CHALMERS
UNIVERSITY OF TECHNOLOGY

Goods flow mapping

- The potential of inland waterway transportation in the region around lake Vänern and Göta Älv river

Master's Thesis in the Master's Programme Supply Chain Management

DENNIS EKBERG
MARTIN WEDBERG

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019
Report No. E 2019:104

MASTER'S THESIS E 2019:104

Goods flow mapping

– the potential of inland waterway transportation in the region around lake Vänern and Göta Älv river

DENNIS EKBERG
MARTIN WEDBERG

Tutor, Chalmers: Violeta Roso
Tutor, company: Sara Rogerson & Vendela Santén

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

Goods flow mapping

- The potential of inland waterway transportation in the region around lake Vänern and Göta Älv river

DENNIS EKBERG

MARTIN WEDBERG

Master's Thesis E 2019: 104

Department of Technology Management and Economics
Division of Service Management and Logistics

Chalmers University of Technology

SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers digitaltryck
Gothenburg, Sweden 2019

Acknowledgements

We would like to express our gratitude towards all the involved persons who has contributed to this study.

Firstly, we want to thank our supervisors at SSPA, Sara Rogerson and Vendela Santén, who gave us the opportunity to write this thesis. They have done their best assisting the project and helping out whenever needed.

Secondly, we want to thank all the interview respondents who gave us important insight and information during the study.

Lastly, a big thank you to our families and friends who has shown interest and support throughout this semester.

Dennis Ekberg & Martin Wedberg

Gothenburg, June 2019

Abstract

As of today, a small share of the total volume of goods transported in Sweden is carried by maritime transportation and Inland Waterway Transportation (IWT) stands for only 0.7% of this volume. Due to the globalisation, supply chains are now operating worldwide to increase their competitiveness which puts requirements on the existing infrastructure. This, to cope with the expected increasing amount of transportation in the future. The transportation network in Sweden is currently unbalanced, with the majority of the volume transported on the road network. Superiority in the transport quality factors reliability, accessibility, connectivity, flexibility and cost is believed to be what causes this imbalance. However, the external effects of road transportation need to be mitigated where IWT is identified as a possible mean to decrease the road transportation. Lake Vänern and Göta Älv River is the longest inland waterway in Sweden with unutilized capacity, thus holding potential to be used as a mean to achieve a better balance in the transport system

There is emerging pressure from authorities in the transport industry to reduce the environmental impact of road transportation. The European Commission strives for sustainable transportation and promotes modal shifts to alternative transport modes with less impact on environment and society. The Swedish government also set environmental policies where the transport system is under pressure. In order to obtain a prosperous transport network, inland waterways offer the potential of extending the current transportation network and become more efficient.

This study concludes that there is undeniable potential for an increased usage of IWT in Sweden, but that there needs to be structural changes made relating to the Swedish IWT framework. The potential for an increased usage of IWT in lake Vänern and Göta Älv river is hard to quantify, due to the different contexts and different factors affecting their suitability for IWT. Reliability, flexibility, connectivity and cost are decisive factors influencing the modal choice for goods transports and especially the suitability for IWT.

Table of Contents

1. Introduction

This introductory chapter presents the background, case description, purpose, research questions, scope and delimitations of the study. Lastly, a presentation of the outline of the thesis follows which intends to guide the reader through the different chapters.

1.1 Background

In order to achieve sustainable and competitive goods flows within the national transport system, focus is transferred to the yet unutilized inland waterway transport system (IWTS) (Caris, Limbourg, Macharis, Lier & Cools 2014). As of today, a small share of the total domestic volume of goods are using transports on sea, and Inland Waterway Transportation (IWT) stands for only 0.7% of this (Trafikanalys 2016). Due to the globalisation, supply chains are now operating worldwide to increase their competitiveness which puts requirements on the existing infrastructure to cope with the expected increasing amount of transports in the future (Mommens & Macharis 2014).

In North-western Europe, transportation on inland waterways are used to a higher extent. Germany, the Netherlands and Belgium are the biggest users of this transport, where Erceg (2018) states that the geographical position and the development of inland waterway infrastructure are common factors for these countries. Meers & Macharis (2015) describes that intermodal transports are important in order to offload the burden from road transportation in serving major ports. Intermodal transport solutions will extend and maintain the current hinterland and at the same time provide connections to lakes, rivers and other ports in order to mitigate the external effects of road transports.

In order to obtain a prosperous transport network, inland waterways offer a potential to extend the current transport network as well as lower the use of road network in the future (Mommens & Macharis 2014). This corresponds to the objective stated by the European Commission, with the goal to reach zero net emissions in 2050 (European Commission 2018). Caris et al. (2014) mentioned a solution of reducing the impact by transferring road transport into more use of fossil free transports, thus enhancing the ecological, societal and economical aspects (Abbasi & Nilsson 2016). The Swedish Government share the vision to reach zero net emissions by 2050, where (Pierrehumbert, 2016) identifies the transportation sector using liquid fuels as the biggest challenge to reach the goals.

According to the capacity report done by Trafikanalys (Garberg, 2016), imbalances exist in the national transport network in Sweden. Road transport is the dominant mode of transport due to the mobility and extensive infrastructure, but is also characterised with several external factors such as congestion, air pollution, accidents and noise (Liedtke, Carrillo Murillo 2012). In relation to rail and sea transports that offers the possibility to absorb bigger volumes leads

to a lower environmental impact per tank. Hence, this proves the importance of this report of investigating the potential of IWT.

1.2 Case description - Inland Waterway Transportation Solution (IWTS) 2.0 project

The IWTS 2.0 project addresses inland waterway challenges and aims at facilitating and creating awareness of how to utilize the waterways in a better way (Northsearegion, 2019). It is funded by Interreg North Sea Region, European Development Fund, but also co-funded by the county of Västra Götaland and the Swedish innovation authority Vinnova. The project is driven by 11 partners from 5 different countries and with the notion of underutilized waterways in Europe the project will showcase proven concepts that then can be adopted by the market. This will be done by piloting 8 small waterway modal shifts, including innovative barge-, waterway-, transhipment-, loading/unloading-, freight flow mapping- and modal shift decision making solutions. The idea is to join forces in order to mobilise potentials and capacity to move freight to the still underutilized waterways. A Swedish reference group is put together in order to involve suitable stakeholders to understand the actors' perspectives and develop practical solutions that is applicable to the Swedish Inland waterways (IWWs). The reference group consists of ship-owners, ports, logistics operators, goods owners, authorities and municipalities. The Swedish contribution to the project is coordinated by SSPA where the stakeholders aims at creating a holistic picture of coastal- and inland shipping in Sweden and how to develop innovative logistic systems within this area (SSPA, 2019). The project consists of six work packages which are put in place in order to facilitate a realisation of the modal shift to waterways, where this study is part of the goods flow mapping (see figure 1).

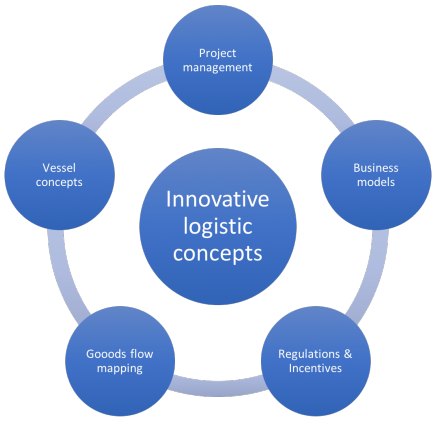

Figure 1.1. The six different work packages towards IWT

1.3 Purpose of the study

The main objective with this study is to identify potential for an increased usage of IWT in lake Vänern and Göta Älv river, based on existing goods flows.

1.4 Research questions

In order to be able to fulfil the purpose of the study, research questions have been formulated. The second research question is further broken down into 4 more specific questions to address different perspectives. These will guide the project where the different chapters are intended to provide information that can be used in order to answer the research questions.

1. What are the inbound- and outbound flows in the counties of Värmland, Västra Götaland and Örebro?
2. What potential can be identified for an increased usage of IWT in lake Vänern and Göta Älv river?
    a. Which goods types are suitable?
    b. What potential goods flows exist in the geographical area that could be transferable?
    c. What potential is there for containerisation?
    d. How do actors in the supply chain consider the use of IWT?

1.5 Scope/delimitations

Delimitations in this study is the geographical area around the river Göta Älv and around lake Vänern, more specifically the counties of Västra Götaland, Värmland and Örebro. As the study aims at examining the potential for an increased use of IWT, by conducting goods flow mapping, a strong focus on the secondary data (national statistics) characterises this report, see section 2.5.2. The secondary data works as preliminary input for answering both of the research questions but empirical information has also been collected from involved actors in order to create a more holistic picture. The data represents information of goods flows of shipments carried out during 2016 and economic and environmental calculations has been excluded in the report as it is considered to lay outside the scope of the research questions.

1.6 Outline of the thesis

The outline of the thesis is constructed as below and presented in order to assist the reader to navigate in the report.

Chapter 2 - Explanation of the methodology used in the study. A combined approach with a quantitative and qualitative research strategy was implemented for this study.
Chapter 3 - Presentation of the frame of reference. The total transport network and the components are presented. These parts include different characteristics of the transport modes and transport quality factors, which are later compiled in respect to IWT.
Chapter 4 - Findings from the goods flow mapping, based on the secondary data provided by Trafikanalys. This chapter intend to answer the first research question of mapping the inbound- and outbound goods flows in the selected counties. The last section will present a constructed case for IWT suitable goods transported between the selected counties, followed by its findings and discussion. This section intends to answer research question 2a.
Chapter 5 - Presentation of the findings from the case study constructed for container shuttle between the ports of Gothenburg and Kristinehamn. The last part of this chapter will present a summary of the potential goods flows, in order to answer research question 2b & c.

Chapter 6 - The empirical findings provided from the interviews are further presented here. Topics regarding the transport quality and their perspective of IWT are discussed. This chapter also provides knowledge required for research question 2d.

Chapter 7 & 8 - Discussion and conclusions are presented in these two last chapters.

2. Methodology

This chapter describes how the study was conducted. First, the research strategy and research design are explained, followed by an illustration of the research process. Then, how the literature study, data collection and analysis have been carried out is presented.

2.1 Research strategy

A mix of a qualitative- and quantitative research approach has been used for this study. The qualitative approach has been used for the empirical findings where the source of information are mainly interviews. The quantitative part consists of the secondary data that has been processed and analysed in order to be able to answer the research questions.

2.2 Research design

The research design of this study can be classified as a case study. A case study features a specific case and its complexity and should be thoroughly examined and analysed from a theoretical standpoint (Bryman and Bell, 2015). When conducting a qualitative research strategy, a case study is an approach which facilitates understanding of complex relationships between factors in the given context and provides depth rather than width (Denscombe, 2014). Also, it enables comparison of factor behaviour in different social settings. In this study, the IWTS on the specific case of lake Vänern and its surroundings is evaluated by collecting data of the specific features of the case. In order to analyse the gathered data, literature has been used in order to create a theoretical framework from where the analysis then stems. The case has been thoroughly examined and where primarily the secondary data has been used. Qualitative data has also been collected from different key stakeholders, in order to ensure to collect important information. Dubois and Gadde (2002) state that the use of a particular case in this way is the best approach to understand the phenomenon and its interactions with the context. They however emphasize that reliance on a theoretical standpoint is necessary in order to avoid biased opinions and views from the context of the case.

2.3 Research process

In figure 2.1, an illustration of the research process of this study is presented. The scope was pre-defined by the supervisors at SSPA which was presented during the first start-up meeting. The following step in the process was then to conduct an initial background study of the case and to start the literature review. The frame of reference was created initially but as the study progressed, additional information was included to support the new aspects identified. As knowledge was gathered, important stakeholders could be identified which was then targeted as potential interviewees where important data could be captured. Important stakeholders were contacted and interviews scheduled. The interviews were conducted

throughout the project, meaning that the interview data has been worked with in parallel to the other steps in the process.

As the goods flow mapping needed input data, secondary data was requested from Trafikanalys which can grant requests of such data for research or statistics creation (see section 2.5.2). The data was then processed in order to be compatible with the GIS-tool used for visualisations in the goods flow mapping. Notable to mention is that the used softwares are Excel, Power Pivot plug-in for Excel and Microsoft Power BI. The following step was to analyse the data and present the findings of the study. The frame of reference together with the empirical findings were then used in order to analyse the findings and conclusions could be drawn.

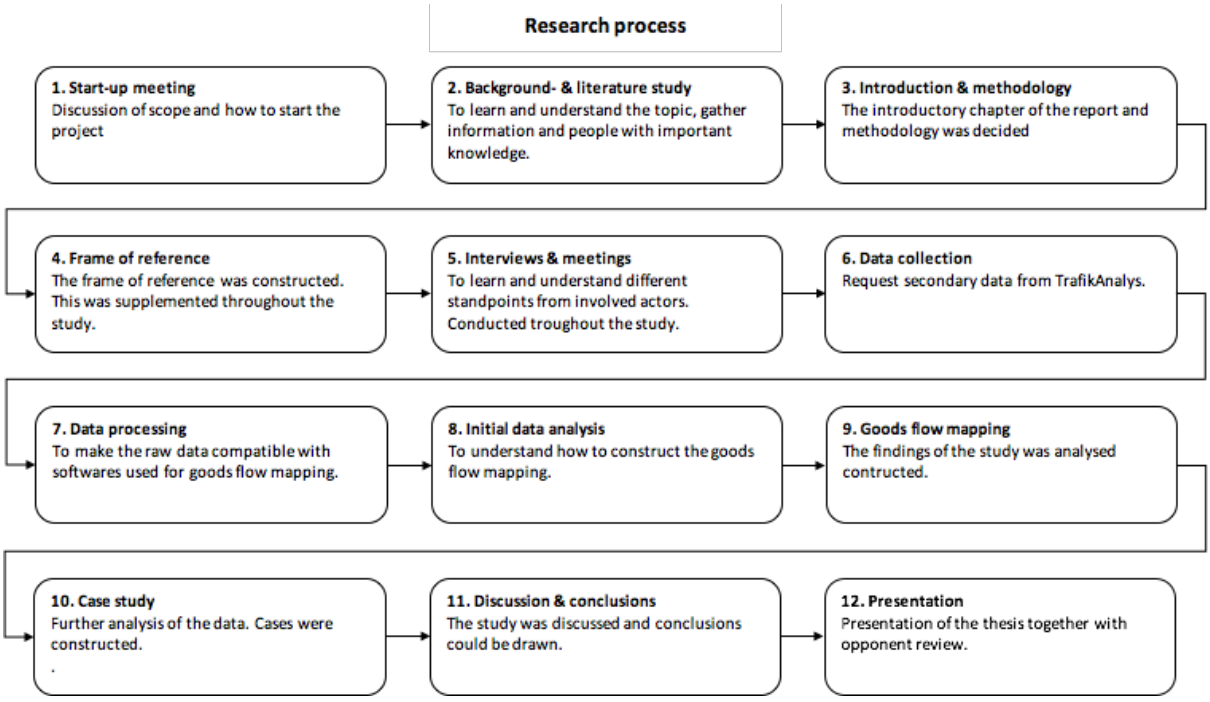

Figure 2.1. A visualisation of the research process

2.4 Literature study

In order to learn what is already known about the topic in general and specifically for the given case study, a literature review was conducted and the theoretical framework was constructed. The literature used for this study was found through Chalmers Summon, Google Scholar, Scopus database and also provided by SSPA and recommended by some of the interviewees. By reviewing the available literature and bibliographies, major references could be identified and later on used as main sources of information in the initial phase of the study, as Bryman and Bell (2015) recommend.

The bibliographies of the articles were also used as additional sources of information to the theoretical framework. Reports from authorities and organisations such as

Transportstyrelsen, Sjöfartsverket and Trafikverket have also been used as a source of information, data and statistics for the Swedish transportation system.

Keywords were configured in the beginning of the study, as Bryman and Bell (2015) recommend. This, in order to be able to find relevant articles in the databases. Examples of these keywords were: inland waterway transportation, IWW, IWT, containerisation, modal choice, transportation systems. The literature has been critically examined by comparing different analyses and conclusions, where the context of the different studies and the age of the articles also has been taken into consideration in the selection criteria.

2.5 Data collection

This section describes the data collection and the different methods used. Also, why these methods have been used is explained.

2.5.1 Interviews

The interviews were conducted with different key stakeholders in the context of the study. As there are several individuals involved in the IWTS 2.0 project with extensive knowledge about the topic in general and also specific knowledge and information about the specific context of this study, interviews were considered appropriate and also important to conduct. This in order to correctly understand the situation. Bryman and Bell (2015) highlights two types of interviewing; quantitative and qualitative. A qualitative interview approach was used in this study since this gives the interviewee the opportunity to present their own thoughts and reflections, rather than simply answering the researcher's questions. As the interviewees was considered to possess both important information as well as experience in the field, their thoughts and reflections were of much interest in order to allow for an as broad understanding as possible. Bryman and Bell (2015) states that qualitative interviewing is a good method when rich and detailed answers are desired. Furthermore, it allows for more open discussions as well as altering of the order of the questions as the interview progresses.

The interviews held was of semi-structured character. According to Bryman and Bell (2015), a semi-structured interview means that an interview guide is prepared before the interview where the topics are quite specific. However, this guide must not be followed completely during the interviews. During interviews, broad topics were discussed but as the interview progressed, the interviewee’s answer decided what question to address next. Examples of these topics are transport quality factors for transportation, IWT suitability, IWT framework, current situation of IWT in Sweden. Sometimes new questions arose and sometimes questions prepared before, were not asked. According to Dubois and Gadde (2002), this is an appropriate approach when the researcher wants to discover new data and dimensions in the given context. Bryman and Bell (2015) also stresses that not asking all the questions in the

interview guide is a characteristic of a semi-structured interview and that most qualitative interviews are a mix of semi-structured and unstructured interviews.

The different interviews held are presented in Table 2.1 where, dates, topics discussed, the interviewees organisational position and the length of the interviews are presented. As it was promised to keep their names anonymous, they are presented as goods owner, port, shipping company, etc.

Actor	Industry	Type of interview	Date	Topic	Duration
Project initiator	Shipping	In person	19 Feb	Discussion of topic in general and recommendations for goods flow mapping	45 min
Port of Vänern	Shipping	Mail exchange	22 Feb	Data and information about port operations	N/A
Municipality of Kristinehamn	Public sector	Telephone	22 Feb	How authorities work with IWT	45 min
Värmland Region	Public sector	Telephone	26 Feb	Potential for IWT and previous projects	45 min
Goods owner	Wood and paper	Telephone	12 Mar	How the raw materials are supplied to the wood and paper industry and transport quality prioritization.	30 min
Consulting company	Traffic consultancy	Telephone	14 Mar	Socio-economic perspective on transportation calculations and previous projects	30 min
Goods owner	Metal	Telephone	15 Mar	Transport quality prioritization, current transportation setup and suitability for IWT	40 min
Shipping company	Shipping	Telephone	02 Apr	Current status of IWT in Sweden, IWT framework and governance, shipping company perspective	85 min
Trafikanalys	Statistics	Telephone	02 Apr	Data design and recommendations of how to process data	25 min
Goods owner	Construction equipment	Telephone	05 Apr	Transport quality prioritization and current transportation setup	25 min
Goods owner	Wood and paper	Telephone	25 Apr	Transport quality prioritization, current transportation setup and suitability for IWT	30 min
Shipping company	Shipping	Telephone	03 May	Current status of IWT in Sweden, problems and enablers, projects toward IWT	50 min
Goods owner	Wood and paper	Telephone	09 May	Transport quality prioritization, current transportation setup and suitability for IWT	30 min

Table 2.1. Presentation of interviews during the study

In addition to the interviews, secondary data has also been collected in order to get a holistic view of the problem and to be able to, if possible, validate numbers and data provided through the interviews. As the official secondary data available was considered to be too accumulated and thus not very useful for the case study, “micro data” from Trafikanalys was requested. Requests of such micro data can be granted to research projects and statistics creation if it is clear that the requested information cannot harm the source of the information (Trafikanalys, 2018).

2.5.2 Secondary data of goods flows

The secondary data contains information about goods flows that was gathered by Trafikanalys in 2016, when they worked with a goods flow investigation. Trafikanalys is the responsible authority for statistics in the fields of, among others, public transport, shipping, road traffic and rail traffic. According to the publicity and secrecy act, micro data relating to these statistics can be submitted for research purposes or other official statistics creation. The following table 2.2 presents the different variables in the data together with a description and if a certain variable is used or not.

Variable	Description	Included in report	Comment
Date	Year, quarter and date of the shipment	No	-
Commodity code	The commodity transported according to NST2007	Yes	Presented as commodity names
Goods type	Grouping of the commodity type according to NST2007	Yes	-
Invoice value	The value of the goods transported in SEK (excl. VAT and transport cost)	No	-
Weight	The net-weight of the goods transported	Yes	-
Carrier type	How the goods are carried during transport	Yes	-
Transport mode	What transport mode utilized - road-, railway- or sea transportation	Yes	-
Industry/Business type	The industry of the sender and receiver	Yes	-
Postal code	The postal code of the sender and receiver	Yes	Not presented explicitly but is used for some visualisations. Needed for compatibility.
Country code	The country code of the sender and receiver	Yes	Presented as country names

Receiving county	In which county the destination is located	Yes	-
Receiving municipality	In which municipality the destination is located	Yes	-
Enumeration variable	Used to compute weights	Yes	Not presented explicitly but used to process the data
Size of company	Number of people employed	No	-
Direction	Import, export or domestic shipment	Yes	-

Table 2.2. Presentation of interviews during the study

2.6 Analysis of the research questions

This section describes the respective approach taken in order to answer the research questions. A presentation of how the research questions have been answered can be found in following figures. The steps are presented in succeeding order where the preceding step work as input to the next step. If a step is running in parallel with, it is stated in the figures 2.3 and 2.4.

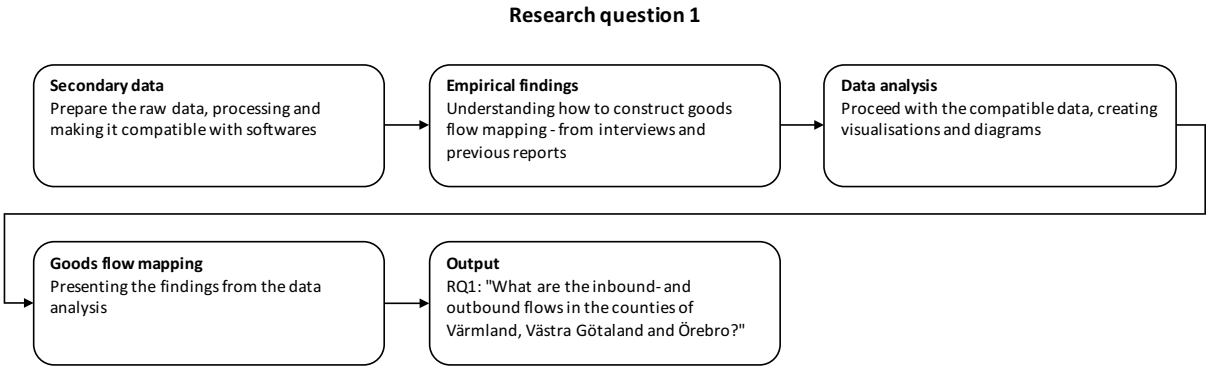

Figure 2.3. Presentation of how RQ1 is answered.

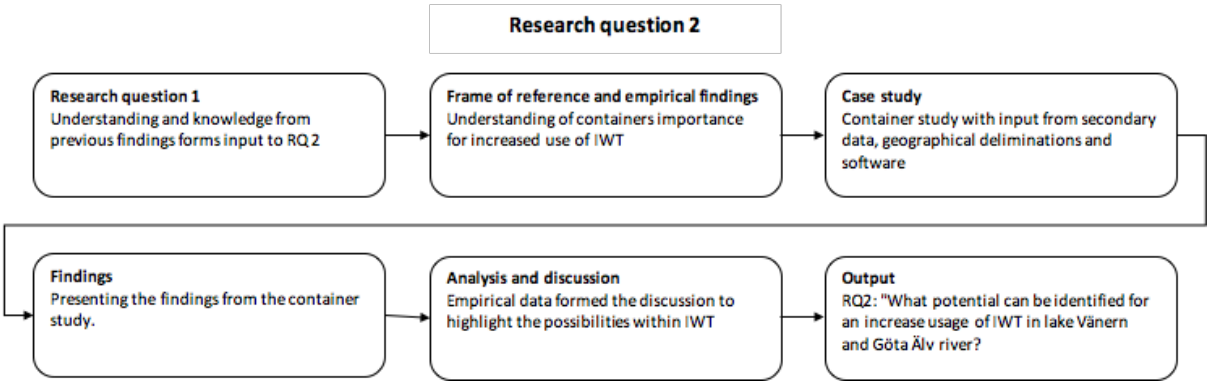

Figure 2.4. Presentation of how RQ2 is answered.

2.7 Analysis of the secondary data

The micro data was received in the file format CSV (comma separated values), which enables large amounts of data to be packaged into small sized files. Initially, three different files were received, containing:

- Inbound shipments from destinations within Sweden to Västra Götaland-, Värmland- and Örebro county
- Outbound shipments from Västra Götaland-, Värmland- and Örebro county, both domestic and export
- Import shipments to Västra Götaland-, Värmland- and Örebro county from foreign countries
- (Additionally, a "meta data" document with descriptions of the different variables was received)

These files then needed processing to be compatible with the softwares used for the data analysis. This proved to be a time-consuming activity, and a large part of the time spent on the project is allocated to this. This, due to the importance of getting the data compatible and user friendly as the largest part of the study revolves around the data. The process of how the data was handled can be concluded into 4 steps, described below.

2.7.1 Step 1 - Compressing the data

Microsoft Excel was intended to be used in order to handle and analyse the data which imposed certain limitations for the data processing. The maximum number of rows is limited to 1.048.576, which the received data exceeded (approximately 1,700,000), meaning that another approach was needed. After investigating the possibilities of how to handle large data amounts, understanding of how to compress the data in a way for to make it compatible with Excel was gathered. By using the Excel plug-in Power Pivot, all the data could be imported into one file. This is done by creating data connections from the server where the data is stored and the software, resulting in a compressed data volume. This, because the data is not handled directly in the software, but instead through the data connection.

2.7.2 Step 2 - Transforming the data

When the data was compressed and compatible with Excel, it needed to be transformed in order for us to understand the variables correctly. Firstly, with the assistance of the "meta data", the input parameters were transformed into appropriate names and certain variables were excluded in the data sheets. As the data also needed to be compatible with the GIS-tool (geographical information system) used, Microsoft Power BI, new columns of custom made variables were created. In order for the GIS-tool to read the data (origins and destinations), the input data needed to include: country name, county name and postal code. By using e.g. lookup commands, these variables could be merged into one cell, making the data compatible to create visualisations.

2.7.3 Step 3 - Creating dynamic dashboards

When the data was transformed, dashboards were created where the different variables could be filtered. This, in order to be able to look beyond the aggregated level and more into detail for certain parameters, e.g. what the outbound flow from a certain municipality is. The dashboards were created dynamically, meaning that all tables and diagrams follow a certain data selection, which enabled a better understanding of how dependencies between different variables exist. For example, filtering on a certain commodity reveals the distribution of the transport modes and the different destinations for the shipments, and by filtering again, this time on one of the transport modes, the destinations will change. A screenshot of how a dashboard can look is presented below in figure 2.2.

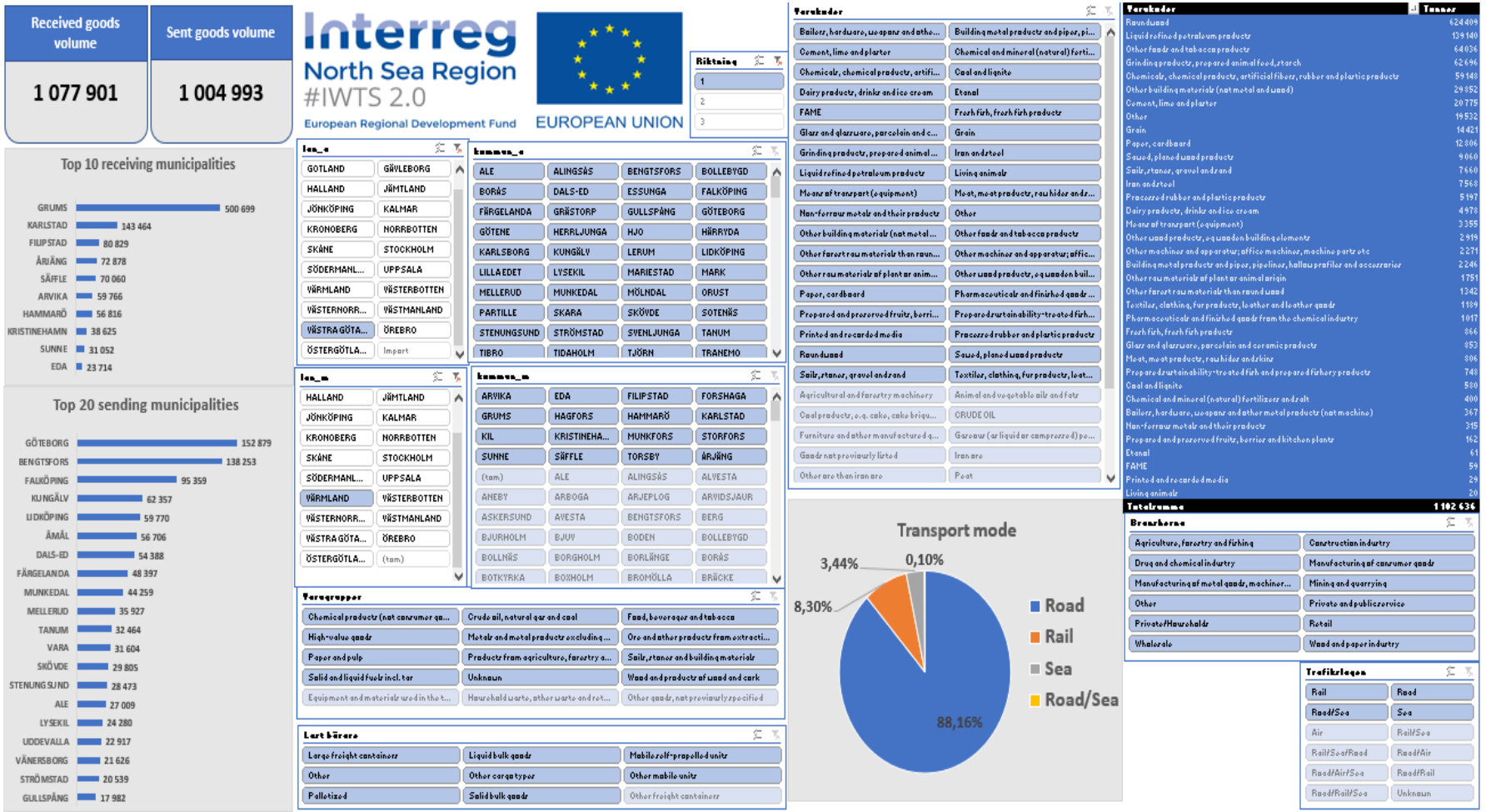

Figure 2.2. Screenshot of the dashboard used for presenting the secondary data

2.7.4 Step 4 - Creating visualisations and diagrams

With the first three steps completed, the data was compatible and user friendly. This enabled us to start creating the map visualisations and diagrams included in the study. Data selections and delimitations within certain variables were made to present reader friendly visualisations, which was done through the dashboards.

3. Frame of reference

This chapter will present the findings from the literature study performed in the project.

3.1 Freight transport and logistics

Freight transport stands for all the movements of goods within the supply chain, hence the importance of coordinated processes and efficient activities to meet customer demand. According to Jonsson & Mattsson (2011), the objective with logistic operations is to achieve space and time utility for the goods flow, i.e. ensuring that goods are at the right place at the right time. To fully understand the complexity in this area, Wandel et al. (1992) introduce a three-layer model, where each component of the freight transport system is described, see figure 3.1. The transport system consists of the infrastructure, material- and transport flow.

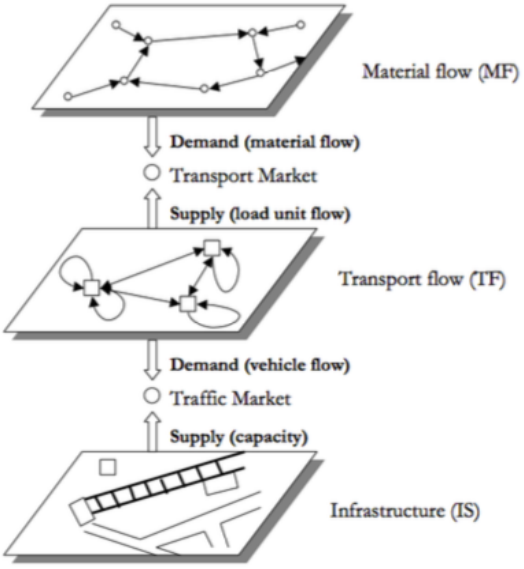

Figure 3.1. The three-layer model – Freight transport systems and their intersections (Source: Lumsden 2012).

Firstly, the *infrastructure* is the fundamental component for carrying out transports since it offers their users equipment and systems to operate on. The primary objective is to connect the whole system with harbours, terminals, railway systems and road networks to establish functional operational conditions (Lumsden 2006; Jonsson & Mattson 2011). The infrastructure is normally funded by the government and changes in the system requires both time and heavily investments.

Secondly, the *transport flow* utilizes the infrastructure and consist of the different modes of transport performing movements of goods between different entities in the supply chain. The transportation flow is defined as the limited resources and units within the transport system that requires planning in order to operate.

Thirdly, the *material flow* is initiated by a need of moving the goods between different nodes in the infrastructure, by the transport flow. According to Lumsden (2006), this concerns both internal and external goods flows within or between different processes or actors along the supply chain.

The freight transport system needs to be defined as one entity to achieve an increased output, where each of the components intends to create synergies in the system when used together, i.e. instead of operating in isolation, a higher efficiency could be reached in combining several components (Jonsson & Mattsson, 2011). In all of these layers in figure 3.1, mutual interdependencies exist, and depending on how the transport system is utilized, this directly affects the three success factors: customer service, capital tied-up and total costs.

Understanding of the intersections between the components ease the decision making and increase the performance of the transports. Between the different layers, where each component intersects, two types of markets exist. The *transport market* constitutes a demand for which material flow needs to be transported or moved from point a to b and where available and suitable transport modes provides the supplying load unit. Depending on the amount or types of transport flow in the system, it requires a certain capacity usage on the infrastructure which creates the *traffic market*. The capacity of the infrastructure determines the limitations of the vehicles and the amount of goods that needs to be moved within the system (Lumsden 2006).

3.2 Transport modes

Transportation is a major function for enabling flow of goods between sender and receiver, due to its ability to connect all the nodes in the transport network and enhance the geographical coverage. In foreign transports, sea transport is dominant since it is able to absorb big volumes over long distances. In comparison to domestic transportation, where road is most commonly used due to the flexibility in door to door deliveries (LIano, De la Mata, Díaz-Lanchas & Gallego 2017). Depending on the context, different outcomes are achieved by the choice of transport modes, both in combination as well as in isolation. Due to the various demand of transports and goods flow, requires differences between the modes in how they are utilized in order to support their specific needs (Hao & Yue 2016). Goods owners and manufacturers has an emerging tendency to minimize cost and enhance the efficiency by involving specialized actors who conduct the movement of goods (i.e. third party logistic provider). This section intends to give the reader a description over the different characteristics each transport mode possess.

3.2.1 Road transportation

Road transportation is the main mode of transport since it offers both connectivity and flexibility, i.e. enables door to door transport due to the design of the infrastructure and with

the availability of vehicles to meet the demand. Rodrigue, Comtois and Slack (2015) describe that the infrastructure, with its growth in spatial coverage, provides an extensive area to operate on which makes the road transport superior to others. Jonsson and Mattsson (2011) support this by discussing road transport as the most significant alternative in deliveries in clustered markets or delivery to end customer. Lindgren & Vierth (2017) discuss high valued (e.g. electronics) and time sensitive goods (e.g. food) as typical characteristics in demand for road transport, since a decrease in the factors capital tied up and lead time are achieved.

The main drawbacks with road transport is the consumption of fossil fuels, noise and congestion on the roads which affect the reliability in the deliveries (Rodrigue, Comtois & Slack 2015). Road transportation is used in various transport setups, long- and short distances and low- and high value goods, where they compete or are mixed with rail and sea, e.g. road and rail/sea compete on low value goods and high volumes, where the transport economy is comparatively lower in shorter distances for road (Jonsson & Mattsson 2011).

3.2.2 Rail transportation

Jonsson and Mattsson (2011) describe that rail transport in relation to road, is able to carry heavier loads over long distances in relatively high speed. But similarities exist in how the transport mode is constrained by its physiography. The effect is that transports are often constrained between two terminals where the goods are further distributed by road or sea to the end destination.

Terminals for transhipment and rail systems are heavy investments that occupate large areas, and the trains are operating in fixed routes constitutes the major drawbacks (Rodrigue, Comtois & Slack 2015). Reis (2014) describe the constraints in both rail capacity and the fixed scheduled, and how this is affected by an increase in demand which lower the flexibility.

However, advantages in fuel economy reflects its attractiveness to support other modes in a transport chain to minimize costs, i.e. the break-even distance (Bhattacharya, Kumar, Tiwari & Talluri 2013). Due to its large capacity, fuel consumption per load unit are low in relation to road transports which makes it a green inland mode (Rodrigue, Comtois & Slack 2015).

3.2.3 Sea transportation

This mode of transport absorbs the biggest volumes per shipments compared to road and rail, but are limited with transport only between harbours (Lindgren & Vierth 2017). The capacity of the shipments and the use of infrastructure enables low operating costs due to economies of scale. Preferably, large volume and low valued goods over longer distance are suitable for sea transports, where no other effective transport mode is able to compete.

Rodrigue, Comtois & Slack (2015) points out the globalisation and the increased demand for long distance and high-volume transport in combination with the containerization lead to a

development in maritime businesses to adapt to the new market changes. There still exist drawbacks with the duration of the transports, as well as the loading and unloading processes which are time consuming and requires planning and suitable infrastructure for performing necessary activities.

3.2.4 Inland waterway transportation

Looking at the current state of domestic transportation in Sweden, it is easily identified that the IWT is not used to any greater extent. In 2016, road transport accounts for 88 % of the domestic transports whereas rail transports (9%) and domestic sea transportation (3%), in which 0,7% is transported on IWW accounts for a much smaller share (Garberg, 2016). There is an underutilized capacity in fairways, locks and ports and the waterways in, or close to, cities are not utilized to the extent that is possible (Garberg, 2016).

IWT could be the basis for the future of intermodal transport chains in Europe, because of the characteristics of the transport mode that enables shipping of large amounts of goods in combination with price advantages (Mircetic et al. 2017). Policy makers from different levels, European to regional, emphasize the importance to stimulate IWT as a part of the intermodal transport chain (European Commission, 2018). Promoting IWT is a long-term priority within Europe in order to achieve a sustainable transport system (Caris et al., 2014). The IWT currently plays an important role in the hinterland connectivity of major Western-Europe seaports. However, since the last decades of the twentieth century, a trend towards an increase of road transport can be identified (Konings & Wiegmans, 2016). At the same time, the share of transports conducted by rail and inland waterways is decreasing, even though there is consensus regarding the importance of the use and development of inland waterways as a mean of transporting goods in our total freight transport system.

In Europe, roughly 14.000 km of the available 29.000 km of IWT are utilized (Mircetic et al., 2017). Of the 1.500 ports located in Europe, a majority is located in the Trans-European Transport Network (TEN-T) corridors. Looking at the use of IWT on waterways from a global perspective, a majority is underdeveloped and underutilized. In the case of Sweden, IWT and coastal shipping has historically played an important role for the Swedish transportation system and industry (Garberg, 2016). As the road- and railroad traffic has been developed, IWT has had problems in competing for the necessary goods volumes to make it competitive in relation to the other modes of transport. Garberg (2016) further explains that lead time, flexibility, frequency and especially price, which is directly decisive, are factors that affects the choice of transport to a greater extent than before. The inherent characteristics of IWT in combination with the prevailing cost structure means aggravating circumstances, especially with low volumes of goods. IWT represents the only mode of transport that is not directly affected by congestion and brings a very high energy efficiency, reliability and safety, yet the potential increase in use of IWT is not fully explored. However, inland waterway navigation is not considered as a truly competitive mode of transport compared to the others (Mircetic et

al., 2017), due to the fact that there are still several barriers that needs to be overcome. These barriers include e.g. lack of integration and fragmentation of its infrastructure together with operational, political and technological aspects that hinders more intensive growth. More about challenges and barriers connected to IWT in Sweden will be accounted for in the following section.

3.3 Comparative advantages of transport modes

European logistics actors think that road transport is more favourable than sea- and rail transports when it comes to flexibility, reliability, frequency and safety (Lindgren & Vierth, 2017). The favouring of road transports stems from the advantage of being able to reach all customers, adapt to changes in the traffic and the vast availability of trucks to respond to changes in demand, i.e. flexibility (Reis 2014). It is possible to order a transport carried by road with short notice and control the departure- and arrival times, whereas the other modes of transport are tied to predetermined schedules and fixed routes. At the same time, the trucks are limited by the maximum allowed weight and thus cannot transport large amounts of bulk cargo to an acceptable price. The same constraint limits the distance of which road transports are economically viable. Looking at rail- and sea transportation, they have a superior loading capacity. The tonne-km cost decreases with increasing volumes and can therefore offer competitive advantages. Sea transports also offer the advantage of not being affected by infrastructural capacity constraints. Table 3.1 summarizes the comparative advantages of the transport modes.

Platz (2008) mentions the specific performance attributes for IWT, where it outperforms road and rail transports. IWT is able to absorb large volumes, lower the transport cost per load unit (i.e. low energy consumption), high safety, less harmful emissions, decrease noise and external effects on the environment. On the other hand, IWT are facing challenges to compete with road and rail transportation in speed, connectivity to nodes, flexibility and weather conditions. In regions which has supportive infrastructure for IWT, comparative benefits are identified such as low operating costs, high reliability but with the expense of slow speed. Erceg (2018) concludes the lack of attracting new IWT users as a major issue, and criticizes the decision-making actors to not take these factors into account when selecting mode carrier. Wiegmans & Konings (2015) argue that IWT are able to compete with road and rail if the number of transhipments in their transport chain is reduced, since this have a direct impact on the transport costs. Caris et al. (2014) implies that the geographical location constitutes an important role for companies performing freight transport. The competitiveness for IWT tends to increase with the ports hinterland, i.e. inland waterway ports contributes to the overall performance of the intermodal transport chain. Hesse & Rodrigue (2004) points out the extensive growth of infrastructure (e.g. terminals and highways) as an enabler for road transports to gain shares in the transport market, which could be similar as for inland waterway development in the future. The authors further describe the vertical integration between production and distribution where

interdependencies exists, i.e. using smaller production batches affects the number of shipments that need to be carried out. In addition, the introduction of the container as a standardized loading unit made it possible to consolidate goods flow from several actors in order to obtain economies of scale (Caris et al. 2014). The table 3.1 below summarize the comparative advantages that exists between the different transport modes.

	Road	Rail	Sea/IWT
Advantages	Speed	Speed	Loading capacity
	Low risk of injury	Scale advantages	Scale advantages
	Reliability		No congestion
	Flexibility		
Disadvantages	Congestion	Capacity constraints	Low speed

Table 3.1. Comparative advantages of transport modes. (adapted from: Lindgren & Vierth, 2017)

3.4 Transport quality factors

Taking the perspective of a transport buyer and goods owners, they choose different transport modes to transport different types of goods (Garberg, 2016). Flodén, Bärthel & Sorkina (2017) accounts for the factors that affects a modal choice where the authors have reviewed available literature in the field. They mean that modal choice is a decision that depends on the combined performance of a number of factors where these factors are appointed different importance for the decision. A number of key factors are presented in their study where cost, transport quality, reliability and transport time are factors most research bring up. However, the range of factors considered in different studies is big, ranging from including 3-4 general factors up to more than 30 detailed factors. They bring up cost as the most obvious factor for a modal choice as it scores high in most researches. Also, the fact that cost is used as a benchmark to evaluate the relative importance of other factors points out the paramount importance of the price of the transport. After most of the basic quality requirements are met, e.g. on-time deliveries and transport damages, most decisions are made based on price.

Flodén, Bärthel & Sorkina (2017) present a model for the most important factors in three overlapping layers with decreasing importance for the modal choice decision: *Benchmark, Qualifiers and Particularities.* Here, cost is constituting the benchmark against which the other factors are valued. They mean that improvements in other factors results in a monetary cost

which then causes the factors to overlap. A change in of the other factors will influence the cost. A two-step approach is often used in this decision - when the quality of a transport is satisfactory the choice is made upon cost. The main quality factors can thus be grouped into the second layer: *Qualifiers.* The third layer includes factors of lower importance but that could be of high importance to individual decision makers. An illustration of the model is presented below, figure 3.3.

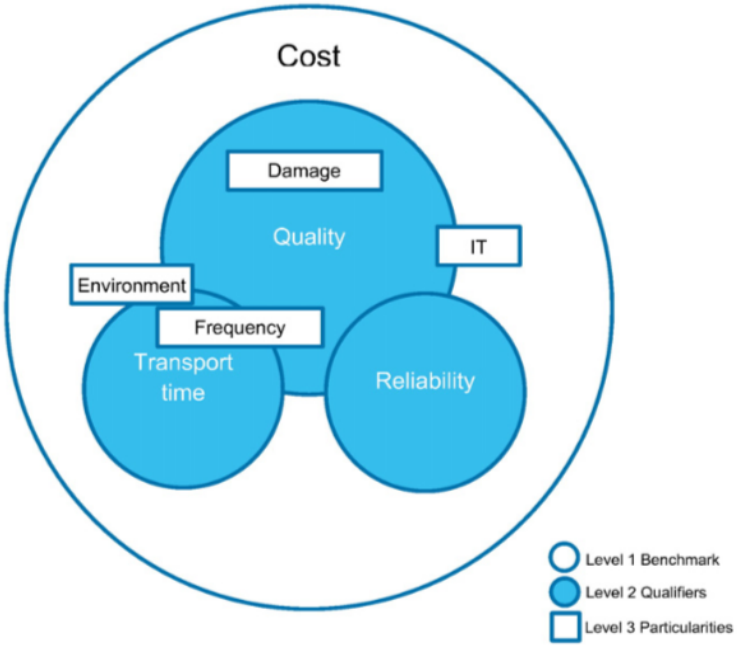

Figure 3.3. A graphical representation of the different layers of factors influencing modal choice. (Source: Flodén, Bärthel & Sorkina, 2017)

Garborg (2016) also points out geographical and infrastructural prerequisites can eliminate a certain transport mode, where e.g. IWT often is suitable when either the sender or receiver is located close to a port. Garberg (2016) also mean that tradition is something that affects what mode of transport that is used to transport goods. When a goods owner has dedicated themselves to one transport mode, there is an inherent aversion towards changing this transportation set up.

The co-founded EU project, LOGIQ found out two types of decision oriented actors in the decision-making process in determining an intermodal transport mode (Mommens & Macharis 2014). The first group was *cost* oriented, here decisions were based upon the lowest price for the transport (i.e. quality was secondary) and the other group was *quality* oriented, they weighted both the factors equally in their decision. Reis (2016) presents in his report the identified key factors involved in transport mode choice, flexibility, reliability, frequency and lead time. Below, each of these factors are described in detail.

3.4.1 Flexibility

This factor refers to the ability of the transport chain to cope with variations in demand and services (Jonsson & Mattsson 2011). Flexibility could be enhanced due to better forecasting or encouragement to customer integration of planned volumes and shipments, i.e. increased resource utilization (Lumsden 2007). A high level of flexibility describes how changes during transports easily could be maneuvered, e.g. avoiding traffic stocking and areas with high congestion. Naim, Potter, Mason & Bateman (2006) presents three factors in determining the transportation flexibility; delivery, volume and access. Delivery and volume concerns parameters such as consignment size, goods type and distance, whilst the latter one measures the ability to meet demand when it is needed.

3.4.2 Reliability

The level of reliability is determined by the ability to perform on time deliveries. Reliability is considered as an important transport quality measurements since this affects the risk of disruptions in the supply chain (Lindgren & Vierth 2017). Medda & Trujillo (2010) claims that ports are unreliable and inefficient due to the often capacity constraint and connections to other modes. Baindur & Viegas (2011) further describe sea transports highly dependent on the weather condition (e.g. which makes this mode less attractive in comparison to road and rail. According to the Swedish Maritime Administration (2016), actors are less likely to shift transport mode which offers a high reliable transport and describe road as the most reliable.

3.4.3 Frequency

Danielis & Marcucci (2007) describe road transport as demand driven and kept away from fixed schedules, whilst rail and sea transport are controlled by both fixed schedules and routes, hence these modes are considered to less frequent alternatives (García-Menéndez, Martínez-Zarzoso & De Miguel 2004). The level of frequency are determinant factors for mode choice, and it is defined as the amount of completed transport per time unit (Lindgren & Vierth 2017). A high frequency of transports requires smaller inventories which decreases the total costs, and enables the supply chain to adjust and respond to unexpected variations in demand, i.e. increased flexibility. Naim et al. (2006) points out that vehicle speed has a positive impact on the flexibility factor.

3.4.4 Lead time

Road transport is superior in comparison to other modes of transport to handle door to door delivery with shortest lead time. This is because sea and rail transport often are more suitable to use over longer distances, where the focus is to take advantage of economies of scale and where road transport are not able to compete (Lumsden 2006). Trade-offs are made between transport cost and time, where lower fuel consumption (i.e. slower speed) decreasing the costs but affects the transport service due to a lower flexibility (Reis 2016). Nottebom &

Cariuo (2013) describe slow steaming as a practice to lower the fuel consumption and the impact on the environment, and at the same time increase the profits. Lindgren & Vierth (2017) mention goods type and how the characteristics for time and value affects the transport mode choice. This corresponds to that low valued goods where lead time is secondary are preferably performed with sea or rail transport. Table 3.2 compare and summarizes the transport modes towards the transport quality factors mentioned above.

	Road	Rail	Sea/IWT
Flexibility	High	Low	Low
Reliability	High-medium	Medium-low	Low
Frequency	High	Low	Low
Lead time	Short	Medium-long	Long

Table 3.2. Comparison of transport modes over the transport quality factors

3.5 Comparative quality factors of the transport modes

Road transport is seen as the most cost-efficient mode of transport for short- and medium distances. Both rail and sea transports demand their goods to be handled in terminals for a modal shift, this implies higher costs in the short- to medium distance interval, where the economy is no longer beneficial (Reis 2016). The choice of transport mode is instead selected upon the type and size of the goods type, the frequency of the shipments and within the time frame of the shipment (Rodrigue, Comtois & Slack 2015; Meixell & Norbis 2008). Reis (2014) also points out these variables as important decisive factors, but mentions safety and flexibility as additional services, i.e. availability of vehicles to adapt to market demand. Furthermore, Janic (2007) and Lu Li & Jian (2018) complement these factors with distance and reliability as main drivers. The respective quality factors and the different transport modes is presented in the table 3.3 below.

Transport Quality	Road	Rail	Sea
Frequency	High	Low	Low
Lead time	Essential	Secondary	Secondary
Distance	< 300 km	> 300 km	> 300 km

Goods type	High-medium value, time sensitive	Low value, space utilization	Low value, space utilization
Consignment size	Small	Large	Large
Safety	Low	High	High
Flexibility	High	Low	Low

Table 3.3. Comparative characteristics of transport modes

3.6 Commonly transported goods types on IWT

To understand what type of goods that is suitable for IWT, statistics of the most commonly transported goods types on IWT are examined. This information is provided by Vänerhamn and Eurostat (2018) and is visualized in the figure 3.4 below.

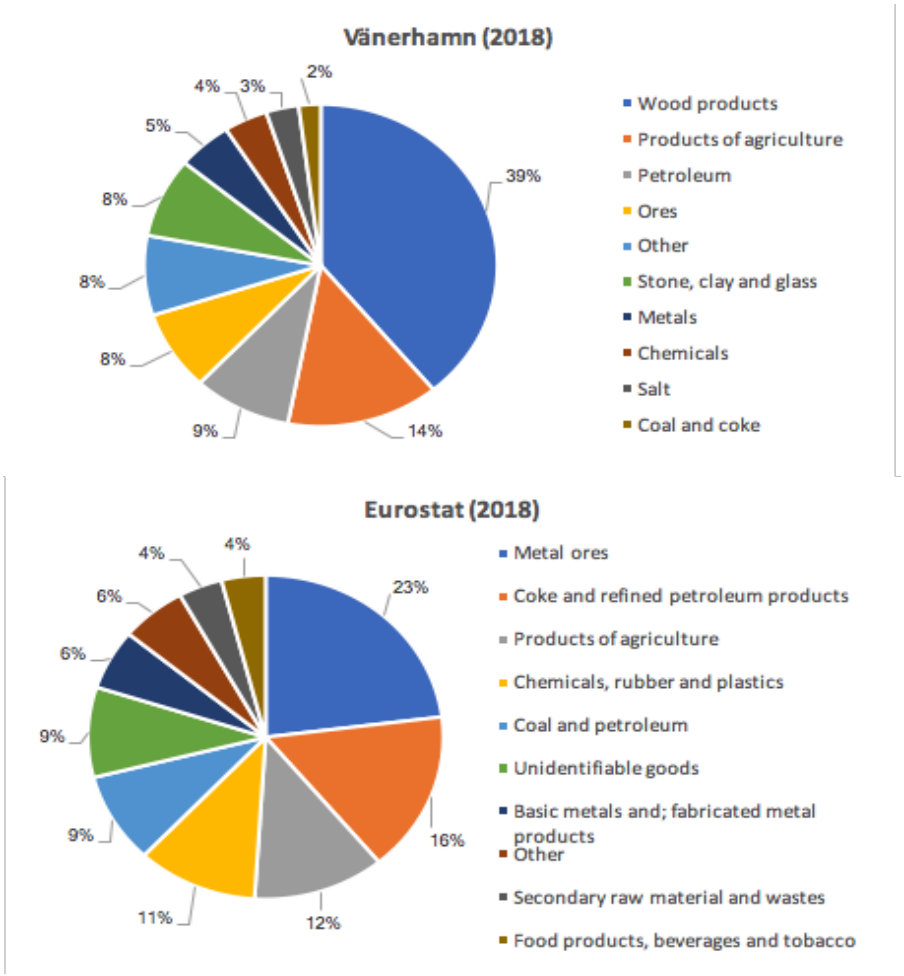

Figure 3.4. Distribution of goods types handled in Vänerhamn and EU according to Eurostat (2018)

3.6.1 Bulk goods

Dry and liquid bulk goods is considered as the main goods for transportation of IWT. Typical characteristics for this type of commodities are the possibility to transport large volumes per shipment (i.e. consignment size) which require less focus on the transport lead time. Wiegmans & Konings (2016) mentions six types of goods types (*ore, coal, chemical-, petroleum products, sand and gravel*) that are suitable for IWT transport due to their specific characteristics. These goods flows are typically transported in large consignment sizes to lower operating costs (i.e. economies of scale), over long distances (except for sand and gravel) and between seaports or industry plants.

2.6.2 Containerization

Containerization enables an increased operational efficiency which enhancing the performance over the transport. This loading unit provides smooth shifts between transport modes, since it is able to hold the cargo through the whole transport chain (Neise 2018). Wiegmans, Witte, Spit (2015) discuss the importance of inland ports and their ability to support container handling in their terminals in order to increase hinterland competitiveness of larger ports. Inland port terminals are then needed to provide efficient intermodal connections with the objective to mitigate the congestion and container handling in larger ports, which also have a positive effect on the reliability factor. Wiegmans & Witte (2017) presents factors for evaluating the performance of an inland port terminal, which are divided into internal and external factors. The internal factors are influenced by the infrastructure and level of operational equipment (e.g. capacity or operational related), and where external factors comprehends the level of coordination and integration of processes between actors involved in the transport chain (Wiegmans & Witte,2017; Caris et al., 2014). Neise (2018) further explains the growth in containerization as a major reason for the increasing volumes in global trade. Consequently, all types of goods are preferably used in container transport nowadays (e.g. and reduced transport costs are possible to achieve.

In the report written by WSP, a visualisation of a SWOT-analysis was presented. This in order to highlight different aspects affecting an establishment of container transportation with IWT on lake Vänern and Göta Älv river. A visualisation of the presented SWOT-analysis can be found in figure 3.5 below.

Figure 3.5. SWOT-analysis of container transportation on lake Vänern. (Adapted from: WSP, 2015)

3.7 External costs of IWT

When comparing the sustainability of the different transport modes from a broader perspective, the external costs generated is useful to assess. Caris et al. (2014) discusses the external costs of IWT and mean that the most important categories are climate change, air pollution, noise, accidents and congestion. Additionally, up- and downstream activities may account for a significant share of pre-combustion processes related to fuel consumption.

In general, IWT is performing well from an external cost perspective, but there are certain areas where the results are not as good and areas where it is lagging behind in the development (Caris et al., 2014). Looking at the positive aspects of IWT, the external noise and accidents are negligible. Environmental costs are very much related to energy efficiency where IWT clearly outperforms both road and rail in bulk cargo and container transports. CO2 emissions are better than for road transports, but SO2, PM and NOX are worse. The sustainability advantage of IWT is under pressure as the development of the other modes is at a more rapid pace. However, IWT can sustain its advantage with additional efforts, where e.g. the external cost calculator for the Marco Polo project takes several alternative fuel technologies into account which shows a wide range of possible environmental performances, depending on which technology used, type of ship and its freight capacity (Brons and Christidis, 2013). Table 3.4 displays which externalities that each transport mode is generating.

Externality	Road	Rail	IWT
Air pollution	X	X	X
Noise pollution	X	X	
Climate change	X	X	X
Accidents	X	X	
Congestion	X	X	

Table 3.4. Transport modes and their external effects. (Constructed from Caris et al., 2014)

3.8 Barriers and key issues for IWT in Sweden

Rogerson & Santén (2018) describe the main barriers and key issues for IWT, specifically for the Swedish setting. These can be grouped into four main categories: regulatory, financial,

service quality and market characteristics. What specific externality these categories account for is summarized in table 3.5 below.

	Externality
Regulatory	Uncertainty in regulations, piloting and fairway fees, agreements with dockers/stevedores for transhipments, investments in infrastructure of other modes, regulations for competing transport modes
Financial	Competitiveness with other transport modes - large trucks and developed railway system, Pre/post haulage costs, additional handling costs, port charges, fairway dues, piloting fees, Fee structures of other transport modes, Uncertainty in costs makes it hard to perform calculations, Investment costs and financial risk in new projects, Lack of qualified personnel
Service quality	Key criteria: cost, lead time, reliability, transport quality, Long lead times vs. Road transportation, especially transhipments, Crane availability, Frequency, Reliability - prioritization of transhipments in ports, Resistance to change transport mode
Market characteristics	Volumes of goods required, Competition from other modes - price competition is hard due to differing fee structures, Conditions of waterways - requirements for vessels, water levels and bridge heights, bridge prioritization, Vessels adapted to waterways and weather conditions - specialized vessels result in limitations, Business models - financially successful for containers, Environmental concerns - other transport modes developing faster

Table 3.5. Barriers and key issues for IWT in Sweden. (Adapted from Rogerson & Santén, 2018)

3.9 Models for evaluating goods flow potential

Meers & Macharais (2015) describe different tools that can be used when evaluating the potential modal shift of a region. Such macro-tools are useful in preparatory phases when scanning a region for modal shift potential and most suitable goods flows. They summarize different models developed for this purpose and describe which determinants used in those models. This gives a hint of which factors to consider when evaluating potential modal shifts in a region. An overview of these determinants is given in the table 3.6 below.

Study	Cost/ price	External cost	Time component	Transport volume	Transport capacity	Goods' characteristics	Transport distance	Accessibility
Rusch (2001)	X		X	X		X	X	X
Blauwens et al. (2006)	X		X	X	X	X	X	X
Jordans et al. (2006)			X	X		X	X	X
Flodén (2007)	X	X	X	X	X	X	X	X
Tsomboulas et al. (2007)	X	X	X	X	X		X	X
Bottani and Rizzi (20007)			X	X		X	X	X

Macharis et al. (2010)	X	X		X			X	X
Meers & Macharis (2015)	X		X			X	X	X

Figure 3.6. Overview of determinants for modal shift included in previous studies. (Adapted from Meers and Macharis, 2015).

3.10 Intermodal transportation

In 2007, the European Commission took action against road transportation by creating transport policies which promote greener modes of transport, e.g. utilization of inland waterways. The solution was to enlighten actors regarding intermodal transports with respect to the advantages that could be gained (Macharis 2011).

Intermodal freight transports are described by Crainic & Kim (2007) as goods transportation between origin and final destination, that utilize at least two different transport modes in a consecutive transport (road, rail & sea) without changing carrier type. Lowe (2005) describe that the objective is to reduce road transportation, and instead shift towards more environmentally friendly transport modes. Lowe (2005) further explain the idea is to benefit from the different characteristics each mode possesses in different transport solutions. Rail- and sea transportation are more profitable and environmentally in cases of longer transit time, but where road transportation is dominant due to the flexibility and ability to complement other modes where no railway or waterway exist.

At the same time, the company need to remain competitive through providing time and cost-efficient transport solutions without interfering with the sustainability factor (Lowe, 2005). Recently, transport companies have shifted their focus from sub-optimizing their transports (i.e. cost-efficient) and instead looking beyond their own interest and integrate other actors in the transport chain. In this way, all actors could gain knowledge and benefit from other competencies to develop processes together (Bhattacharya et al. 2014). Intermodal transports are today seen as a prerequisite in handling goods movements from door-to-door, which indicate the importance of integration and commitment from the actors. Jacobsson, Arnäs & Stefansson (2017) agree with this trend, and presents an identified area in the intersection between the actors. Since the intermodal transport chain is considered as a complex operation with often several actors, solid processes need to be in order. The crucial activity to reconsider are transhipments, which need to be supported by processes to enhance efficiency and cost. To handle congestions, the unloading/loading activities need to be govern and planned in collaboration, generating a better flow and accessibility to terminals for other modes.

The implementation of standardized container flows made it possible to perform cost and time efficient transhipments, and are a vital component for promoting intermodal shifts. For example, the higher cost of transhipment (in relation to road) to barge transports on inland

waterway are recaptured, especially in larger distances, since barges are able to take advantage of economies of scale and lower the haulage costs (Macharis 2014).

Barge transports on inland waterways can provide safer transports of hazardous goods due to their unutilized capacity. Barge transports are constrained by their substantial need of infrastructure, which indicates that supplier and/or customers preferably need to be located nearby inland waterway ports. This limit the modal choice options in the pre- and post-haulage (Mommens & Macharis 2014).

From a socio-economic perspective, the reduced amount of road transports will lead to lower noise levels as well as reduced congestions in and around ports areas since the emissions of fossil fuels are transferred to less energy consuming vehicles, such as rail or sea. The issue with port congestion could be mitigated, hence the importance of assessing all transport modes available (Lowe 2005).

According to the literature, the key beneficial outcomes of intermodal transport are:

- reduced emissions of fossil fuels
- lowered noise and energy consumption
- alleviation of the imbalances in the transport infrastructure
- increased safety of hazardous goods

3.11 Hinterland transportation

The continuing growth of container transports are affecting the performance in ports due to increasing volumes to handle. The globalisation creates a higher demand for worldwide transports, which puts challenges on the ports to comprehend with this actuality. As a consequence, port congestion is identified as a major issue, since it especially has impact on the scheduled activities that are performed in the port (Visser, Konings, Pielage & Wiegmans 2007).

The increasing containerisation at the ports creates pressure to increase the capacity in order to raise the productivity, but this alternative demand heavy investments and requires space, which often is limited in urban areas (Roso, Woxenius & Lumsden 2009). Since ports often are located in connection to larger cities, precautions and regulations for the environment needs to be followed. Alternative solutions emerge in order to enhance the competitiveness of ports, where Visser et al. (2007) advocate hinterland transports as an enabler to reduce the congestion in especially the ports, as well in the whole transport infrastructure.

The hinterland accessibility is defined as the ability for the port to reach the inland markets, i.e. offer integrated connections to provide an effective and reliable supply chain (Franc & Horst 2010). To integrate the port with intermodal activities and in turn create efficient and coordinated actions, the key success factor lies within the level of commitment from the

involved actors. In this way, ports are able to govern and cope with delays and the inherent deviation that exist in the sea transportations. Zweers, Bhulai & Van Der Mei (2018) mention barges as the main transport mode for hinterland container transport, because the characteristics offered (e.g. less emissions and lower costs) are most suitable in comparison to rail and truck.

4. Goods flow mapping

This chapter will present the secondary data, visualised with maps, tables and diagrams. The chapter is further divided into sub-chapters that will focus on the specific counties included in the study: Västra Götaland, Värmland and Örebro and also how they interact with each other. In each section, visualisations and data are presented in order to highlight significant information. No data selections (filtering) has been made, which means that all information available is presented. The last section in this chapter will investigate the potential in respect to suitable IWT goods identified in order to have sufficient data to provide an answer to the first research question.

The first sub-chapter provides a holistic view and is intended as an introductory chapter. The data is presented on an aggregated level and highlights significant shares of the volume. A division between domestic flows and import/export flows has been made. For the domestic flows, origins and destinations together with the goods types with respective commodities are presented. For the import- and export flows, the industry is also included.

The following sub-chapters present each of the counties in more detail and are instead divided into sections describing inbound- and outbound flows separately. Here, more variables are included: origins and destinations, goods types and commodities, business types/industries and transport modes and goods carriers are presented.

The data of the commodities are set as a subgroup to the goods types, e.g. *roundwood* is a product from *agriculture, forestry and fishing*

4.1 Introduction - Total goods flows

The total volume of transported goods in the secondary data is summarized to 128 million tonnes, see figure 4.1. Dividing all the goods flows on three categories based on direction shows the following distribution: Domestic (58%) represent the goods flows that stay within the Swedish borders, either with destinations in one of the three counties (inbound), or origins in one of the three counties (outbound). Import flows (23%) represent the inbound flow with origins outside Sweden with destinations in the three counties. Lastly, the export

flow (19%) represents the outbound flow with destinations to foreign countries, with origins in one of the three counties.

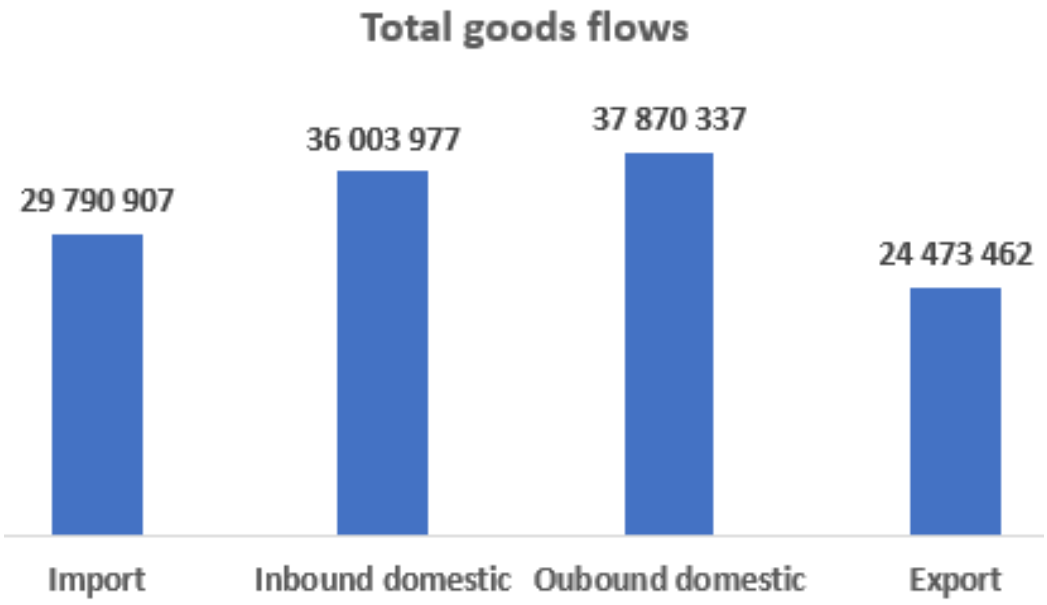

Figure 4.1. Total goods volume divided between the flows

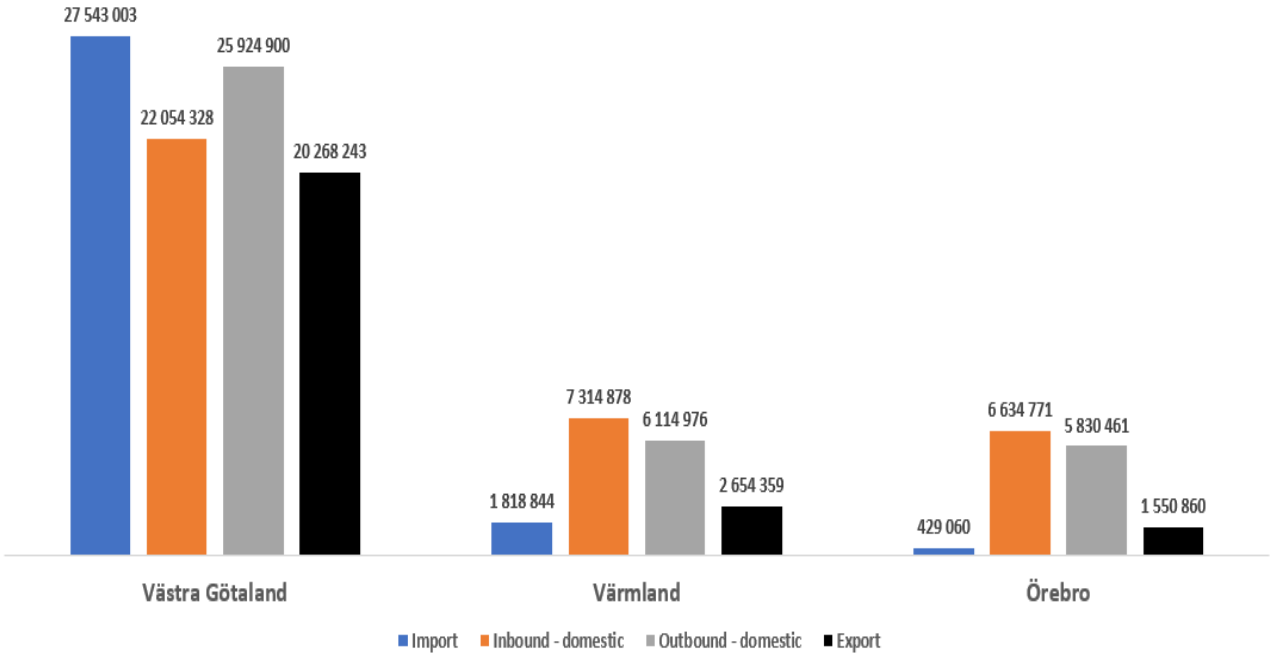

Figure 4.2. Bar chart of inbound- and outbound goods flow in respective county

Looking further into each county, significant differences exist in where the volume is allocated. Västra Götaland represent large share of the volume, followed by Värmland and Örebro. The data is divided between each of the counties and the respective volumes of inbound and outbound goods flows are shown in figure 4.2 above.

4.2 Domestic goods flows - Inbound

This section presents the goods flows with destinations in one of the counties. It identifies where goods are received for consumption or storage and represents the inbound flow for domestic shipments. The total inbound domestic goods flow for this data selection is summarized to 36 million tonnes and figure 4.3 below shows the counties respective share of the inbound volume.

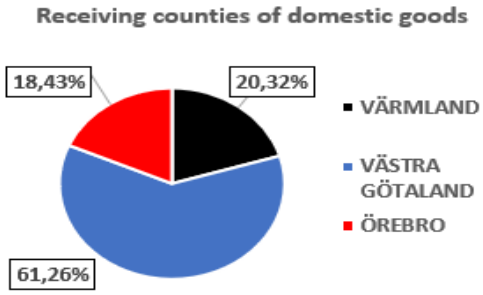

Figure 4.3. Distribution of inbound goods flow between selected counties

The map visualization in figure 4.4 below illustrates the domestic inbound goods flow in the regions. The bar charts included provide information regarding top 10 receiving and sending municipalities based on total weight.

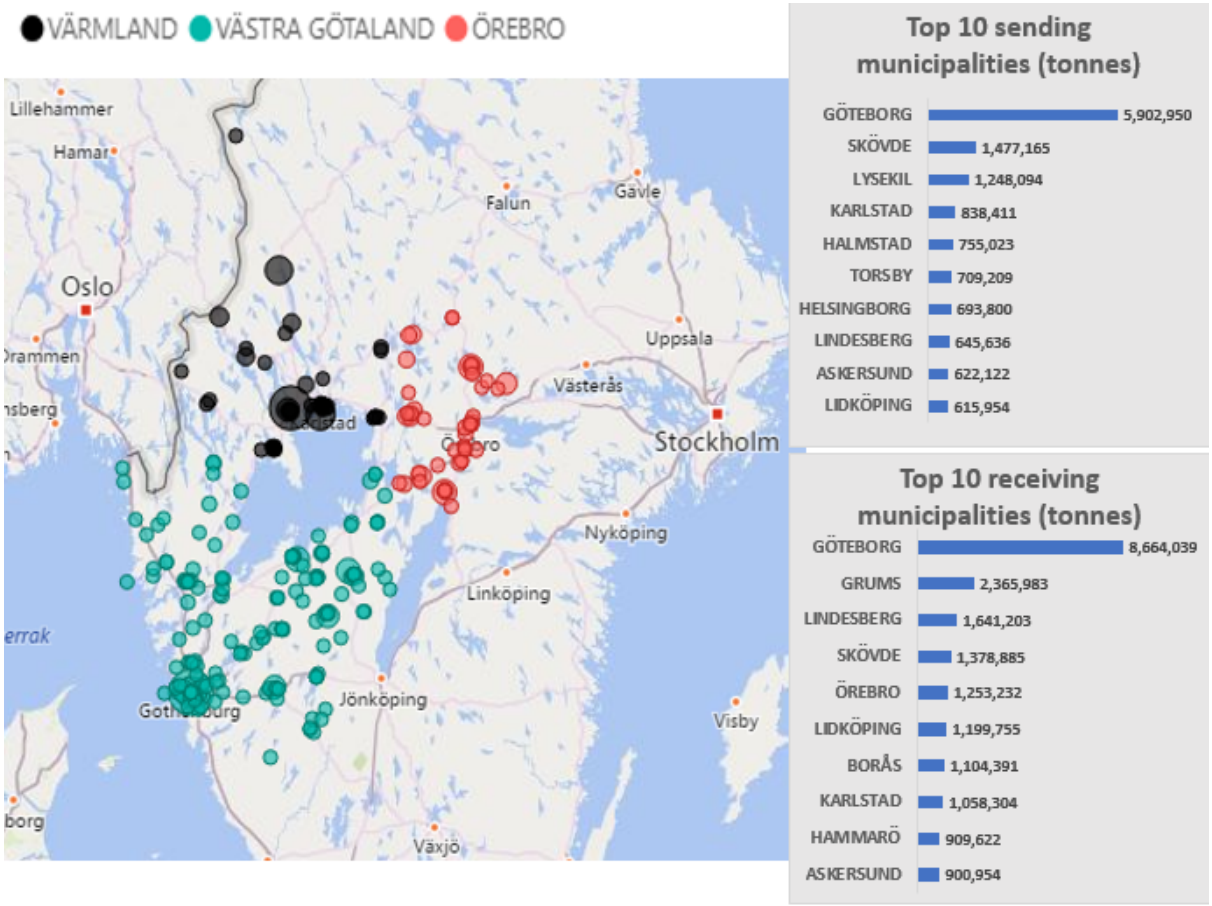

Figure 4.4. Map visualisation of municipalities with inbound domestic goods flow

Clustered areas of consuming entities appear around larger cities and to highlight the top 3 receiving municipalities, the following is revealed. The largest share of the goods received in Gothenburg are transported from locations within the county, especially from Gothenburg (45%) and Lysekil (13%). The construction industry is transporting the largest share of the volume transported to Gothenburg, followed by the wholesale- and *the* manufacturing of metal goods industry.

In Grums, almost 56% of the received volume originates from municipalities within the same county, i.e. Värmland, except from the largest contributor - Hällefors which is located in Örebro. The industry in Grums are within the wood and paper industry and is mostly receiving commodities from the goods type *products from agriculture, forestry and fishing*.

The industry with largest volume in Lindesberg are within wood and paper (85%) and manufacturing of metal goods, machinery and transport (7%). The goods are sourced mainly from Örebro (37%) and surrounding counties such as Västmanland, Gävleborg, Södermanland and Dalarna transported by road (93%) and rail (7%).

4.2.1 Goods types and commodities

This section presents the goods types and commodities with destinations in the selected counties. The visualisation of the goods types in figure 4.5 includes all inbound domestic data, whereas figure 4.6 only shows the top 10 commodities, representing approximately 76% of the total goods volume in the counties. The following sections will provide information of the goods types and commodities with the largest shares.

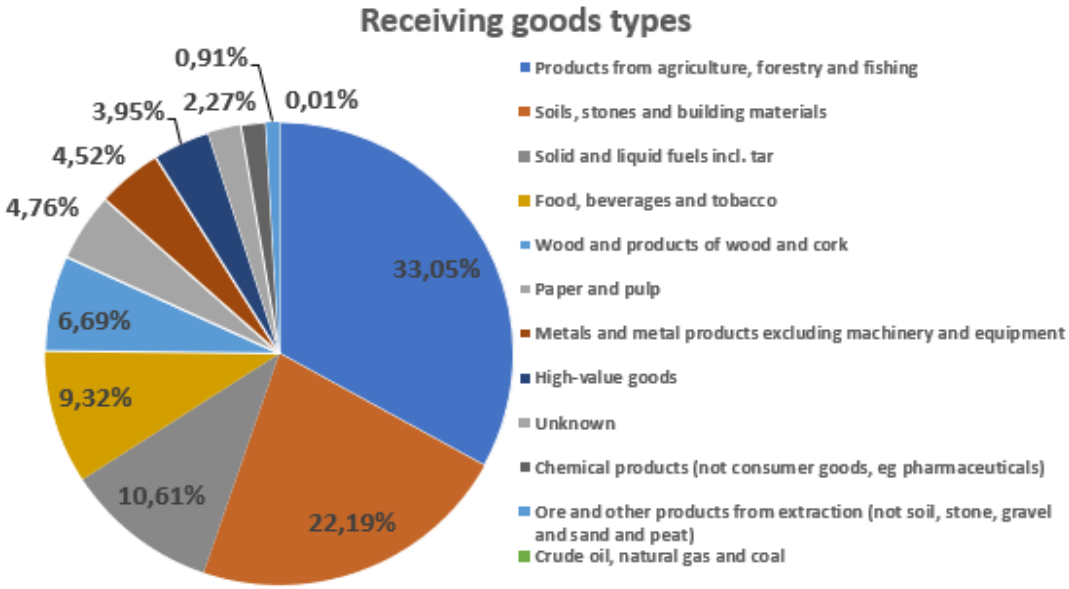

Figure 4.5. Allocation of consumed goods types in the selected counties

The largest volume is found in the goods type *products from agriculture, forestry and fishing* where the destinations are found primarily in Värmland (41%). The commodity with the

largest volume is *roundwood,* where 83% are consumed in Grums (wood and paper industry) with connections to Örebro and Dalarna.

A majority of the inbound volume is supplied by road transportation and the largest industries are wood and paper (67%), agriculture, forestry and fishing (13%) and manufacturing of consumer goods (11%). Most of the businesses within the wood and paper industry are located in Värmland and Örebro. The biggest volumes within the agriculture, forestry and fishing industry have destinations in Västra Götaland and Örebro where the main contributor of this is Torsby in Värmland. The manufacturing of consumer goods industry is located in Västra Götaland, with large volumes transported to Lidköping, Falköping and Skövde, Götene and Borås.

Soils, stones and building materials are transported by road transportation, with destinations in Västra Götaland (91%). This goods type is provided by the construction industry with commodities such as *soils, stones, gravel and sand*, *other building materials (not metal* and *wood) and cement, lime and plaster*.

The goods type *solid and liquid fuels incl. tar* is either transported by road (56%) or sea (44%). Almost all volume consists of the commodity *liquid refined petroleum product*s, with destinations in Gothenburg and Lysekil.

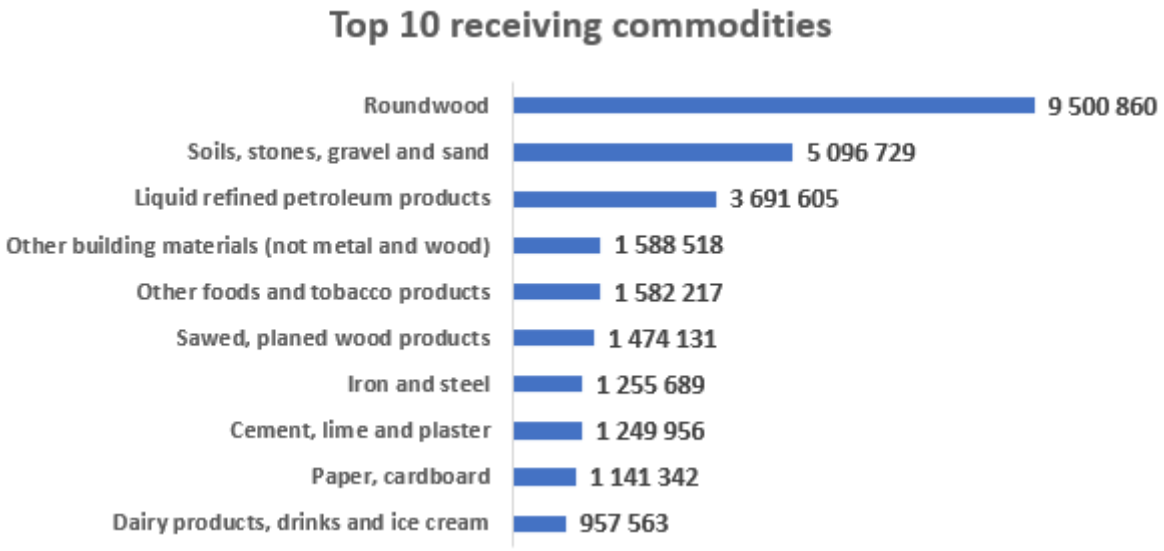

Figure 4.6. Top 10 commodities consumed in the selected counties

The commodity *roundwood* represents 26% of the inbound volume (see figure 4.6), where destinations within Värmland corresponds to half of this volume, most of the volume is transported in Grums due to the typical business type.

Looking into the commodity *soils, stones, gravel and sand*, where all transports are done by road carried as solid bulk goods (85%) or in large freight containers (13%). Västra Götaland

stands for almost 95% of the consumed volume, especially in Gothenburg (59%), Skövde (14%) and Lerum (8%).

The commodity *other building materials (not metal and wood)* are supporting the construction industry with the largest volumes. These transports are performed by road, where half of the volume is palletized goods. 89% of this volume is received in Västra Götaland, mainly in Gothenburg and Borås. These goods flows have origins in Västra Götaland (60%) or from the southern part of Sweden, Halland (18%) and Skåne (7%).

4.3 Domestic goods flows - Outbound

This section presents the goods flows with origins in one of the counties. It identifies where goods are produced and represents the outbound flow for domestic shipments. The outbound goods flow in this data selection is summarized to approximately 37.9 million tonnes. The figure 4.7 below presents the allocation between the selected counties.

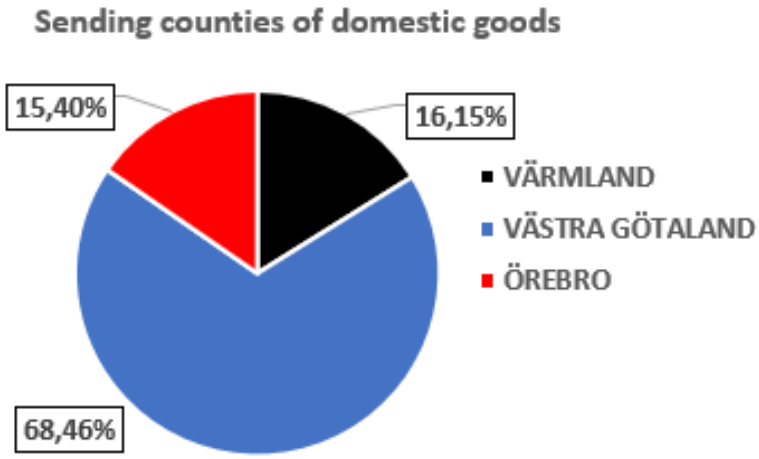

Table 4.7. Distribution of inbound goods flow between selected counties

The map visualization below in figure 4.8 illustrates the domestic outbound goods flow from the regions. The bar charts included provide information regarding top 10 sending and receiving municipalities based on total weight. They correspond respectively for 52% and 42 % of the total shares.

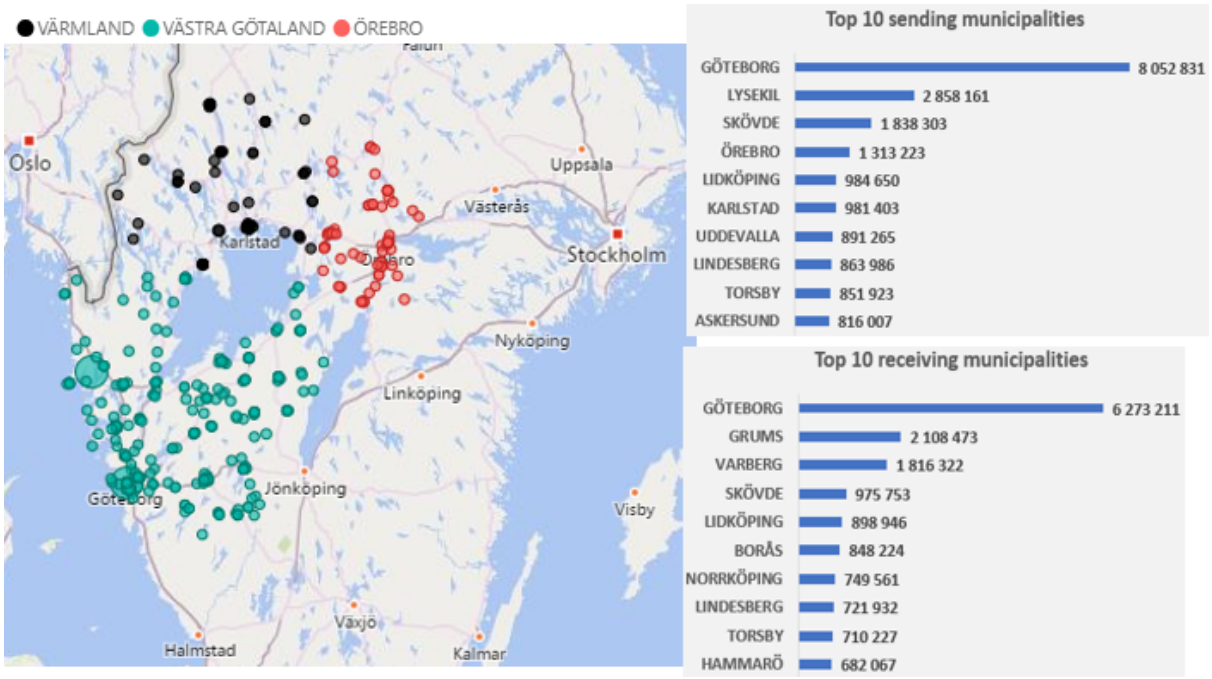

Figure 4.8. Map visualisation of municipalities with outbound domestic goods flow

Outbound shipments from one of the counties are sent to 290 destinations in Sweden, mainly to municipalities within Västra Götaland (40%), Värmland (16%) and Örebro (10%). From Gothenburg, 21% of the outbound volume can be found. For example, *liquid refined petroleum products* are distributed by sea where Lysekil, Karlshamn, Helsingborg, Stockholm and Norrköping are receiving most of the volume. A large share of road transportation is also identified for the outbound goods flows from Gothenburg.

Goods flows with origins in Lysekil is almost solely represented by *liquid and refined petroleum products* (95%). These goods flows are transported with either sea (95%) or road (5%). This could be explained, due to the characteristics, that liquid bulk goods are compatible with sea transportation since it is able to absorb large volumes. The destinations of this commodity are spread out between ports in Sweden, receiving the goods and further distribute it as domestic flows. The remaining share is distributed by road to access nearby municipalities in Västra Götaland (89%), since this mode offers higher accessibility for these distances.

The goods flows originating from Skövde are either carried as solid bulk goods (54%), in large freight containers (31%) or as palletized (10%). Västra Götaland is the county where most of the volume are transported to (73%), with largest share allocated in Skövde, Lidköping, Falköping and Gothenburg.

4.3.1 Goods types and commodities produced in the regions

This section further presents what goods types and commodities that are produced in the counties and transported as domestic outbound flows. The visualisation of the goods types in

figure 4.9 includes all outbound domestic data, while figure 4.10 presenting top 10 commodities represent 80% of the total volume.

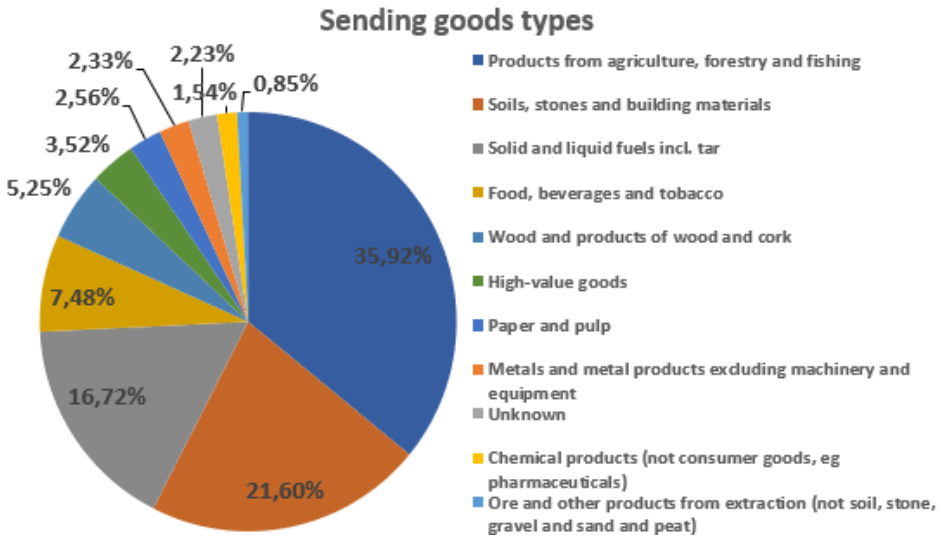

Figure 4.9. Allocation of produced goods types in the selected counties

Products from agriculture, forestry and fishing represent the largest produced volume, where largest share are identified in Torsby, Hällefors, Hagfors and Arvika. Notable to mention, there exist 77 sites in total, and 49 are located in Västra Götaland which also accounts for largest share (46%). Rail transportation with origins from Hällefors, Falköping and Uddevalla of the commodity *roundwood* corresponds to 8% of this goods type where the top destinations are Varberg and Grums.

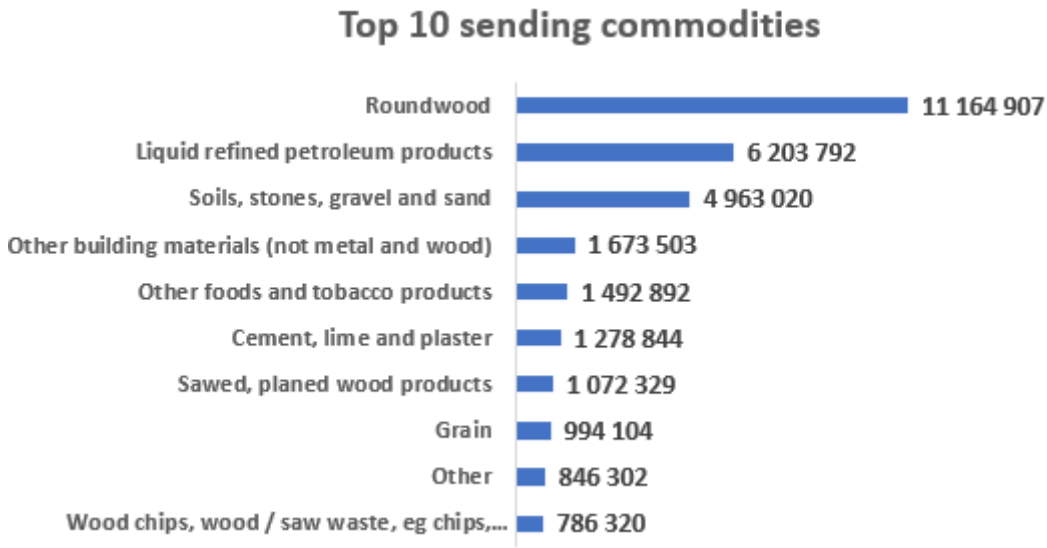

Figure 4.10. Top 10 commodities produced in the selected counties

Roundwood is either transported by road (91%) or rail (9%). Värmland is the largest receiver of this commodity (40%) with large shares in Torsby, Hagfors, Arvika and Filipstad. The wood and paper industries, consuming mostly of this commodity are located in Grums, Varberg, Torsby and Hammarö.

Liquid refined petroleum products only origins from Västra Götaland (96%) and Värmland (4%). Sea transportation represents 71%, whilst road transportation is the remaining 29%. The largest flows are transported from Gothenburg (49%), Lysekil (44%) and Karlstad (4%) and the largest receiving municipalities are Göteborg (25%), Norrköping (7%), Lysekil, Karlshamn and Gävle with (6% each).

The majority of the volume of *soils, stones, gravel and sand* is produced in Västra Götaland. especially in Gothenburg (62%), Skövde (15%), Mölndal and Alingsås (7% each). Almost all of volume is transport with road as transport mode, with origins in Västra Götaland. Up to 93% of the volume is transported to municipalities within the county (Gothenburg, 60% and Skövde, 14%) and the remaining volume is spread out to all of the other counties.

4.4 Import flows

This section presents the import goods flows with destinations in one of the counties. It identifies where goods are received for consumption or storage and represents the inbound flow for import shipments. The total weight in this data selection is summarized to almost 29.8 million tonnes and the top five contributors account for approximately 75%. Russia, Norway and Denmark account for the largest shares, followed by Great Britain and the Netherlands. The commodities with large consumed volume are *crude oil* and *liquid refined petroleum products*, which together stands for 84% of the volume. In figure 4.11, the distribution of imported goods volume to the selected counties is shown.

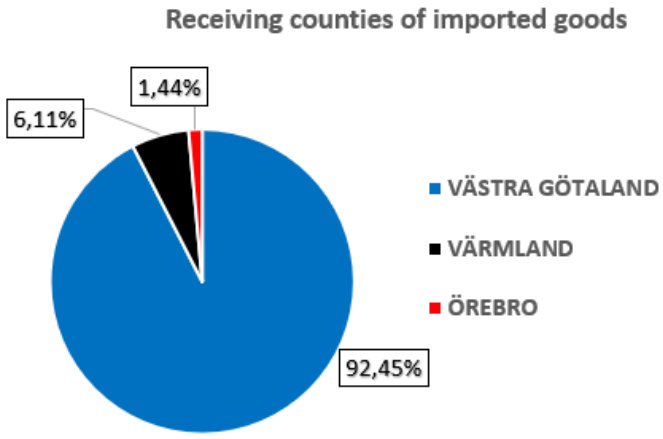

Figure 4.11. Distribution of the imported volume to the receiving counties

The map visualization below in figure 4.12 illustrates the import inbound goods flow to the regions. The bar charts included provide information regarding top 5 import markets and commodities based on total weight.

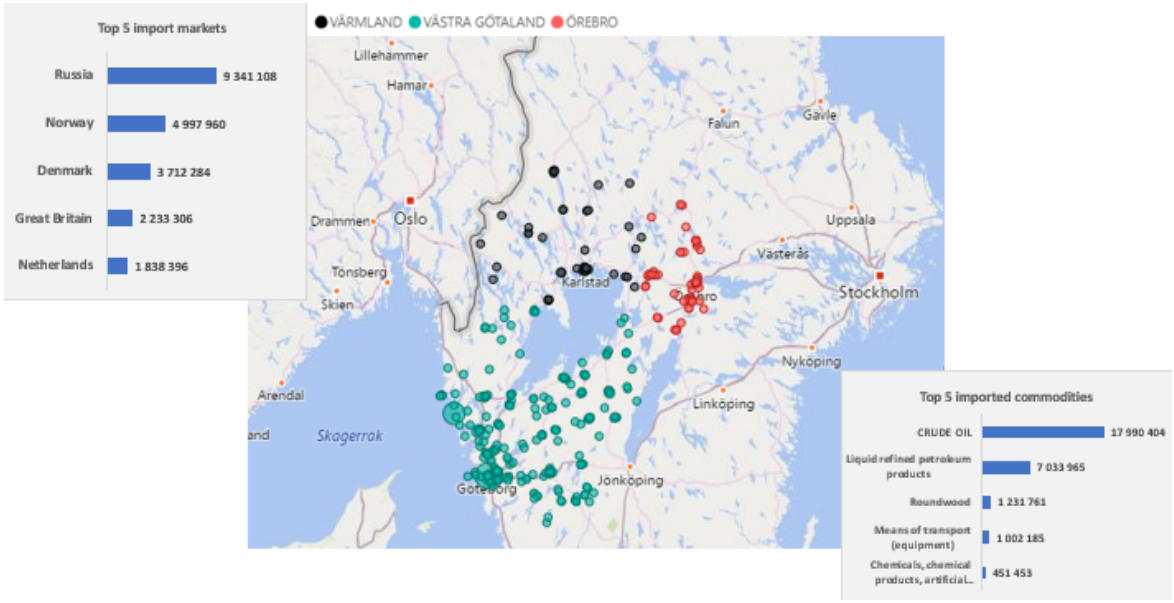

Figure 4.12. Destinations in each region of imported based on their goods flow

The 10 largest receiving municipalities stands for 95% of the total imported volume and the respective shares are shown in the figure 4.13. Significant volumes are allocated to Gothenburg and Lysekil since the ports located here function as main gateways to ocean traffic. This is explained by the data, since it shows that up to 86% of the imported data are transported on the sea to the Swedish market.

Table 4.13. Top ten municipalities based on import

Russia is the main import market for *crude oil* and *liquid refined petroleum products*, with a large share of the total volume with destinations in Lysekil (86%), Gothenburg (9%) and Stenungsund (5%).

80% of the imported goods from Norway is transported by sea with destinations in Gothenburg (77%), Lysekil (21%) and Stenungsund (2%). The remaining 12% are transported by rail, to industries within wood and paper and agriculture, forestry and fishing with destinations in Grums and Lindesberg. The commodities received consist of *roundwood* and *wood chips, wood / saw waste, e.g. chips, pellets*.

The goods from Denmark are imported with sea (96%) and road (4%) transportation. Goods transported by sea are equal to the flows from Russia and Norway, i.e. liquid bulk goods. Except from these, a smaller share of the commodity *chemical and mineral (natural) fertilizers and salt* are imported to Stenungsund. Looking further in the commodities transported on road, identified destinations of the commodity *iron and steel* are located in Karlstad and Nora. To Svenljunga and Vårgårda, goods are imported on road to support businesses in manufacturing of consumer goods and wholesale.

4.4.1 Industries

Figure 4.14 shows from which industry the goods flows originate from, where mining and quarrying and manufacturing of consumer goods stand for significant shares. In Lysekil, two of the world's largest petroleum companies Preem and ST1 refineries are located which explains these large volumes from the mining and quarrying sector. From the manufacturing of consumer goods, 86% are received in Västra Götaland, Örebro (11%) and Värmland (4%) with origins in Germany, the Netherlands and Denmark. The largest imported volumes in the wood and paper industry are consumed in Värmland (89%), i.e. Grums, Karlstad and Hammarö with goods flows originating mainly from Norway and Lithuania.

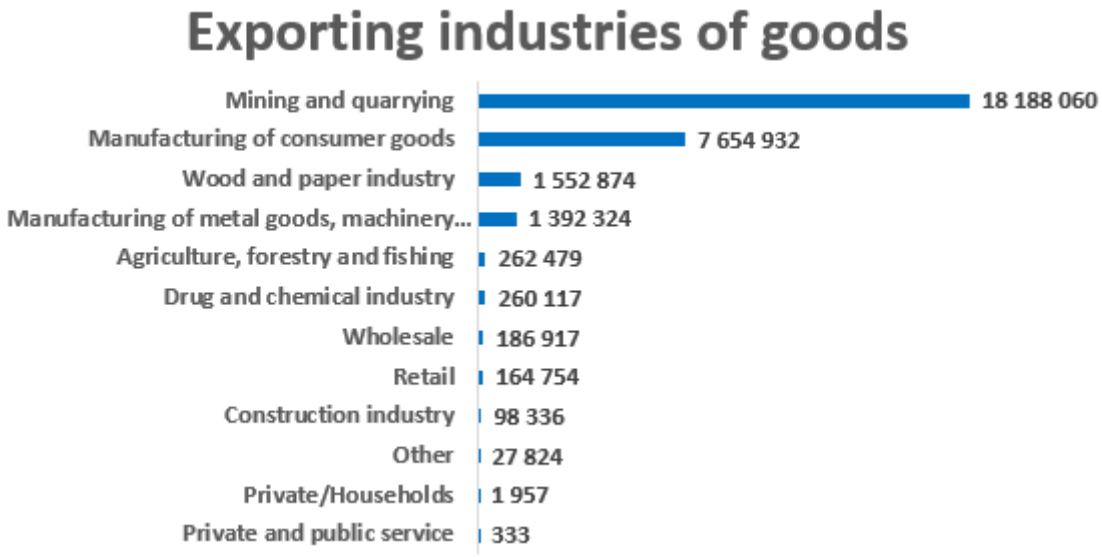

Figure 4.14. Allocation of the existing business types of the importing actors

4.5 Export flow

This section presents the export goods flows with origins in one of the counties. It identifies where goods are produced and represents the goods flow for export shipments. The total exported volume from this data selection is summarized to approximately 24.5 million tonnes and the top five export markets (53%) are listed in figure 4.16. The top five commodities are also listed, notable is that the commodity *liquid refined petroleum products* stands for the majority of the volume (63%). Sea transportation absorbs largest volumes (65%) followed by road (16%), road/sea (14%) and road/rail (5%). The distribution of exported volume between the counties are shown in figure 4.15, where Västra Götaland stands for the largest share.

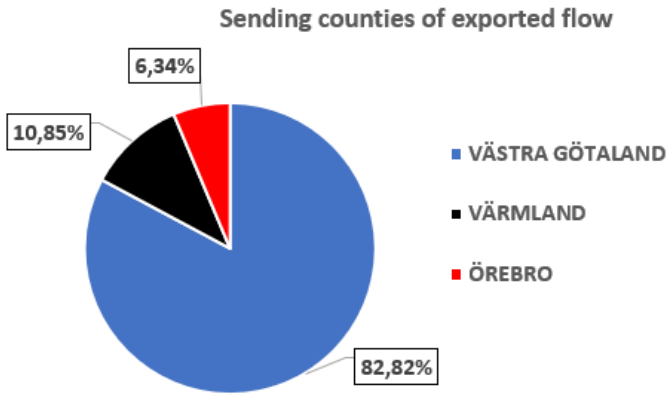

Figure 4.15. Weight distribution of the sending counties

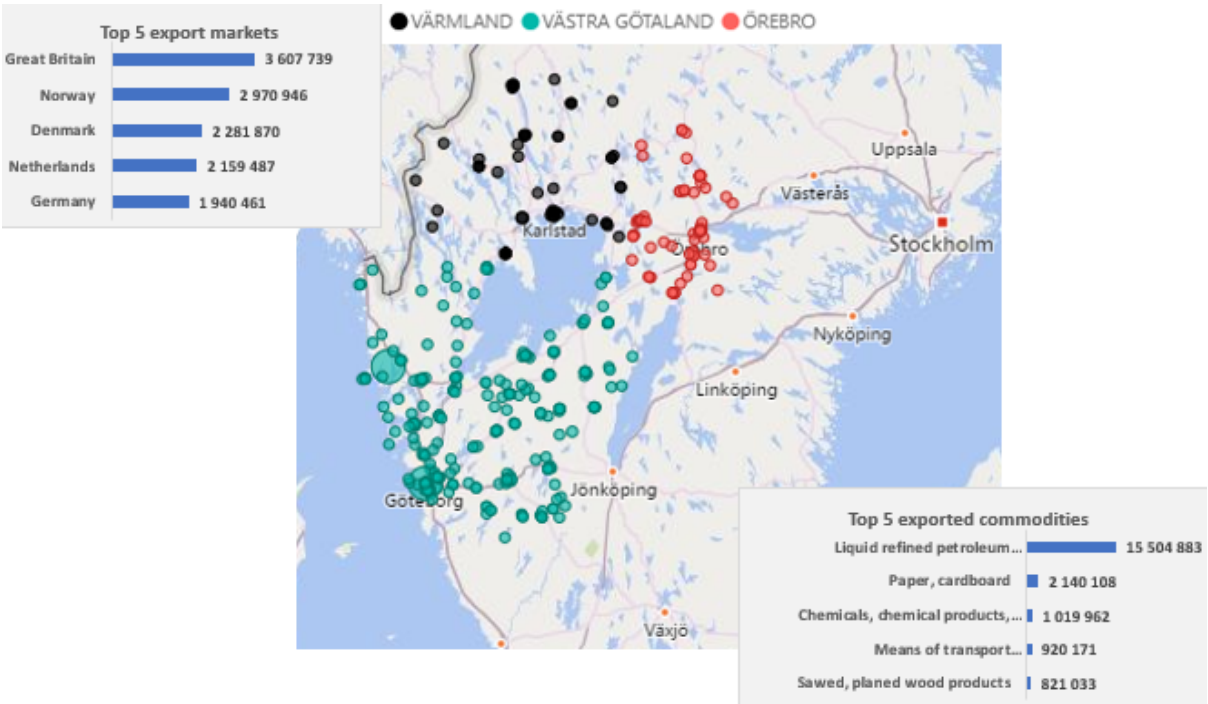

Figure 4.16. Map visualisation of municipalities in selected counties exporting goods

In the figure 4.16, visualisation of all of the 76 exporting municipalities are shown, where larger volumes are located at the west coast in Västra Götaland, more specific in Göteborg

(36%), Lysekil (30%) and Stenungsund (5%). The top 10 exporting municipalities are presented in the figure 4.17 below, which accounts for 83% of the total exported volume, with mostly of the volume exported from the ports. This could be explained since the export data is designed in the same way as the import data, where goods are distributed to the major ports identified in Västra Götaland and then further distributed as export flow.

To Great Britain large volumes are exported. These flows are mostly *liquid refined petroleum products* (87%), but also *paper, cardboard, dairy products, drinks and ice cream*, *sawed, planed wood products* and *chemicals, chemical products, artificial fibers, rubber and plastic products* are commonly exported commodities. Export flows to Norway is transported by sea (55%) or road (44%). Sea transportation originates from Gothenburg (96%) and Lysekil (4%), carrying the commodity *liquid refined petroleum products*.

The Scandinavian countries, Norway, Denmark and Finland together stands for 45% of the exported volume from Gothenburg, where sea transportation stands for 86%. All goods flows from Lysekil consist of the commodity *liquid refined petroleum products* and are transported to Great Britain (29%), the Netherlands (13%), Spain (8%) and Ireland (7%). From Stenungsund, the commodity *chemicals, chemical products, artificial fibers, rubber and plastic products* (54%) are majority of the volume, together with *liquid refined petroleum products* (41%).

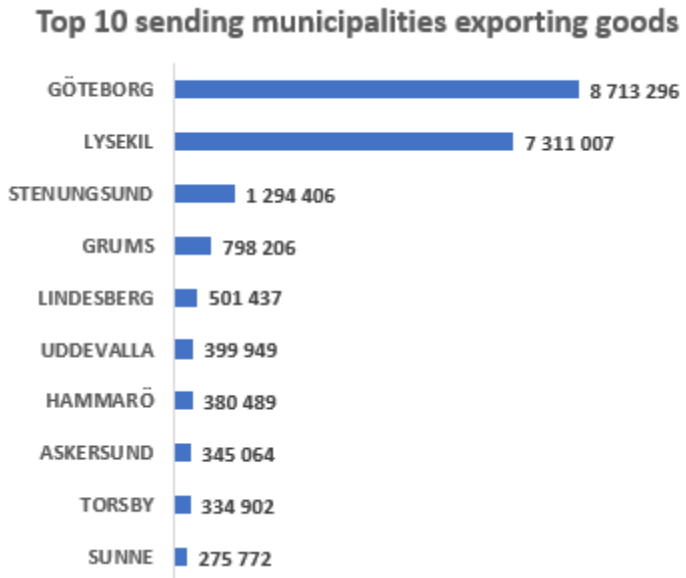

Table 4.17. Top 10 exporting municipalities

4.5.1 Industries

Figure 4.18 below presents the allocation between the different industries that are exporting to foreign countries. *Liquid refined petroleum products* stand for all volume within the wholesale business. Great Britain, the Netherlands, Norway and Denmark are main export markets of this volume. The business type other, which is hard to define, export 82% of the

volume from Västra Götaland. Värmland is largest exporter in wood and paper industry with 63% of the volume, Örebro 23% and Västra Götaland 14%. The goods produced are exported with larger volumes to China, Germany, Norway and Italy of the commodities *paper, cardboard* (65%), pulp (13%), *roundwood* (10%), *sawed, planed wood products* (9%) and *chemicals, chemical products, artificial fibers, rubber and plastic products* (2%).

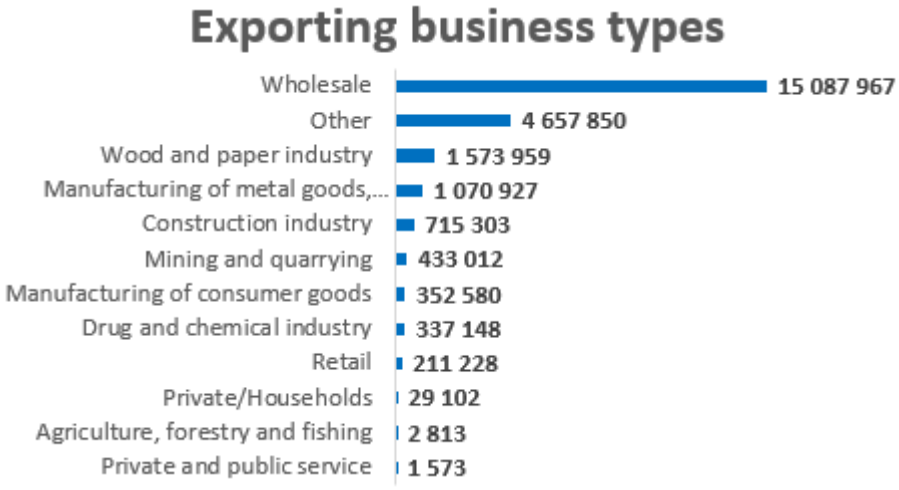

Figure 4.18. Business types exporting goods

4.6 Västra Götaland goods flows

The total goods flows in Västra Götaland county account for the largest share of the data analysed. They are summarized all together to 95.8 million tonnes, divided between directions, as illustrated in the figure 4.19 below. The goods flows are evenly distributed between consumption (Inbound goods flow) and production (outbound goods flow), i.e. a balance in the flow exists.

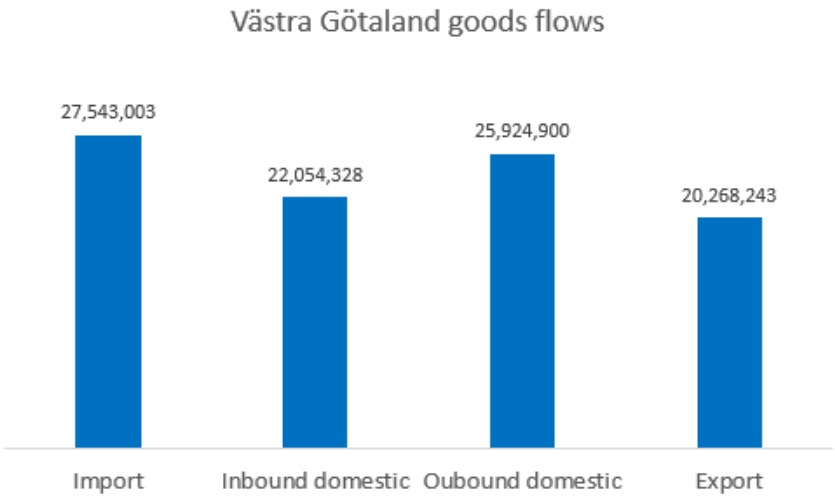

Figure 4.19. The total goods volume in Västra Götaland divided per flows

4.6.1 Inbound goods flow

The inbound goods flow, i.e. import and domestic, are approximately 49.6 million tonnes, almost only transported by sea (52%) and road (41%). Industries consuming larger volumes are within the mining and quarrying (38%), manufacturing of consumer goods (20%) and construction (15%), wholesale and retail (6% each). The countries where the largest volumes are imported from are Russia, Norway and Denmark.

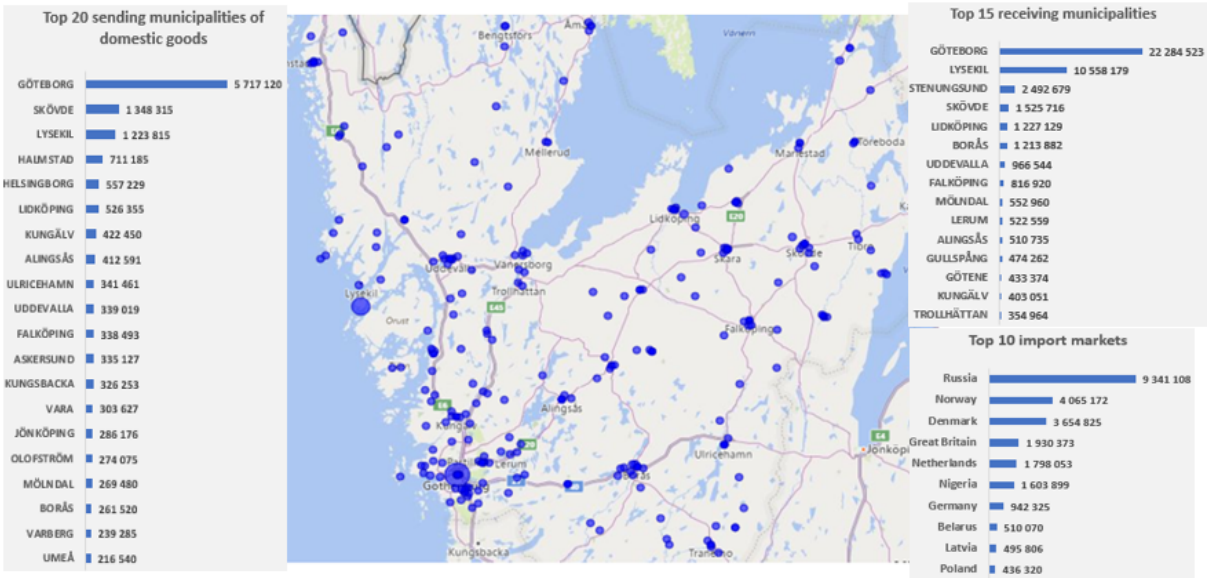

Figure 4.20. Destinations of inbound goods flow within Västra Götaland

Figure 4.20 presents the destinations of the inbound flows to Västra Götaland. Gothenburg and Lysekil represents the largest receiving municipalities with 47% of the total volume for this data selection.

The top 15 receiving municipalities accounts for nearly 90% of the total inbound goods volume. Looking further where the domestic flows originates from, Gothenburg is the main provider followed by Skövde, Lysekil, Halmstad and Helsingborg.

The sending municipalities are transporting over 22 million tonnes as domestic goods flow, where large volumes originates from are representing counties such Västra Götaland (64%), Halland (7%), Skåne (5%), Jönköping (4%) and Örebro (3.5%). The data includes 275 different origins (within Sweden) of goods flow to Västra Götaland.

To Västra Götaland, large flows of the goods types *soils, stones, gravel and sand* (33%), *liquid refined petroleum products* (19%) and *roundwood* (7%) can be found. These goods are mainly transported as liquid or solid bulk goods or in large freight containers.

Västra Götaland county are importing 27.5 million tonnes in total. The top 10 import markets are listed in the figure 4.20, and stands for 90% of the total import. The largest imported volumes are mainly representing the commodities *crude oil* (65%) and *liquid and refined*

petroleum products (26%). Except from these highly volume consuming commodities, *means of transport (equipment)*, *chemicals, chemical products, artificial fibers, rubber and plastic products* and *iron and steel* are represented. These goods are often transported as palletized goods where consuming industries such as manufacturing of metal goods, machinery and transport and drug and chemical industry are identified.

4.6.1.1 Industries

The largest volumes of inbound flows originates from the mining and quarrying industry and the manufacturing of consumer goods industry, see figure 4.21. The import flow accounts for 95% of the total volume with destinations to either the port in Lysekil (52%) or in Gothenburg (46%). Russia, Norway, Denmark and Nigeria are main contributors with a share around 83%.

The goods originating from the construction industry are only from Sweden where road transports are used for 99% of the volume where goods types are *soils, stones, gravel and sand*, *other building materials (not metal and wood), cement, lime and plaster* and *iron and steel.*

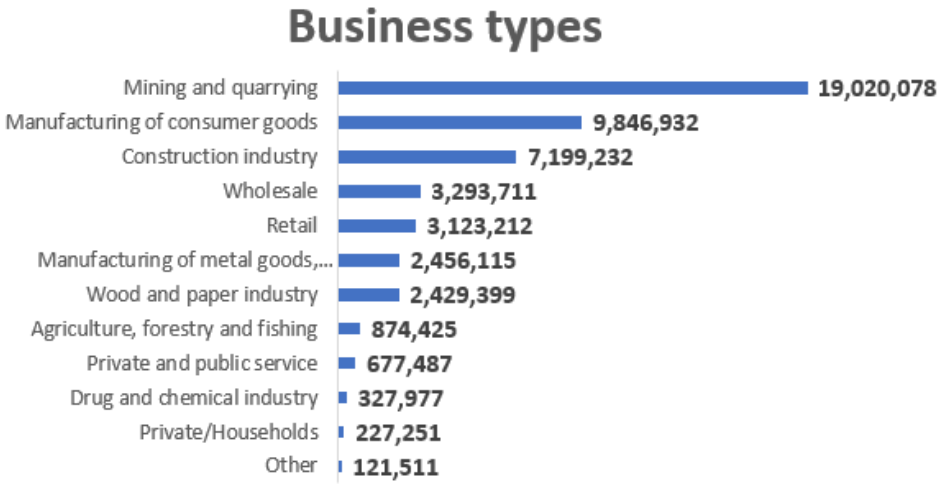

Figure 4.21. Distribution between the business types where inbound goods flow originates from

4.6.1.2 Goods types and commodities

The biggest volumes of goods transported to Västra Götaland is *crude oil* which is transported as import flows with sea transport to the ports in Gothenburg and Lysekil as explained previously. Goods flows of *solid and liquid fuels, incl tar*. (see figure 4.22) are 70% imported and 25% of the volumes have origins in either Gothenburg or Lysekil, which should account for last mile distribution to the final destination of the goods from the ports. Regarding *soils, stones and building materials,* 99,5% is domestic transportation with origins in Sweden, where approximately 40% is sent within Gothenburg. *Food, beverages and tobacco* is 90% domestic flows and 10% import with origins in a wide spread of countries. *High value goods* have an even share of import/domestic transportation where significant shares origins from Gothenburg and Olofström. Gothenburg is also the destination for 62% of the volumes in this goods type. *Wood products and products of wood and cork* includes 70% *sawed, planed wood*

products with 98% of the origins in Sweden. The distribution of the top 10 received commodities can be seen in figure 4.23 below, which stands for 84% of the inbound goods flow.

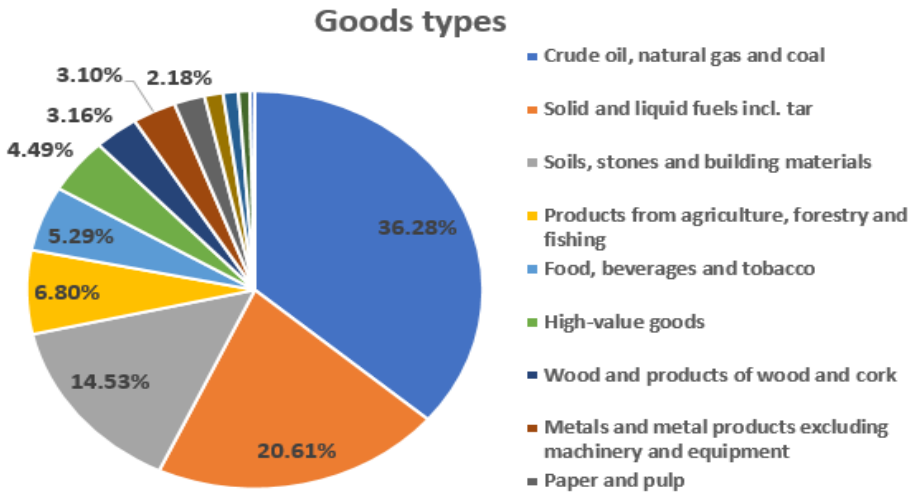

Figure 4.22. Distribution of inbound goods types

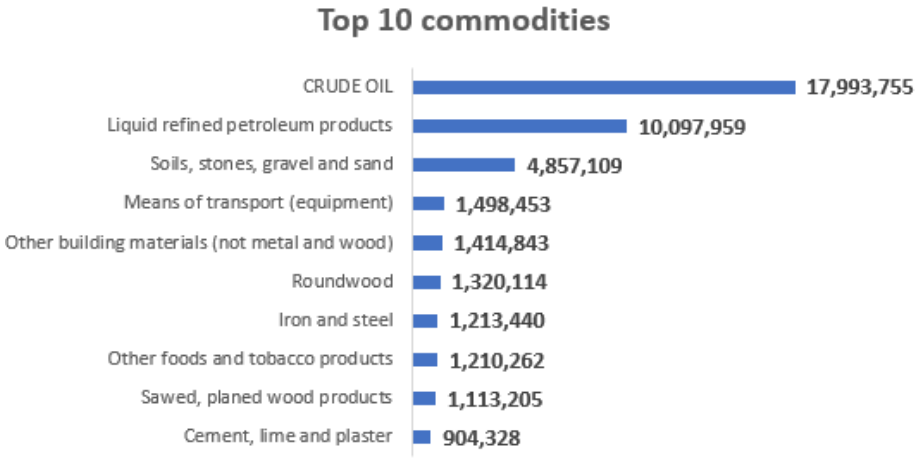

Figure 4.23. Top 10 commodities inbound goods flow

4.6.1.3 Transport modes and carrier types

Sea transportation accounts for 54% of the goods flows with Västra Götaland as destination, see figure 4.24 where almost everything is imported liquid bulk goods.. The domestic sea transport are mainly between the ports of Lysekil and Gothenburg, and in small parts from Piteå, Karlshamn and Stenungssund.

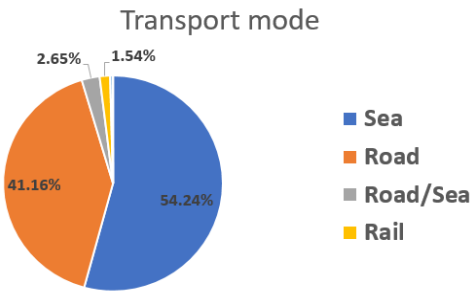

Figure 4.24. Weight distribution of the transport modes used

Half of the volume that are transported on road are flows consisting of the commodities *soils, stones, gravel and sand* (24%), *liquid refined petroleum products* (7%), *other building materials (not metal and wood)* (7%), *roundwood* (6%) and *other foods and tobacco products* (6%). Road is clearly the dominant transport mode in the domestic flows and the import flows are mainly transported by sea. Below, the carrier types used for the transports are presented in figure 4.25.

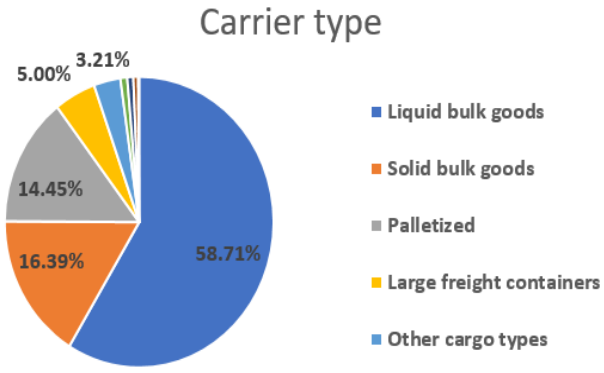

Figure 4.26. Carrier types carrying the inbound goods flow

4.6.2 Outbound goods flow

From the Västra Götaland county, almost 26 million tonnes are produced and transported as domestic goods flow. The export flows are summarized to approximately 20 million tonnes which together equals nearly to 46 million tonnes as the outbound goods flow from this county. The export flows are collected in the same way as the import data, where the ports in Gothenburg (43%), Lysekil (26%) and Stenungsund (6%) are main contributors to this volume. The industries producing the largest volumes that are transported as domestic goods flows are within construction industry (29%), wholesale (21%), wood and paper industry (17%) and retail (11%).

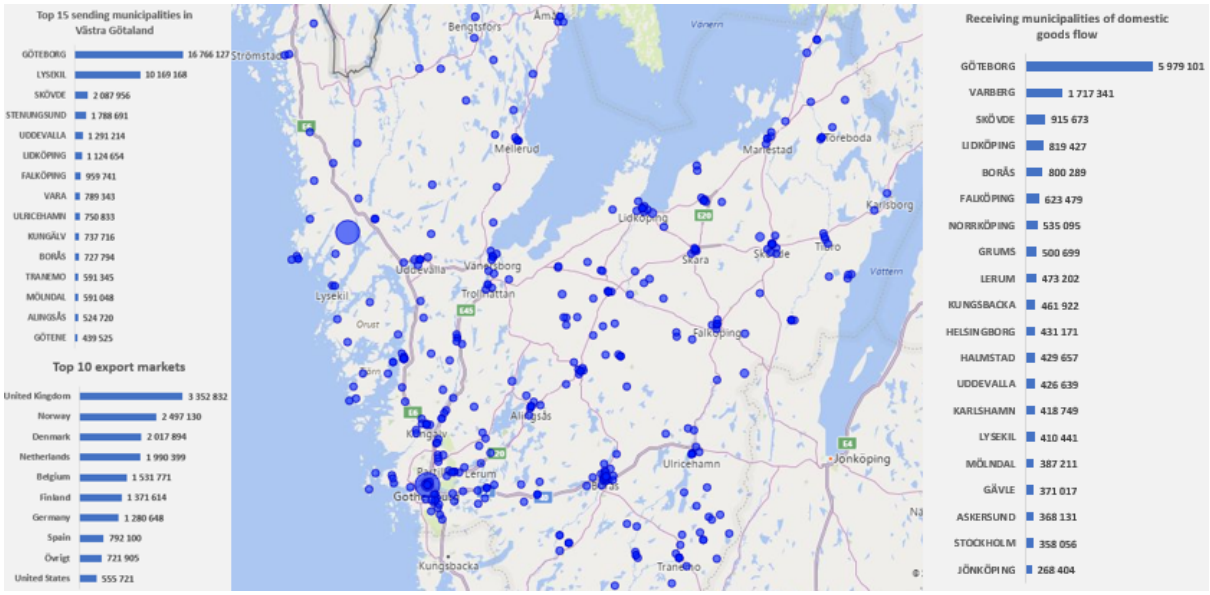

Figure 4.27. Origins of outbound goods flow from Västra Götaland

The map visualisation in figure 4.27 provide an understanding of where the goods originates from and where the destinations of the larger volumes are located, a. A clustered area of businesses is located within the Gothenburg area and in the beginning of the river Göta Älv. The top 15 sending municipalities listed in the figure above stands for 85% of the total outbound goods flow, volume producing industries are found within the construction-, wholesale- and retail industry.

The top 20 receiving municipalities of the domestic goods volume with origin in Västra Götaland are listed in the figure 4.27. Together they account for nearly 65% of the volume. Sea transportation accounts for 50% of this share with where 48% represents export flows and the remaining 52% are transported as domestic flow, containing *liquid refined petroleum products*. This commodity is distributed to 15 of 21 counties within Sweden, where almost all volume originates from Lysekil (62%) and Gothenburg (37%).

The top 10 export markets accounts for nearly 80% of the total exported volume. The large volumes (i.e. 77%) are identified as the commodity *liquid and refined petroleum products* with

origins in especially Gothenburg and Lysekil. Looking beyond at the remaining 23% of the volume, the goods types are more evenly distributed, with larger shares of *high-valued goods, chemical products (not consumer goods, e.g. pharmaceuticals), paper and pulp, metals and metal products excluding machinery and equipment* and *soils, stones and building materials*. The export goods have destinations in 106 different countries.

4.6.2.1 Industries

In the Västra Götaland county, wholesale stands for the largest of the outbound goods volume (44%), see figure 4.28. This industry is transporting their largest volumes (i.e. 94%) of the commodity *liquid refined petroleum products*, where nearly 75% are exported to countries such Great Britain, Netherlands, Norway, Denmark and Finland. The origins of this commodity are from the ports in Lysekil and Gothenburg.

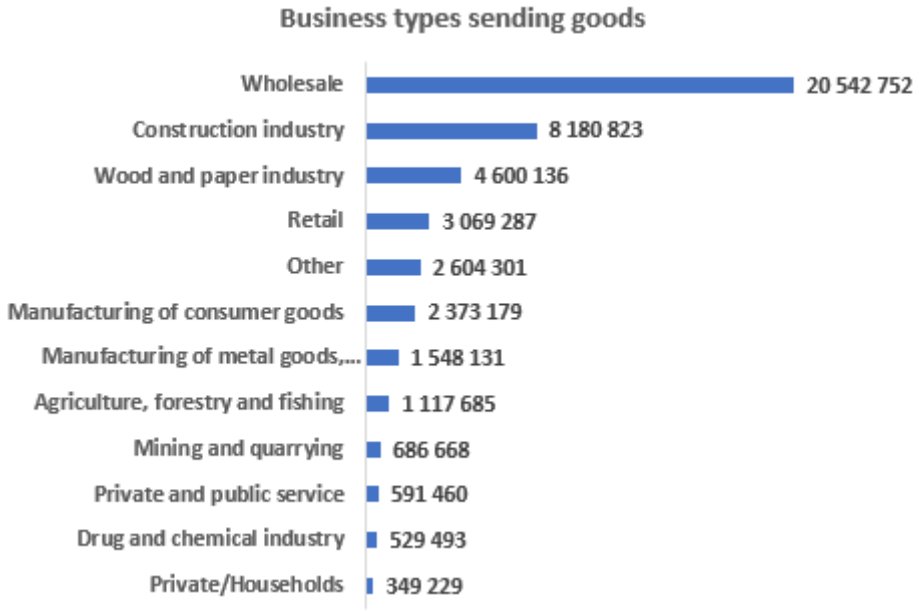

Figure 4.28. Weight distribution of the existing business type (i.e. producing industries)

The construction industry is only exporting nearly 9% of their volume, with high shares in Norway and Denmark. The rest are distributed as domestic flows, where 80% of the volume originates from Gothenburg (48%), Skövde (17%), followed by Uddevalla, Mölndal and Vara with smaller shares. The destinations of the domestic flows are distributed to all the counties within Sweden, with around 80% located in Västra Götaland. The commodities *soils, stones, gravel and sand, other building materials (not metal and wood)* and *cement lime and plaster* accounts for 90% of the domestic volume. These are almost completely transported on the road as solid bulk goods, palletized goods or with a large freight container.

The volumes for the wood and paper industry are within the commodities roundwood (81%), *paper, cardboard* (8%) and *sawed, planed wood products* (5%). Only 5% of the volumes are exported, mainly to Norway, Germany and Denmark. In the domestic flows, rail accounts for transporting 12% of the volume with destinations in Varberg, Grums and Karlshamn. Rail are

almost completely transporting the commodity *roundwood* on carrier type solid bulk goods with origins in Falköping and Uddevalla.

4.6.2.2 Goods type and commodities

Almost half of the goods volume concerning the goods type *solid and liquid fuels incl. tar* and particularly the commodity *liquid refined petroleum products*. Beside this commodity, which are highlighted earlier, *soils, stones and building materials* together with *products from agriculture, forestry and fishing* are notable to mention due to their relatively large volumes (see figure 4.29).

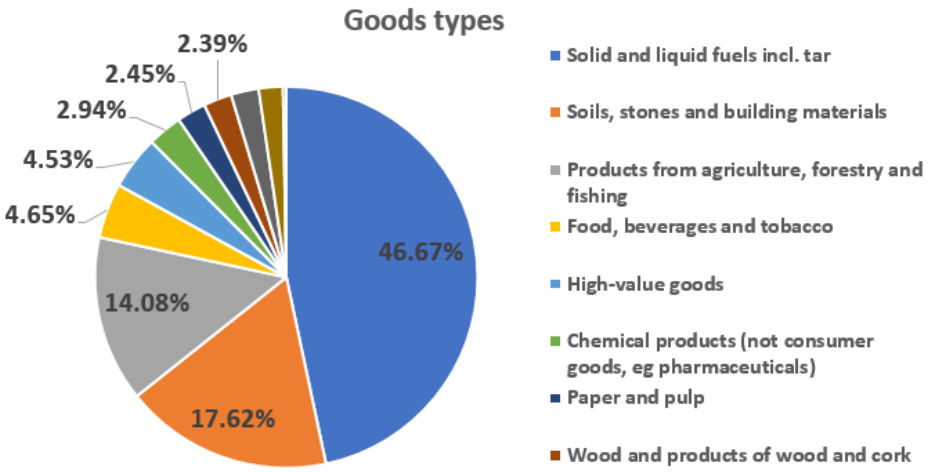

Figure 4.29. Distribution of the produced goods types

The commodities within the goods type *soils, stones and building materials* are identified as volume consuming in the construction industry, where almost 80% of the destinations in the domestic goods flow are located in Västra Götaland. The transport mode used are almost completely by road, mainly on the carrier type palletized. This goods type includes the commodities that could be seen in figure 4.30, *soils, stones, gravel and sand* together with *other building materials (not metal and wood)* and *cement, lime and plaster*. The top 10 commodities accounts for 85% of the outbound goods volume.

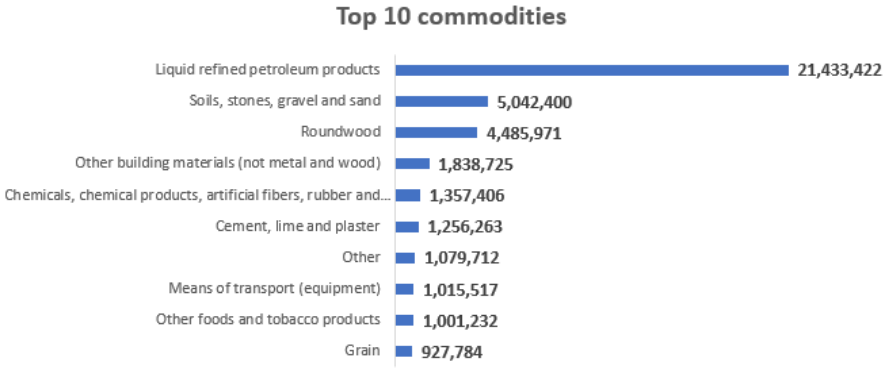

Figure 4.30. Top 10 commodities with largest produced volume

Products from agriculture, forestry and fishing are representing the commodities *roundwood*, *grain*, *unprocessed milk* and *other forest raw materials than round wood*. Large volumes

originate from Falköping, Lidköping, Uddevalla and Vara, then transported by road (89%) or rail (8%) to destinations in such Varberg, Lidköping, Borås and Grums. The industries located in these destinations are mostly within the wood and paper industry, in manufacturing of consumer goods or in agriculture, forestry and shipping.

4.6.2.3 Transport modes and carrier types

The figure 4.31 below shows the distribution of the total volume between the transport modes used in the flows. Road and sea are clearly the main alternative for transporting goods from this county, where road transports are used within the construction-, wood and paper- and retail industry whereas sea are mainly from the wholesale industry.

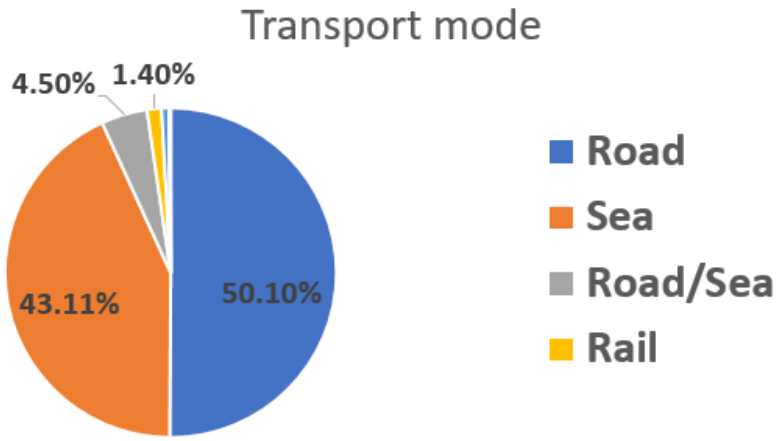

Figure 4.31. Distribution of the transport modes in outbound goods flow

For domestic goods flows, road is the main transport mode. The goods are transported on the carrier types solid or liquid bulk goods or as palletized. Large volumes are produced in Gothenburg, Lysekil, Skövde and Lidköping where *liquid refined petroleum products, soils, stones, gravel and sand* together with *roundwood* account for the largest volumes.

In the export flow, sea is the dominant transport mode due to their ability to transport large goods volumes of the liquid bulk goods within the wholesale industry as mentioned earlier.

Looking into the typical carrier type used in the goods flows are presented in figure 4.32. Larger volumes are carried as liquid or solid bulk goods, where liquid bulk goods are more common as export flow and solid bulk goods are majority in the domestic flow.

The goods carried as palletized are mostly represented by *food, beverages and tobacco, soils, stones and building materials* and *high-value goods.*

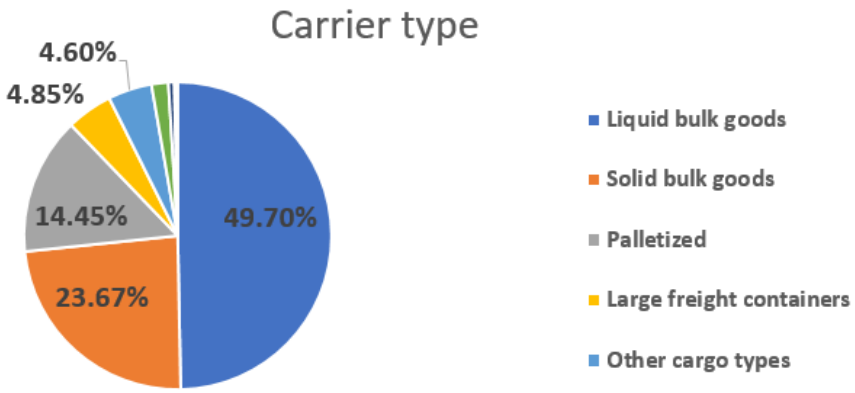

Figure 4.32. Distribution of the carrier type with largest transport volume

4.7 Värmland goods flows

Total goods flow in the region of Värmland are summarized to approximately 17.9 million tonnes. In the figure 4.33, the domestic transports are dominant in this region where both import and export volumes are relatively small. This is explained by the heavy volumes of wood and paper industry where raw materials are sourced locally and transported with trucks to the production facilities, often located within the county.

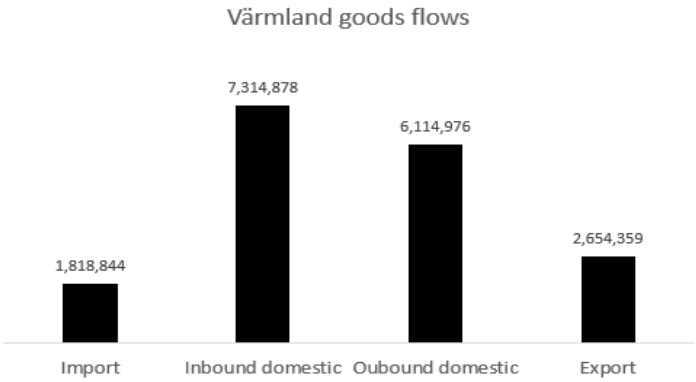

Figure 4.33. Distribution of the inbound and outbound goods flows in Värmland

4.7.1 Inbound goods flow

Total inbound goods flows contains both import and domestic transports and are estimated to approximately 9.2 million tonnes. The wood and paper industry (i.e. 72%) are the most volume consuming business type which is significant for the entire county, where Grums, Hammarö, Karlstad and Torsby are consuming the most of this volume.

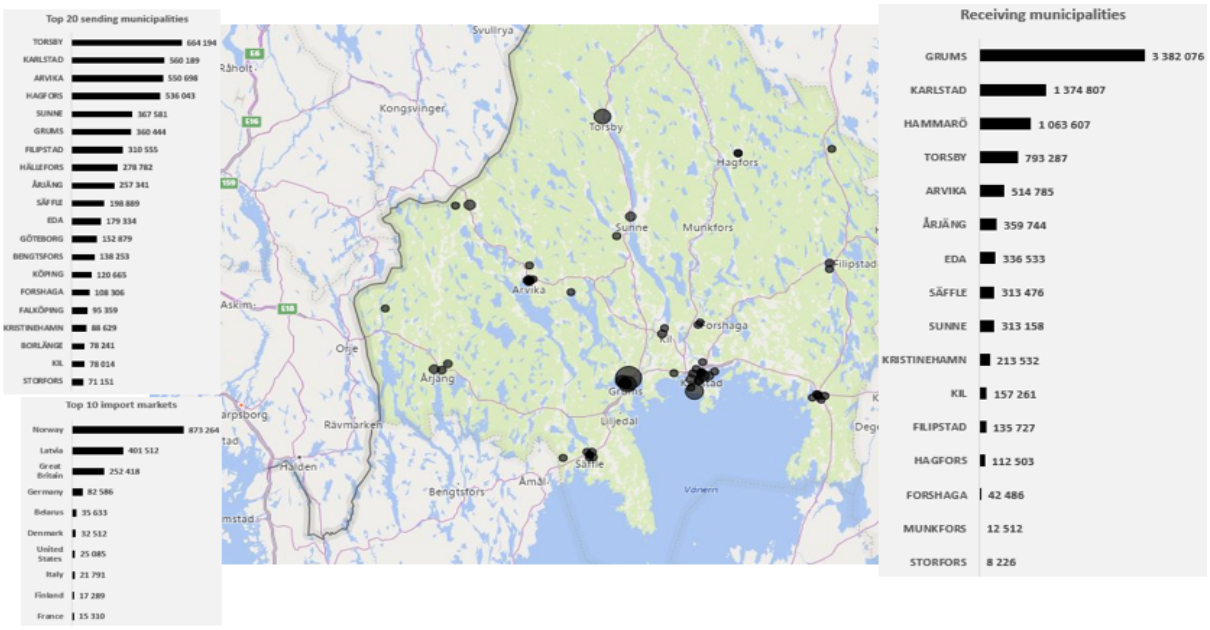

Figure 4.34. Map visualisation of the destinations of inbound goods flows in Värmland

Notable is that the top three receivers, which accounts for 64% of the volume (i.e. Grums, Karlstad and Hammarö) are located in the same area, in the northwest corner of lake Vänern, see figure 4.34. Common imported goods types to these destinations are *products from agriculture, forestry and fishing* and *paper and pulp* within the wood and paper industry.

The top 20 sending municipalities above accounts for approximately 5.2 million tonnes, which are equivalent to 71% of the total inbound flow to Värmland county. Top seven municipalities are the main contributors to the inbound goods flow, and all are located in the same county. The data reveals that 60% of the volume origins from locations within Värmland, Västra Götaland and Örebro accounts for respectively 15% and 5% each. There exist 257 different locations in Sweden where goods consumed in Värmland originates from, mainly from Värmland (60%) and Västra Götaland (15%).

The top 10 import markets accounts for almost 97% of the total volume, equivalent to 1,76 million tonnes. The import flows originates from 38 different countries. The larger volumes from Norway are transported by either rail or road as transport mode, with final destinations to Grums, Årjäng and Hammarö. The imported commodities are *roundwood* or *chemicals, chemical products, artificial fibers, rubber and plastic products*.

The imported goods flows from Great Britain are using intermodal transport with the combination road and sea. Karlstad are the main destination of this flow, consisting of the commodity *paper, cardboard* which are transported as palletized goods.

4.7.1.1 Industries

Värmland are synonymous with wood and paper industry where most of the volume is concentrated (see figure 4.35), due to their geography with large areas of forestry. The largest volumes are consumed in Grums, Hammarö, Karlstad and Torsby. The deforestation are mainly performed in the north part of the county, in Arvika, Hagfors, Torsby and Sunne.

From Torsby, Årjäng and Kil goods flows from the Agriculture, forestry and fishing industry are transported. This industry entirely use road as transport mode, with the carrier type solid bulks goods consisting of the commodities *roundwood* and *chemicals, chemical products, artificial fibers, rubber and plastic product*s.

Commodities such as *liquid refined petroleum products* and *other foods and tobacco products* represents the retail industry. The largest share of the volumes within retail originates from Värmland (33%), Västra Götaland (25%) and Stockholm (20%). The goods are transported by road as liquid bulk goods with large volumes consumed in Karlstad and Kristinehamn.

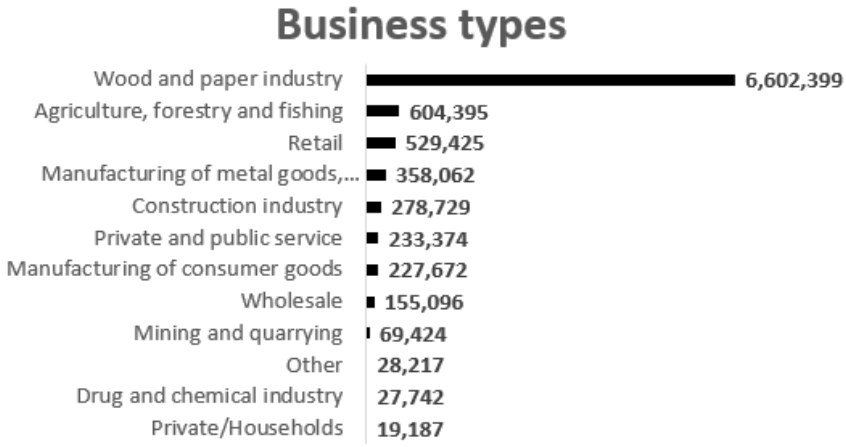

Figure 4.35. Distribution of the business types of inbound goods flow

4.7.1.2 Goods type and commodities

Figure 4.36 presents the distribution between the different goods types consumed in Värmland. Largest shares allocated are products from agriculture, forestry and fishing (67%) together with *wood and products of wood and cork (6%)* and *paper and pulp (6%)*. The top 10 commodities stand for 91%, see figure 4.37. Commodities representing the goods type agriculture, forestry and fishing are *roundwood, other forest raw materials than roundwood* and grain, with destinations mainly in Grums.

The commodities *wood chips, wood / saw waste, e.g. chips, pellets* and *sawed, planed wood products* are consumed in Karlstad and Grums, and road is the only transport mode for these goods, i.e. wood and products of wood and cork. Nearly 55% of the goods type paper and pulp is imported volumes, allocated to *paper, cardboard* and *pulp*.

The commodity *liquid refined petroleum products* is mostly consumed in Karlstad and Kristinehamn. The data reveals that Karlstad, together with Gothenburg, Nacka and Lysekil is supplying this market, and that there exist a form of storage of this commodity in the ports.

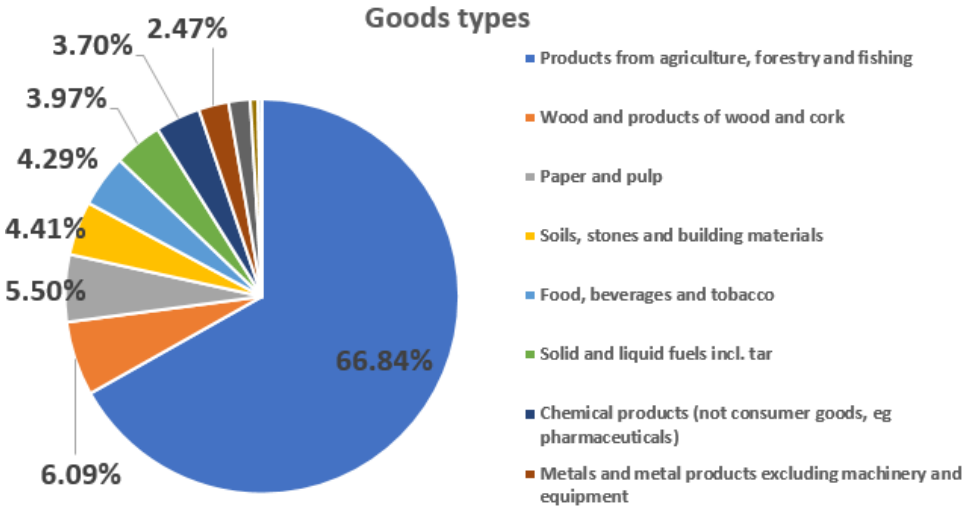

Figure 4.36. Distribution of the goods types transported to Värmland

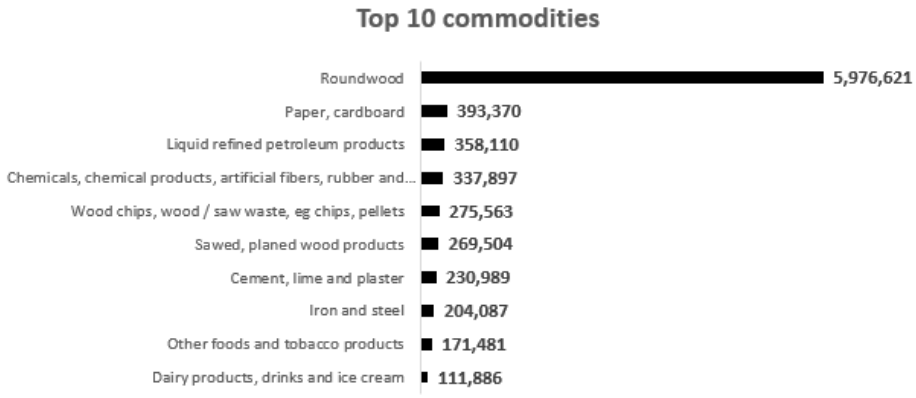

Figure 4.37. Top 10 commodities sent to Värmland

4.7.1.3 Transport modes and carrier types

Road transportation is the dominant mode of transport within Värmland, see figure 4.38. This is due to the geography and the existing infrastructure that are suitable for especially road and rail transport. Road transport are providing goods flows especially in the domestic flows, from Värmland (61%) and Västra Götaland (14%) or in the importing flows, mainly from Norway. The transported goods consist of *roundwood, liquid refined petroleum products* and *chemicals, chemical products, artificial fibers, rubber and plastic products.* A large share of the volume transported by road is performed within the county. These goods are mainly using solid bulk goods, other cargo types or palletized as carrier type.

Rail are used to a large extent to transport *roundwood* to Grums and Karlstad. The goods volumes are mainly originating from Hällefors, Falköping and Borlänge in the domestic flow and Norway in the importing goods flows.

Sea transportation is represented by 90% of imported goods. From Latvia, imports flows consist of the commodity *roundwood.* From the ports in Västra Götaland (i.e. Gothenburg and Lysekil), 10% of the total inbound volume of the commodity *liquid refined petroleum products* is shipped from here. The remaining volume of 90% is transported by road transportation, with liquid bulk goods as carrier type.

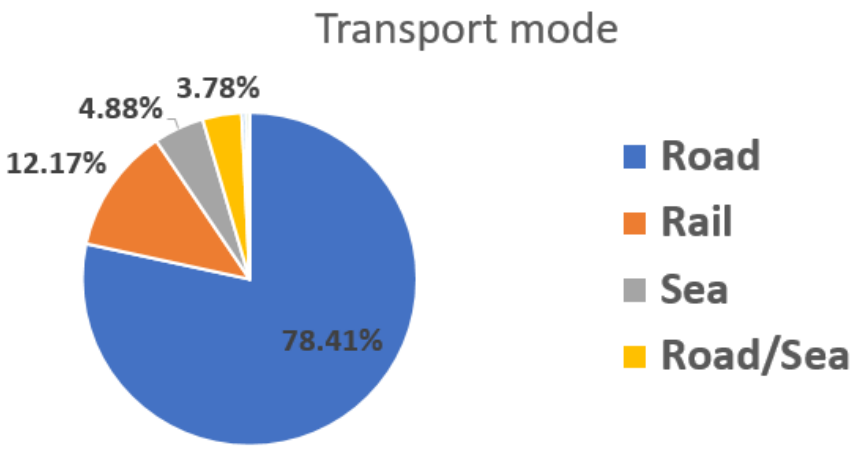

Figure 4.38. Distribution of the transport modes used

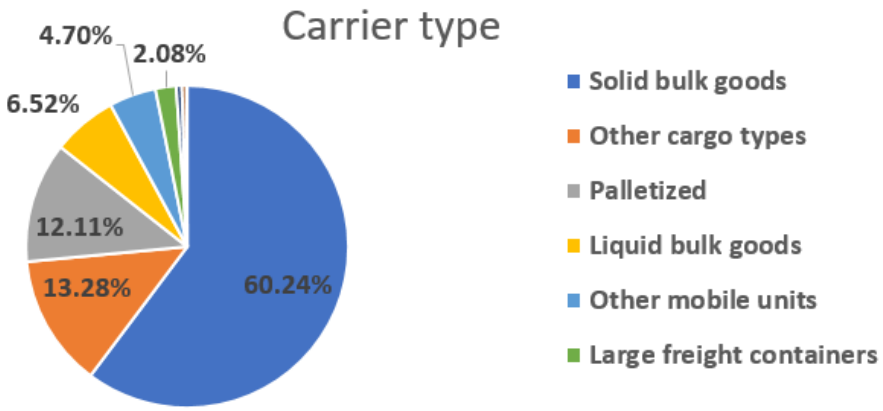

Figure 4.39. Distribution of the different carrier types

4.7.2 Outbound goods flow

The total outbound domestic goods flows accounts for around 8.75 million tonnes, where Karlstad and Grums together stands for the largest shares (30%). The goods flow is divided between outbound domestic and export with respectively 6.1 million tonnes and 2.65 million tonnes each.

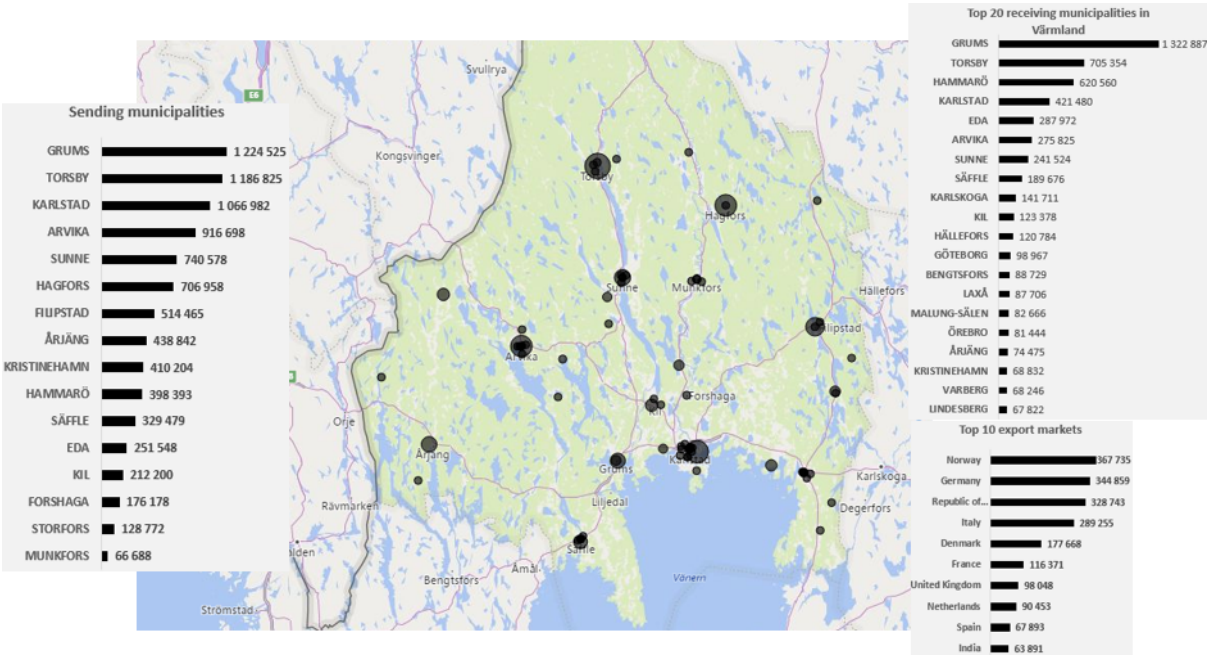

Figure 4.40. Map visualisation of where goods originates from in Värmland

The production of goods in this region are more evenly distributed between the municipalities, see figure 4.40. More than half of the volume produced are allocated to the goods type *products from agriculture, forestry and fishing* (52%).

Looking at the destinations of where the domestic goods flow from Värmland are consumed, large volumes are located in Värmland (50%), Örebro (9%), Västra Götaland (8%) and Dalarna (3%). A detailed overview of the receiving municipalities is visualised in the figure 4.40, where the top 20 destinations accounts for 59% of the total outbound volume.

The top 10 export markets accounts for 73% of the total exported goods flow from the region. *Paper and pulp* together with *wood and products from wood and cork* corresponds to the goods types that are in majority of the export flows (i.e. accounts for 80%**).** The goods are transported in large freight containers or as palletized goods, mainly used with the transport modes road or road and sea in combination. Swedish goods are exported to destinations within 83 countries.

4.7.2.1 Industries

Despite from the wood and paper industry (61%), which are significant for this county, the remaining volumes are divided between agriculture, forestry and fishing (6%), retail (4%) and

manufacturing of metal goods, machinery and transport (4%) and public and private services (3%), see figure 4.41.

The deforestation within the wood and paper industry is performed in all parts of the county, but larger volumes are identified in the northern parts of Värmland, in Sunne, Torsby, Arvika and Hagfors. Close to 15% of this volume are exported, mainly to China, the rest are transported to Grums, Hammarö and Torsby where the largest production facilities are located.

The industry defined as other only sends goods as export flows, more precisely the commodities *paper, cardboard* and *sawed, planed wood products*. These goods are transported by road or in combination with sea, with destinations in Norway, Italy and Germany. The commonly used carrier types are palletized or large freight container.

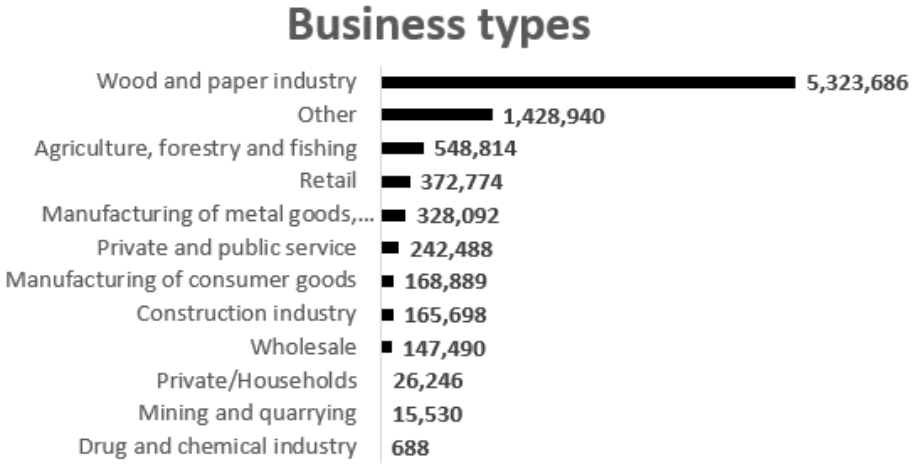

Figure 4.41. The industries and their produced volume

4.7.2.2 Goods types and commodities

Due to the specific characteristics of this county, the top three goods types relating to the wood and paper industry stands for the largest volume (85%), see figure 4.42. These goods types are not assigned as export flow, 70% of the consumption are instead performed within Sweden, where over 50% of the volume remains in Värmland. Notable to mention, nearly 70% of the volume are both produced and consumed within Värmland. The goods flow are provided by road as main transport mode (80%), where *roundwood* stands for approximately half of the goods volume. Other identified commodities are *paper, cardboard* and *sawed, planed wood products*. The top 10 commodities produced in Värmland stands for 91% of the total goods flow, see figure 4.43.

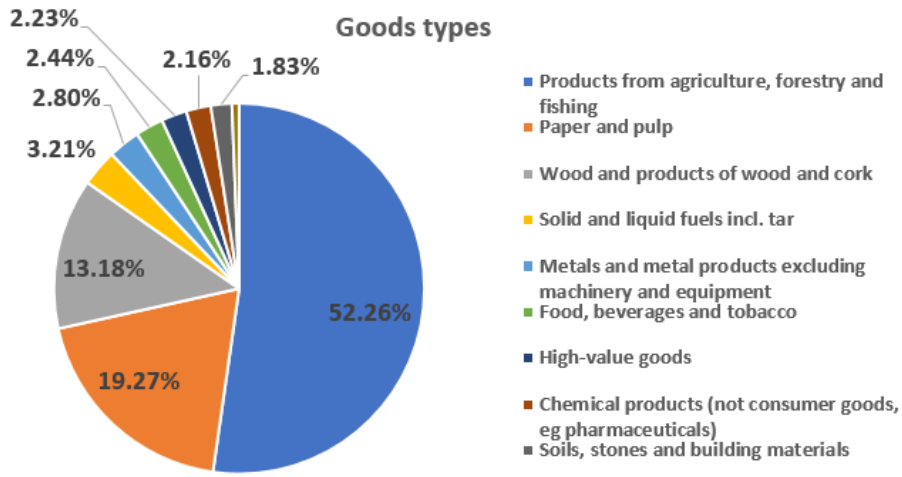

Figure 4.42. Distribution of the goods types produced

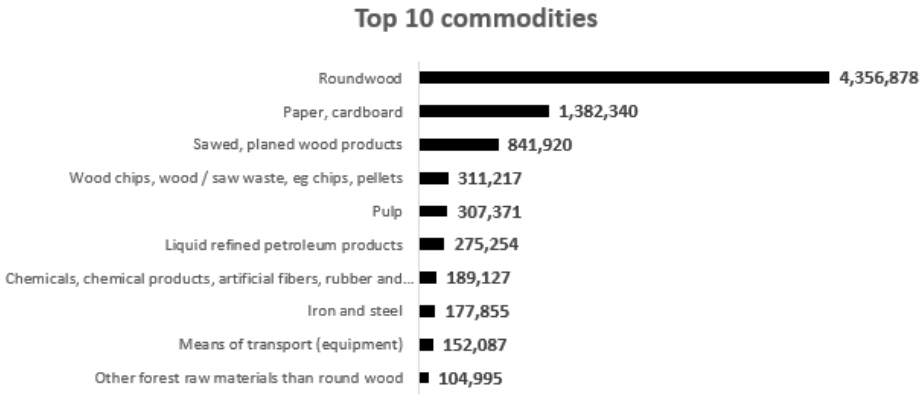

Figure 4.43. Top 10 commodities with largest volume

4.7.2.3 Transport modes and carrier types

Road are transporting the majority of the outbound goods volume, using mostly the carrier types solid bulk goods (72%) and palletized (11%), which is presented in the figures 4.44 and 4.45. The common destinations are within or in the surrounding counties, where 64% corresponds to locations within Värmland. In the municipalities Torsby, Hagfors and Arvika the largest volumes of the commodity roundwood are produced.

The intermodal transport with road and sea are only assigned to the export flow, including goods types from *paper and pulp* and *wood and products of wood and cork* with common destinations in Italy, Great Britain and Republic of China. The largest share of the goods are originating from Grums and Arvika and transported in large freight containers or as palletized.

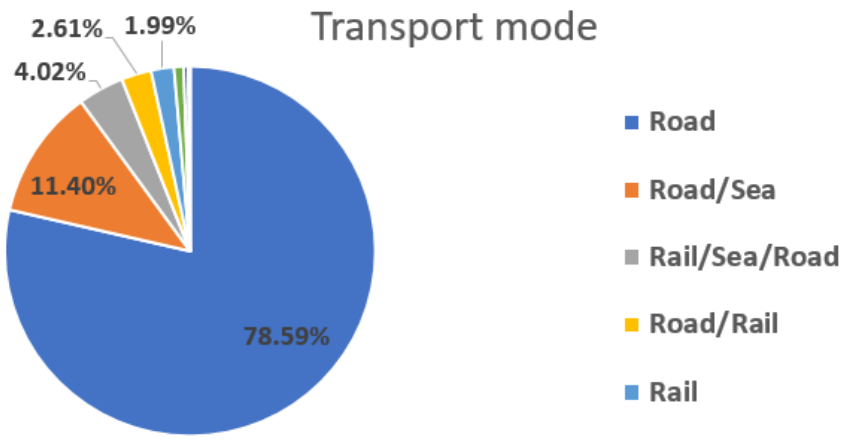

Figure 4.44. Distribution of the transport mode with largest volume

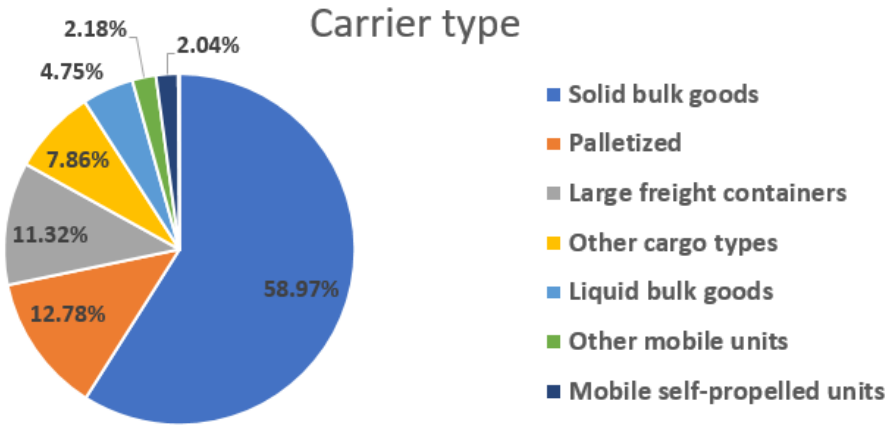

Figure 4.45. Distribution of the carrier types loading the goods volume

4.8 Örebro goods flows

The total goods volume in Örebro county stands for the smallest share of the selected counties in this report, approximately summarized to 14.5 million tonnes. In Örebro, most of the volume are either transported as domestic inbound or outbound flows in comparison to the foreign trade flows, which accounts for smaller shares, this is visualised in figure 4.46.

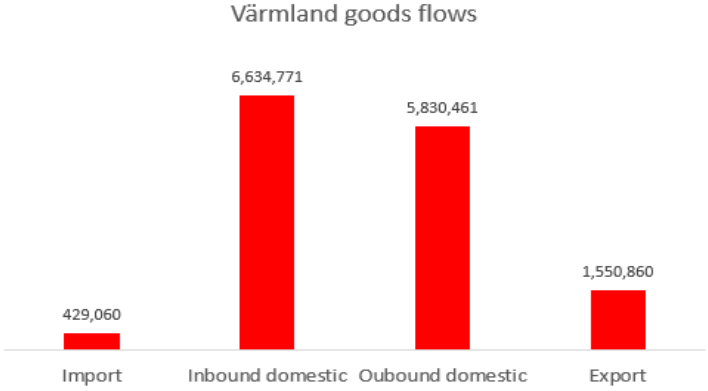

Figure 4.46. Distribution of inbound and outbound goods flows

4.8.1 Inbound goods flow

The inbound goods flow consist of both the import and inbound domestic transports with a total volume to nearly 7.1 million tonnes. Similarities exist in the goods flow between Värmland, with specific characteristics identified within the wood and paper industry (51%) where the typical transport mode is road transports (91%).

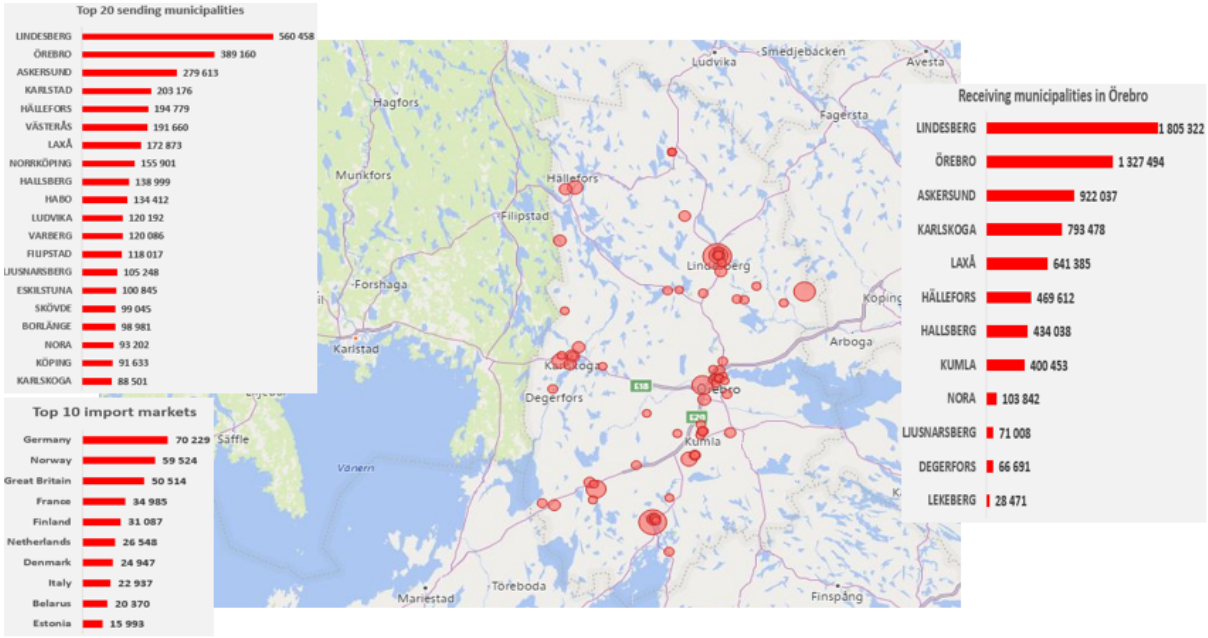

Figure 4.47. Map visualisation of the destinations of inbound goods flow in Örebro

In Örebro county there exist fewer destinations due to the relatively smaller area in combination with less producing and consuming actors, i.e. 12 municipalities in total. A clustered area with large share of the volume are identified in Örebro, Lindesberg, Askersund and Karlskoga as visualised in figure 4.47.

Figure 4.47 illustrates the top 20 municipalities of where most of the volumes transported to Örebro county originates from. These origins account for 52% of the total volume and are mainly located in other domestic municipalities or within the county, which are equivalent to the remaining goods flows as well.

The imported goods flows are mainly from European countries as can be seen in the figure 4.47, which stands for 83% of the exported volume. From Germany, large volumes are transported with road and sea, i.e. intermodal transport, with destinations in the top four municipalities as presented in the figure 4.47. The goods volume is mainly representing the commodities *iron and steel* and *means of transport (equipment)*.

4.8.1.1 Business type

For the inbound flows to Örebro county, the industries sending the goods are presented in figure 4.48 below. Goods flows are originating from surrounding counties, with majority of

the volume produced in Örebro or from the southern parts of Sweden, i.e. Gothenburg, Halland and Skåne.

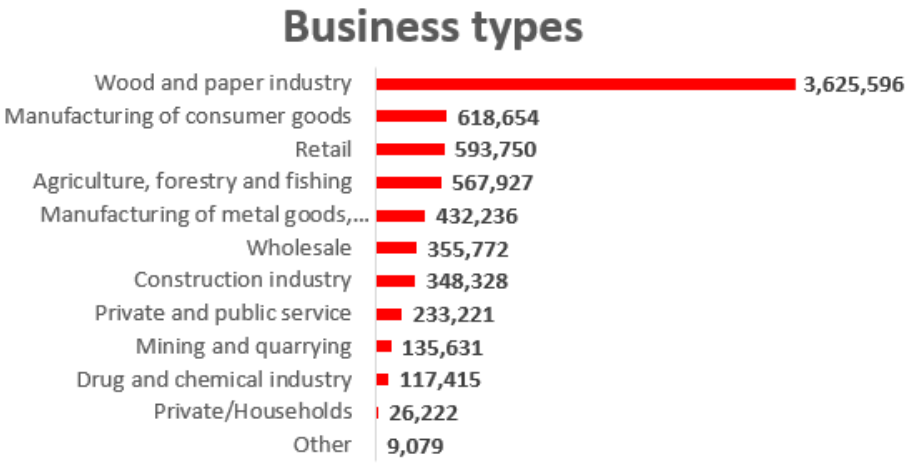

Figure 4.48. Business types of inbound goods flow

Within the manufacturing of consumer goods, the flows are mostly represented by the goods types, *food, beverages and tobacco* and *high-value goods*. The largest shares are imported from Germany and Estonia. Largest share of the volume within retail consist of the goods types *food, beverages and tobacco* and *solid and liquid fuels incl. tar*. Notable to mention are that these goods flows originates from locations within Sweden, where Värmland stands for a share of 18%.

The wood and paper industry is supplying businesses located in Lindesberg, Askersund, Karlskoga and Laxå. The transports are almost only performed by the modes road (95%) and with rail (4%). The large volumes consumed are dedicated to the commodities such as *roundwood*, *pulp* and *paper, cardboard*.

4.8.1.2 Goods type and commodities

Road transportation is providing goods flows of *products from agriculture, forestry and fishing* with destinations almost entirely in Lindesberg, transported as solid bulk goods.

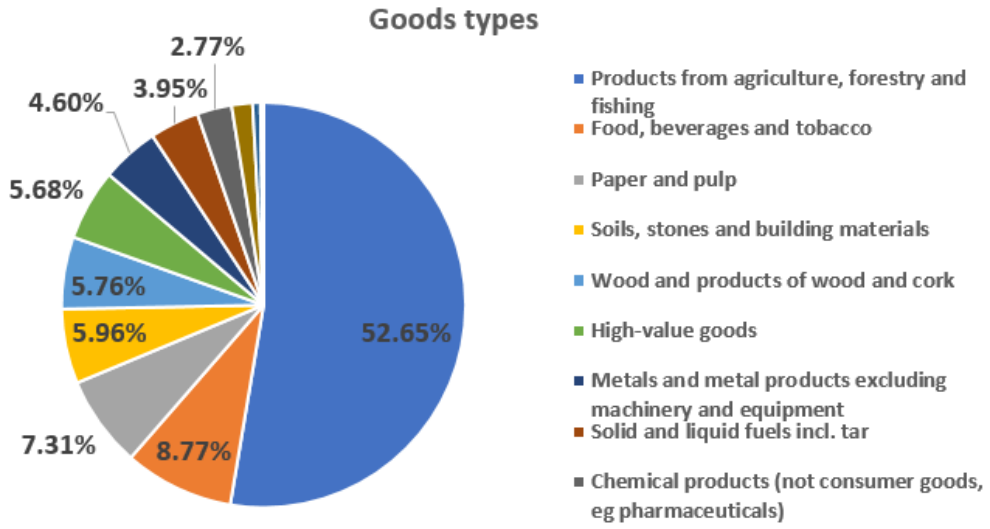

Figure 4.49. Distribution of goods types received

Looking into *food, beverages and tobacco*, consumed volumes are identified in Örebro, Kumla, Hallsberg and Karlskoga. These domestic goods flow includes the commodities *other foods and tobacco products* and *dairy products, drinks and ice cream*. Close to 4% of the inbound goods volume are assigned as import, with large shares originating from Finland, France and Germany. The commodities included in the import flows with largest share are within *meat, meat products, raw hides and skins* and *other foods and tobacco products*. The top 10 commodities in figure 4.50 accounts for 79% of the total goods volume.

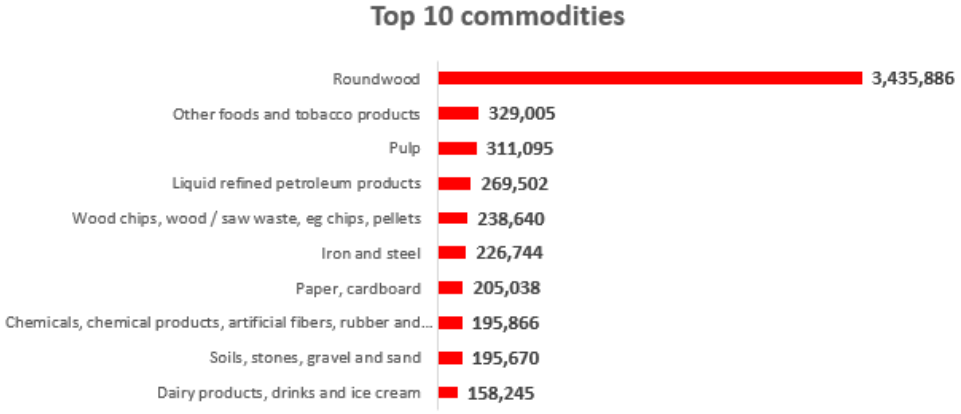

Figure 4.50. Top 10 commodities received (consumed volume)

4.8.1.3 Transport mode and carrier type

As seen in figure 4.51, road as transport mode stands for the largest share of the volume. Commodities such *roundwood* and *soils, stones, gravel and sand* are transported as solid bulk goods (see figure 4.52), with origins completely in Sweden.

Looking further into the goods transported by rail, this flow consist of large volumes related to industries operating within wood and paper (41%) and manufacturing of consumer goods (26%). The industries are located in Örebro (42%) and Lindesberg (41%), with largest volume

allocated to origins in Varberg and as import goods flow (i.e. Germany, Norway and the Netherlands)

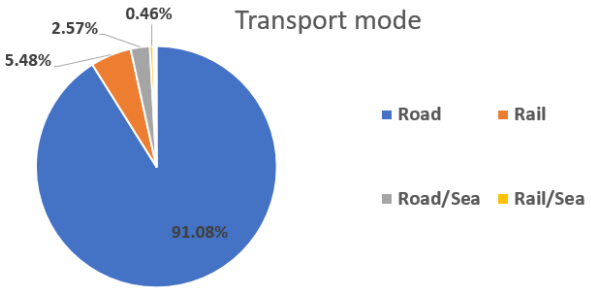

Figure 4.51. Distribution of the transport modes

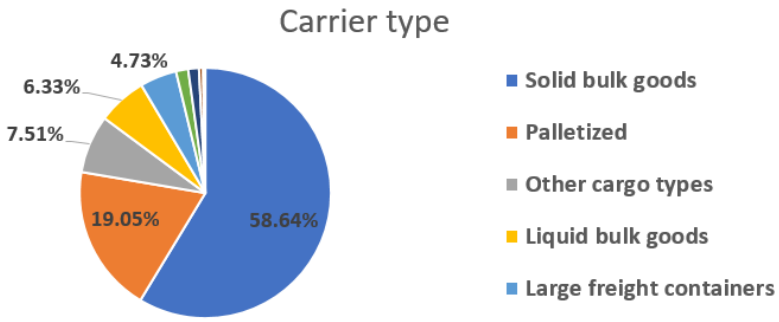

Figure 4.52. Distribution of the different carrier types

4.8.2 Outbound goods flow

The total produced goods volume in Örebro county are approximately 7.4 million tonnes, where exported volume accounts for around 21%. The largest volumes are produced in Örebro (19%) Lindesberg (18%) and Askersund (16%) and operating in industries within wood and paper (46%), wholesale (9%) and manufacturing of consumer goods (9%).

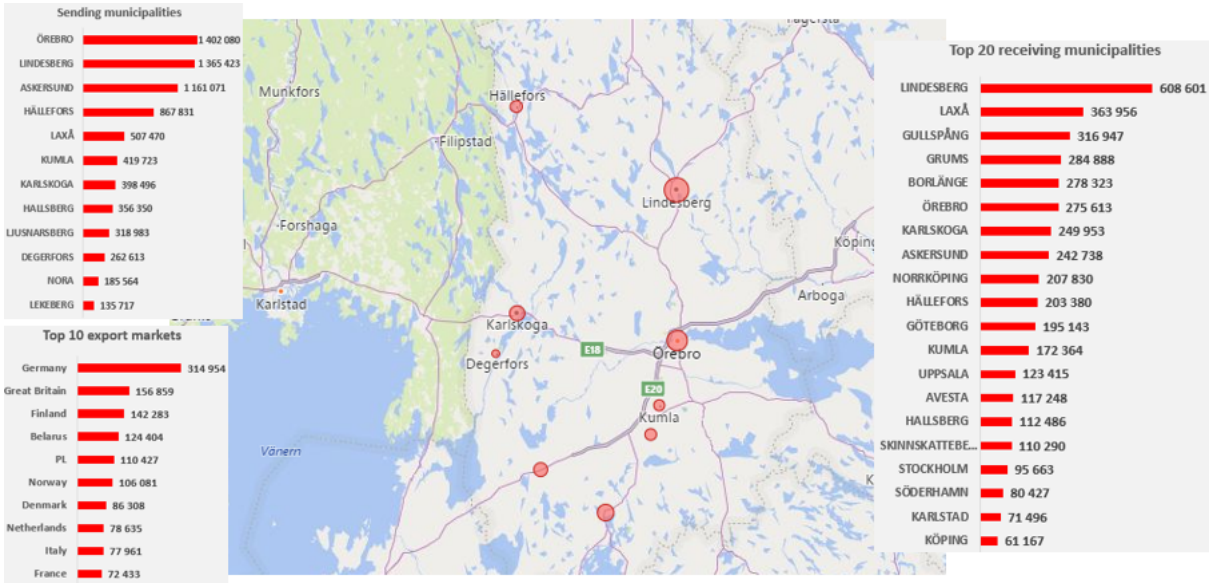

Figure 4.53. Map visualisation of the origins where goods are produced

In the figure 4.53, a visualisation over the 12 different locations where goods are produced within the county. The production are more evenly distributed in this county with larger volumes of the commodities *roundwood* and *other ore than iron ore*.

The goods that are produced in Örebro county are further transported as either domestic or export goods flows. The domestic goods are transported to 288 different locations within the Swedish borders, the top 20 receiving municipalities stands for 72% of the total domestic volume (56% of total outbound flows). The commodities with large volumes, consumed by the top 20 receiving municipalities are *roundwood* (54%), *other foods and tobacco products* (8%), *other ore than iron ore* (6%) and *pulp* (5%).

The top 10 export markets stands for 82% of the exported volume, where most of the volume origins from Lindesberg and Askersund. Exported goods have destinations in 53 different countries.
From Lindesberg, the goods types paper and pulp and ore and other products from extraction (not *soil, stone, gravel and sand* and *peat*), with main destinations in Poland, Denmark and Germany. In Askersund, mining and quarrying are main industry which exports to countries such as Germany, Finland and Belarus.

4.8.2.1 Business type

In the figure 4.54, the distribution of the producing business type in Örebro county are visualised. Close to 60% of the volume within the wood and paper industry are produced in Lindesberg, Hällefors and Laxå. From Hällefors and Lindesberg, large volumes of goods are transported by rail to Grums and Borlänge (i.e. domestic flows). The export flow by rail consist of destinations mainly in Denmark and Germany. Laxå are completely transporting domestic goods by road, where half of the volume are consumed in Laxå, Karlskoga, Gislaved and Älvkarleby.

Within the retail business, all the goods flows are transported by road as transport mode. The goods type identified with the largest shares of the volume are *food, beverages and tobacco* (40%) and *high-value goods* (34%). Örebro accounts for the largest produced volume, accompanied with Kumla and Ljusnarsberg with smaller shares. The recipients are located in Örebro, Västra Götaland and Stockholm county.

Goods within manufacturing of consumer goods industry originates especially from Örebro and Askersund, where the distribution of the volume are spread out on several municipalities, with destinations within Östergötland, Örebro, Västra Götaland and Stockholm county.

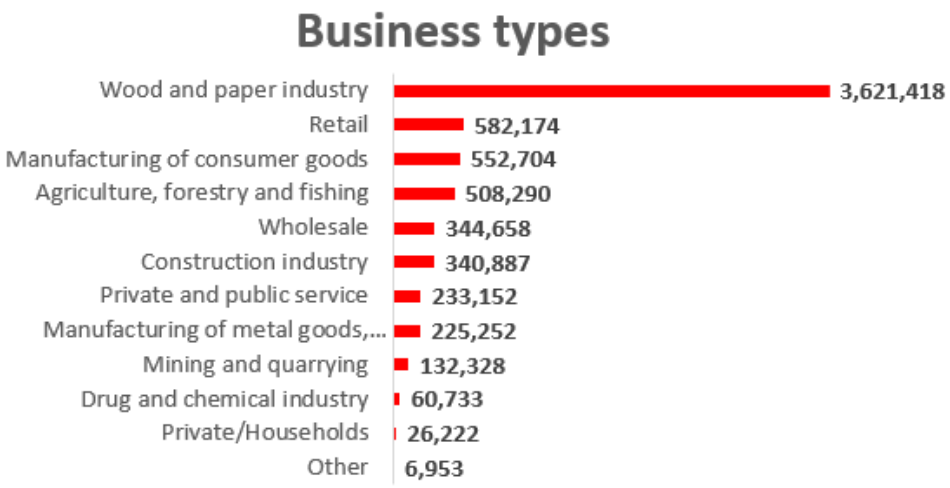

Figure 4.54. Distribution of the producing industries

4.8.2.2 Goods type and commodities

The top 10 commodities stands for 81% of the total produced volume within the county, see figure 4.56. These commodities represent the goods types *products from agriculture, forestry and fishing*, and smaller shares of the volume are divided between *paper and pulp* and *food, beverages and tobacco*, which are presented in figure 4.55

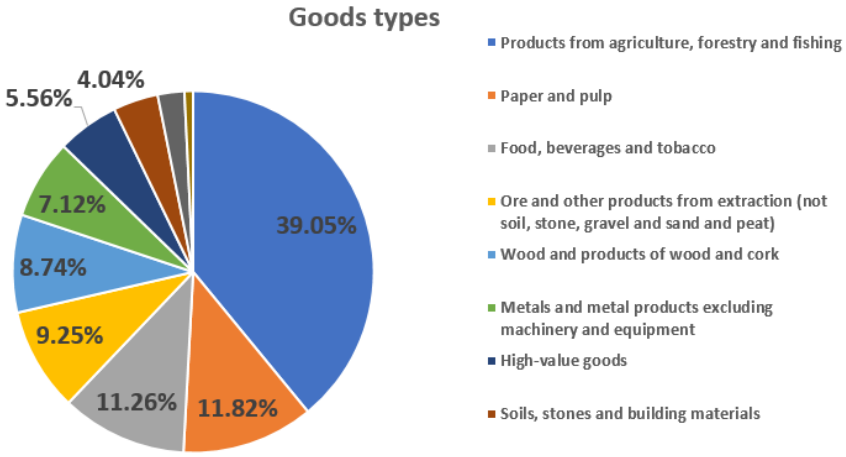

Figure 4.55. Distribution of the produced goods types

Looking into the domestic flows, a large share of the transported volumes are within wood and paper industry, where roundwood are produced in largest volumes. In comparison with the export flow, which instead consist of large producing volumes divided between the commodities *paper, cardboard, other ore than iron ore, iron and steel* and *dairy products, drinks and ice cream*.

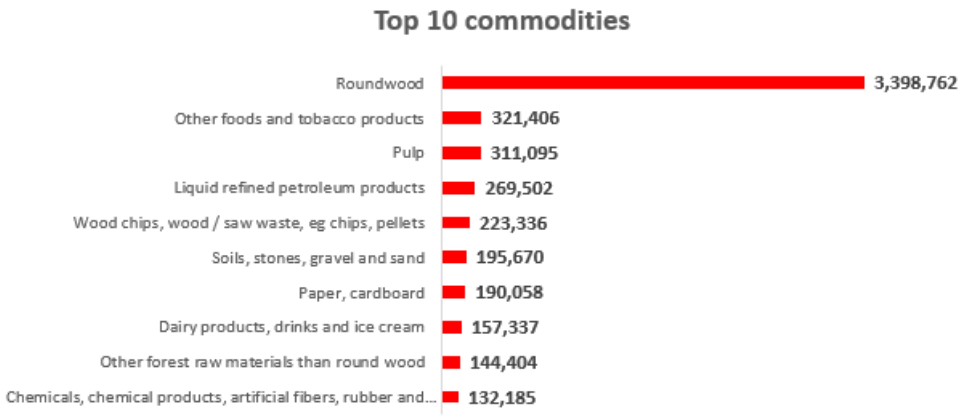

Figure 4.56. Top 10 commodities produced with largest volume

4.8.2.3 Transport mode and carrier type

The dominant transport mode in the outbound flows are road, with 92% of the volume transported as domestic flows, which could be seen in figure 4.57. The municipalities with the largest transported volumes in the domestic flows are Örebro, Askersund and Lindesberg. These goods flow are transported as solid bulk goods and palletized goods, with largest recipients in the counties Örebro (42%), Västra Götaland (14%), Östergötland (7%) and Västmanland (6%).

The large share of the export flows are transported as palletized or other cargo types. The majority of the palletized goods types are *paper and pulp* and *metals and metal products excluding machinery and equipment*. Looking into the commodities for other goods types, *iron and steel* and *pulp* are identified as the commodities accounting for the largest volume.

Rail transports are providing goods flows between Hällefors and Lindesberg to Grums and Borlänge. From Lindesberg, *paper and cardboard* are exporting large volumes to Denmark, Germany, Italy and the Netherlands, total exported volume stands for 27% of the volume with rail as transport mode. In the figure 4.58, the distribution of total volume between the different carrier types, solid bulk goods are transporting large volumes of *roundwood* and palletized goods are evenly distributed between *other food and tobacco products, paper, cardboard* and *sawed, planed wood products*. Both these commodities currently using road as transport mode.

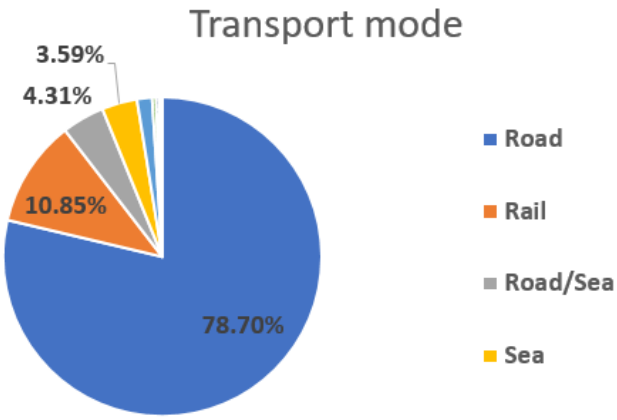

Figure 4.57. Distribution of the transport modes share of the volume

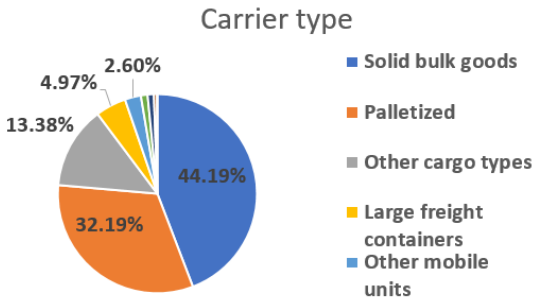

Figure 4.58. Distribution of the carrier types transporting goods

4.9 County summaries

The following sections will present summaries for the respective counties. Here, data from the counties is compiled with the intend to highlight the most significant factors that are synonymous for respective county are mentioned. This in order for the reader to grasp the most important content of the large amount of data presented.

4.9.1 Västra Götaland county

Västra Götaland is the biggest contributor to volumes in this study, both for inbound- and outbound flows. It is the biggest county by size with Gothenburg city as the second biggest city in Sweden, meaning that many industries and companies are located here. The proximity to one of Scandinavia's largest ports is one of the reasons for this being a strategic location for industries to have production facilities in.

A large share of the import flows are shipped to Gothenburg and Lysekil because of the ports located here. The same applies for outbound flows where the largest shares are sent from here. As the goods flow mapping show, significant shares of the volume can be identified for the mining and quarrying-, manufacturing of consumer goods-, wood and paper-, and the construction industry which relates to the commodities transported to this area. “Crude oil”, “liquid refined petroleum products”, “soils, stones gravel and sand” and “roundwood” account for large shares in the same way as the industries.

Looking at the transport modes carrying the goods, a majority is transported by sea which are shipped from the ports. Road transportation also accounts for a large share, where the interviewed goods owners have explained that goods are transported by road to terminals and warehouses for value-adding activities, stuffing of containers and transhipment for further transportation. Rail transportation is also used in the same way but for much smaller volumes. Gothenburg is also identified as the biggest contributor for the domestic flows which implies that it constitutes a node where these terminals and warehouses most often are located.

4.9.2 Värmland county

Värmland is synonymous with the wood and paper industry where all of the top contributors in the different factors are related to this industry. Significant shares of destinations can be found in municipalities where companies have their production facilities. Looking at the commodities transported, roundwood clearly constitutes the largest share. This because of the deforestation taking place within the county where companies source the raw materials, in this case roundwood, locally. The roundwood that originates from the county is transported by road due to the available infrastructure where there is no other viable option.

Both Karlstad and Kristinehamn have ports connecting to lake Vänern where goods are transported. The interviewed goods owners explained that the goods transported on lake Vänern are solely export flows with destinations such as Great Britain, which also is confirmed by the shipping company. Reasons for not using IWT for domestic transportation are mostly answered by the respondents with economical and suitability reasons. Road transports are favourable in several dimensions, hence the large share of road transportation identified.

4.9.3 Örebro county

Örebro act as the smallest county investigated in this report, both by volume and size (12 municipalities). There exists a balance within the domestic flows to and from the county, but looking at the foreign trade, import flows are significant lower than the exported volume from this county.

The destinations of the inbound volume stretch from Laxå in south to Hällefors in north (101 km), which implies that the actors/industries are located in and around urban populated municipalities within a relatively small area in the county. Outbound goods flows also represent wood and paper industry, where the origins is mainly located in Örebro, Lindesberg and Askersund.

The typical commodity, transported as domestic goods is roundwood, except from this, the volume is distributed evenly with goods types such as other foods and tobacco products, pulp and liquid refined petroleum products to mention some of them. The railway system

connecting goods flows from the deforestation in Hällefors and Lindesberg, to destinations to Grums and Borlänge. Otherwise, only road transportation is utilized in all the remaining goods flows. The export flows consist of the commodities, paper, cardboard, other ore than iron ore, iron and steel and dairy products, drinks and ice cream.

4.10 Goods flow mapping for IWT suitable goods

This section intends to describe the specific characteristics in the goods flows generated from each of the selected counties, with respect to IWT feasibility. By identifying and thoroughly analyse these goods flows, the potentials could be summarized in order to present the inbound and outbound flows between the three counties. The findings in this section will be used to answer the first research question.

4.10.1 Translation of goods volumes into number of shipments

In order to present the potential of this goods flows, it needs to be translated into number of transports. By looking at each of the six flows, an average road transportation weight could be determined. The data reveals that the average weight per shipment for road transportation with this data selection is approximately 30 tonnes. This also corresponds to the approximation made for a presentation regarding “Citylogistik med pråm” made for Vänertinget 2019, where 300.000 tonnes yearly would replace 10.000 road transports – equivalent to 30 tonnes per shipment. This is used as a benchmark to quantify the potential for IWT.

4.10.2 IWT suitable goods

By matching the statistics of the distribution between commodities handled in the ports of Vänern and the main type of goods transported on IWT presented by Eurostat (2018) with the commodity codes included in the secondary data, 26 different commodities were identified. This selection of commodities is then further examined to understand how goods with fitting characteristics for IWT is transported in the area around the focus area. This is intended to provide insight and answers to research question 1 from an IWT perspective.

The following commodities were identified, see table 4.1. This data selection provides 75% of the total goods volume, where distribution is 53% domestic flows and 47% import/export flows. These are further examined for the respective counties in different directions in order to better understand the flows.

Identified commodities for IWT		
• Glass and glassware, porcelain and ceramic products	• Grain	• Processed rubber and plastic products
• Solid refined petroleum products	• Roundwood	• Other forest raw materials than round wood

• Liquid refined petroleum products	• Crude oil	• Solid refined petroleum products
• Soils, stones, gravel and sand	• Peat	• Meat, meat products, raw hides and skins
• Chemical and mineral (natural) fertilizers and salt	• Potato	• Other wood products
• Sawed, planed wood products	• Iron ore	• Coal products, e.g. coke, coke briquettes
• Chemicals and chemical products	• Other ore than iron ore	• Wood chips, wood / saw waste, e.g chips, pellets
• Non-ferrous metals and their products	• Iron and steel	• Dairy products, drinks and ice cream
• Prepared sustainability-treated fish and prepared fishery products	• Other foods and tobacco products	

Table 4.1. Identified commodities suitable for IWT

4.10.3 Inbound- and outbound flows to the counties

To compare the flows of these commodities with origins in the counties, Västra Götaland, Värmland and Örebro are set as senders in the data selection. This provides the allocation Västra Götaland (66%), Värmland (18%) and Örebro (16%) with a total volume of approximately 31 million tonnes. This represents the total outbound flows of the selected commodities from the counties with destinations in all of Sweden. When the counties instead are set as receivers, flows with destinations in the counties are summarized to 28 million tonnes where the allocation then becomes Västra Götaland (57%), Värmland (23%) and Örebro (20%). This represents the total inbound flows of the selected commodities with origins in all of Sweden.

4.10.4 Flows between the counties

By looking at how these commodities are transported between the counties, see figure 4.59, the following is identified. Disregarding the flows to other Swedish counties and only looking at the flows between the three counties provides a total volume of approximately 20.5 million tonnes. This data selection shows that 87% of the shipments with origins in Västra Götaland have destinations within the county, 7% are shipped to Värmland, and 6% to Örebro. In Värmland, 84% stays within the county, 10% have destinations in Örebro and 6% in Västra Götaland. Örebro sends 63% of the volume within the county, 23% to Västra Götaland and 14% to Värmland. The tonnage is presented in figure 4.59. The respective shares are further examined in the following sections. As domestic transportation within the counties means that the route never crosses the IWT area, these volumes are not investigated as a potential for an increased usage of IWT. A prerequisite for potential to be identified, is that current goods flows must have a route crossing, or travelling along the waterways.

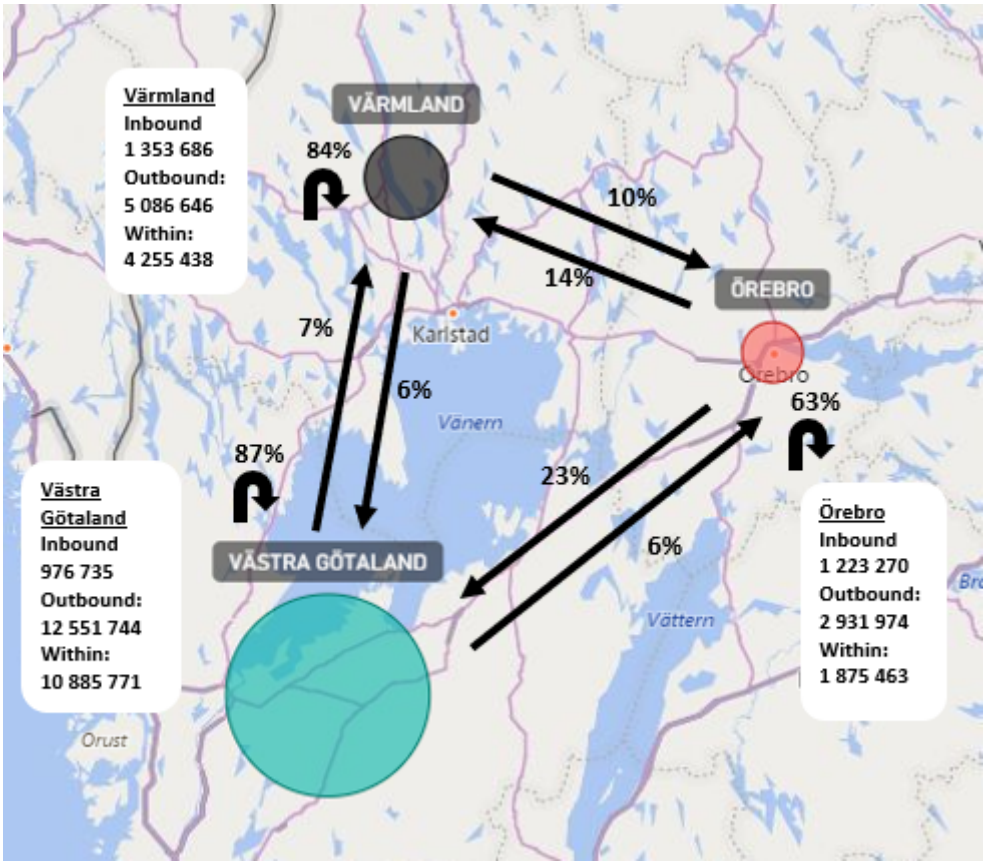

Figure 4.59. Visualisation of the goods flows between the counties

4.10.4.1 Västra Götaland → Värmland (904.000 tonnes)

This goods flow represents approximately 30.100 shipments carried out by road transportation yearly. 80 shipments carried by of rail transportation is also identified here.

70% of the flow consists of *roundwood*, carried by 20.800 shipments where all of the 80 rail transports identified is transported from Falköping to Grums. The road transports originate from the west side of the lake, stretching from Munkedal to Bengtsfors, supplying mainly Grums, Karlstad, Årjäng and Säffle. Looking beyond the roundwood, into the remaining 30%, *liquid refined petroleum products* represent the largest share (103.000 tonnes). This flow originates from Gothenburg and Uddevalla and consist of 3.400 road shipments, with 75% of the destinations located in Karlstad, Kristinehamn and Grums. Arvika is also identified as a common destination (8%). *Other foods and tobacco products (64.000 tonnes)* is transported from Kungälv, Gothenburg and Partille with 2.100 road shipments, where half of the volume is transported to Karlstad and Kristinehamn. These three commodities represent 87% of the flow whereas the remaining 13% are spread out into smaller shares of different commodities.

4.10.4.2 Västra Götaland → Örebro (721.000 tonnes)

This goods flow represents approximately 24.000 shipments carried out by road transportation yearly. No rail transportation is identified. Again, *roundwood* clearly

represents the largest volumes (73%) but the origins are instead found on the east side of the lake. The second and third largest volumes of commodities are *other foods and tobacco products* (38.500 tonnes), transported from Götene and Gothenburg to mainly Örebro and smaller shares to Hallsberg, and *processed rubber and plastic products* (37.600 tonnes) where flows from Tranemo to Hallsberg and Örebro also are identified.

4.10.4.3 Värmland → Västra Götaland (364.000 tonnes)

This goods flow represents approximately 11.100 shipments carried out by road transportation yearly. Additionally, rail transportation represents 30.000 tonnes. *Roundwood* represent 42% where several flows can be identified between several origins and destinations.

The remaining 58% consist of 73.000 tonnes *sawed, planed wood products* – approximately 2.400 road shipments. Åmål receives half of this volume where the distance is very short and not feasible for IWT. Between Karlstad and Gothenburg flows of this commodity is also identified (13.500 tonnes), representing 450 road shipments.

The third largest volume consist of *grain* (23.500 tonnes), equivalent to 785 road shipments. These flows originate from Säffle, Karlstad and Kristinehamn with destinations mainly in Lidköping, Götene, Uddevalla and Trollhättan.

Grouping the commodities *chemicals and chemical products, other foods and tobacco products* and *iron and steel (49.000 tonnes)* where 96% originates from Arvika, Kristinehamn, Karlstad and Torsby and is transported to destinations with proximity to ports, e.g. Gullspång, Lidköping and Gothenburg.

4.10.4.4 Värmland → Örebro (531.000 tonnes)

This flow has no direct potential for a modal shift to IWT, since the routes does not cross or travel across the waterways. However, it provides information connected the first research questions and therefore is accounted for. This goods flow represents approximately 17.700 shipments carried out by road transportation yearly. No rail transportation is identified.

Roundwood represents 60% of this, 320.000 tonnes and 10.600 shipments. 21% represents *liquid refined petroleum products* transported from Karlstad. Further, the following commodities are identified; 29.500 tonnes of pulp (6%), 19.000 tonnes of *sawed, planed wood products (4%)* and 14.500 tonnes of *dairy products, drinks and ice cream (3%)* transported from Värmland county to Örebro county.

4.10.4.5 Örebro → Västra Götaland (628.000 tonnes)

This goods flow represents approximately 20.900 shipments carried out by road transportation yearly. No rail transportation is identified. The share of *roundwood* is clearly smaller for this flow, only 9%. Instead, *other ore than iron ore* represents the largest volumes, 251.000 tonnes transported from Askersund to Gullspång, equivalent to 8.400 shipments. The second largest volumes are found within *sawed, planed wood products* (100.000 tonnes) where 80% of the volume is transported from Karlskoga to Gothenburg. 81% of the volume sent from Örebro is consumed in the following municipalities, Gullspång (49%), Gothenburg (19%), Skövde (7%), Tranemo (3%) and Götene (3%). 86% if the flow originates from Askersund (53%), Karlskoga (16%), Laxå (9%) and Örebro (8%).

4.10.4.6 Örebro → Värmland (409.000 tonnes)

Just as for the opposite direction, i.e. Värmland → Örebro, this goods flow has no direct potential for a modal shift to IWT. The following can be presented shortly. This goods flow represents approximately 4.800 shipments carried out by road transportation yearly and rail transportation is identified transporting 265.500 tonnes.
82% represents *roundwood* transported mainly to Grums and Karlstad, equivalent to 300.000 tonnes. *Iron and steel, peat, other foods and tobacco products* and *wood chips, wood/saw waste* together represent 13%.

4.10.5 Goods flows summary

This section will summarize the goods flows between the counties. The visualisation in figure 4.60, intends to provide assistance for the reader to easy comprehend the specific flows that are generated within these counties. In the table 4.2, the flows are summarized, based on the data selection presented in the previous section. The data shown in the table includes the specific flow, the distribution between commodities, transport mode and lastly the total identified volume suitable for IWT.

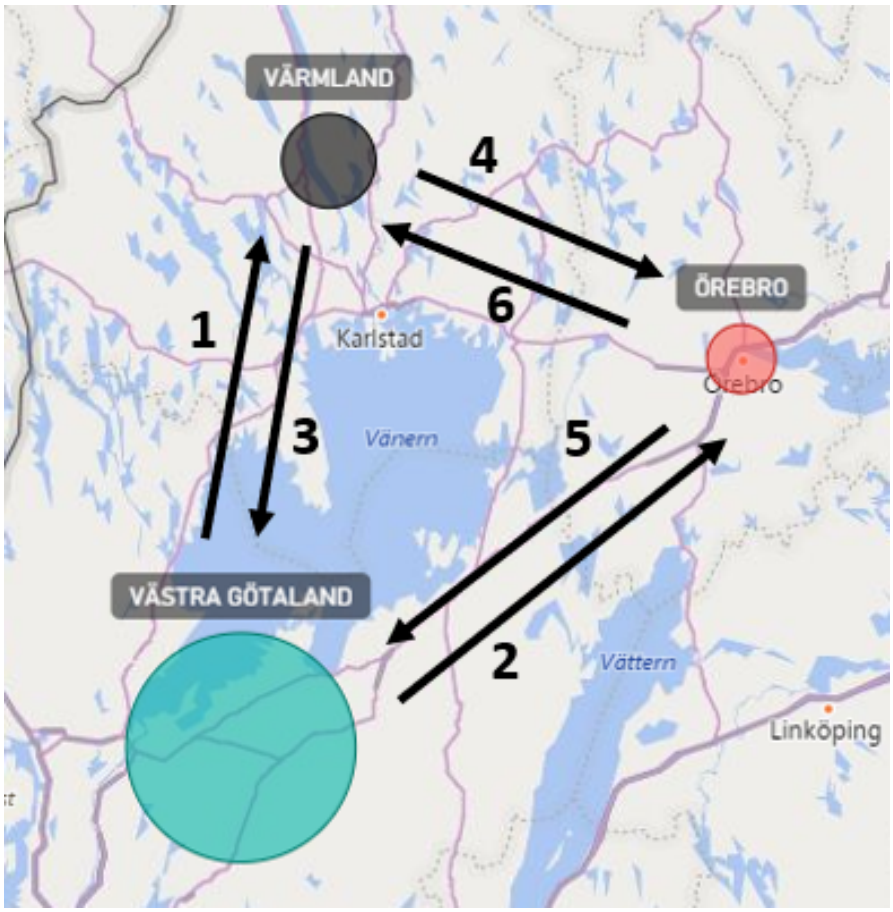

Figure 4.60. Existing goods flow between the counties (explained below)

Looking at the table 4.2 and comparing the transport modes, road transportation stands for around 90% of the total volume in all counties, whilst rail is only used in flow (1), (3) and (6) in small shares.

Large volumes of goods flows carrying *roundwood,* which exist in most flows, especially with origins in Västra Götaland (flow 1 & 2). This high volume creates imbalances in the flows, which is mostly the case of flow (1) and (3). In the remaining flows, the volumes are more even. The flows between (4) and (6) are connected by railway system, as seen in flow (6), but where only road transportation is used in flow (4).

Flow	Total tonnage	# of road shipments	Commodities	Top senders (≈80%)	Top receivers (≈80%)
1. Västra Götaland -> Värmland	904 000	30 100	Roundwood (70%) Liquid refined petroleum products (11%) Other foods and tobacco products (7%)	Bengtsfors, Gothenburg, Falköping, Åmål, Kungälv, Dals-Ed, Färgelanda, Munkedal, Mellerud, Tanum, Stenungsund, Ale, Uddevalla	Grums, Karlstad, Årjäng, Säffle

2. Västra Götaland -> Örebro	**721 000**	**24 000**	**Roundwood (73%) Other foods and tobacco products (5%) Processed rubber and plastic products (5%)**	**Tranemo, Gullspång, Karlsborg, Töreboda, Götene, Ulricehamn, Mariestad, Skövde, Falköping, Tidaholm, Lidköping, Vara, Herrljunga, Skara, Hjo**	**Askersund, Karlskoga, Hallsberg, Örebro**
3. Värmland -> Västra Götaland	**364 000**	**11 100**	**Roundwood (42%) Sawed, planed wood products (24%) Grain (6%) chemicals and chemical products, other foods and tobacco products & iron and steel (13%)**	**Årjäng, Karlstad, Säffle, Sunne, Torsby, Kristinehamn,**	**Bengtsfors, Gothenburg, Gullspång, Åmål, Borås, Lidköping**
4. Värmland -> Örebro	**531 000**	**17 700**	**Roundwood (60%) Liquid refined petroleum products (21%) Pulp (6%) Sawed, planed wood products (4%) Dairy products, drinks and ice cream (3%)**	**Karlstad, Filipstad, Storfors, Kristinehamn**	**Karlskoga, Hällefors, Laxå, Örebro**
5. Örebro -> Västra Götaland	**628 000**	**20 900**	**Other ore than iron ore (40%) Sawed, planed wood products (16%) Roundwood (9%)**	**Askersund, Karlskoga, Laxå, Örebro**	**Gullspång, Gothenburg, Skövde, Tranemo**
6. Örebro -> Värmland	**409 000**	**4 800**	**Roundwood (82%) Iron and steel, peat, other foods and tobacco products & wood chips, wood / saw waste (13%)**	**Hällefors, Örebro, Karlskoga**	**Grums, Karlstad, Kristinehamn**

Table 4.2. Table summarizing the goods flows between the counties

4.11 The total transport network

The comparative analysis of the existing flows identified as suitable for IWT, is based upon the three-layer model (Wandel et al. 1992). The intention of this model is to provide a detailed description of the goods flows, in order to fully comprehend the complexity within the flows. Jonsson & Mattson (2011) describes the importance of identifying how the transport system is utilized and find synergies which determines the performance of the current system.

4.11.1 Infrastructure

Looking on how the infrastructure is currently utilized will assist the description of the current nodes with goods flows. Lumsden (2006) advocates that by identifying the nodes of goods flows, the whole system could be mapped in order to identify important locations (e.g. ports, railways and roads) that enables different transport modes to connect the whole system. In the figure 4.60 below, the connections within the railway system and the ports (i.e. Gothenburg, Lysekil & Vänerhamn) are visualized. The road transport system is not visualized as the spatial coverage is extensive and the visualization intends to highlight the infrastructure of rail- and IWT transportation to promote intermodal transports.

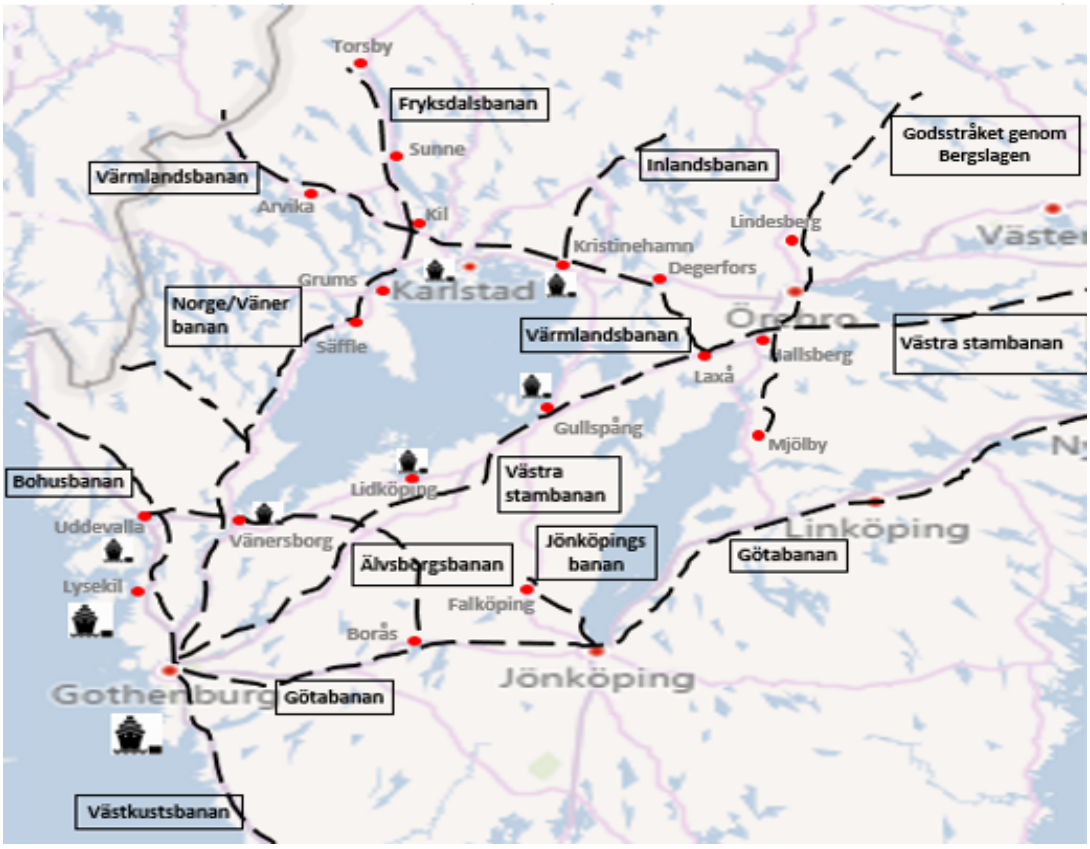

Figure 4.60. Map visualisation of how the infrastructure is connected

In Värmland, the physiography is synonymous with large areas of forest and sparsely located municipalities. The railway system offers connectivity to other counties, which also is the case within the county. The connectivity provides intermodal transports with the ports and the road network, which indicates that there exist alternatives for road transportation.

Looking at the design of the road infrastructure in Västra Götaland, which is the largest area in the data selection with several locations of producing and consuming actors. This explains why road transportation represents large volumes in this county due to the accessibility to complement other modes. Looking at the railway system, there exist several connections with rail from Gothenburg, with Västra stambanan and Norge/Vänerbanan linking together three Vänerhamn ports.

Örebro constitute the county with the smallest area, with similarities to Värmland, almost all volume is concentrated to fewer municipalities in comparison to Västra Götaland where volume is concentrated around Gothenburg. The railway system connects to Vänerhamn ports in Värmland, and links together the largest municipalities within the county.

4.11.2 Transport flow

The transport flow is determined based upon what is offered by the infrastructure, i.e. the provided capacity and their connecting nodes. As presented in the goods flow mapping, road transportation is commonly used in all counties, especially in Västra Götaland and Värmland.

The wood and paper industry is synonymous with Värmland, with deforestation of *roundwood* performed in the northern parts (e.g. Torsby, Arvika, Hagfors & Sunne) and consumed in the southern parts (Grums, Karlstad & Hammarö). The railway system is in this case underutilized because of the dominance of road transportation, although there exist connections between sending and receiving municipalities.

Sea transportation enables large volumes to be transported over long distances, which is the actuality in Västra Götaland. The large imported volumes of *crude oil* and *liquid refined petroleum products* are received in the ports of Gothenburg and Lysekil, where the existing infrastructure facilitates intermodal shifts to road or rail in order to supply the inland markets. The supply to Värmland use sea transportation for 15% of this volume, whilst road transportation still stands for the remaining volume. In Örebro, the large volumes moved by rail transports to Värmland shows that there exist connections for transhipment in the port of Kristinehamn. However, road transportation stands for all goods flows to Västra Götaland.

4.11.3 Goods flow

This part identifies significant volumes and the related commodity that exist in the different counties. By evaluating the common commodities that creates the demand for transports, the type of transport mode most suitable within the transport market could then be easily decided to cope with the specific context. The identified goods flows in the case is considered to be compatible for container flows, with existing connections linking the infrastructure together to enhance the usage of IWT which proves the potential. This highlights the

importance of the geographical location which limits the alternatives of transport modes, and where often road transportation is the solution.

5. Case study - Container

This case is constructed in order to highlight the goods flow between the port of Gothenburg to the port in Kristinehamn. The findings provided will then be analysed by comparing the theoretical- and empirical findings to be able to answer research question 2.

5.1 Background

In 2014, when the Swedish government first implemented the NAIADES II package for inland waterway transport, the idea of initiating a container feeder between Port of Gothenburg and Kristinehamn emerged. In the report done by Seadvise, three reasons in favour for this are mentioned. Firstly, the passage is by far the longest inland waterway the exist in Sweden. Secondly, both inbound and outbound flows exist to support a container shuttle. Lastly, the port of Gothenburg is Scandinavia's largest container terminal with connections to foreign trade. Kristinehamn is a strategic location with good possibilities for a container terminal and depot in order to handle the transhipments effectively.

The main objective with this study is to identify potential for an increased usage of IWT in Sweden. As an IWT vessel with Vänermax is superior to the alternative transport modes in transporting large volumes, e.g. one ship corresponds to around 130 units of road transports or 100 cargo units of rail transports, the underutilized capacity in the fairways points at a big potential for IWT. This case is created in order to investigate the potential for containers transported with IWT. By analysing the secondary data and provide mappings of commodities judged as potentially suitable for container transportation, the potential is evaluated.

5.1.1 Translation of goods volumes into number of shipments

In order to present the potential of this goods flows, the presented weights need to be translated into number of road transports and additionally in this case, the number of containers. However, due to the different characteristics and the available information regarding the commodities this could not be distinguished in the available time frame of the project. Instead, the weights will be translated into number of road shipments as in the previous sections to point at the potential reduction of road transportation IWT could bring with 30 tonnes as an average weight per road transport.

5.2 Identifying suitable goods flow

In order to find the goods suitable for container transportation on inland waterways in Sweden, the secondary data is used. As the carrier type for the transports is included, the data selection based upon what commodities that are transported in containers has been made. The reasoning is that since there are container flows containing these identified commodities, the goods characteristics are then compatible with a containerisation. The tonnage presented in the figure represent all the volume transported in containers according to the data. This indicates how common it is for a commodity to be transported in containers. The numbers

presented in the following goods flow mappings represent the total volumes of the selected commodities, i.e. carried by other carrier types than containers. Step 1 and the following step 2 together provides a framework for what is investigated in the case. Below, table 5.1 presents the identified commodities that further down will be evaluated.

Commodity	Tonnage	Commodity	Tonnage
Paper, cardboard	1,633,288	Gaseous (as liquid or compressed) petroleum products	14,722
Iron and steel	928,446	Grain	12,293
Soils, stones, gravel and sand	694,717	Prepare sustainability-treated fish and prepared fishery products	8,587
Other building materials (not metal and wood)	355,773	Meat, meat products, raw hides and skins	6,854
Sawed, planed wood products	273,632	Textiles, clothing, fur products, leather and leather goods	6,271
Pulp	132,315	Chemical and mineral (natural) fertilizers and salt	4,881
Glass and glassware, porcelain and ceramic products	123,619	Other wood products, e.g. wooden building elements	3,906
Cement, lime and plaster	111,416	Grinding products, prepared animal feed, starch	3,688
Wood chips, wood / saw waste, e.g. chips, pellets	109,448	Other raw materials of plant or animal origin	2,806
Other machines and apparatus; office machines, machine parts etc.	94,327	Coal products, e.g. coke, coke briquettes	2,279
Dairy products, drinks and ice cream	76,339	Prepared and preserved fruits, berries and kitchen plants	1,604
Other foods and tobacco products	66,421	Peat	1,286
Processed rubber and plastic products	57,516	Pharmaceuticals and finished goods from the chemical industry	968
Chemicals, chemical products, artificial fibers, rubber and plastic products	52,866	Boilers, hardware, weapons and other metal products (not machine)	894
Fresh fish, fresh fish products	46,137	Means of transport (equipment)	128
Furniture and other manufactured goods	35,464	Animal and vegetable oils and fats	16

Building metal products and pipes, pipelines, hollow profiles and accessories	29,478	Coal and lignite	1
Non-ferrous metals and their products	28,209	**Total**	**4 933 371**

Table 5.1. Commodities currently transported by container

5.3 Identifying catchment area

In order to delimit the geographical area for the case, a selection of municipalities has been made, these are listed in table 5.2. The so-called catchment area intends to include the municipalities with proximity to the port of Gothenburg. The same applies for the area around Kristinehamn where a larger distance has been included. This because intermodal transports are required to provide enough volumes in order for a container feeder to work. The selection is made based upon the information provided from Vänerhamn regarding their catchment area to include realistic flows. With the framework presented and delimitations in the data selection made, the visualisations can be made. The following section presents the findings for the case study.

Västra Götaland to port of Gothenburg	Värmland to port of Kristinehamn		Örebro to port of Kristinehamn	
Gothenburg (0)	Kristinehamn (0)	Munkfors (67)	Degerfors (20)	Lindesberg (71)
Mölndal (6)	Storfors (26)	Säffle (70)	Karlskoga (24)	Ljusnarsberg (79)
Partille (15)	Karlstad (35)	Sunne (80)	Lekeberg (46)	Ludvika (111)
Ale (21)	Hammarö (38)	Hagfors (83)	Laxå (46)	Smedjebacken (118)
Härryda (23)	Forshaga (43)	Torsby (111)	Nora (58)	Vansbro (134)
Kungälv (24)	Filipstad (45)	Årjäng (112)	Hällefors (58)	Avesta (148)
	Kil (50)	Arvika (115)	Kumla (62)	Säter (148)
	Grums (57)	Eda (121)	Hallsberg (63)	Borlänge (150)
			Örebro (63)	Hedemora (151)

			Askersund (66)	Gagnef (153)

Table 5.2. Municipalities and counties included in the catchment area

5.4 Container goods flow mapping

In order to analyse the goods flows, the data of domestic flows between the Gothenburg area and Kristinehamn area are divided between the two nodes in both directions. This in order to be able to distinguish different characteristics of the different flows.

5.5 Domestic flows from Gothenburg area

In the Gothenburg area, approximately 194.000 tonnes are identified as potential goods flow for IWT going north to Kristinehamn. The bar chart in figure 5.1 presents the contribution for each of the six sending municipality in tonnes, where Kungälv and Gothenburg are main contributors. Notable to mention is that all the domestic goods flows to Kristinehamn currently use road as the transport mode. All the destinations in the surrounding counties are shown (36 different locations), but the top 15 receiving municipalities are highlighted in the figure below, which represent almost 94% of the total volume.

From Kungälv, the commodity *other foods and tobacco products* are mainly consumed in Borlänge and Karlstad. These goods flows come from the wholesale- and retail industry. The goods is transported as palletized goods and this flow stands for approximately 21% of the domestic flow to the Kristinehamn area for this data selection.

From Gothenburg, the commodities *other foods and tobacco products* and *dairy products, drinks and ice cream* are supporting the retail business located especially in Värmland. The receiving municipalities representing the largest volumes are Eda, Borlänge and Karlstad.

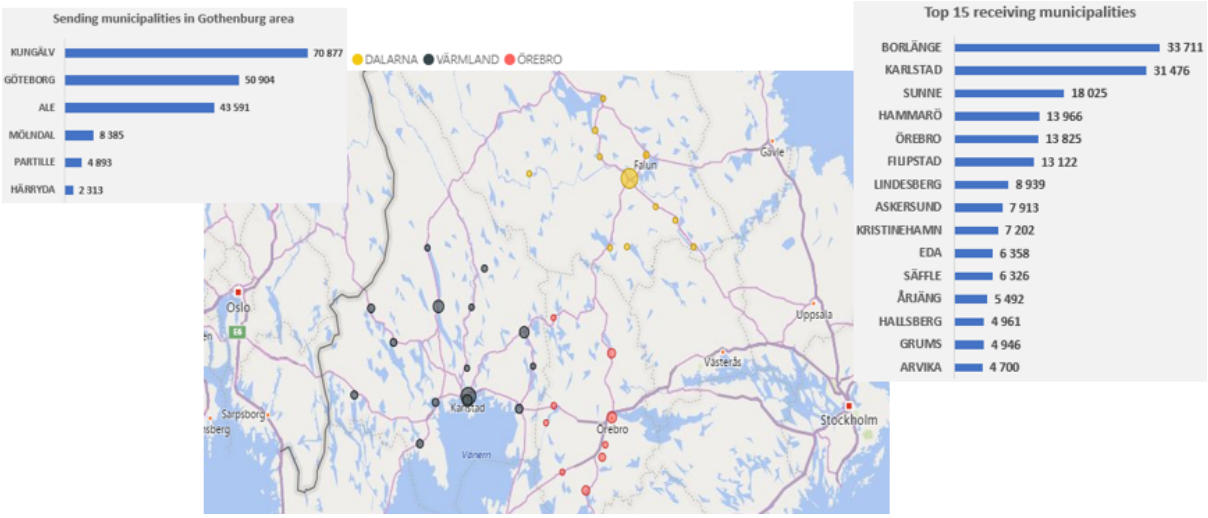

Figure 5.1. Destinations of the domestic goods flow from Gothenburg area

The inbound data reveals that the largest consuming volumes are identified in Värmland county, close to 62% of the identified goods volume (figure 5.2). In Värmland, the retail- and wood and paper industry are the biggest, with highest share of the volume located in Karlstad. Currently, all the goods flows to Värmland are transported as palletized goods or liquid bulk. The goods flows to Värmland consist mainly of goods types within *food, beverages and tobacco* (66%) and *chemical products (not consumer goods, e.g. pharmaceuticals)* (11%).

Ale is supplying Örebro with large volumes of the commodity *chemicals, chemical products, artificial fibers, rubber and plastic products* to destinations in Lindesberg and Askersund. From Gothenburg, the commodities *other foods and tobacco products* are transported to Örebro and Hallsberg,

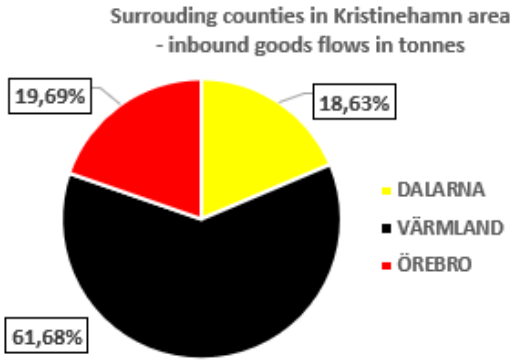

Figure 5.2. Allocation of receiving counties of potential goods flow

5.6 Flow maps - north going

The findings from the Gothenburg area presents two commonly produced goods types, *food, beverages and tobacco* and *chemical products (not consumer goods, e.g. pharmaceuticals)* (82% together). Both these goods types are mostly produced by industries within the retail-, wood and paper-, wholesale- and manufacturing of consumer goods industry.

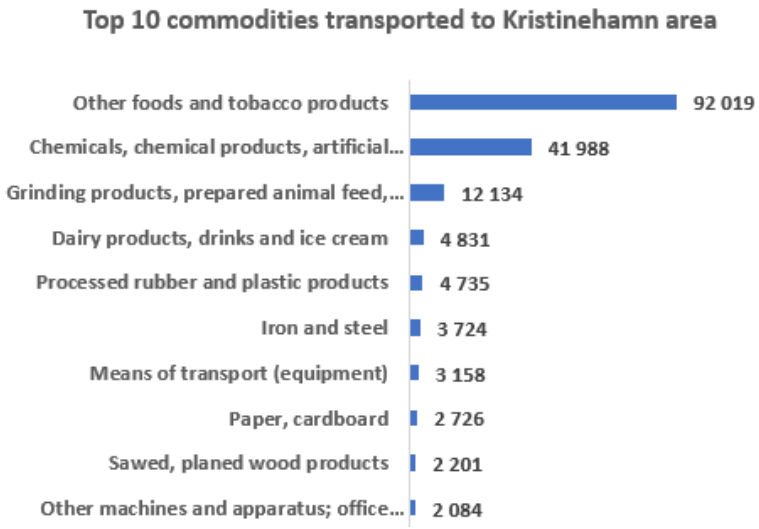

Figure 5.3. Top 10 commodities transported to Kristinehamn area

From the initial 35 identified commodities, 26 are found in the flow from this data selection. Top 10 of these 26 represent 92% of the volume which is presented below in the figure 5.3. By mapping these 10 commodities for this flow the following illustration in figure 5.4 can be presented.

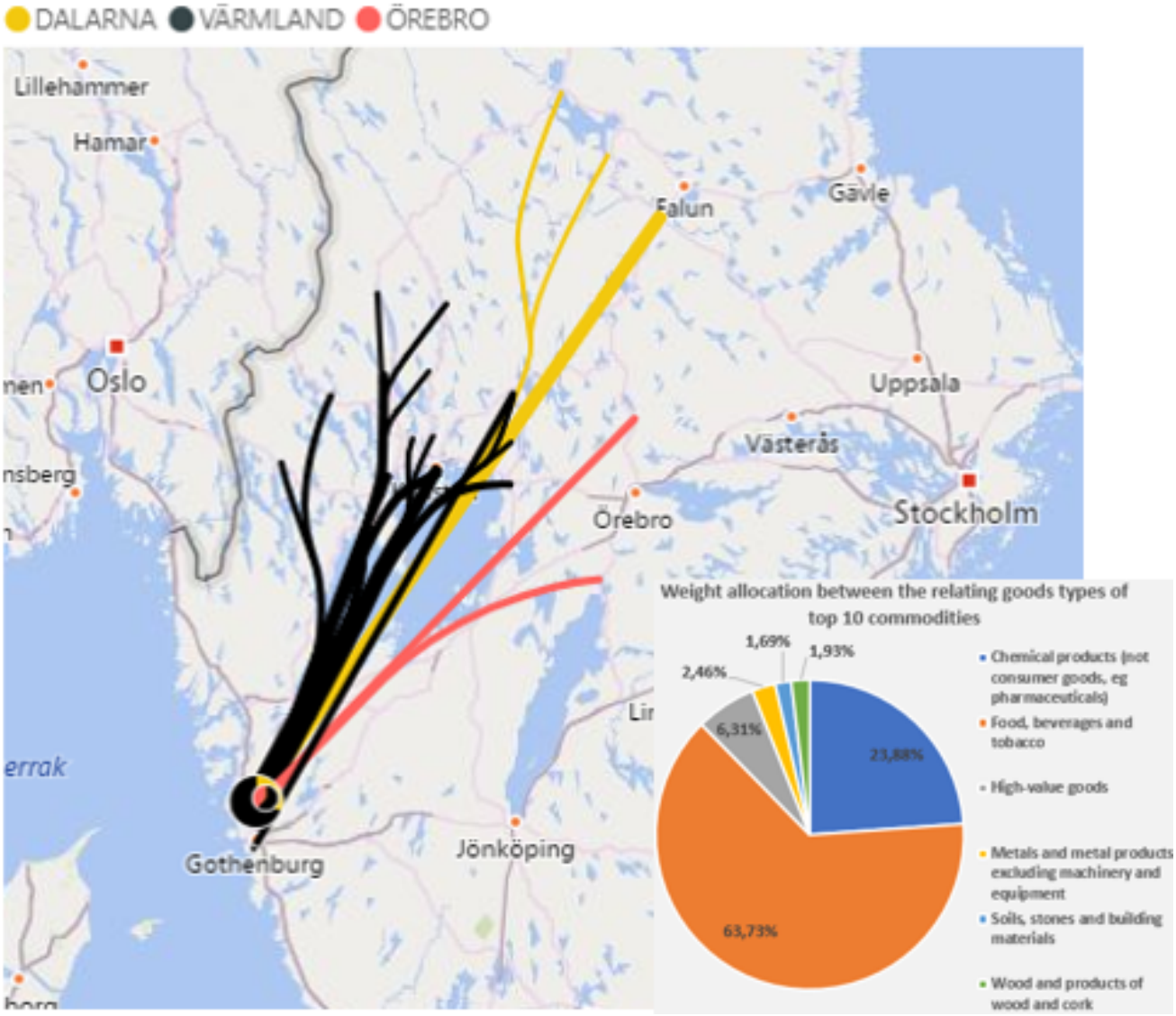

Figure 5.4. Visualisation of goods flows representing top 10 commodities with origins in the Gothenburg area

The destinations with the highest goods flows are located in Borlänge, Karlstad and Sunne. The municipalities that are sending almost all of the total volume originates from Kungälv, Gothenburg and Ale. Currently, all goods flows from the Gothenburg area are made by road transportation. The thick line with destinations in Borlänge (close to Falun), corresponds to the flows mainly from Kungälv and smaller shares of the volume with origins in Gothenburg.

5.7 Domestic flows from Kristinehamn area

In the Kristinehamn area, the suitable goods volumes identified are approximately 524 000 tonnes. Almost 93% of the volume are transported to Gothenburg, mostly to industries within manufacturing of metal goods, machinery and transport (43%), wood and paper industry (32%) and wholesale (15%). The domestic flows are generally using road (61%) and in particular rail (39%) as transport modes, where rail transportation only has Gothenburg as destination.

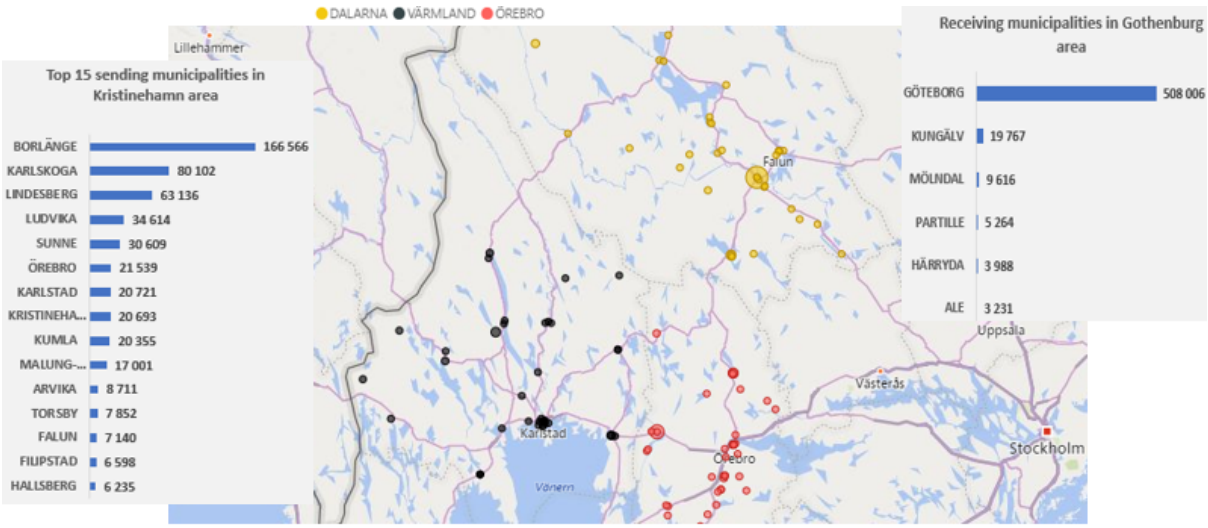

Figure 5.5. Origins of goods flows from Kristinehamn area

The figure 5.5 visualize the origins of the identified suitable container flows, the bar chart presents the top 15 sending municipalities, where a majority of the origins are located in either Dalarna or Örebro county. The top 15 municipalities are currently sending 95% of the volume to the Gothenburg area, but in total there exist 39 different origins in Värmland and Örebro, these are shown in the figure above.

Looking further into the specific commodities and their related transport mode, differences are identified between rail and road transports. From Borlänge in Dalarna county, close to 76% of the volume consist of the commodity iron and steel, which is transported by rail to Gothenburg. Other commodities such as *pulp, paper, cardboard* and *sawed, planed wood products* accounts for the remaining 24% of the total volume.

The goods flows using road transportation are transporting palletized goods. Other commodities with large volumes are *sawed, planed wood products* and means of transport (equipment), where most of the volumes originates from within Örebro county.

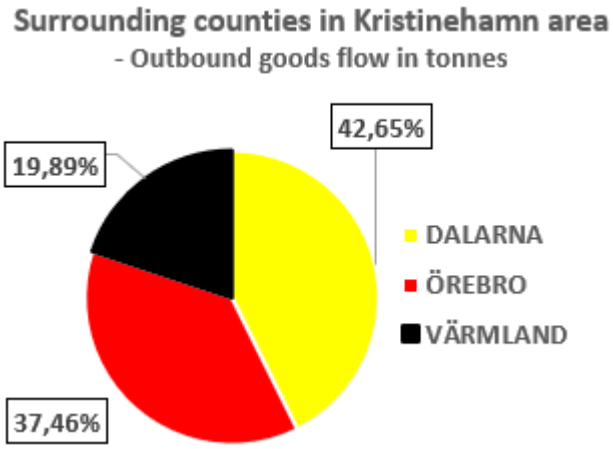

Figure 5.6. Allocation of sending counties of potential goods flow

The weight distribution where goods are produced are visualised in figure 5.6. Örebro stands for the largest volumes, with production located in Karlskoga. In Lindesberg, flows from the manufacturing of metal goods, machinery and transport industry can be identified. The common destination of almost all goods volume are located in Gothenburg.

5.8 Flow maps – south going

The top 10 commodities identified as suitable goods flows corresponds to 96% of the domestic volume transported to the Gothenburg area (figure 5.7). 24 of 35 commodities are included in this data selection.

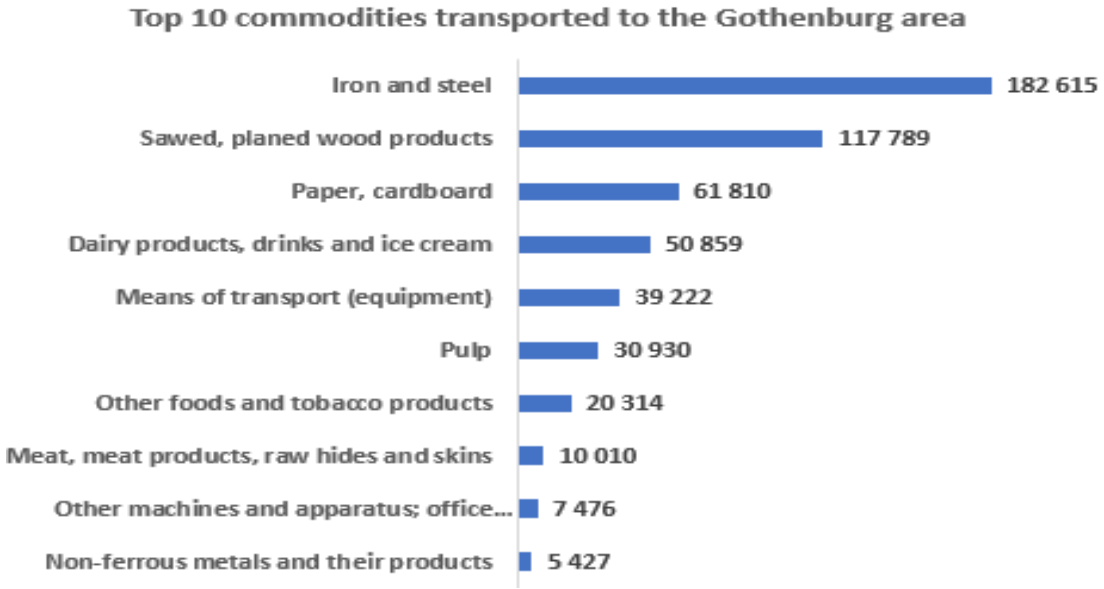

Figure 5.7. Top 10 commodities transport to Gothenburg area

Nearly 10% of the identified goods flows are already transported in containers and the data reveals that rail (80%) is the most commonly used transport mode for transporting containers in this direction. Most of the volume originates from Borlänge (88%) and smaller shares in Kristinehamn and Örebro, within the manufacturing of metal goods, machinery and transport industry. Notable to mention, 92% of the goods flow from Borlänge are transported with rail

as transport mode, which corresponds to the thick line visualised in figure 5.8. The different transport modes providing the goods flows are presented, together with the commodities with iron and steel representing the largest share.

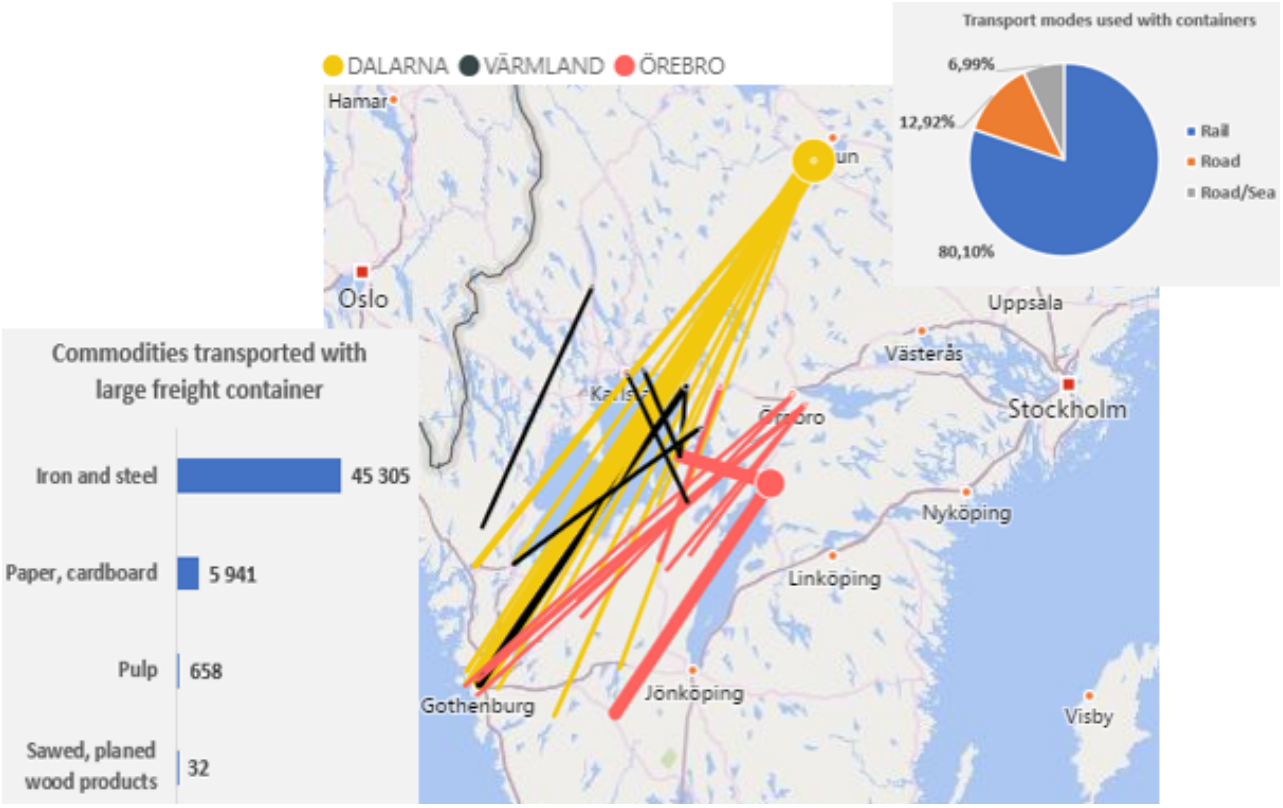

Figure 5.8. Goods flows of commodities transported by large freight container

5.9 Import/Export goods flows

To further present the goods flows, import and export flows are presented. The data selection becomes different as the import data only regards inbound shipments to either Västra Götaland, Värmland and Örebro, the imported volumes to the municipalities located in Dalarna county cannot be accounted for.

5.9.1 Imported goods flows to Kristinehamn

This section presents the imported goods flows with destinations within the selected counties Värmland (62%) and Örebro (38%). The volume identified as suitable container goods flows are approximately 964 462 tonnes, mainly consumed by industries such as wood and paper (39%) and manufacturing of metal goods, machinery and transport *(37%).*

In the left side of the figure 5.9, the 10 top import markets corresponds to 86% of the total volume. Great Britain, Germany and Norway accounts for 56% of the imported goods.

From Great Britain, approximately 290.000 tonnes are transported in total, which mostly contains the commodities *paper and cardboard* transported as palletized goods. From Germany, the total import volume are 127.000 tonnes, and the top commodities are *iron and*

steel and *means of transport (equipment)* followed by *chemicals, chemical products, artificial fibers, rubber and plastic products* and a small share of *paper and cardboard*. Lastly, the import volume from Norway are nearly 81.000 tonnes and are only transported by road, mainly to Hammarö in Värmland county (83%). The commodities consumed here are *chemicals, chemical products, artificial fibers, rubber and plastic products* which are transported as liquid bulk goods (i.e. the carrier type).

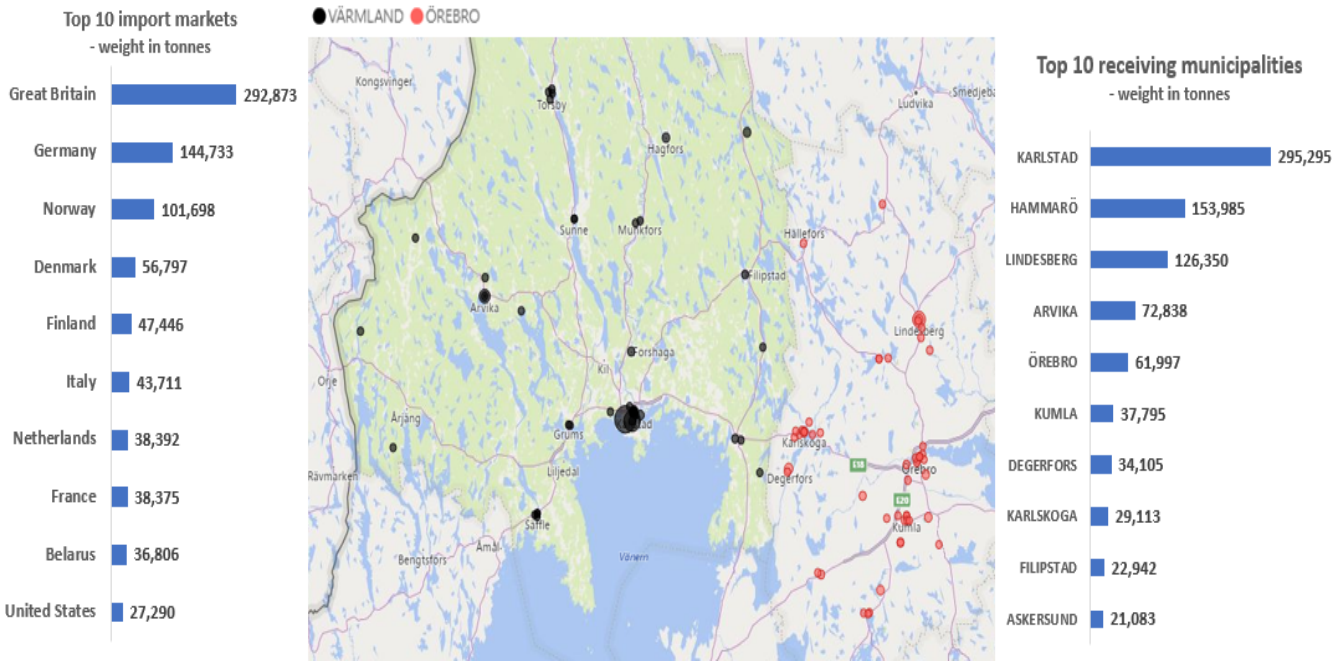

Figure 5.9. Destination of imported goods

5.9.2 Identified potential goods flows

The top 10 receiving municipalities, i.e. where industry and other consuming sites are located in Värmland and Örebro corresponds to 89% of the total volume. The top 10 imported commodities represent nearly 920.000 tonnes (95%), see figure 5.10. Currently, nearly 12% of the imported goods are transported in large freight containers. Looking further into the specific factors concerning container goods flow, commodities as *pulp*, *iron and steel* are mostly consumed with origins from European countries. Palletized or liquid bulk goods are the most common carrier type used in the imported goods flow.

The transport mode used most frequent is road or rail or as an intermodal solution in combination with sea, where road and sea flows are more dominant. This is due to the logic behind the data, where all the goods are first shipped to the Port in Gothenburg and then considered as further transport defined as the domestic inbound goods flow to Värmland and Örebro. The import data contains 28 of the 35 unique commodities.

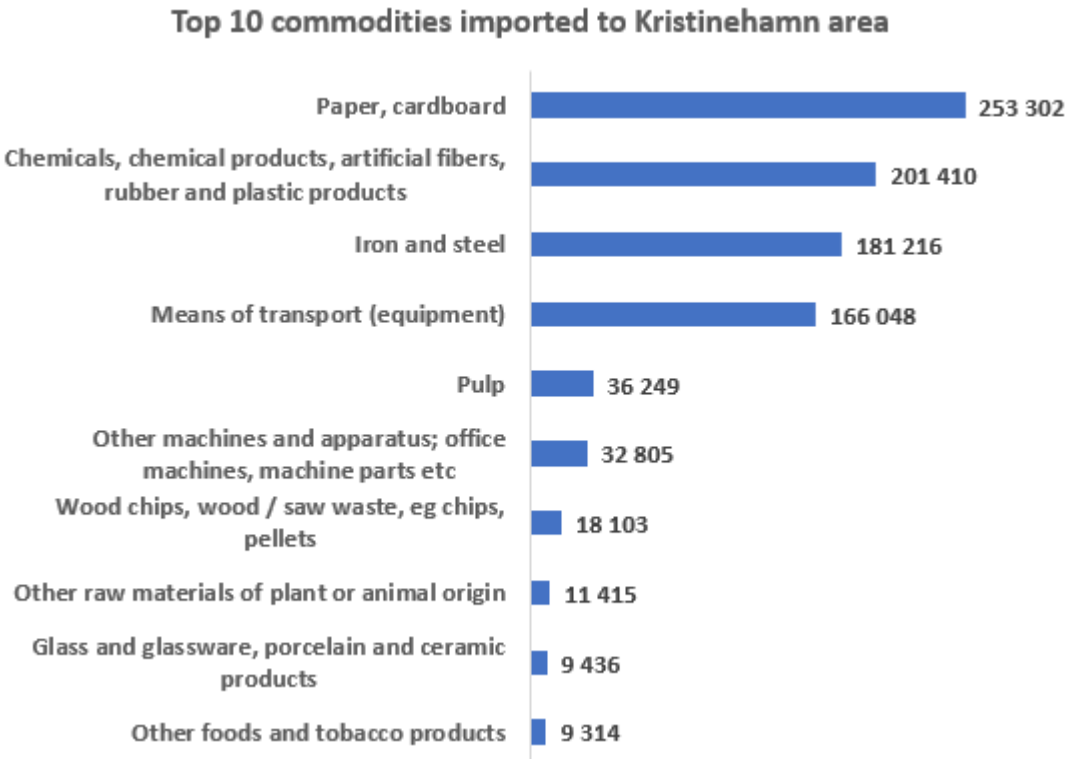

Figure 5.10. Top 10 imported commodities with largest volumes

5.10 Exported goods flow from Kristinehamn

This section further investigates the goods in the export flows from the selected counties Värmland and Örebro. 23 of 35 commodities are included in this data selection, with a volume of approximately 3.7 million tonnes, and more than half of this consist of *paper and pulp*. The largest volumes originate from Grums, Hammarö, Lindesberg and Sunne, consisting of the commodities *paper, cardboard* and *pulp* with Germany, Republic of China and Italy as common destinations.

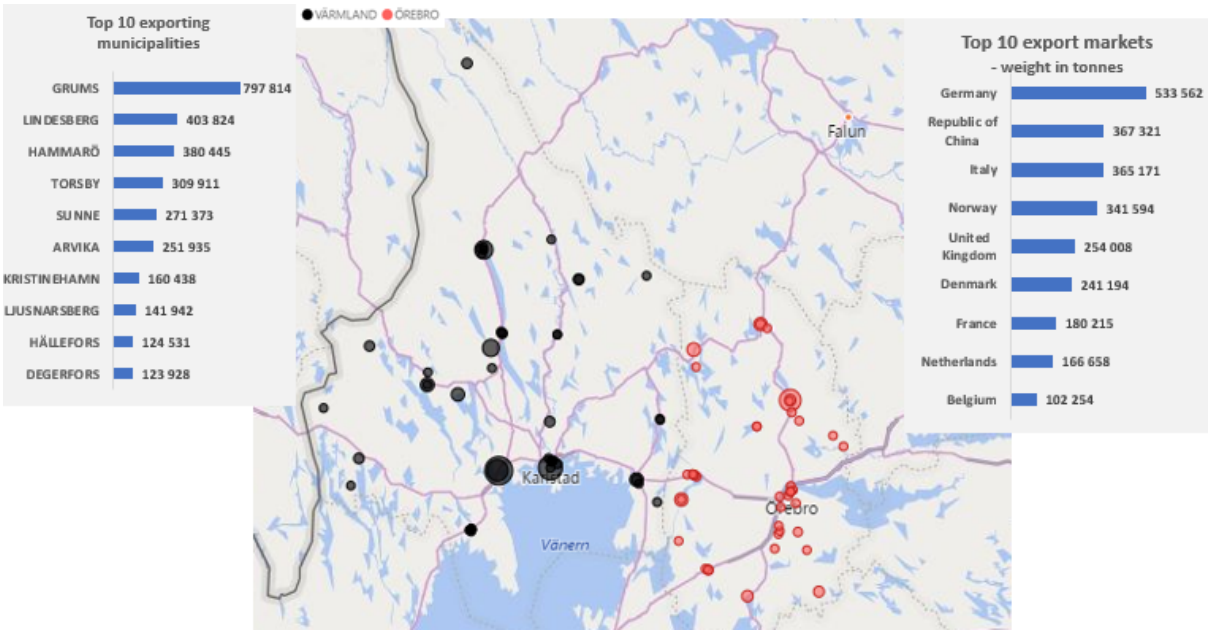

Figure 5.11. Map visualisation of where goods originates from

5.10.1 Identified potential goods flow

The top 10 commodities exported from Värmland and Örebro corresponds to 93% of the volume, see figure 5.12. The most common producing industries identified are wood and paper and manufacturing of metal goods, machinery and transport.

Large freight containers and palletized are the most common carrier types (i.e. stands for 61%), with goods flow usually consisting of the commodities *paper, cardboard*, *iron and steel*, *sawed wood products, pulp* and *dairy products, drinks and ice cream*.

The republic of China and Germany are main importers of the commodities paper, cardboard and iron and steel. The commodity *paper, cardboard* originates from Hammarö and Grums in Värmland, and *iron and steel* are mainly produced in Degerfors, Hagfors and Hällefors in Örebro.

Norway is the main importer of *sawed, planed wood products* and stands together with Great Britain for more than half of the exported volume, mostly with origins in Grums, Arvika, Laxå and Karlskoga.

Close to all exports flows concerning the commodity *pulp* originates from especially Sunne (88%) and Grums (11%). Their largest volumes are exported as palletized goods (90%) to countries outside the EU, such as Republic of China, India, Islamic Republic of Iran and Vietnam.

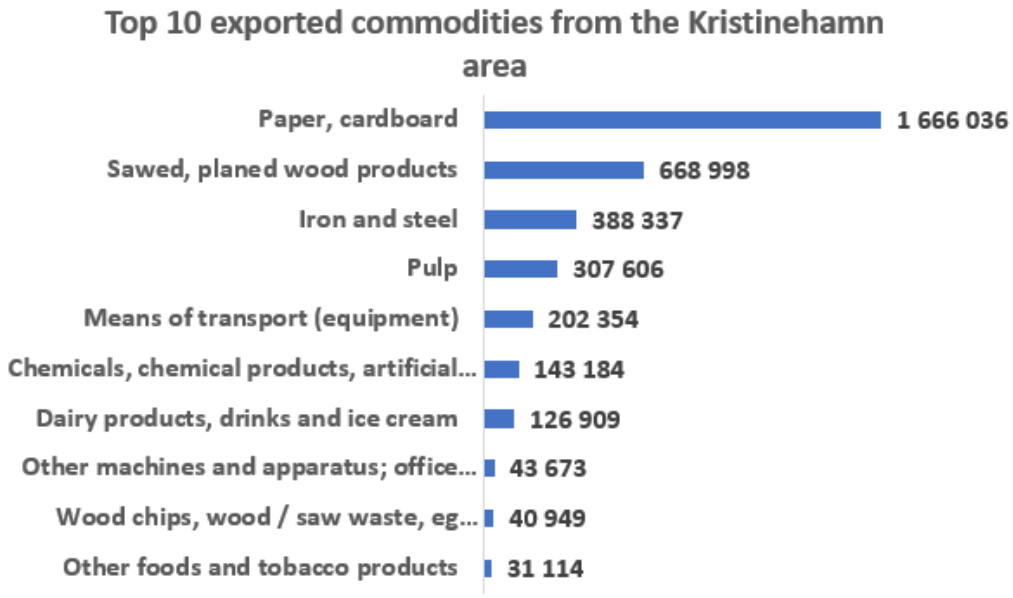

Figure 5.12. Top 10 exported commodities from Kristinehamn area

5.11 Case summary of the potential goods flows

In this concluding part, the total potential is summarized to provide a complete overview of the current state. Firstly, the domestic flows, i.e. in-/outbound flows, are presented, with location in the surrounding area of the ports in Gothenburg and Kristinehamn. Lastly, the potential in the foreign flows, represented by the import and export flows is presented.

5.11.1 Gothenburg area → Kristinehamn area

Starting with the goods flow with origins in the Gothenburg area, with a potential of approximately 200 000 tonnes, the largest volumes are transported mainly from Gothenburg and Kungälv, which are located strategically in connection to river Göta Älv. The sections below will highlight some of the nodes which points out the highest potential for suitable IWT goods, which corresponds to a weight of 83 466 tonnes.

Gothenburg, Kungälv & Partille → Karlstad

Karlstad is identified as a potential receiving municipality (i.e. largest receiver in Värmland), with existing goods flows consisting of *other foods and tobacco products,* which represent the largest volumes received from this data selection. This volume is summarized to 23 347 tonnes.

Ale, Mölndal & Gothenburg → Örebro

The goods flows from Ale, Mölndal and Gothenburg to Örebro, where industries such as manufacturing of consumer goods and retail operates, are summarized to 12 804 tonnes. The produced commodities are *other foods and tobacco products, other machines and apparatus; office machines, machine parts etc.* and *sawed, planed wood products* to mention some of the largest shares.

Ale, Mölndal & Gothenburg → Lindesberg & Askersund

The goods flows between Ale and Lindesberg and Askersund are summarized to 16 221 tonnes, transporting chemicals, chemical products, artificial fibers, rubber and plastic products.

Kungälv & Gothenburg → Borlänge

The goods flow from Kungälv and Gothenburg to Borlänge contains 31 094 tonnes of the commodity *iron and steel.* This flow is suitable as containerized goods, which increases the potential of developing intermodal freight transport processes to support the transhipments in the terminals performed in the port. Since the produced goods in Borlänge are currently transported with by rail transportation indicates the importance of integrating intermodal transports with connections in Kristinehamn.

5.11.2 Kristinehamn area → Gothenburg area

This goods flows are presenting higher goods volumes suitable for containerisation and are calculated to 549 877 tonnes. Almost all of the goods with origins in the Kristinehamn area are received in Gothenburg (93%). Borlänge represent the largest sending municipality in the data selection. The part below will highlight some of the nodes which points out the highest potential for suitable IWT goods, corresponds to 163 611 tonnes.

Karlskoga → Gothenburg

The large volumes sent from Karlskoga, located nearby Kristinehamn (27.5 km), are identified as suitable for containerisation. The closeness to IWT and flows consisting of the commodity sawed, planed wood products, make this node interesting to evaluate for modal shift, the total volume received in Gothenburg is 80 098 tonnes.

Karlstad → Gothenburg

Karlstad are sending 20 377 tonnes of goods with either rail- or road transportation, with Gothenburg as solely destination. sawed, planed wood products. Rail transportation stands for 12%, with goods from wood and paper industry, i.e. sawed, planed wood products to Gothenburg. Road transportation (88%) is transporting non-ferrous metals and peat.

Lindesberg → Gothenburg

Lindesberg, located 95 km from Kristinehamn, sending goods volume of total 63 136 tonnes to Gothenburg. This existing flow handle the commodities *means of transport (equipment)*, *paper, cardboard* and *other foods and tobacco products.* Currently, these goods are transported by rail 27% and road (73%). The connection to Kristinehamn with intermodal transport make it possible to alleviate the use of road transportation in the area.

5.11.3 Import → Kristinehamn area

In this part, the foreign flows are further explained, and the first flow presented is the imported goods flow. The following part will highlight a few goods flows where potential for modal shift to IWT is feasible, this volume corresponds to 383 998 tonnes. The total potential volume suitable for containerisation, from the import flows is 964 409 tonnes.

Great Britain → Degerfors, Lindesberg, Örebro, Kristinehamn, Hammarö & Karlstad

The import flows from Great Britain is transported intermodal, with road/rail and sea transportation. Since these goods show ability for sea transports, it also raises potential for IWT flows. A clustered area around Kristinehamn area is identified in this data selection, with destinations in Degerfors, Lindesberg, Örebro, Kristinehamn, Hammarö and Karlstad. The total imported volume to this area is 281 451. 88% of the volume is currently transported by road and sea. Wood and paper industry is located in Karlstad and Hammarö, Karlstad is importing the commodity *paper, cardboard* and Hammarö consuming the commodity *chemicals, chemical products, artificial fibers, rubber and plastic products.* The business type

manufacturing of metal goods, machinery and transport consuming the commodities *means of transport (equipment)* and *iron and steel.* The location of these sites are in Karlstad, Lindesberg and Örebro.

Notable to mention here, is that 12% of the import flows are transported by rail to Degerfors since their accessibility to the railway with connection to the port in Kristinehamn. The commodity consumed here is iron and steel, within the manufacturing of metal goods, machinery and transport.

Germany → Askersund, Karlskoga, Karlstad, Örebro, Filipstad & Hagfors (Iron and steel)
The goods flows transporting the commodity iron and steel are imported from business types manufacturing of metal goods, machinery and transport and manufacturing of consumer goods. The goods volume are in total 58 687 tonnes.
In Askersund, where manufacturing of consumer goods are located, 25% of the volume is consumed here.

Karlskoga, Karlstad and Örebro constitute a clustered area nearby Kristinehamn, receiving the remaining 75% of the volumes of iron and steel, together with Filipstad and Hagfors which are located in the northern part of Värmland.

Germany → Arvika & Lindesberg
Arvika and Lindesberg imports the commodity *means of transport (equipment)* from Germany, the total volume identified is 43 860 tonnes. 64% are transported intermodal (road/sea) to Arvika and Lindesberg, whilst road transportation accounts for 36% to Arvika.

5.11.4 Kristinehamn area → Export

The export volumes from Värmland and Örebro are identified as the largest potential based on volume. The total export flows generate a volume of 3 717 452 tonnes. In the following part, some specific flows with IWT potential are further highlighted and explained in detail. This volume represents 2 246 962 tonnes of exported goods.

Paper and pulp → Export
This goods type is origin from production in wood and paper industry, where there exist 10 sending municipalities which are located in approximately the same area, around Kristinehamn. These are Grums, Hammarö, Lindesberg, Kristinehamn, Forshaga, Säffle, Karlstad, Örebro, Hallsberg and Karlskoga. Together they stands for 1 536 800 tonnes of the commodity *paper, cardboard.* 53% of the volume in this data selection identifying large freight container as the carrier type. This area produce and transport large volumes that would be beneficial for IWT to intercept.

Wood and products of wood and cork → Export

This commodity is exported from 11 different locations, with most of the volume with origin in Värmland (83%). The transport mode is either unimodal (road) or intermodal (road and sea), which shows clear feasibility for IWT. Torsby, Grums, Hallsberg and Årjäng stands for 80% of the production of the goods type *wood and products of wood and cork.* The total exported volume is 710 162 tonnes. Denmark and Norway are main importer from Grums, whilst Torsby's top importers are Germany, Denmark, France and Italy.

5.12 Case summary - goods flow

The data reveals that there exist suitable goods flows for containerisation, in both directions. The identified volume is summarized in the table 5.3, where the outbound goods flows from Kristinehamn are (flow 2 & 4) are significant larger in relation to the inbound flows . This actuality creates a demand for repositioning of empty containers available in the Kristinehamn area, in order to facilitate the imbalances that exist in the flows.

Flow	Total tonnage	# of road shipments	Commodities	Top senders (≈80%)	Top receivers (≈80%)
1. Gothenburg area -> Kristinehamn area	200 000	6 600	Other foods and tobacco products (52%) Chemicals, chemical products (21%)	Gothenburg, Kungälv	Borlänge, Karlstad, Sunne, Hammarö, Örebro, Filipstad, Lindesberg, Askersund, Kristinehamn, Eda, Säffle
2. Kristinehamn area -> Gothenburg area	550 000	11 500	Iron and steel (33%) Sawed, planed wood products (21%) Paper, cardboard (11%) Dairy products, drinks and ice cream (9%)	Borlänge, Karlskoga, Lindesberg, Ludvika, Sunne, Örebro, Karlstad, Kristinehamn	Gothenburg
3. Import -> Kristinehamn area	964 000	26 400	Paper, cardboard (26%) Chemicals and chemical products (21%) Iron and steel (19%) Means of transport (equipment) (17%)	Foreign trade - (Port of Gothenburg)	Karlstad, Hammarö, Lindesberg, Arvika, Örebro, Kumla, Degerfors
4. Kristinehamn area -> Export	3 717 000	86 300	Paper, cardboard (45%) Sawed, planed wood products (18%)	Grums, Lindesberg, Hammarö, Torsby, Sunne, Arvika, Kristinehamn, Ljusnarsberg, Degerfors, Hällefors	Foreign trade - (Port of Gothenburg)

			Iron and steel (10%) **Pulp (8%)**		

Table 5.3. Identified goods flows suitable for containerisation

6. Empirical findings from interviews

This section will present the empirical findings from the study. The source of information are the respondents from the interviews which include goods owners, a shipping company, people with knowledge and experience of IWT from municipalities and the region of Värmland, Vänerhamn, and consultants' active in the field. A total of 13 people was interviewed from which the following has been compiled.

6.1 Current transportation from an IWT-perspective

When studying the situation of IWT in Sweden from our point of view, the underutilized capacity in the Swedish waterways raises questions regarding why road- and rail transportation remains dominant. During interviews with primarily goods owners, but also with other actors in the distribution chain, their current transportation setup together with their standpoint towards IWT has been assessed. This, in order to create understanding of how transport buyers reason in their logistics operations and their openness to consider changing their current transportation setup.

The attitude towards the use of IWT is positive among all of the interviewed goods owners. An optimism towards the transportation option can be identified but it all comes down to the suitability together with the relative advantages that can be captured by using IWT. Geographical location is decisive when assessing the possibility to use IWT. If the receiving facility is too far away from a port, other transport modes becomes more favourable.

6.1.1 Goods owners perspective

There are companies transporting some of their volumes using lake Vänern and Göta Älv river for their export flows. No interviewee expressed that they use this transportation option for domestic transportation. This is also strengthened from discussions with the shipping company where the interviewee states that IWT is used only for export flows. Domestic shipments are instead either sent with road transportation or to some extent rail transportation. This also applies for export shipments where the goods are most commonly sent down to Gothenburg for warehousing, stuffing of containers and transhipment and then further transportation to the end destination.

The SECU-system was identified as a big contributor to the volumes from Värmland where a customized container unit is used to transport goods from the wood and paper industry. Here, the SECU containers are transported with rail down to Gothenburg, transhipped to RoRo-vessels and transported to bigger ports in the Netherlands. From here, the goods are transferred to TEU containers for the final transportation to destinations. The suitability for IWT was discussed in relation to this flow where there are problems with stackability of the containers. Wheels are mounted on the containers which then enables RoRo-vessels to carry the carrier type. The SECU-system has been developed in order to optimize the flows from

the wood and paper industry and the suitability and transferability to IWT is deemed low due to the already made investments.

When discussing the possibility to ship goods in containers using IWT some goods owners expressed that they have the possibility to ship their goods in containers with available equipment, but choose not to due to both economic and suitability reasons. However, if there would be better economic incentives, large volumes would be transferable to IWT. As the different transport modes often have different reliability related to on time arrivals, due to different length in lead times and with the inherent deviation, a certain imbalance between the use of transport modes comes naturally. The goods owners expressed a certain concern about reliability with IWT during the interviews. Also, the possibility to track and trace shipments means that they can inform customers of delays, which in some cases mean that a longer lead time is acceptable.

6.1.2 Shipping companies' perspective

One of the shipping companies operating in lake Vänern explained how they work with longer contracts of agreement with customers where the responsibility of the transportation is then laid on the shipping company. They try to balance the flows in both directions to their best ability. There is also a spot market with shipments of more sporadic nature, where these customers are acquired by direct contact with goods owners or by transport agents hired by goods owners. In this market, price is always the number one priority for the transport buyers. In order to achieve balance in their flows, raw materials such as coal are exemplified as goods transported on the inbound route.

The distribution between the transport modes is evidently unbalanced where IWT has a significantly smaller share, especially for domestic transportation. Discussions regarding the attitudes towards changing a transport setup for a goods owner indicates that there is an inherent resistance and tradition in the industry. It demands both the behaviour of actors as well as the context to change, whether it is increased volumes, higher frequency or other factors and in order to make a modal shift happen towards IWT, the price must drop drastically, according to one of the interviewees.

When discussing with the shipping company, more freely and on a more aggregated level, questions regarding industries in general that may be more suitable for a change to IWT were asked. The reasoning was that industries, such as the mining and petroleum industry, with high exposure to the public opinion in environmental aspects do their best to make their operations less polluting. As progress is made within other segments of their business, they try to find low hanging fruit in other segments where transportation then comes naturally. If higher demands and restrictions are being imposed on companies with a purpose to attract more volumes to IWT, these industries may consider the option more thoroughly.

6.2 Goods owners transport quality priorities

The transport quality factors mentioned in the theoretical framework were discussed with the goods owners in order to understand how the factors that are affecting their transportation options and what goods owners prioritize regarding transportation.

Assessing the answers from the interviewees on the questions related to their priorities regarding the transportation of goods, shows a range of different transport quality factors. The majority had a customer focused answer to this and their reasoning was that happy customers is always a priority. This means more practically that the right goods should arrive to the customers facility at the right time.

The price is also something that is recurrent throughout the interviews, even though not expressed as a number one priority in most cases. However, it always works as a benchmark when goods owners' asses their transportation options.

Also, the environmental aspect of transportation is recurrent and expressed as one of the most important factors. With legislations and emission fees this comes naturally as a mean of getting economy in the logistics. Answers regarding the ability to use environmental friendly transports as a marketing tool and a part of the company's CSR strategy was also experienced during the interviews. This also indicates a lean towards a price priority among goods owners, even though not expressed explicitly.

The bigger companies have dedicated departments of their logistics operations which handle their supply chain. In these cases, all transport quality factors are assessed in their transport setups and depending on their optimization factor, their transportation will look in a certain way. Other plants within the same organisation may affect the transportation setup from another facility which implies a complexity in the transportation choice. Geographical location is one of the key aspects in this matter where a proximity to the water and an availability to port services are decisive. The nature of the business type and goods characteristics are also factors that affects what is prioritized and in turn how the transportation and goods flows will look like. If the goods owner is smaller on the other hand, a stronger correlation to price priority can be identified. This because of the third-party involvement that is more evident with smaller businesses.

6.3 Governance of the IWT framework

As the Swedish IWT framework differs from other European countries with a more established IWT system, questions regarding important aspects for the Swedish system was asked to the respondents. The pilot fee system and the governance from authorities are identified as the main differences and a big reason to the underutilized waterways in Sweden.

One of the most interesting aspects affecting IWT is the pilot fee system and how the involved authorities govern and control the Swedish IWT framework. The questions regarding how the fee structures and legislations works for IWT in Sweden are answered by the interviewees with lengthy answers. There is a clear and recurrent opinion that the current system is not working and if a balance between the traffic modes is what is expected to be achieved, reorganisations on different aspects needs to be done. Efforts aimed at simplifying and strengthen the competitiveness of the system has been going on for 17 years and yet the system remains unoptimized.

There seems to be a mutual understanding between key stakeholders among actors in the supply chain, about the fees being imposed and unnecessary. With today's technologies, there is no need for a piloting service on lake Vänern. The system is built up in a way where Transportstyrelsen decides where piloting is needed and under what circumstances which then constitutes the framework. Another authority, Sjöfartsverket, then operates the piloting and sets the price of the service. Sjöfartsverket needs to finance their own business and thereby charge fees. There is a clear dissatisfaction among the interviewed actors, especially the shipping companies and project initiator, of how the question has been handled by authorities with lengthy lead times for decisions to be made and changes implemented. The goods owners have also expressed understanding of how the fee structures affects IWT negatively. A stolidity among the authorities is undeniable.

The interviewee from the shipping company means that IWT needs to be classified as an own transport mode in order for it to work in Sweden and thus be separated from other sea transports. The reasoning is; since IWT is not competing with the sea transports carried out today, as it concerns export flows, it should not be treated the same. With the aim of reducing road and rail traffic, while increasing IWT, the benchmarks and comparisons should be made between those three transport modes where IWT is treated separated from conventional sea transports.

At the start of 2018, a new pricing model was introduced by Sjöfartsverket. This is a result of a government mission from June 25, 2015 where the purpose, according to Sjöfartsverket was to ensure a balanced economy in the services provided by Sjöfartsverket. This in turn is a result from the NAIADES II package which only was implemented partially in Sweden with less requirements on the technical aspects of the vessels. Only taking it half-way did not result in any incentives to change transport mode and status quo remained. Transportstyrelsen was assigned the governmental mission to implement an IWT framework, but the mission did not include the purpose to relieve the road- and rail network and facilitate a modal shift towards IWT. Therefore, the current IWT framework in Sweden is constructed without any purpose to create a balanced transport system, as expressed by one of the respondents.

In practice, the framework makes the piloting more expensive than necessary as the shipping company can be charged for up to 10 hours when in reality it is not needed at all. It also means that the captain of the boat never actually drives the boat in the lake, instead the person from the piloting service is. As price is one of the most important factors when goods owners assess transportation options, the pilot fee system complicates the situation. Comparing it to other European systems it is clearly more complicated. The piloting service in Lake Vänern is not needed with the technical improvements that has been made since the establishment of the framework, and thus it constitutes a big hindrance for an increased IWT. Comparing it to how it works in the Netherlands and Belgium, IWT is exempted from piloting and the system is integrated with the other transport modes. Safety is often an advantage for IWT and something that is utilized in Europe, whereas in Sweden it often constitutes a concern from the authorities. For European actors, it is about self-preservation to avoid accidents and large efforts are aimed at keeping the operations safe. Hazardous goods are brought up as an example as it often is forced to be transported on IWW due to the increased safety it brings. That in turn also constitutes an example of a potential increase in usage of IWT in Sweden and a proof of different priorities in different countries traffic systems.

Discussions regarding how the governance and subsidies work between the different transport modes also reveals an imbalance. For example, ports are often municipality govern which demands investments and resources to operate and maintain them whereas the road- and railway system is more funded by the government. The fees debited by the ports in Vänern are also considered unbalanced. Road transportation that arrives to the ports facilities for transhipment are free of charge while hefty fees are put on the ships docking at the ports.

6.4 Examples of potential for increased IWT

The following sections will present examples of application areas and future potential that was discussed during the interviews. This is presented in order to show that there are ambitions and possibilities to use IWT to a greater extent than today.

There are several initiatives that has been made with the aim to improve the competitiveness of IWT in Sweden. During the interviews, the respondents came up with several examples of how to increase the use of IWT. In discussions with involved persons from the county of Värmland it was explained how the work with IWT is carried out in their organisation. Efforts aimed at getting the industry to work against an increased usage of the waterways has been made and government missions connected to regional development has been worked with where the transportation is one important aspect. Värmlandsbanan is exemplified as a project where efforts have been made in order to increase the capacity as it is an important factor for the industries in the region. Cooperation between municipalities can also be identified where e.g. Vänersamarbetet has been put together to work with questions regarding industries and IWT. Concrete examples of goods owners with potential transferable flows was also presented during interviews. Also, the benchmark with other European countries IWT

frameworks was discussed where the example of hazardous goods transportation being forced to be transported with IWT in other European countries.

6.4.1 Example 1 - Goods owner

In this organisation, a dedicated department handles the solutions for transportation and logistics. The volumes are large and concerns of the capability with IWT was identified. However, with the decision of a reconstruction of the locks in Trollhättan, new possibilities open up and the efficiency of IWT may improve. With the right incentives, volumes are transferable to IWT according to the respondent. Regarding sustainability in transportation, there are ongoing projects and efforts aimed at reducing the environmental impact of their logistics operations, e.g. the use of biofuels for their truck transports between their facilities and the port of Karlstad.

6.4.2 Example 2 - Goods owner

Volumes of their current business was expressed in exact numbers. Finished product flows of 125.000-140.000 tonnes yearly among approximately 1000 containers carrying 25.000 tonnes and 40.000 tonnes transported with bulk vessels. With their geographical location close to a port, a transfer to IWT would not mean any major changes for their operations and thus a positive attitude towards the question was experienced. When discussing the matter in closer detail, a scheduled container feeder was concluded to be the most important thing for the company. If a fixed schedule of departing vessels would be established, planning could be done in accordance to this. As large enough volumes must exist in order for a container feeder to work, an understanding of this together with a willingness to contribute was identified.

6.4.3 Example 3 - Goods owner

The factors that could enable IWT transportation for the first leg of the transport to the port of Gothenburg was expressed by one of the respondents. Availability of equipment for container stuffing, availability of containers through a depot strategically located, enough frequency and a proven concept that IWT is reliable. A strong customer orientation was expressed and the most important transport quality factor was reliability related to on-time arrivals, whereas price was expressed as secondary. The proven concept mentioned needs to be presented to the decision makers as tradition is something that affects the transportation choice strongly in the industry. Also, because it is a matter of large volumes that are transported to Gothenburg for further oversea transportation, which puts high pressure on the reliability.

6.4.4 Example 4 - Shipping company

An upcoming project together with a petroleum company was discussed. The project aims at establishing transportation of goods from Lysekil to the refineries in Karlstad, through Göta Älv river and lake Vänern. As exact data of distances, number of trailers etc. is available it is

an interesting project since it can quantify the exact emission savings to be captured. Even though trucks would be needed in such a setup e.g. for last mile transportation, the external effects will decrease. In order for this to work in an efficient way, an expansion of the IWT zones would be needed. This, in order for the IWT vessel to be able to operate on the full route along the coast strip from Lysekil to Gothenburg where the goods would be transported.

With all the pieces in place; the customer is ready, the volumes exist, the vessel type is set and all the calculations are made in the preparatory phase, the only thing that stops it is the framework and the slowness in the authorities' decision making. Since such a decision needs to be taken through different levels of authorities, the latest information communicated to the initiator was that it can take up to six months for the European Commission to present a decision for the project. This may not seem as a long period of time but during this time, the shipping company and the project itself becomes paralyzed and nothing can be done more than waiting for a decision.

6.4.5 Example 5 - socio-economic calculations by consultants

A discussion with a consulting company operating in the transport sector, regarding an old project where calculations were made on an IWT case from a socio-economic perspective (e.g. transportation costs, emissions levels and congestion effects). The case included container feeder traffic from Gothenburg to Uddevalla to replace road transportation on the same route. Three different scenarios were presented where the scenario of a warehouse located in connection to the port was shown to be profitable. The other two scenarios failed to provide a positive outcome due to transhipment costs as the warehouse was not located in connection to the port. This strengthens the importance of geographical location when assessing transportation options, where a proximity to port services can make big differences on such calculations.

6.4.6 Example 6 - prerequisites and problems with container transportation using IWT

This case is created from the interview conducted with one of the shipping companies, involved in promoting container transportation with IWT. The discussions are summarized to what follows in the coming sections.

The biggest problem with a container feeder is that the entire economical risk is put on the shipping company in the initial phase, which usually means one year of preparations etc. When establishing a container feeder, large capital investments must be made, and since the shipping companies operating in lake Vänern are rather small, they do not have the economic resources to do this and the risk is too high. To enter the container segment, investments in IT-systems also needs to be done, which in turn means more administrative work.

The interviewee then compared this to the Netherlands and Belgium where the IWT system is more integrated with the transportation system, as bigger actors see the potential and work more focused towards an increased IWT. Here, it is usually a bigger actor that controls the container flows and charters vessels to maintain the schedule and if empty containers need to be positioned, one way trips are bought from the spot market. In the same manner as in Sweden, the shipping company undertakes the economic risks but as it often is a bigger actor with established administrative resources and IT-systems in place, the investments become relatively smaller. Additionally, the shipping company and IWT services then works under the same rules as the road transportation and the vessels are seen as “trailers on waterways”. In Sweden, the equivalent actor does not see the possibilities with barge traffic on inland waterways which results in the dominance of road- and rail transportation that can be identified today.

When discussing the prerequisites for establishing a container feeder in Sweden and specifically which volumes that are needed to make it sustainable, it was concluded that approximately 400 containers (20 foot) per week is needed in order to get started. With today’s situation of IWT in Sweden, these volumes do not exist. Additionally, the ports operating in the area needs to change business strategy where an active participation towards an increased usage of the waterways is needed in order to support the effort made by the initiators for such projects. The ocean shipping companies also needs to realise the benefits of moving depots and distribution centers to smaller ports located in the hinterland of smaller ports. This, in order to become more efficient in transhipment operations and to attract bigger volumes.

7. Discussion

In this chapter, the previous chapters are discussed together in order to present the conclusions for the study. Firstly, a quantitative discussion will be presented where highlighted numbers in the report are addressed. Further, the insight and knowledge of goods flows gathered from the goods flow mapping, the empirical understanding provided by interviewing involved actors together with the theoretical framework, together provides the input required to discuss different factors affecting the real potential for IWT in Sweden.

7.1 Quantitative discussion

The highlighted numbers presented further are firstly for the goods flows between the counties surrounding lake Vänern (section 4.10) followed by the numbers from the constructed container case (chapter 5). In order to distinguish potential for IWT and present quantitative conclusions, different factors are discussed. Namely; the different commodities transported in the flows, geographical locations of the destinations and origins, identified flow imbalances and rough estimations of what the volumes represent in number of road transports. The following sections intends to quantify the investigated flows to present a picture of how many road transports that is represented for the presented goods volumes.

7.1.1 Flows between the counties quantified

With this data selection, 26 commodities were included, representing approximately 3.600.000 tonnes. Road transportation represent the only transport mode in most of the directions where estimates of what the volumes of these flows generates in number of road transports. With a rough estimate where one road shipment carries on average 30 tonnes, the amount of shipment included is 108.600. Table 4.2 presents the numbers in detail where at first sight, imbalances seem to occur. However, looking at the top contributors where 80% of the volume is allocated to reveals that there are flows in both directions between the counties with the same nodes. Gothenburg is an example of a node highly represented in the cases where Västra Götaland is included. The same applies for other nodes such as Karlstad, Kristinehamn, Karlskoga and Örebro. A common factor for these, except Örebro, is a proximity to ports. From Örebro county, extra transhipments will be required as intermodal setups are needed to reach access to IWT. The flows between these nodes with the selected commodities identified as suitable for IWT generates approximately 11.300 road transports.

Significant volumes of *roundwood* was identified, where no potential for a modal shift to IWT is considered realistic. The nature of the wood and paper industry, especially for sourcing of raw material, where the products are sourced locally and transported through the assisting road infrastructure, making no other transport choice viable. This is identified from the data analysis and strengthened by the interview with one of the goods owners.

Looking beyond the *roundwood***,** approximately 1.530.000 tonnes remains which is then estimated to 51.100 road transports. Commodities within this share are for example *sawed, planed wood products, other foods and tobacco products, iron and steel, grain, peat.* For these commodities, the same logic as for *roundwood* cannot be distinguished, pointing at longer distances and better feasibility for IWT.

7.1.2 Container case quantified

With this data selection, 35 commodities were included, representing approximately 5.400.000 tonnes. This is estimated to 131.000 road transports with 30 tonnes per shipment. Additionally, approximately 1.500.000 tonnes are transported with other transport modes where rail and maritime transportation is included. This implies that the waterways have been used for some of the volumes where respondents from the interviews has explained that they have export flows utilizing maritime transportation, e.g. to Great Britain.

The shares of foreign trade in this scenario are significantly larger than the domestic flows where an imbalance between the Gothenburg area and Kristinehamn area also is identified. The volumes of the outbound flows from the Kristinehamn area are much larger than the inbound, meaning that there exists no balance with this data selection. Nodes located close to ports are identified here as Gothenburg, Grums, Hammarö and Kristinehamn where goods volumes are found. Between the nodes in the Kristinehamn area and Gothenburg, including foreign trade flows carried by road transports is summarized to approximately 32.000 road transports.

Additionally, from Gothenburg several flows to different destinations are identified within the Kristinehamn area, consisting of a total of 58.000 tonnes and equivalent to approximately 1.900 road transports.

Looking at what the goods flows consist of, *paper and cardboard* is identified in both directions of the foreign trade flows. The same applies for *iron and steel*. The domestic flows do not show the same balance between the commodities. To the Kristinehamn area, *other foods and tobacco products* together with *chemicals and chemical products* are found whereas the opposite direction shows flows consisting of a larger variety of goods. *Iron and steel, sawed, planed wood products, paper and cardboard, dairy products, drinks and ice cream* represent the largest volumes in the south going direction.

7.2 The modal choice

There is undeniably potential for IWT to be used as a mean to achieve a better balance in the transport system. Jonsson & Mattsson (2011) advocates a holistic view of the transport system where synergies between the different components can result in higher efficiency. One of these components are transport buyers and goods owners, where the ultimate

decision of how to transport goods is taken. During interview with goods owners, a recurrent topic has been their reasoning for transporting goods and how IWT could be an integrated part in their supply chains. The transport quality factors included in the theoretical framework has been used in order to assess their prioritizations and to explain why goods are transported in certain ways. The transport modes with relating transport quality factors are discussed in the following sections.

Rodrigue, Comtois & Slack (2015) mean that that **road transportation** is the main transport mode as it offers both connectivity and flexibility, which is strengthened for this study, both by the goods flow mapping and the findings from the interviews. The prevailing infrastructure facilitates the large share of road transportation used today where the connectivity and flexibility of the transport mode constitutes major benefits in comparison to the other alternatives. Road transportation has a wide spread of application areas and is used in various transportation setups (Jonsson & Mattsson, 2011) which can explain the dominance of road transportation presented in the goods flow mapping, especially for domestic transportation.

Looking at the drawbacks of road transportation, Rodrigue, Comtois & Slack (2015) conclude the main disadvantages as the external effects generated, e.g. emissions, noise and congestions. These effects may in turn affect the reliability of the transport, which is brought up as the most important transport quality factor by many of the respondents. The congested area around the port of Gothenburg affects the connectivity and flexibility of road transportation, where IWT is a possible tool to decrease the utilization of the road network. However, from a goods owners' perspective where reliability often is the most important factor, this dilemma is known but due to previous experiences with delays and abruptions for shipments using IWT, the reliability of the transport mode becomes questioned. Geographical location is concluded to have major impact on the potential to transfer goods to IWT, which relates to the connectivity of the transport modes. Without suitable infrastructure and equipment, road transportation often becomes the only reasonable transportation option.

Looking at **rail transportation**, the secondary data reveals that it is usually single or a few commodities shipped in relatively high volumes. The origins and destinations are fixed to the entities located close to the railway system, pointing at the lack of flexibility of rail transportation, as described by Jonsson & Mattsson (2011). The respondents often describe that road transportation is used to the largest extent, but rail transportation is used for some of the volumes where this transportation setup is proven economically viable, which is a result of the fuel economy achieved in the transports. The capacity constraints in the railway system is also expressed as a hindrance for using it more.

Lindgren & Vierth (2017) describe **sea transportation** as able to absorb the biggest volumes per shipments, but limited between harbours. Looking at the import volumes to the counties, especially Västra Götaland, the largest volumes are transported to ports located along the

coastline (Gothenburg and Lysekil). Crude oil evidently represents the largest volumes transported here, showing that large volumes are transported over long distances. These goods flows are further distributed, mainly by road transportation, where example 4 from the empirical findings presents an alternative approach for petroleum products. This shows that commitment from actors can change a transportation setup, favouring IWT in this case. Even though waiting for authorities to perform the administrative process, the project is ready to launch.

Wiegmans & Konings (2015) argue that **IWT** is able to compete with road- and rail transportation if the number of transhipments in the transport chain is reduced, since this have a direct impact on the total transport cost. Again, the geographical location is here an important factor for the potential for IWT, as Caris et al. (2014) states. Transhipments are brought up as an important factor for goods owners when assessing their transportation options as it has significant impact on the transportation cost. Depending on where the facilities of the goods owners are located, the suitability for IWT in their logistics operations differ. As one of the respondents (located in connection to a port) explained, their operational activities are not impacted by changing from road transports to IWT, but just a matter of planning. This demands a fixed schedule for departing IWT vessels. The available infrastructure and equipment located in connection to their facility makes this possible and in this case, the number of transhipment can in fact be reduced if the goods are transferred to IWT. In the case of a goods owner being located further away from a port, transhipments together with an increased complexity for the first mile transportation often eliminates IWT as an option. This due to the possible positive effects being eliminated by higher costs and additional routes.

The **distribution between the transport modes** is naturally unbalanced, where different transport options are more or less competitive depending on the specific context. The fact that road transportation holds many advantages from a goods owners' perspective is reflected in the goods flow mapping and as reliability is considered very important, flexibility and connectivity in turn becomes crucial. Flodén, Bärthel & Sorkina (2017) presents a model with different layers of factors affecting a modal choice, where cost constitutes a benchmark against which the other factors are valued. They mean that modal choice is a decision that depends on the combined performance of a number of factors where these factors are appointed different importance for the decision.

The **cost of a transportation** is not always decisive where one of the respondents meant that "they pay for the transport quality offered". However, a price consciousness is always present for the transport buyer where a higher cost must be motivated by a better transport performance. This implies, as IWT will have a hard time competing on lead time, flexibility and accessibility, that the price must become lower. It is not a static equation with one correct answer. Depending on cost structures (fees), service quality requirements, suitability with

existing infrastructure and equipment etc., the transport mode is chosen. If the context changes, the combined performance of the included factors may result in that alternative transport modes becomes prioritized.

Tradition is also something that affects company's transportation setup, as stated by Garberg (2016) and by some of the interview respondents. When a goods owner has dedicated themselves to one transport mode, there is an inherent aversion towards changing this transportation setup. In order for goods owners to change their mind-set, a change of context must happen, where at least one of the transport quality factors must change in order for the combined performance to favour other transport modes, as one of the respondents meant.

Respondents expressed that tradition affects the modal choice for goods owners in general and in particular for the wood and paper industry. In general, tradition affects all the modal choices, where road transportation has historically been prioritized in Sweden. The small share of IWT identified in Sweden today is believed to be a result of the "Swedish way" where the history has decided the future path to take. Comparing it to countries where IWT is more established and widespread a different approach has been taken where it is instead treated as an integrated component in the system. The governance also differs where a more active commitment towards utilizing the waterways fully can be identified from the study.

For the wood and paper industry in particular, one of the respondents meant that the industry is rather conservative and relies on already established transportation setups. This relates to the willingness to try new options in the form of IWT, where a stable base volume is needed in order to get projects going. The need for a proven concept is considered big, as goods owners seek reliable transportation setups, but in order to be able to display the transport performance of such a transport setup, the base volume is needed. As there already exist projects aimed at using the inland waterways for transports, these need to be promoted and sponsored to show the industry that their reliability concern will be taken care of and their goods will arrive to the customers on time.

As **sustainability** is a big part of the reason to promote IWT in Sweden, the potential can also be highlighted from an environmental friendly perspective. During the interview with the shipping company, also responsible for producing new IWT vessels, sustainability of the transport mode was discussed. Brons and Christidis (2013) mean that the development of the other transport modes is at a more rapid pace, putting IWT vessels under pressure. However, the respondent explained that the new vessels produced are "beyond legislation", performing well above the requirements demanded by regulations. These vessels use LNG fuels which is the reason for the better performance. Even though being 15-20% more expensive to manufacture and thus also more expensive to purchase, there are industries looking beyond the price of a vessel to be able to align their logistics operations with their sustainability goals.

Electrification of the vessels travelling along the waterways is also possible which would strengthen the transport modes sustainability claim even more.

The **socio-economic performance** can also be improved by establishing new IWT transport solutions where the interviewed consultants explained that with the right prerequisites in place, positive outcomes can be generated. This also points at the importance of streamlining the supply chain to reduce the amount of transhipments and strategically place the nodes in order for the transports to be performed effectively.

7.2 Containerization for IWT

With the understanding of containers being a high potential area for IWT in Sweden, the "Container Case" was constructed to highlight suitable goods for containers and how they currently are transported in the focus area. Looking into the factors affecting a container shuttle between Gothenburg and Kristinehamn, the report written by WSP (2015) have concluded the situation by presenting a SWOT-analysis (See figure 3.5).

The strengths are put forward as firstly a strategic location with proximity to available volumes of import- and export flows with good connecting infrastructure. There are also already established terminals with available port functions. These can be concluded as major strengths and considered prerequisites for freight operations. They are also internal factors, as Wiegmans & Witte (2017) suggest. Concluded to also constitute a prerequisite for this is a container depot connected to the port, to facilitate empty container positioning, which have good possibilities to be established. With the internal factors in place, there are also strengths identified as external factors which represent the collaborations between the shipping companies' active in the region.

Opportunities are presented as the capacity constraints in the land infrastructure together with the underutilized capacity in the waterways. This is exactly why IWT has large potential to be used as a mean to achieve a more balanced transport system. As one IWT vessel carrying containers can remove up to 130 truckloads from the road infrastructure, the opportunities are considered large. The renovation of the locks in Trollhättan has also been decided, where the capacity in turn will increase, giving even more incentives for establishing this IWT solution.

The weaknesses and threats relates to all the factors causing IWT to not be considered a truly competitive mode of transport compared to the others as stated by Mircetic et al (2017). These factors are also included in the barriers and key issues for IWT presented by Rogerson & Santén (2018). There are pieces of the puzzles that need to be put in place for IWT to truly live up to its full potential, which are highlighted in different ways throughout this thesis. A long-term availability of goods volumes is needed in order for the initiators (see the following section) to be able to display proven concept for the industry, hopefully to result in a change

in transportation setup which is also needed from the industry. This implies the importance of attracting goods volumes, which is considered as a main driver for the other factors to be able to change in favour of IWT. The other threats included in the SWOT-analysis relates to the IWT framework, and discussed in the following section.

7.3 The decision makers

IWT solutions are available and potential for an increased utilization of the Swedish waterways is undeniable. The question of why the transport system remains unbalanced leads to the discussion of how the framework controlling the rules and regulations affects IWT. In order to display this, the decision-makers are grouped into three different levels where the following model has been created (see figure 7.1):

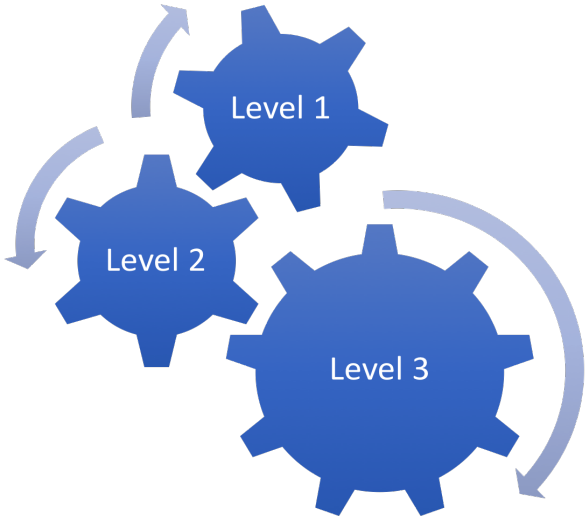

Figure 7.1. Model of the three levels of decision-makers

- **Level 1: Authorities**
  - European commission
  - Swedish government with politicians
  - Transportstyrelsen
  - Sjöfartsverket
  - Other involved authorities
- **Level 2: Initiators**
  - Shipping companies (Avatar Logistics)
  - Municipalities with focused IWT associations
  - Research institutes (SSPA, authors of this thesis)
- **Level 3: Goods owners**
  - Companies generating goods flows

The authorities in the first level of decision making sets the overall rules for the transport system. The rules and regulations for transportation is decided where missions are delegated

to the other authorities involved, e.g. Sjöfartsverket. A holistic approach where a prosperous transport system should be the overall goal where the efforts should be aimed at achieving balance and utilizing the infrastructure in the best possible way. The example of implementing the NAIADES II only partially with technical alleviations on the vessels displays insufficient efforts at trying to increase the utilization of the waterways. From the understanding gathered from this study, the holistic approach from the authorities is questioned by the authors.

The second level represents the initiators. This is where the work aimed at promoting IWT is done. A big actor in this level is Avatar Logistics, actively trying to establish logistics solutions for IWT. This is also where the biggest optimism towards the transport mode is identified and where the potential for IWT is trying to be captured. Such initiators play a big role in promoting IWT and changing the rules of the game in order to be able to meet customer demand with competitive offers.

Included here are also municipalities active in the promotion, where a self-interest for an increased use of the port services is present as the ports located around lake Vänern and Göta Älv river often are owned by the municipalities. Research institutes such as SSPA also contributes with investigations and research aimed at promoting IWT, where this thesis is included.

The third and last level of the model constitutes the goods owners. These are the ultimate decision makers of how goods are being transported. As discussed in the beginning of this chapter, their modal choice depends on several factors but with the right prerequisites, decisions will be taken in different ways and alternative transport modes will probably be used to a larger extent. The first level of decision makers needs to see the underlying levels as an extension of their own organisation and facilitate the necessary work carried out in the second level, which in turn can affect the third and ultimate level to make their transport choices according to what is needed to create balance in the transport system. Just as streamlining a supply chain, the different levels and their intersections need to be fine-tuned to achieve a better output.

7.3.1 The pilot fee system

As accounted for in the empirical findings, the pilot fee system is affecting the economic perspective of transportation. It is classified as a regulatory barrier for an increased IWT in Sweden by Rogerson & Santén (2018). The situation of IWT in Sweden, and specifically on lake Vänern and Göta Älv river, has been examined in this study where this is a hot topic among those whose daily work revolves around IWT. The respondent from one of the shipping companies explained that approximately half of his working time has been allocated to process authorities with the aim of facilitating IWT in Sweden. This implies the large impact the pilot fee system has on the potential for an increased usage of IWT.

As this is considered to be outside of the scope of the study, that mainly focuses on the goods flow mapping, it could be argued that this topic thus should be delimited. However, as it would be unrealistic to discuss a future potential for IWT without addressing the pilot fee system, it is included to the degree of where it is explained and concluded to need revision. Further investigation of how the framework should be composed is therefore delimited.

What can be concluded without digging too deep is that if Sweden wants to accomplish balance in the transportation system and reduce external effects of transportation, a holistic approach must be taken where the different systems for the transport modes needs to be integrated as one entity. Political processes are slow and the administrative processes are ineffective, which the actors trying to establish goods flows on the waterways, are well aware of. This results in less actors willing to take a chance to try to establish transportation setups using IWT to any larger extent than today. There are goods flows suitable for IWT to and from the port of Gothenburg, utilizing lake Vänern and Göta Älv river, but the rules of the game needs to be changed in order for the transport system to become more balanced. The respondents advocate a new classification of IWT to be able to achieve a framework imposing equal shares of fees to IWT, rail- and road transportation.

8. Conclusions

The purpose of this study was to identify potential for an increased usage of IWT in lake Vänern and Göta Älv river, based on existing goods flows. To fulfil this purpose, research questions were formulated, which have guided the project. The first research question is answered by the goods flow mapping, where the three counties' inbound- and outbound goods flows have been accounted for in chapter 4. This question addresses all goods flows on an aggregated level, whereas the rest of the study is focused on IWT. A comparative analysis of the goods flows between the counties is also presented in order to highlight the flows in the area around lake Vänern and Göta Älv river, that provides understanding related to the first research question. To provide a summarized answer to the first research question – "What are the inbound- and outbound flows in the counties of Värmland, Västra Götaland and Örebro", figure 4.2 answers exactly this:

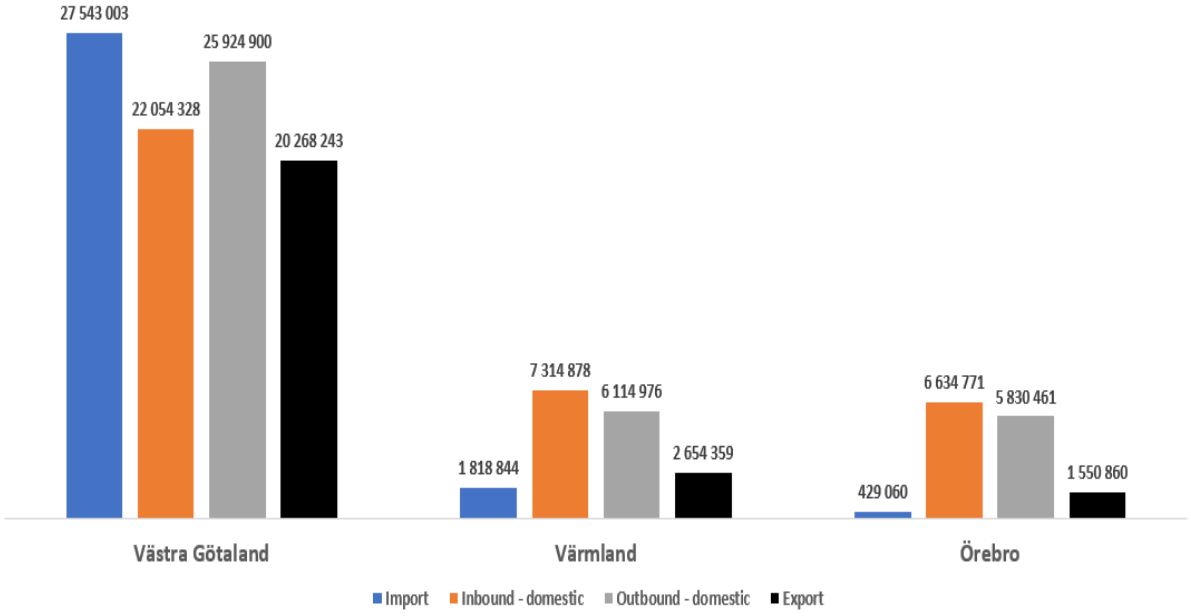

Figure 4.2. Bar chart of inbound- and outbound goods flow in respective county

Research question 2a, "Which goods types are suitable?", is answered by comparing the statistics of the most commonly transported goods types both in Sweden and in Europe and then matching these with the included commodities in the secondary data. 26 commodities where identified as suitable for IWT. However, after investigation, *roundwood* can be concluded as not transferable goods flows due to the geographical location and nature of the sourcing of the raw material for the wood and paper industry. Additionally, 35 commodities were identified as suitable for containerisation, which also provides insight on which goods types that are suitable for IWT.

To answer research question 2b, "What potential goods flows exist in the geographical area that could be transferable?" the goods volumes has been summarized to approximately 5.430.000 tonnes, representing 182.000 road transports. The answer to research question 2c

“What potential is there for containerisation?”, lies within these numbers as well, where the constructed container case intends to assist this investigation. In total 3.900.000 tonnes are carried by road transportation in the container case, representing 131.000 road transports. However, these answers are rough estimations due to the difficulty to identify reasonable averages for different flows of commodities.

Research question 2d, “How do actors in the supply chain consider the use of IWT?” is answered by chapter 6 where the interviews conducted are presented. It can be concluded that there is a positive attitude towards IWT and with the right prerequisites and proven concept, there exist goods flows that could utilize the waterways to a higher degree.

Question 2abcd provides the insight and knowledge needed to answer the overall research questions of what potential that can be identified for an increased usage of IWT in lake Vänern and Göta Älv river. As this study has mainly focused on goods flows, since being a part of the work package “goods flow mapping”, the main findings show that there are existing goods flows suitable for a transfer from the road network to the inland waterways, if barriers and key issues can be solved. The exact quantification of this cannot be presented through this study since there are several other factors affecting the real potential.

This study concludes that there is undeniable potential for an increased usage of IWT in Sweden, but that there needs to be structural changes made relating to the Swedish IWT framework in order to facilitate a balanced transport system. The potential for an increase usage of IWT in lake Vänern and Göta Älv river is hard to quantify, due to the different contexts and different factors affecting their suitability for IWT. Reliability, flexibility, connectivity and cost are decisive factors influencing the modal choice for goods transports and especially the suitability for IWT.

9. List of References

Abbasi, M. & Nilsson, F. (2016). Developing environmentally sustainable logistics: Exploring themes and challenges from a logistics service providers’ perspective. Transportation Research Part D, Vol. 46, pp.273-283.

Bhattacharya, A., Kumar, S. A., Tiwari, M. K. & Talluri, S. (2014). An intermodal freight transport system for optimal supply chain logistics. Transportation Research Part C, Vol. 38, pp.73-84.

Brons, M. & Christidis, P., 2013. External Cost Calculator for Marco Polo Freight Transport Project Proposals. Call 2013 Version. Joint Research Centre, Seville, Spain.

Caris, A., Limbourg, S., Macharis, C., van Lier, T. & Cools, M. (2014). Integration of inland waterway transport in the intermodal supply chain: a taxonomy of research challenges. Journal of Transport Geography, vol. 41, pp. 126-136.

Crainic, T. D. & Kim, K.H. (2007). Chapter 8 Intermodal Transportation. Handbooks in Operations Research and Management Science. Vol. 14, pp.467-537.

Danielis, R. & Marcucci, E. (2007). Attribute cut-offs in freight service selection. Transportation Research Part E, Vol. 43, pp.506-515.

Erceg, B. C. (2018). Legal Framework of European Inland Waterways and Croatian Legislation on Inland Waterways Navigation – Problems of Non-Harmonized Rules. European Scientific Journal.

European Commission. (2018). 2050 long-term strategy. Retrieved 2019-03-01 from www.slv.se/en-gb/group1/Food– Health/Keyhole-symbol/.

Flodén, J., Bärthel, F. & Sorkina, E. (2017) Transport buyers choice of transport service – A literature review of empirical results, Research in Transportation Business & Management, Volume 23, Pages 35-45,

Franc, P. & Van Der Horst, M. (2010). Understanding hinterland service integration by shipping lines and terminal operators: a theoretical and empirical analysis. Journal of Transport Geography, Vol. 18(4), pp. 557-566.

Garberg, B. (2016). Regeringsuppdrag: Analys av utvecklingspotentialen för inlands- och kustsjöfart i Sverige. Norrköping: Sjöfartsverket.

García-Menéndez, L., Martínez-Zarzoso, I. & De Miguel, D-P (2004). Determinants of Mode Choice between Road and Shipping for Freight Transport: Evidence for Four Spanish Exporting Sectors. Journal of Transport Economics and Policy, vol. 38(3), pp.447-466.

Hao, C. & Yue, Y. (2016). Optimization on Combination of Transport Routes and Modes on Dynamic Programming for a Container Multimodal Transport System. Procedia Engineering, vol. 137, pp. 382-390.

Jacobsson, S., Arnäs, P. O. & Stefansson, G. (2017). Access management in intermodal freight transportation: An explorative study of information attributes, actors, resources and activities. Research in Transportation Business & Management, Vol. 23, pp.106-124.

Jonsson, P., & Mattsson, S.-A. (2011). Logistik - Läran om effektiva materialflöden. Lund: Studentlitteratur AB.

Liedtke, G. & Carillo, D, G, C. (2012). Assessment of policy strategies to develop intermodal services: The case of inland terminals in Germany. Transport Policy, Vol. 24, pp. 168-178.

Lindgren, S. & Vierth, I. (2017) Vad styr valet av trafiskslag för godstransporter? En kunskapsöversikt. Diarienr. 2016/0634-7.4. VTI, Linköping.

Llano, C., De la Mata, T., Díaz-Lanchas, J. & Gallego, N. (2017). "Transport-mode competition in intra-national trade: An empirical investigation for the Spanish case," Transportation Research Part A: Policy and Practice, vol. 95(C), pp. 334-355.

Lumsden, K. (2006). Logistikens grunder. Lund: Studentlitteratur, AB.

Lu Li, R. Z. & Jian, W. (2018) Reliability analysis on rail. International Journal of Transportation Science and Technology.

Macharis, C., Caris, A., Jourquin, B. & Pekin, E. (2011). A decision support framework for intermodal transport policy.

Medda, F. & Trujillo, L. (2010) Short-sea shipping: an analysis of its determinants. Maritime Policy & Management, Vol. 37(3), pp.285-303.

Meers, D. & Macharis, C. (2015). Prioritization in modal shift: determining a region's suitable freight flows. European Transportation Research, Vol. 7(23), pp.1-12.

Meixell, M. J. & Norbis, M. (2008). A review of the transportation mode choice and carrier selection literature. The International Journal of Logistics Management, Vol. 19(2), pp.183-211.

Mircetic, D., Nikolicic, S., Bojic, S. & Maslaric, M. (2017). Identifying the barriers for development of inland waterways transport: a case study. MATEC Web Of Conferences, (November 8, 2017), vol. 134, pp. 1-6.

Mommens, K. & Macharis, C. (2014). Location analysis for the modal shift of palletized building materials. Journal of Transport Geography, Vol. 34, pp.44-53.

Naim, M. M., Potter, A. T., Mason, R. J. & Bateman, N. (2006) The role of transport flexibility in logistics provision. The International Journal of Logistics Management, Vol. 17(3), pp.297-311.

Neise, Rolf. (2018). *Container logistics: the role of the container in the supply chain*. [Books24x7 version] Available from: http://common.books24x7.com.proxy.lib.chalmers.se/toc.aspx?bookid=141405. [19-03-12].

Nortsearegion. (2019). Inland Waterway Transport (IWT) offers relatively slow, cheap, climate friendly hinterland transport alternatives for commodities transported in large quantities or bulk. The energy input per t/km is superior to rail, road transport. Many waterways in Europe remain widely un-/underused in the past decades. Retrieved 2019-02-17 from https://northsearegion.eu/iwts20/.

Notteboom, T. & Cariou, P. (2013) Slow steaming in container liner shipping: is there any impact on fuel surcharge practices?, The International Journal of Logistics Management, Vol. 24(1), pp.73-86.

Pierrehumbert, R. (2016). How to decarbonize? Look to Sweden, Bulletin of the Atomic Scientists, Vol.72(2), pp.105-111.

Reis, V. (2014). Analysis of mode choice variables in short-distance intermodal freight transport using an agent-based model. Transportation Research Part A, Vol. 61, pp.100-120.

Rodrigue, J-P., Comtois, C. & Slack, B. (2015). The Geography of Transport Systems, New York: Routledge.

Rogerson, S., Santén, V., Svanberg, M., Williamsson, J. & Woxenius, J. (2018) Modal shifts to inland waterways: dealing with barriers in two Swedish cases. Pp. 1-8.

Roso, V., Woxenius, J. & Lumsden, K. (2009). The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography, vol. 17(5), pp.338-345.

Sihn, W., Pascher, H., Ott, K., Stein, S., Schumacher, A. & Mascolo, G. (2015). A green and economic future of inland waterway shipping. The 22nd CIRP conference on Life Cycle Engineering, pp.317-322.

SSPA. (2019). Inland Waterway Transport Solutions (IWTS). Retrieved 2019-02-15 from https://www.sspa.se/how/research/inland-waterway-transport-solutions-iwts.

Visser, J., Konings, R., Wiegmans, B. & Pielage, B-J. (2007). A new hinterland transport concept for the port of Rotterdam: organisational and/or technological challenges? Research in agricultural & applied economics. Pages: 22.

Wiegmans, B. & Konings, R. (2015). Intermodal Inland Waterway Transport: Modelling Conditions Influencing Its Cost Competitiveness. Asian Journal of Shipping and Logistics, vol. 31, no. 2, pp. 273-294.

Wiegmans, B., Witte, P. & Spit, T. (2015). Characteristics of European inland ports: A statistical analysis of inland waterway port development in Dutch municipalities. Transportation Research Part A, Vol.78, pp.566-577.