently from sea to low quantities more frequently via rail. This has led to an increase in the demand for containers to be shipped by rail, leading to capacity issues and at the same time increase in price. This rise in demand for rail freight and the lack of container availability has increased the challenge of shipping goods by rail. This problem although, can be defeated by increasing the number of containers and developing the Eurasian corridor.

In conclusion, these are some risks which could disrupt or create hindrance in the supply chain for paperboard, leading to increase in lead times and reduction in service performance. Firstly, the technical limitation of unstandardized rail track gauges is in line with what Zhang and Schramm (2018) discusses in challenges of using BRI. Another limitation that was similar to that discussed in theory by OECD (2018) is the technological gap in the different countries in the Eurasian land bridge. This affirms that there still exist challenges which is due to lack of regulation of operational and technological infrastructure. A new finding that was pointed out under technical limitations was the concept of stuffing. This concept was related to rail freight which could incur higher transit times or lead to delays but was not pointed out by research papers.

Secondly, the capacity limitations of containers due to exponential rise of companies using rail freight under BRI was also pointed out by CRCT (2018). Although, CRCT (2018) did not explicitly mention about the limited capacity but the rise in number of trains operated per annum pointed out in the direction of a future risk of limited capacity in the BRI route. Another reason which attributed to limited capacity is the global pandemic of COVID-19. This was a novel finding considering that the extensive literature related to BRI did not mention pandemics as a risk that could disrupt the process of shipping.

Lastly, Pomfret (2019) suggested that reduction in operating costs was due to national rail companies and freight forwarders. Although, this was the reason, but another major factor was subsidies provided by China itself. This made the Eurasian Land Bridge economical and now with the reduction in subsidies, it would be interesting to see how the demand would fluctuate and have an impact on the overall shipping costs.

7. Discussions

The purpose of this chapter is to review the performance of rail compared to sea from different aspects like costs, service performance. Furthermore, this section also provides relevant insights in performance of visibility for the two modes of transportation, environmental impact and other reasons associated to the performance of each mode of transportation.

7.1 Total Logistics Cost

TLC is a combination of the inventory carrying costs and transportation costs as discussed by Sheffi et al. (1988). Transportation cost is affected by the volumes being transported and transportation modal choice, while inventory carrying costs are affected by lead times, frequency, size of shipments, variation of lead times and demand and the value of the product being transported and stored.

It was possible to notice in section 6.1 that the increase in transportation cost is higher than the reduction in inventory carrying costs, which has a considerable impact on TLC. It also showed that rail freight transportation has a higher cost per container compared to sea freight, which led to the increase in the total transportation cost by 121%. As transportation cost values in negotiations are normally given as a cost per container, the total transportation cost increases linearly with increase in the cost per container, as shown in section 6.1.3. There are multiple reasons for this increase. One reason attributed to the rise in transportation cost is the reduced capacity and the higher operating costs. As a block train can accommodate just 41 containers, it fails to achieve economies of scale leading to higher cost per container. At the same time, there is an increase in the operational costs since the containers need to be custom cleared when it passes from one country to another. In addition, due to the technical challenges explained in shipping routes parts in section 5.8.3 and 6.5.2, containers need to be transferred from one train to the other. These activities incur higher transit times and greater cost due to the use of operating equipment and manpower. Finally, the rise in shipping cost of rail is due to the reduction in subsidy by the Chinese government for using rail transport in the BRI as explained in section 6.5.1.

The second part of TLC is the inventory carrying costs which is a combination of in transit costs, safety stocks and cycle stock as explained in section 4.2.2. In-transit costs saw a considerable difference due to its dependence on lead times. With lower lead times for rail as shown in section 5.8.3, duration of time for which the paperboard will be in transport is less and in turn reduces the tied-up capital while goods are in-transit. Safety stock on the other hand, which is an integral part of the inventory carrying costs is dependent on LT, LT variation and demand variation. Out of these three factors which affect the safety stock, demand variation plays the biggest role in impacting safety stock levels and the cost associated to it as shown in section 6.1.3. Also, since the demand variation of paperboard was not sporadic, it did not have a big difference on safety stocks while using rail.

Finally, the value of product, acts as a huge factor as well which impacts the overall TLC. Since the product have a low unit price, it does not lead to a substantial reduction in the inventory carrying cost. This shows that there exists a direct relation between the unit cost of the product and inventory carrying costs, which further affects the TLC as shown in section 6.1.3.

7.2 Environmental Impact

The door to door carbon emissions for rail freight far exceeds the emissions produced by sea freight as presented in section 6.2.3. The main carriage is responsible for majority of the emissions occurrence as it involves the maximum distance travelled leading to higher fuel consumption. This shows that capacity of the mode of transport is a major factor, which affects the emissions for a mode of transportation. Parameters like fuel consumption do not have a major impact on the carbon emissions, when shipping large quantities of containers. Rather they have a direct relation to the capacity that a transport mode can accommodate. In a single journey, sea can ship 20,000 containers while a block train can ship only 41. This means a block train with its existing capacity, will need to operate approximately 487 times to ship the same number of containers that sea freight can handle in a single journey. Hence, the environmental impact for sea and rail are not comparable but if Tetra Pak plans to use a mode with lower lead time like air, rail could be an ideal alternative in terms of environmental impact.

7.3 Service performance

Service performance measures like lower lead times and higher on time performance is an important aspect that Tetra Pak considers while choosing a mode of transportation. The lower transportation times and better service performance as discussed in section 3.3 and 5.8.3 respectively are its unique selling point. Similarly, in this case, the transit time for shipping paperboard using rail is much better compared to sea as presented in section 6.3. This increase in service performance not only enables faster availability of paperboard but also affects the inventory carrying costs as shown in section 6.1.3.

Furthermore, visibility can also be considered an aspect of service performance for Tetra Pak. In order to reduce losing track of containers and achieving visibility in the supply chain, tracking is important for Tetra Pak. Tracking of containers can be a challenging task in sea freight as the vessels have capacities of 20,000 containers which have a higher potential to get lost. Also, tracking of shipments is a challenge in sea as there are connectivity issues which does not allow accurate and live location sharing. Maersk which acts a freight forwarder to Tetra Pak is currently working on a project that will address these issues and enable live tracking of shipments on sea. The overall performance of visibility of containers on rail is better compared to sea but the challenge here is that the train is not owned by the freight forwarders. Hence, freight forwarders either need to be in constant touch with rail companies to check the location of the shipment and then update the information or equip the container with a GPS which will incur additional costs. Here lies another trade-off that needs to be considered while selecting the mode. On one hand sea freight could provide better visibility due to freight forwarders owning the vessels and the technology advancement in the future while rail with lower capacity is much easier to handle and reduces the risk of losing containers. Overall, the tracking or visibility in both rail and sea freight have their own advantages but due to the live tracking feature under development by Maersk, sea freight will have an upper hand.

In conclusion, from the discussion between the two modes of transport it is evident that there exists several trade-offs that one needs to consider while choosing the modal choice as mentioned by Rodemann and Templar (2014) and Seo et al. (2017). Section 6 presented that sea freight is much better suited for shipping low value commodities over longer distances which results in higher cost savings. But advantages for rail freight such as lower lead times, higher responsiveness to customers and its availability during emergency situations makes a strong argument to use rail, which was in line with what Lumsden (2007) discusses. In this case, the organisation under study, i.e. Tetra Pak will need to prioritize between lower cost and higher service performance leading to higher customer responsiveness. This will ensure that the company achieves a balance and achieve flexibility, which is explained by Lu et al. (2016). This is like what is discussed and presented by Liberatore and Miller (1995). Overall, this chapter discussed and presented that selecting a modal choice involves various trade-offs that a company needs to consider which is supporting the literature presented in the section above. Figure 7.1 below summarizes the performance of two modes of transport for the chosen performance measures.

Sea		Rail	
	TLC = $ 394 822 (USD)		TLC = $ 639 025 (USD)
	Carbon emissions = 76602 tonnes		Carbon emissions = 1,65,009 tonnes
	Lead time – 88 to 92 days (door to door)		Lead time – 65 days (door to door)
	86% on time performance		Lead Time variation of 2 days
	Better visibility performance		Higher risks and challenges involved

Figure 7.1: Overall comparison of sea and rail freight

We would recommend Tetra Pak that, from the chosen performance measures, the economic aspect which is TLC should be given a higher weightage and looked into more, as sustaining the business economically is of utmost importance. This will be more so given the current situation with a global pandemic which is affecting several businesses across industries. Also, with the current scenario, sea would not only have a lower TLC but have a better performance impact. This would portray Tetra Pak in good light across industries and make it a responsible one. This would mean that service aspect would have to take a back seat in the current situation but as explained earlier, choosing a mode of transport comes with trade offs and Tetra Pak should be opt for better economic and environmental aspect over service performance.

8. Conclusions

The final section of the thesis would provide insights into recommendations for Tetra Pak based on the three different aspects discussed in the previous sections. It will also aim to answer the research questions that will fulfil the objective of this thesis. Furthermore, it will also include, in brief, the areas for future research that Tetra Pak should investigate for low value and high value products.

8.1 Research questions answered

The purpose of this thesis is to conduct a feasibility analysis of change in mode of transportation from sea to rail from an economic, environmental and service performance standpoint, while proposing a better understanding of the advantages and challenges of rail freight for paperboard material going from Scandinavia to China at Tetra Pak.

RQ1: *How is the performance of the current sea freight route in terms of economic, environmental and service aspects?*

The current sea freight used by Tetra Pak was investigated using the qualitative and quantitative data available in the information systems and by interviewing the responsible stakeholder. This was done in order to ensure that the source of the information was reliable at the same time that it allowed deeper insights into the advantages and challenges of the current setup for sea freight mentioned in section 5. The as-is analysis in section 6.1.1 revealed the different costs calculated associated to TLC and further discussed how sea freight performs on aspects like environmental impact, on time performance and visibility. In terms of economic and environmental aspects, sea freight performs better than rail as shown in section 7. The main reason attributed to the high performance, is the fact that sea freight provides better capacity. This enables the freight forwarders to leverage the concept of economies of scale make the journey cost efficient and emit reduced CO_2 when compared to rail. Also, since this mode of transport is being used for a long period of time, it has matured, and the operations related to it are quite efficient. The performance of the current sea freight is shown in Table 8.1 below.

Table 8.1: Sea freight performance

Mode	TLC (USD)	Carbon emissions (in tonnes)	On time performance
Sea	394822	76602	86%

RQ2: *How would be the performance of rail freight be in terms of economic, environmental and service aspects?*

In order to investigate the rail freight situation that will be used by Tetra Pak to ship base materials, the authors had to be in contact with the relevant freight forwarding companies which provided rail solutions. Along with external organisations, it was also important to be in line with the expectation of the organisation under study in order to retrieve the correct information and the ensure the analysis is being performed with the correct data. The solution of to be analysis in section 6 showed that there was an increase in the cost of shipping paperboard from Sweden to China via rail, as well as the carbon emissions. The main reason attributed to the rise on cost was discussed in section 7.1 which involved several factors like higher cost of shipping, reduction in subsidiary for using rail by China and the lack of capacity to ship container in a single block train. Similarly, the reason for higher carbon emissions was also recognized due to the capacity limitation of rail shipments. Since Tetra Pak did not use any rail freight from Sweden to China, the on-time performance was collected from rail freight forwarders and compared based on variation of lead time. This showed that the lead time variation of rail would be maximum two days which means the on-time performance for rail will be better when compared to sea. The overall performance of rail freight is shown in Table 8.2 below.

Table 8.2: Rail freight performance

Mode	TLC (USD)	Carbon emissions (in tonnes)	On time performance (LT variation)
Rail	639025	165009	2 days

RQ3: *What are the risks and challenges to implement rail freight from Scandinavia to China?*

Since, Tetra Pak will be using the routes in BRI to ship base materials for the first time, it was of importance to consider and investigate the risks involved in this process. The data required to answer this research question came from interviewing the experienced rail freight forwarders and the stakeholders which were involved in the negotiations within Tetra Pak. This study showed that there exist some risks that could in future affect the cost of shipping via Eurasian Land bridge. These risks were related to trade relations between Sweden and China as well as the countries involved in BRI. Other challenges which were mentioned in section 6.5 were related to the technical limitations that tend to have an effect on the cost and prevent smooth and efficient process of shipping containers through BRI. Some these were in line with what the existing literature had been presented in section 3.6.3.

8.2 Final thoughts

8.2.1 Contribution to Theory

BRI is a relatively novel topic where companies had not realised its potential to make trade efficient between Europe and other countries in the east like China, until now. This project was built on a strong foundation of relevant concepts and literature which is well known and developed by credible sources. However, there did not exist much literature on the comparison between the conventional mode of transport which is sea freight compared to the developing mode of rail under BRI. This study makes a minor contribution to theory by developing the area of modal choice selection in the BRI context. This study, more specifically, adds to the qualitative information like risks and challenges that could potentially occur while using the routes under BRI. It also sheds light on other important aspects to consider in modern times like carbon emissions and service performance, visibility while choosing a mode of transportation. Finally, this thesis further builds on the literature of trade-offs that one needs to consider while choosing the mode choice.

8.2.2 Contribution to Practice

This study contributes to practise in ways more than one. Starting with BRI itself, it presents the advantages and challenges of using rail under BRI. It informs the readers of operational and financial repercussions of using rail freight while shipping raw materials across continents. It provides knowledge on how to analyse a mode of transportation based on the overall logistics costs involving inventory costs and transportation costs which would provide a holistic view on the financial performance. The study also presents performance metrics like the service performance and environmental impact which should also be taken into consideration while selecting mode of transportation. Another important takeaway from this study for the practitioners is that the decision of choosing a modal choice involves trade-offs mainly between costs and customer responsiveness. It also provides insights into the different aspects of using BRI for shipping goods from Europe to China and further discusses some limitations that should be investigated before using the routes under BRI.

8.2.3 Limitations

As with every thesis, this study also has its limitations. Firstly, this thesis is limited to a single organization and within that it is limited to a single business unit. Within the business unit, the analysis was conducted for a single raw material. This failed to show the true picture of how the financial metrics would differ for different products. Furthermore, the demand data for paperboard was for a specific year and hence, the analysis was a result of the same. Secondly, in the analysis, the calculation for safety stocks was performed using the method used by the planning department. Hence, if a practitioner using a different method to calculate inventories, will not be able to use this as a basis for analyzing the inventory costs. Finally, the data collected from interviews for rail freight is restricted to just two freight forwarders. This limits the information for rail freight to be used through the BRI routes. It will be essential in the future to collect more and detailed information from other forwarding companies to understand the best setup in terms of lower operating costs at the same time reduction in the risks associated to it.

8.2.4 Future research

According to the analysis, it is recommended that Tetra Pak should not use rail freight for shipping paperboard from Sweden to China. This recommendation is proposed considering not just because of the higher costs but also, due to the impact it would have on the environment. Furthermore, the risks and challenges identified with the rail freight in BRI context, strengthens the argument of not using rail for paperboard. However, if there is a drastic reduction in the transportation cost of shipping container via rail as shown in the sensitivity analysis or there happens to be an increase in the unit price of the raw material, rail can be considered as a much viable and economical mode.

It is also recommended to Tetra Pak that for the future, it will be interesting to analyse the how the total logistics costs would change if the it plans to ship spare parts which are much more valuable than paperboard and would leverage the lower lead times and higher on time performance provided by rail. Further, also analyse and compare the feasibility of rail versus air transport. This would provide the organisation with good insights on all the different modal choice for different kinds of products that it has to offer in the most efficient manner.

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Appendix

Interview guide

All interviews conducted we semi structured with the aim to understand various flows, processes and retrieve qualitative and quantitative information. The questions were restricted to the subject that the interviewee was responsible for. The questions were sent out to the interviewees before the interview via email. This was done so that the interviewee was not caught unaware and had answers to questions before the interview began. Below, the readers will find the questions asked to different stakeholders along with the objective for that particular interview.

1. Tetra Pak GT&T for sea freight

Purpose: To develop understanding of sea freight and the routes used for shipping.

Main Questions:

1. How are shipments booked for transporting paperboard from Sweden to China?
2. What is the sea route that is followed for shipping paperboard from Sweden to China?
3. What are the costs and lead times to ship containers from Sweden to China?
4. What are the challenges related to sea freight?

2. Tetra Pak GT&T and Maersk for rail freight

Purpose: To develop understanding of rail freight, the routes used for shipping and challenges associated to them.

Main Questions:

1. Which companies (3PL) offer rail from EU to China?
2. Frequency of trains from EU to China?
3. What is the current capacity of rail and what we can expect for the future?
4. What are the distances travelled in each different route? door to door?
5. What is the cost per container on rail shipments? What volume is considered?

6. What is the available capacity for rail shipments from Gävle to China (containers)
7. What is the cost per container considering using all capacity?
8. What are the current challenges of shipping goods from EUR to CN by rail (complex legal environment, technical limitation, imbalanced cargo volume)?
9. How is the rail performance compared to sea in Maersk (EUR to CN), historically?
10. What are the instances when companies have opted for rail instead of sea or air?
11. Could rail perform better on environmental aspects than sea?
12. Could Maersk provide rail freight from Gävle to Chinese ports?
13. There have been reports that China plans to pull the plug on BRI. What happens then? do rail shipments stop completely?

3. Geodis for rail freight and services provided to TP

Purpose: To understand the services provided by Geodis and benefits and challenges associated to rail freight.

Main Questions:

1. What are the responsibilities of Geodis while working with TP?
2. According to Iris, sea freight has better performance than that of rail for shipments from EUR to CN. This tends to remain the same?
3. What are the challenges of shipping goods by rail from EUR to CN?
4. For shipments with the same origin and same destination that can have more than one route, do they have different costs?
5. How does Geodis prioritize the routes for sea and rail shipments?
6. What are the current challenges related to shipment visibility?

4. Tetra Pak Integrated Planning and China material planner

Purpose: To understand of processes related to planning and inventory of base materials.

Main Questions:

1. How does base material manage their inventories when it come to ordering or review policy?
2. How do you calculate the inventory levels for paperboard?
3. How do you calculate Safety stock?

4. How do you calculate total inventory costs? Do you consider ordering or holding costs per product?
5. Do you consider service levels?
6. What is the Unit of demand (pallets, kgs, reels) and time unit (weeks, months)?
7. Which demand data is analyzed to manage base material inventory?
8. How many SKU's are shipped from BK to the Chinese factories?
9. Are there SKUs of paperboard that are more critical and demand faster delivery times? Which ones?
10. Are there air shipments being used for SKU? Under what circumstances do you use air shipments for SKU?

5. Tetra Pak Integrated Logistics and Tetra Pak China Logistics

Purpose: To understand the different costs associated with respect to storage and transport at Chinese factories.

Main Questions:

1. What is the inland transportation cost per truck? Always FTL?
2. What is the transit time for the shipments going from the Chinese port to factories?
3. What is the distance travelled from port to factory?
4. What is the unit price of each paper material SKU?
5. For Kunshan and Beijing what is the inland freight cost per ton from the seaport to the factories?
6. Do Kunshan and Beijing use external warehouses? If yes, what is the cost per ton?
7. What costs are included in the Other local expenses? Please provide some examples