IMPROVING COST-EFFICIENCY AND REDUCING ENVIRONMENTAL IMPACTS OF INTERMODAL TRANSPORTATION WITH DRY PORT CONCEPT – MAJOR RAIL TRANSPORT CORRIDOR IN BALTIC SEA REGION

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Abstract

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Transportation plays a major role in the gross domestic product of various nations. There are, however, many obstacles hindering the transportation sector. Cost-efficiency along with proper delivery times, high frequency and reliability are not a straightforward task. Furthermore, environmental friendliness has increased the importance of the whole transportation sector. This development will change roles inside the transportation sector. Even now, but especially in the future, decisions regarding the transportation sector will be partly based on emission levels and other externalities originating from transportation in addition to pure transportation costs. There are different factors, which could have an impact on the transportation sector. IMO’s sulphur regulation is estimated to increase the costs of short sea shipping in the Baltic Sea. Price development of energy could change the roles of different transport modes. Higher awareness of the environmental impacts originating from transportation could also have an impact on the price level of more polluting transport modes. According to earlier research, increased inland transportation, modal shift and slow-steaming can be possible results of these changes in the transportation sector. Possible changes in the transportation sector and ways to settle potential obstacles are studied in this dissertation. Furthermore, means to improve cost-efficiency and to decrease environmental impacts originating from transportation are researched.

Hypothetical Finnish dry port network and Rail Baltica transport corridor are studied in this dissertation. Benefits and disadvantages are studied with different methodologies. These include gravitational models, which were optimized with linear integer programming, discrete-event and system dynamics simulation, an interview study and a case study. Geographical focus is on the Baltic Sea Region, but the results can be adapted to other geographical locations with discretion.

Results indicate that the dry port concept has benefits, but optimization regarding the location and the amount of dry ports plays an important role. In addition, the utilization of dry ports for freight transportation should be carefully operated, since only a certain amount of total freight volume can be cost-efficiently transported through dry ports. If
dry ports are created and located without proper planning, they could actually increase transportation costs and delivery times of the whole transportation system. With an optimized dry port network, transportation costs can be lowered in Finland with three to five dry ports. Environmental impacts can be lowered with up to nine dry ports. If more dry ports are added to the system, the benefits become very minor, i.e. payback time of investments becomes extremely long.

Furthermore, dry port network could support major transport corridors such as Rail Baltica. Based on an analysis of statistics and interview study, there could be enough freight volume available for Rail Baltica, especially, if North-West Russia is part of the Northern end of the corridor. Transit traffic to and from Russia (especially through the Baltic States) plays a large role. It could be possible to increase transit traffic through Finland by connecting the potential Finnish dry port network and the studied transport corridor. Additionally, sulphur emission regulation is assumed to increase the attractiveness of Rail Baltica in the year 2015. Part of the transit traffic could be rerouted along Rail Baltica instead of the Baltic Sea, since the price level of sea transport could increase due to the sulphur regulation. Both, the hypothetical Finnish dry port network and Rail Baltica transport corridor could benefit each other. The dry port network could gain more market share from Russia, but also from Central Europe, which is the other end of Rail Baltica. In addition, further Eastern countries could also be connected to achieve higher potential freight volume by rail.

Keywords: Dry port concept, rail transportation, intermodal transportation, Rail Baltica, transport corridor, Baltic States, Russia, Finland, environmental impacts
Articles

The thesis consists of an introductory part and the following seven articles:


Contribution of the author

Publication I
Main author. Gathered most of the data. Created the models and conducted the analysis required for the paper. Participated in all stages of preparing the paper and wrote most of the paper. The paper was accepted through a double-blind review process.

Publication II
Main author. Gathered most of the data. Created approximately half of the models. Participated in all stages of preparing the paper and wrote most of the paper. The paper was accepted through a double-blind review process.

Publication III
Co-author. Did most of the literature review. Participated in all stages of preparing the paper. The paper was accepted through a double-blind review process.

Publication IV
Main author. Did most of the empirical part of the paper, discussion and conclusions. Co-author was mainly responsible of the literature review. The paper was accepted through a double-blind review process.

Publication V
Main author. Data gathering and creation of analysis with the second author. Wrote most of the paper. The paper was accepted through a double-blind review process.

Publication VI
Co-author. Made one-week visit to Estonia to gather data for empirical part of the article. In addition, wrote most of the empirical part of the article.

Publication VII
Co-author. Made the simulation model, which was used to research the topic. In addition, did write most of the empirical part of the article.
Acknowledgements

The journey from the start of the dissertation process to the public examination has been quite a long, enjoyable and foremost a very interesting ride. This work would not have been possible without assistance and support from various people.

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Last, but definitely not the least, is my family. Thank you - my beloved wife Emmi - for such a great support during the whole journey. I am truly thankful for your love, patience and understanding. Furthermore, my sons - Valtteri, Veeti and Viljami - earn a great gratitude for being such a brilliant guys! You have taught me the most important things of life. In addition, it has been very easy to put the dissertation and work in the background, when I arrive at home and have delightful discussions, games and plays with you.

Kouvola, September 2015

Ville Henttu
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<th>Definition</th>
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<tr>
<td>BSR</td>
<td>Baltic Sea Region</td>
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<tr>
<td>CO₂e</td>
<td>Carbon Dioxide Equivalent</td>
</tr>
<tr>
<td>DES</td>
<td>Discrete-Event Simulation</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
</tr>
<tr>
<td>ILU</td>
<td>Intermodal Loading Unit</td>
</tr>
<tr>
<td>JSC RZD</td>
<td>Russian Railways</td>
</tr>
<tr>
<td>LNG</td>
<td>Liquefied Natural Gas</td>
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<tr>
<td>PPP</td>
<td>Public-Private-Partnership</td>
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<tr>
<td>SD</td>
<td>System Dynamics</td>
</tr>
<tr>
<td>SECA</td>
<td>Sulphur Emission Control Area</td>
</tr>
<tr>
<td>TEN-T</td>
<td>The Trans-European Transport Network</td>
</tr>
<tr>
<td>TEU</td>
<td>Twenty-Foot Equivalent Unit</td>
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</table>
Part I: Overview of the thesis
1 INTRODUCTION

1.1 Research Background and Motivation for the Research

Transportation plays a significant role both in global cost structure and environmental impacts. Transportation sector employed more than 10 million people and accounted for 4.6 percent of gross domestic product (GDP) in the European Union (EU) in the year 2010 (European Commission, 2011b, 2013a). Furthermore, it is the only sector that has just recently been able to decrease greenhouse gas (GHG) levels, but this is mainly the consequence of the recession, which decreased the demand of the transportation sector temporarily (European Commission, 2013a), i.e. global emissions originating from the transportation sector have increased each year until a small drop during the years 2008-2010. At the same time, other main sectors have maintained or decreased their emission levels during the last three decades (European Commission, 2013a). Total carbon dioxide equivalent (CO$_2$e) emissions were nearly 5,006 million tons in EU-27 countries in 2010, whereas the same emissions originating from the transportation sector were almost 1,220 million tons, which accounts for about 24 percent of total CO$_2$e emissions, i.e. transportation sector creates almost a fourth of the total CO$_2$ emissions in EU-27 countries. At the same time, in 1990 total CO$_2$e emissions were 5,766 million tons in total in EU-27 countries, but the transportation sector polluted 959 million tons, which accounted for less than 17 percent of total emissions (European Commission, 2013a).

Even though various regulations motivate to decrease global emissions (see e.g. European Commission, 2001 and 2011a), they have still increased steadily at the world level as is illustrated in Figure 1. EU has set different emission reduction targets multiple times. Targets for the year 2020 were set by the EU in 2007 (base year is 1990), and they were accepted through the climate and energy package in 2009 (European Commission, 2014b). The targets are: 20 percent reduction of GHGs, 20 percent of energy consumption in the EU should originate from renewable sources and 20 percent reduction in primary energy consumption by improving energy efficiency. Updated objectives were set in White Paper (European Commission, 2011a), and the target year is 2050 (base year is again 1990): No more conventionally-fueled cars inside EU
member cities, 40 percent use of low carbon fuels in aviation, 40 percent decrease in shipping emissions, 50 percent shift of medium distance passenger and freight journeys from the road to rail or sea transport and the aim is that the above-described reduction targets will decrease emissions originating from the transportation sector by 60 percent by 2050.

![Figure 1 Global CO₂ emissions during 1960-2010 (in kilotons). Source: World Bank (2014)](image)

Importance of the environmental sustainability is visible also in the private sector (especially in larger companies located in developed countries). Many companies have started to create sustainability reports (see e.g. IKEA Group, 2012; Nokia, 2014; The Volvo Group, 2014) during the last five or ten years (Morhardt, 2009). Sustainability normally includes three main aspects, which are economic, social and environmental sustainability (Hansmann et al., 2012; Orlitzky et al., 2011). It is very visible that maintaining sustainability is one of the most important goals of the private sector. Summary of the sustainability report outcomes regarding transportation, environmental measures and other environmental aspects in observed companies can be seen in Table 1.
Table 1 Summary of companies’ sustainability reports.

<table>
<thead>
<tr>
<th></th>
<th>Transportation</th>
<th>Environmental measures</th>
<th>Other environmental aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finnair</td>
<td>Optimization of fleet</td>
<td>Fuel saving measures, CO₂ measures</td>
<td>Waste recycling, biodiesel, energy consumption</td>
</tr>
<tr>
<td>H&amp;M - Conscious actions sustainability report 2012 and 2013</td>
<td>Transportation mode selection to decrease CO₂ emissions (approximately 90% of H&amp;M products from production centers are transported by sea or rail transport)</td>
<td>CO₂ measures</td>
<td></td>
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<tr>
<td>IKEA Group</td>
<td>Increasing volume of less polluting transport modes, straight deliveries from factories to stores (decreasing total distance), utilization of fuel-efficient trucks</td>
<td>CO₂ measures</td>
<td>Increasing filling rate, decreasing package size</td>
</tr>
<tr>
<td>Itella’s principles of environmental accounting 2012</td>
<td>Route planning, combination of transport modes, ecological driving, low-emission biogas, electric vans, natural gas, electric mopeds</td>
<td>CO₂ measures (target is to reduce CO₂ emissions by 30% by 2020 from 2007 amounts)</td>
<td>Carbon-neutral Itella Green: CO₂ emissions are reduced through internal measures, climate projects etc.</td>
</tr>
<tr>
<td>Nokia - People &amp; planet report 2012 and 2013</td>
<td>Public transport usage increased to decrease emissions</td>
<td>GHG measures (targets for GHG levels of offices, CO₂ emissions per employee, CO₂ levels of logistics etc.)</td>
<td>Smaller packages, recycling</td>
</tr>
<tr>
<td>Nokia Siemens Networks - Sustainability report 2011, 2012 and 2013</td>
<td></td>
<td>CO₂ measures</td>
<td></td>
</tr>
<tr>
<td>The Volvo Group - Sustainability report 2012 and 2013</td>
<td>Focuses on most fuel-efficient transport modes or combination of modes to minimize emissions (truck instead of a plane, or train instead of truck if possible)</td>
<td>CO₂ measures, fuel consumption of the product (from 45 to 27 liters per 100 km from year 1975 to 2012)</td>
<td></td>
</tr>
<tr>
<td>UPS - Corporate Sustainability report 2012 and 2013</td>
<td></td>
<td>CO₂ measures (intermodal shifting has decreased CO₂ emissions by 3.3 million tonnes)</td>
<td></td>
</tr>
<tr>
<td>Volkswagen</td>
<td></td>
<td>CO₂ measures</td>
<td></td>
</tr>
<tr>
<td>Wärtsilä Corporation</td>
<td>Transportation optimization</td>
<td>Many annual measures such as CO₂, nitrogen and sulphur oxides</td>
<td>Environmental products and services</td>
</tr>
</tbody>
</table>


As can be seen from Table 1, many of the observed companies have already started documenting how they manage their operations to improve their sustainability. Additionally, the volume of companies creating and updating their sustainability reports have increased significantly during the last fifteen years. GRI (2014) maintains a database, which includes sustainability reports from various companies. There were 3,769 sustainability reports included in the database in the year 2012, whereas only eleven reports were included in 1999.
A regulation possibly impacting the transportation sector in the Baltic Sea Region (BSR; including also Finland) is IMO’s sulphur regulation (Annex VI), which became stricter starting in 2015, i.e. sulphur content of exhaust gas of sea vessels sailing in Sulphur Emission Control Area (SECA, which consists of the North Sea, Baltic Sea, coastline of North America and United States Caribbean Sea) cannot surpass 0.1 percent (IMO, 2014c). Sea vessels can either use more expensive fuel (sulphur content 0.1 percent), implement sulphur scrubbers (they will recover exceeded sulphur) or use alternative non-sulphur fuel. Alternative fuels include e.g. liquefied natural gas (LNG) based sea vessels can be used in SECA, but these are currently very few (Viking Grace is the only one sailing in Baltic Sea during the writing of this thesis; see e.g. Viking Line, 2014). The research shows that sulphur regulation has a large impact on sea transport mode’s cost level. This has been assumed to have some effect also on the whole transportation system, especially in countries near SECA area (e.g. Finland, Sweden, Russia and Baltic States). One of the main impacts could be a considerable shift from sea transport to inland transport mode, since inland transport could become less expensive than sea transport for certain directions and locations near SECA due to increased sea transportation costs. Amount of sea transport in the Baltic Sea and North Sea could decrease, and these freight flows would be partly or wholly conducted by alternative inland transportation (road, rail or inland waterway transport). Efficient and cost-competitive inland transport will play an even larger role, if this change occurs. (Cullinane and Bergqvist, 2014; ECSA, 2010; Entec, 2010; Holmgren et al., 2014; IMO, 2014a, b, c; Jalkanen et al., 2013; Jiang et al., 2014; Kalli et a., 2009; Swedish Maritime Administration, 2009)

There are two principal possible solutions, which could decrease the amount of emissions originating from transportation: Current transport modes can be improved to be environmentally less harmful. Transport modes can also be replaced with other transport modes, which create fewer environmental impacts (Henttu, 2010, 2011; Lättiä et al., 2013; VR Group, 2014). Of all the different transport modes, rail transport creates only about one percent of emissions originating from the transportation sector, since it is not used as much as other transport modes such as sea or road, but also because it creates less environmental impacts than e.g. road transportation. Rail transport’s lower volume of externalities results in less polluting energy sources. If the energy is produced by renewal and low polluting form, emissions originating from rail
are near zero level. However, if the energy is produced by coal plants, rail transport’s environmental benefits decrease. Further advantages can be achieved, because one train can carry significantly more freight than road transport, which increases efficiency and thus economies of scale affecting both cost-efficiency and volume of environmental impacts. Additional competitive advantage is achieved for rail transport due to lower friction, when moving the rolling stock. The friction is higher, if road transport is utilized. (Ahn and Rakha, 2008; European Commission, 2013a, 2014b; Henttu, 2010, 2011; Henttu and Hilmola, 2011; Lätilä et al., 2013; Janic and Vleugel, 2012; Lipasto, 2013; Olofsson and Telliskivi, 2003; Ricci and Black, 2005; Roso, 2009a; VR Group, 2014)

Inland transportation is currently conducted mostly by road transport in Finland, but also in Europe as a whole. Rail transport has its own market share: the share has slightly decreased during the last two decades in the EU (share of rail ton-kilometers of total ton-kilometers if pipelines are excluded was 21 percent in 1995, but 18 percent in 2011 according to European Commission, 2013a), but also in Finnish scale (share of rail ton-kilometers of total ton-kilometers if pipelines are excluded was 28 percent in 1995, but 26 percent in 2011 according to European Commission, 2013a). In addition, regarding the Finnish transportation system, the dry port network is very underdeveloped. Similar pattern is also visible in the north-south direction in the Baltic States (road transport is the main transport mode in this direction using Via Baltica as the main transport corridor). However, east-west directed transit traffic to and from Russia through the Baltic States is dominated by rail transport. This indicates that rail transport can prevail over road transport in a certain environment, if the infrastructure, border-crossing operations and other related factors are in order. (European Commission, 2013a; Eurostat, 2014)

In this dissertation, the focus is on intermodal transportation, in which rail is the main transport mode. On the other hand, other connected transport modes are as important as rail, since they are vital in certain parts of the whole transportation chain. The starting and ending legs are commonly conducted by road transport due to its flexibility. Sea transportation is required to pass sea areas (the Baltic Sea, if Finnish import and export between other European countries are observed). Although rail transport is the main studied transport mode in this thesis, the other transport modes are also researched and
discussed. Furthermore, focus is narrowed towards the dry port concept, which is one way to utilize intermodal transport. This focus was selected, since the dry port concept was not a very deeply researched area in a Finnish geographical context. In addition, the utilization of rail in the dry port concept could create both environmental and cost-efficiency related benefits, which were chosen as the main researched factors in this thesis. There are also other factors, which are affected, if different transportation approaches (e.g. unimodal road transport versus intermodal transport) are used. These factors include e.g. lead time and service level. Cost-efficiency and environmental impacts were chosen to be the main researched factors, since the cost-efficiency plays a major role for the transport service customers. The environmental impacts are not the most important factors for the customers or logistics companies, but the importance is increasing on a yearly basis. Due to various emission level targets (see e.g. European Commission, 2011a, 2014b), it can be assumed that the significance of a reduction of environmental impacts will increase further in the future.

1.2 Research Purpose and Research Questions

Main purpose of this thesis is to study, how cost-efficiency and environmental impact level of freight transportation could be improved. The first main topic of the dissertation is the dry port concept and its possible benefits, if it would be implemented in Finland. In addition, the optimal amount of dry ports is an important aspect, which is studied in this dissertation. The dry port volume is researched both from the viewpoint of minimizing costs and environmental harms. The other main studied target is a global rail transport corridor called Rail Baltica. The available freight volumes are reviewed, since they are vital for the rail transport corridor to be successful. Furthermore, the possible benefits of connecting the dry port network with the global rail transport corridor are discussed. Also, the ability of a connected dry port network and rail transport corridor for tackling different possible factors influencing the price level of transportation are researched. The IMO’s sulphur regulation has been studied to increase the sea freight price level, which could result in a modal shift to inland transportation. The dry port network and rail transport corridor could be one solution for the modal shift. Finally, the importance of transport mode selection and organization of transportation overall is studied.
The main research question is formulated as follows: *What advantages can be achieved by connecting a dry port network with a global rail transport corridor?* The main research question is further divided into four sub-questions:

RQ1: What kind of dry port network would optimize cost-efficiency and environmental impacts?

RQ2: Is there enough demand and willingness to support the dry port network and the rail transport corridor?

RQ3: Could the dry port network and the rail transport corridor improve future outlook regarding IMO’s sulphur regulation?

RQ4: What similarities do patient and freight transportation share, and can these be exploited to improve the cost-efficiency of transportation?

All the sub-questions are answered in different publications included in Part II of this thesis. Table 2 summarizes the connections between different research questions and included publications.

<table>
<thead>
<tr>
<th>Research questions</th>
<th>Publications</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
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<tbody>
<tr>
<td>RQ1: What kind of dry port network would optimize cost-efficiency and environmental impacts?</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RQ2: Is there enough demand and willingness to support the dry port network and the rail transport corridor?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RQ3: Could the dry port network and the rail transport corridor improve future outlook regarding IMO’s sulphur regulation?</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>RQ4: What similarities do patient and freight transportation share, and can these be exploited to improve the cost-efficiency of transportation?</td>
<td></td>
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RQ1 is answered in articles I-III. RQ2 is answered based on articles IV-VI. RQ3 is researched and discussed mainly in articles I and V, whereas RQ4 can be answered based on the results of article VII. All the sub-questions and the main research question are answered in the conclusions chapter at the end of the introductory part of this thesis.

Main studied transport mode is rail, but other related transport modes are also taken into account in the research. Rail transport’s advantages and disadvantages regarding cost structures, price level, transporting freight and pollution in a dry port network and along a major railway corridor are researched. Main geographic context in the first three
articles (these can be found in Part II of this thesis) is Finland. Geographical focus is widened in publications four and five to take also North-West Russia and the Baltic States into account, which are located along the Rail Baltica transport corridor. Sixth article focuses on international rail transportation between Estonia and its rail connection destinations. Seventh article has a different viewpoint, since it studies passenger transportation flows inside a Finnish healthcare district. Seventh article is included in this dissertation to create more versatile discussion and comparison at the end of the dissertation.

1.3 Definitions of Main Terms

Baltic Sea Region

Countries, which border the Baltic Sea, are considered as the Baltic Sea Region (BSR). These countries are Denmark, Estonia, Finland, Germany, Latvia, Lithuania and Russia. However, this thesis mainly focuses on Finland, Russia and the Baltic States.

Transport corridor

In this thesis, transport corridor refers to the main transport corridors located in Europe, which are planned to be created or renovated. The main transport corridor in this dissertation is called Rail Baltica. It is part of the North Sea-Baltic Corridor, which connects sea ports located on the Eastern shore of the Baltic Sea with the sea ports of the North Sea. Rail Baltica rail transport corridor would connect Finland, Estonia, Latvia, Lithuania, Poland and Germany. The connection between Finland and Estonia would be established by short sea shipping. Furthermore, Russia could be connected to the rail corridor, since it is a border neighbor of Finland, Estonia and Latvia i.e. it is located at the Northern end of Rail Baltica.

Freight transportation

This thesis focuses mainly on freight transportation. Freight can be categorized to be e.g. dry bulk or general cargo. Freight transportation is conducted with different transport modes. The main transport modes are road, rail, inland waterway, sea and air
transport. Rail freight market includes all freight transportation, which is transported by rail. When freight is being transported from point A to point B, it is called transport flow.

**Passenger transportation**

Transportation of passengers include transportation of humans. One article included in this thesis studies transportation flows of patients, which is one form of passenger transportation. It also includes both public and private transportation of passengers. Passengers can be transported with similar transport modes other than freight. These include e.g. private vehicles, trains, busses, airplanes and cruise vessels.

### 1.4 Structure of the Thesis

The thesis is divided into two parts. Part I is the introduction of this thesis. Part II includes seven different publications, which are part of this thesis, i.e. the introduction part is based on these seven publications and their results.

Since three out of seven of the author’s journal articles are concentrating on the dry port concept (articles I-III), first literature review chapter explains the dry port concept. The review also takes into account intermodal transport, since the dry port concept is one way of utilizing and organizing of intermodal transport. Next literature review chapter focuses on transit traffic through Finland and the Baltic States (Estonia, Latvia and Lithuania). Transit traffic is reviewed, since it is crucially important for the success of the Rail Baltica transport corridor. Transit traffic could build most of the possible freight volumes in the Baltic States and Finland for Rail Baltica. In addition, transit traffic could be transported through a dry port network. Third literature chapter reviews alternative aspects that have an impact on the price level of transportation (e.g. IMO’s sulphur regulation, which increased its impact at the start of the year 2015).

Chapter 5 explains used methodologies in the published journal and seminar articles, which are part of this dissertation. Publications are summarized in Chapter 6, and discussion and conclusions are made after that in Chapter 7 and Chapter 8. Outline of the thesis is illustrated in Figure 2.
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**PART II**
The original publications

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**Figure 2 Outline of the dissertation.**
2 INTERMODAL TRANSPORTATION AND DRY PORT CONCEPT

Research and practical issues regarding dry ports focus in intermodal freight transportation, i.e. passenger transport is not included in the dry port research. This chapter creates an up-to-date literature review regarding the dry port concept. Due to its intermodal transportation characteristics, intermodal transportation is reviewed and discussed at the start of this chapter.

In freight transportation, there is an optimized co-operation level between rail and road transport, which emits the least and is as well the most sensible cost-wise solution for the customer (VR Group, 2014). This is important when choosing utilization levels of transport modes in intermodal transportation. In most cases, it is not rational to minimize emission levels, since in these cases, the costs of transportation are normally considerably high. Compromise between emission levels and transportation costs is usually the best option. However, companies are not commonly ready to pay more, if it is needed for fewer environmental impacts originating from transportation, i.e. price level is a significantly more important factor than the emission level. (Kim and van Wee, 2011; Macharis et al., 2010; Macharis and Bontekoning, 2004; Rutten, 1998)

2.1 Intermodal Transportation

Research regarding intermodal transportation was very popular during the 1990s (see e.g. Hayuth, 1987; Rutten, 1998; Slack, 1996; Woxenius, 1998). Intermodal transportation is the transportation of intermodal loading units (ILUs) by at least two different means of transport from point A (consignor) to point B (consignee). Freight located inside ILU stays untouched during the whole intermodal journey. Different used transport modes can be, for example, road, rail and sea transport (including inland waterways). Road transportation is only used for the initial and final legs of the intermodal freight movement (Ricci and Black, 2005). An example concerning intermodal transport is visualized in Figure 3. (Hayuth, 1987; Rutten, 1998)
The difference between intermodal and unimodal road transport is that the main transport mode in intermodal transport is a transport mode other than road transport. In Figure 3, principal transport mode for intermodal transport is rail transport. It could also be e.g. sea transport. The ILU is first loaded in the starting point of the intermodal journey. Then it is transported to intermodal terminal A or B by road transport, i.e. road transport is used for the first leg of the transport, unless there is a rail connected terminal available in the starting point. Main leg of the transportation chain is conducted by rail transport between intermodal terminals A and B. Road transport is again utilized to transport freight to its final destination from terminal A or B, where ILU is unloaded. In unimodal road transport, main transport mode is road, which is actually the only used transport mode during the whole transportation chain. (Arnold et al., 2004; Bergqvist, 2008; Hayuth, 1987; Rutten, 1998)

Intermodal terminal is a place, where transport mode can be changed from one to another (e.g. from road to rail, from sea to rail or from sea to road and vice versa). Furthermore, different services can be available at intermodal terminals. These are e.g. storage, depot, maintenance of ILUs and customs procedures. Versatile equipment is available in intermodal terminals, and they can be used to make smooth transshipments between different transport modes. Intermodal terminals have access to at least two separate transport modes. Different transport mode accesses can be, for example, access
to rail and road network and to an airport. In addition, inland waterways can be accessed by some inland intermodal terminals. (Monios, 2011; Rutten, 1998)

Different kinds of intermodal terminals are e.g. sea ports and inland intermodal terminals. Sea ports naturally have access to sea transport, but in most cases also to road and rail transport modes. Inland intermodal terminals are located inland, i.e. they do not have direct sea transport access, unless they have access to inland sea transport via a river or lake. (Monios, 2011; Rutten, 1998)

The most commonly used intermodal load-units are containers, swap bodies and semi-trailers. A container is a simple steel box with standardized measures, construction strength and fastening devices. A swap body is a detachable lorry equipped with support-legs and a semi-trailer is a lorry trailer with rear wheels (Woxenius, 1998). Containers are the most commonly used standard units for unit-load concept as they are designed for easy and fast handling of freight (Vasiliauskas and Barysiené, 2008).

2.1.1 Break-Even Point of Intermodal Transportation

Costs of intermodal transport are composed of both transporting freight and transshipments during the whole intermodal transportation chain (Macharis et al., 2010; Macharis and Bontekoning, 2004). One of the reasons for using intermodal transport lies on the possibility to decrease the total costs of transportation. This is explained in Figure 4.
Figure 4 Cost and distance function of unimodal road transport and intermodal transport.
Source: Modified from Rutten (1998)

Thinner line represents the road transport, whereas the thicker line represents intermodal transport (main transport mode is rail). Total transportation costs of unimodal transport increases with the same speed during the whole observation period. Cost per one kilometer depends on the distance, i.e. longer transport distances can be less expensive per kilometer than shorter ones. The final cost of unimodal transport is more visible and thus easier to calculate for decision-makers. The cost decrease possibility of intermodal transport is based on the possibility of the main transport mode being less expensive than road transport. In the described case in Figure 4, costs per kilometer for rail transport are less than the costs per kilometer for road transport in the unimodal road transport scenario. However, road transport for pre-haulage and post-haulage is more expensive than road transport for the whole transportation distance in unimodal transport. Due to the explained reasons, it is important to utilize rail transport enough so that the break-even point is reached. This is the point, where intermodal transport and unimodal road transport create an equal amount of total costs. If the break-even point is reached and surpassed, then intermodal transport becomes more cost-efficient than unimodal road transport. If the break-even point is not reached, then unimodal road transport creates fewer expenses and is therefore the more cost-efficient transport mode. (Arnold et al., 2002; Havenga, et al., 2012; Macharis et al., 2010)
Furthermore, time of delivery should be considered, when considering the use of intermodal transport. Figure 4 illustrates that freight is not moving in terminal areas, where the freight is transshipped from road to rail or vice versa. This could increase the total delivery time of the freight, if compared to unimodal road transport.

2.1.2 Advantages and Disadvantages of Intermodal Transportation

In long transportation legs, less expensive transport modes can be utilized. Transshipment between different transport modes is not as time-consuming in intermodal transportation, since freight inside the loading unit (e.g. container) stays untouched in the intermodal terminal. Furthermore, rail and sea transport are in most cases creating less environmental impacts than road transport. In addition, greater volumes can be transported with intermodal transport, since trains and especially sea transport vehicles can carry larger freight amounts than one truck. This can create economies of scale and price discount possibilities. (Bontekoning et al., 2004; Choong et al., 2002; Havenga et al., 2012; Rahimi et al., 2008; Ricci and Black, 2005; Roso, 2009a; Slack, 1996; Woxenius, 1998)

Containerization can reduce time spent at intermodal terminals, since handling of containers is faster and simpler due to its standardized characteristics. Also, there is no need for stuffing and stripping in intermodal terminals, i.e. freight inside containers stays untouched in intermodal terminals during transshipment between different transport modes. Damage to goods and packaging costs are thus reduced, since these processes are eliminated at intermodal terminals. Increasing usage of intermodal transportation decreases the utilization of road transport, since the main transport modes of intermodal transportation are other than road (e.g. sea and rail). This development can help locations, which have congested road networks due to considerable freight carrying by road transport vehicles. (Bontekoning et al., 2004; Choong et al., 2002; Ricci and Black, 2005; Roso, 2009a; Woxenius, 1998)

Environmental benefits can possibly be achieved with intermodal transport, since the amount of road transport can be decreased with increased utilization of intermodal transport. Road transport pollutes more emissions than e.g. rail or sea transport even if
diesel locomotives are used (Lipasto, 2013). Size of the sea vessel or train and source of the electricity have an influence on the emission amount per one ton-kilometer (higher fill rate decreases emission per ton-kilometer). In their study, Liao et al. (2009) compared CO₂ emissions between two different scenarios: In the first, truck-only transportation is used for hinterland transportation, and in the second, intermodal coastal shipping is used for long haulage, and road transport for the final transportation leg. Results show that CO₂ emission amounts can be decreased considerably by replacing the road transport with intermodal transport (reduction can be up to 60 percent). According to Hanaoka and Regmi (2011), utilization of Asian dry ports has led to decreased congestion and vehicle emissions in the studied area. In their study, Janic and Vleugel (2012) calculated that by substituting road with rail transport on a chosen Trans-European freight transport corridor, externalities (including e.g. emissions and congestion) could be decreased by approximately 30 percent. Based on Lipasto (2013), diesel train (including shunting) emits 26 g of CO₂ per one ton-kilometer. CO₂ emissions originating from the electric train in Finland are 9.2 g of CO₂ per ton-kilometer, which is 65 percent less than emissions originating from the Finnish diesel train (Lipasto, 2013). Nonetheless, a EURO 5 class semi-trailer combination with 70 percent load pollutes 54 g of CO₂ per one ton-kilometer (Lipasto, 2013). If electricity is created using environmentally friendly renewable energy sources, then rail transport emits almost nothing. If, however, e.g. coal plants are used to create energy, then emission amounts are high. Due to this reason, emission amounts originating from electric trains can vary highly in different geographical locations based on the source of electricity. (Ahn and Rakha, 2008; He et al., 2005; Kousoulidou et al., 2008; Smit et al., 2008; Stanley et al., 2009; Zanni and Bristow, 2010)

However, there are also disadvantages and challenges regarding intermodal transportation. First of all, suitable carriers are needed to transport the ILUs. Furthermore, handling equipment is needed, either attached to the transportation vehicle or located in the intermodal terminal, where transshipment from one transport mode to another is accomplished. In the case of intermodal container transport, empty container management is also important (Chang et al., 2008; Choong et al., 2002; Shintani et al., 2010; Song and Dong, 2011). Managers usually pay attention mainly to loaded containers, but commonly do not take care of empty containers. This could lead to non-efficient transportation. It also has to be noted that there exists transportation
imbalances between different regions, and this hinders empty container management. Additionally, since intermodal transportation utilizes more than one transport mode, the level of complexity of transportation increases. In addition to an increased amount of transport modes, the number of different actors during the transportation chain also increases. This can also impede tracking and tracing of freight. Efficient organization of intermodal transport plays an important role. (Bontekoning et al., 2004; Choong et al., 2002; Ricci and Black, 2005; Roso, 2009a; Woxenius, 1998)

2.2 Dry Port Concept

Dry port concept is a way to perform intermodal transportation. In the concept, sea port is connected by a rail connection with an inland intermodal terminal. Additionally, dry port offers services (depot, consolidation, warehousing, etc.), which are usually offered in a sea port area. Main transportation mode in the concept is rail transport, which can be utilized between the sea port and inland intermodal terminal. Leveque and Roso (2002) and Roso et al. (2009) define the concept as: “A dry port is an inland intermodal terminal directly connected to sea port(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a sea port.” This definition is used in the overview of this thesis and also in publications presented in Part II of this thesis. (Flämig and Hesse, 2011; Hanaoka and Regmi, 2011; Roso, 2008, 2009a, 2009b; Roso et al., 2009)

Various identified benefits of the dry port concept are e.g. increased capacity of the sea port and decreased congestion of the road network. Since rail transport shows better environmental performances than other transport modes (level of environmental impacts depends on how the energy is produced). Approximately 53 percent of the whole Finnish rail network (5,944 km) was electrified at the end of the year 2013, and 65 percent of the Finnish rail traffic energy was produced with renewable energy sources (Finnish Transport Agency, 2014; VR Group, 2014). Figure 5 visualizes the difference between conventional transportation and dry port network implemented transportation. (Bergqvist, 2013; Cullinane and Wilmsmeier, 2011; Roso, 2008, 2009a, 2009b; Roso and Lumsden, 2010)
Upper part of Figure 5 is representing conventional transportation, in which the main transport mode is road transport, i.e. the majority of freight transportation is done by road transport vehicles. In addition, rail transport is used between the sea port and city, but all the other connections between shippers and the sea port are road connections. Numerous road connections to and from the sea port increase the possibility of congestion in the sea port area. In addition, large road transport volume increases environmental impacts of the local transportation system, since road transport emits significantly more than rail transport, especially if alternative rail transport uses electricity (the source of also electricity plays an important role. Renewable energy
sources are considerably more environmentally friendly than e.g. energy produced in a coal plant). However, diesel trains create fewer environmental impacts than road transport overall, but the difference is smaller.

The lower part of Figure 5 represents the dry port concept. In this case, all the shippers are connected to dry ports (there are three different dry ports in Figure 5: short distance, medium distance and long distance). In this case, shippers leave and/or collect the freight from dry ports. Connection between dry ports and the sea port is conducted by rail transport, which decreases the level of congestion, since there are fewer trucks arriving and leaving the sea port, because one train can transport significantly higher volume of freight than one truck. Due to a lower volume of environmental impacts of rail transport, the level of externalities can be decreased by utilizing the dry port concept. However, in Figure 5, all the shippers use dry ports, but this is not usually the case in real life. There is an optimal amount of dry port or rail transport usage in each unique geographical location.

### 2.2.1 Dry Port Characteristics and Different Possible Offered Services

Dry ports can be defined by the distance between the dry port and sea port to close, midrange and distant dry ports (Roso et al., 2009). Different dry ports share similar advantages, but they also have individual benefits. All the different dry ports can decrease congestion in the sea port area, in the sea port city and in the road network. This in turn improves sea port and dry port access for road transport companies and decreases distances traveled by road transport companies. Furthermore, utilization of dry ports makes the modal shift from road to rail possible, which will lead to lower environmental impacts from the transportation system. (Woxenius et al., 2004; Roso, 2009a, b; Roso et al., 2009)

In addition, dry ports can be separated on the basis of how they have been developed. Dry ports are usually connected to one sea port and this complex is called a dry port dyad. According to Wilmsmeier et al. (2011), dry ports are created either inside-out or outside-in. Inside-out development starts from the dry port side, i.e. from the actors located in the hinterland of the sea port. Main driving force for the development of the
Dry port dyad in outside-in development is the sea port. According to Bask et al. (2014), the development of a dry port dyad can also be bi-directional, which is called outside-and-inside.

Dry ports offer similar services as what are offered at sea ports. These are e.g. depot, consolidation, warehousing, maintenance of ILUs, customs clearance and tracking and tracing of ILUs (Roso, 2007). It depends both on the size of the dry port and decision-making of local public and private sectors, what services the dry port offers to its customers. It is possible that all traditional sea port services are offered in the dry port area or only one or two services are available.

2.2.2 Real-Life Dry Port Examples

There are many dry ports located in the world of which two examples are represented in this sub-chapter. These are the dry port network connected to the Port of Gothenburg and a dry port (Virginia Inland Port, VIP) connected to the Port of Virginia. (Railport Scandinavia, 2014; The Port of Virginia, 2014)

The Port of Virginia is located on the east coast of the USA in the state of Virginia (The Port of Virginia, 2014). The sea port consists of five separate facilities, which are Newport News (a roll-on/roll-off bulk terminal), Norfolk (a container terminal), Portsmouth (a bulk and container terminal), Virginia Inland Port (a dry port located in the hinterland of the actual sea port), Virginia International Gateway (a private container terminal) and Richmond (an inland river terminal). VIP is naturally connected to all the facilities of the Port of Virginia. VIP allows the actual sea port, the Port of Virginia, to extend itself inland by circa 350 km, which is the distance between the sea port and the dry port, i.e. VIP is a midrange dry port (The Port of Virginia, 2014). The implemented dry port in the hinterland of the Port of Virginia improves competitiveness of the sea port. More than 2.2 million twenty-foot equivalent units (TEUs) were transported through the Port of Virginia in the year 2013, which has so far been the highest container throughput of the sea port. 34 percent of the cargo was transported by rail from and to the sea port area, whereas road transport was used for 62 percent of
cargo flows and barge for 4 percent. There are five train departures to and from VIP during each week. (The Port of Virginia, 2014)

A good example of efficiently operating a dry port network can be found from Sweden. Port of Gothenburg (the sea port is located in the South-West of Sweden) is the main Swedish container sea port with 858,000 TEUs transported in the year 2013. 393,000 of these were transported by rail from and to the Port of Gothenburg in 2013 (Port of Gothenburg, 2014a, b), which accounts for about 46 percent. Port of Gothenburg has a rail connection to 22 inland intermodal terminals located in Sweden. Part of these can be defined as dry ports, and the most part as conventional inland terminals. The main difference is in the service level: Dry ports offer a higher variety of services, whereas conventional inland terminals may only offer transshipments between road and rail transport modes. There are in total 24 daily train shuttles (six shuttles were available in 2006), which transport containers between the Port of Gothenburg and inland intermodal terminals. Rail shuttle service has been able to decrease the share of road transportation, which led to a decrease of 60,700 tons of CO₂ in the year 2012 (Railport Scandinavia, 2014).

One of the main characterizing factors of many dry ports is the fact that they have a rail connection to a sea port, which has a deep-sea transport connection and high container throughput volume. Explanatory factor for this could be that freight transported by deep-sea transportation is not in much of a hurry when it is transshipped in the final sea port. The journey has already taken many days or even weeks and thus the final lead time is not that critical (according to SeaRates, 2014, it will take more than 30 days to reach the Port of Shanghai from the Port of Rotterdam). In the case of short-sea shipping, fast lead time is often more important and thus faster transshipments and final transport modes are accomplished. Road transport is normally the fastest, since utilization of road transport after the sea port usually eliminates the usage of one additional transport mode. If rail transport is utilized after the sea port, usually road transport is also needed at the end of the journey, because rail can only rarely transport the freight to its final destination.
2.2.3 Main Researched Topics Regarding Dry Port Concept

Most researched topics concerning the dry port concept during the last five to ten years are represented in the following sub-chapters. Costs of transportation and possibility to decrease these costs with dry port implementation in the transportation system is one of the researched areas, but there are not that many studies addressing this problem (see e.g. Kim and van Wee, 2011; Cullinane and Wilmsmeier, 2011). This is one reason why costs and how to decrease them with a dry port network is researched in this dissertation. On the other hand, public-private-partnership (PPP) is studied in many research articles (e.g. Bergqvist and Egels-Zandén, 2012; Rodrigue et al., 2010), since this kind of relationship is needed in most geographical locations, if dry ports are implemented. This is due to the reason that dry ports are rather expensive to create, and they also need commitment from both the public and private sector to gain enough cargo flows to justify their existence. Regionalization is also quite a researched area: dry ports are always part of some certain region and thus have more influence for nearby rather than farther locations (Liao et al., 2009; Monios, 2011). Rail transport’s ability to create fewer environmental impacts have gained awareness for decades, and this has also resulted in some research works (see e.g. Hanaoka and Regmi, 2011), which estimate the dry port network’s environmental benefits. Black et al. (2013) created a list of success factors of dry ports defined by previous studies. The list is presented in Table 3.
Table 3 Success factors of dry ports defined by various authors.

<table>
<thead>
<tr>
<th>Success factor</th>
<th>Defined by author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced information systems</td>
<td>Roso (2012); Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Better usage of regional transport infrastructure</td>
<td>Rodrigue and Notteboom (2012)</td>
</tr>
<tr>
<td>Capacity problems in seaport reduced</td>
<td>Roso et al. (2009); Roso (2008); Rodrigue and Notteboom (2012); Cullinane and Wilmsmeier (2011)</td>
</tr>
<tr>
<td>Container tracking</td>
<td>Hanaoka and Regmi (2011); Roso (2012)</td>
</tr>
<tr>
<td>Cooperation between the actors of the transport system</td>
<td>Roso (2012); Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Coordination among various government agencies</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Development of supporting infrastructure</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Development of value added services</td>
<td></td>
</tr>
<tr>
<td>Discuss operational agreements in advance</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Double-stack trains</td>
<td></td>
</tr>
<tr>
<td>Emission reductions</td>
<td>Roso and Rosa (2012); Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Expanding or reinforcing hinterland</td>
<td>Cullinane and Wilmsmeier (2011); Roso (2012); Roso and Rosa (2012)</td>
</tr>
<tr>
<td>Facilitating international trade</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Good intermediary location</td>
<td>Rodrigue and Notteboom (2012)</td>
</tr>
<tr>
<td>Government logistics policies/support</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Lower cost of living to attract distributions centres into area</td>
<td>Cullinane and Wilmsmeier (2011)</td>
</tr>
<tr>
<td>Lower distribution cost</td>
<td>Roso et al. (2009); Hanaoka and Regmi (2011); Cullinane and Wilmsmeier (2011)</td>
</tr>
<tr>
<td>Lower land cost and taxes</td>
<td>Cullinane and Wilmsmeier (2011)</td>
</tr>
<tr>
<td>Market driven development</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Marketing support by local economic agencies and state</td>
<td>Cullinane and Wilmsmeier (2011)</td>
</tr>
<tr>
<td>Modal shift from road to rail</td>
<td>Roso et al. (2009); Hanaoka and Regmi (2011); Cullinane and Wilmsmeier (2011)</td>
</tr>
<tr>
<td>Public-private ownership or government</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Railway connection</td>
<td>Roso et al., (2009); Roso and Lumsden (2010); Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Stimulating economic development</td>
<td>Roso (2009a); Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Streamlining of institutional and regulatory frameworks</td>
<td>Hanaoka and Regmi (2011)</td>
</tr>
<tr>
<td>Temporary warehousing facility</td>
<td>Rodrigue and Notteboom (2012); Cullinane and Wilmsmeier (2011)</td>
</tr>
</tbody>
</table>

Source: Modified from Black et al. (2013)
2.2.3.1 Costs of Transportation

Large part of the dry port research focuses mainly or at least partly on the possibility to decrease costs of transportation by implementing a dry port or dry ports (see e.g. Chang et al., 2008; Choong et al., 2002; Cullinane and Wilmsmeier, 2011; Flämig and Hesse, 2011; Henttu and Hilmola, 2011; Henttu et al., 2011). This is quite a natural research focus, since the implementation of a dry port requires high investments, and these investment costs should be covered after implementation of the dry port during the predefined time-span. Otherwise, if investment costs cannot be covered, then implementation of a dry port is most probably not sensible, since it costs more than it creates revenues or profits. Furthermore, it is important that utilization of a dry port can create cost advantages against other competitive transport modes (Cullinane and Wilmsmeier, 2011). Estimating transportation costs from a dry port implemented transportation network is more complicated than estimating costs from unimodal road transport due to the increased amount of variables (number of operators and utilized transport modes increase), which have a influence on total costs (Kim and Van Wee, 2011). Without transportation cost benefits, it usually is not beneficial to invest in the creation of a dry port. There are also environmental benefits to be achieved by utilizing a dry port (Bergqvist and Egels-Zandén, 2012; Hanaoka and Regmi, 2011; Henttu et al., 2011; Liao et al., 2009), but these benefits are usually not enough to justify the creation of a dry port without considerable internal transportation cost benefits, because companies using transportation services seldom choose a transport mode with lower environmental impacts, if it is the more expensive mode (City of Warsaw, 2011, 2012).

2.2.3.2 Co-operation and Public-Private-Partnership

Many stakeholders are involved in the dry port implemented transportation network (Flämig and Hesse, 2011; Haralambides and Gujar, 2011; Rodrigue and Notteboom, 2012; Witte et al., 2014). The amount of stakeholders increases, while the sea port is expanding in the hinterland area, since more actors are needed to organize the whole transportation system. This will also increase the importance of communication between local and global stakeholders to achieve smooth flows of both information and freight (Bergqvist and Egels-Zandén, 2012). According to Bergqvist (2013), it is
important that the roles of all actors related to the dry port are clearly defined. Clear
definition is even more important if the size of the dry port is larger.

Furthermore, PPP plays a significant role in dry port investments and maintenance
operations due to the high investment costs, and cannot thus be only funded by the
private or public sector in most cases (Haralambides and Gujar, 2011). Both sectors are
important due to high costs, but also due to the transportation system, which is partly
public and partly private. Private companies are transporting freight by different
transport modes, but public road or rail networks are utilized. In addition, a dry port
needs to be connected to public transport networks. Bergqvist and Wilmsmeier (2009)
point out that not only national coordination, but also EU-wide cooperation is
important. Increased amount of stakeholders in the system and also the hinterland
expansion considerably increase the importance of the quality of the hinterland strategy
by both the sea port and the dry port (Van den Berg and De Langen, 2011). However,
dry ports can also be utilized to relieve bureaucracy as is the case regarding some
particular dry ports in Brazil (Ng et al., 2013).

2.2.3.3 Location Selection and Regionalization

Some of the dry port related studies are focusing on how to choose a geographical
location for the dry port or inland intermodal terminal. Rahimi et al. (2008) developed
a model, which minimizes vehicle-miles in the system by placing dry ports in optimal
locations. Added dry ports can reduce vehicle-miles in the model, which in turn
decreases congestion on the road network and its sea port connections. Furthermore,
emission levels reduce due to the decreased amount of road transport in the model.
Similar location-allocation method was also utilized by Feng et al. (2013). Fuzzy
analytical hierarchy process was used by Ka (2011), to identify optimal dry port
locations in China. According to Flämig and Hesse (2011), it is possible that the amount
of conflicts regarding planning arise, if more dry ports are added in the system.
Conflicts are based on decision-making regarding dry port locations and required land
area.
Sea port actions can be expanded to its hinterland area as the importance of hinterland transport is recognized. This is called regionalization. Sea ports aim to improve their customer services and logistics cost level with regionalization (Notteboom and Rodrigue, 2005; Rodrigue and Notteboom, 2010). In addition, case studies have researched dry port related regionalization development in various geographical locations. Indian dry port development has been researched by Haralambides and Gujar (2011), Spanish inland terminals have been studied by Monios (2011) and Russian dry port development by Korovyakovsky and Panova (2011). A broader focus has been demonstrated in the research of Notteboom (2010) as he researched the situation of European sea ports and their main hinterland corridors. Furthermore, main dry ports of different continents have been studied by Roso and Lumsden (2010) and an overview of Asian dry ports has been accomplished by Hanaoka and Regmi (2011). Rodrigue and Notteboom (2012) made a comparison of European and North American intermodal rail systems. According to them, there are both similarities and differences due to regional and local governance and regulations regarding dry ports and their rail connections in the compared environments.
3 DEVELOPMENT OF RAIL TRANSPORTATION SECTOR IN THE BALTIC STATES AND FINLAND

Rail transportation volume development is the main topic of this chapter. Geographic focus is on the Baltic States and Finland, since these countries are having large transit traffic volumes with Russia, i.e. large volume of Russian import and export is transported through Finland and the Baltic States. Besides, rail transport mode is utilized widely on certain transportation activities regarding transit traffic.

Rail freight market has been completely free for competition in all EU countries since the year 2007 (European Commission, 2013b). However, the progress of deregulating the rail freight market in EU countries started earlier as all the main railway lines of trans-European networks were deregulated in 2003 (ORR, 2014; UIRR, 2014). Basically, a company with the required licenses and safety certifications can operate on the European rail network, if it manages to apply for capacity from the rail network. European Commission is aiming to increase the share of rail transport, since it would decrease environmental harm originating from transportation. This is outlined in the White Paper (European Commission, 2011a). This is also aimed with liberalization, since it is estimated that deregulation will increase competition in the European rail network, which would lead to more efficient rail services. This, in turn, could increase the modal share of rail transport mode and thus decrease environmental impacts originating from the transportation sector. Additionally, the increase in the supply of railway services could increase the overall demand of services due to the latent demand (Brey and Walker, 2011; Vij et al., 2013).

3.1 Rail Baltica Rail Transport Corridor

There are currently (in the year 2015) nine principal transport corridors located in Europe, which are planned to be created, modernized or renovated (European Commission, 2014a). These corridors were chosen by the Trans-European Transport Networks (TEN-T) of European Commission. Rail Baltica would be part of the North Sea-Baltic Corridor, which connects sea ports of the Eastern shore of the Baltic Sea with sea ports of the North Sea. There is already a rail connection, which mostly follows
the alignment of the forthcoming Rail Baltica rail transport corridor. However, it is not as direct as the final alignment will be. In addition, the current connection is partly in poor shape, which limits the maximum speed considerably on some locations along the connection. The line has already been partly renovated, especially during the last five years. Furthermore, the gauge width of the north-south rail connection is currently 1,520 mm (the Russian standard) in the Baltic States. It has been decided that the gauge width will be converted to European standard (1,435 mm) along the Baltic States, which would enable a smoother connection along the whole corridor. Finland is part of the corridor with a ferry connection between Estonia and Finland. There have also been discussions regarding a possible tunnel connection between the Finnish and Estonian capital cities (Helsinki and Tallinn), which would increase the efficiency of the whole transportation chain along Rail Baltica (Sweco, 2014; Yle, 2014). Rail Baltica is the rail link that would connect cities together in BSR. The rail connection is visualized in Figure 6. However, North Sea-Baltic Corridor continues further to west from Berlin also reaching sea ports located on the North Sea (e.g. Port of Antwerpen and Port of Rotterdam). (AECOM; 2011; European Commission, 2014d; Railway Gazette, 2014)
3.2 Freight Traffic of North-West Russian Sea Ports

The world’s largest country, Russia, has a long shared border with Finland and the Baltic States. In addition, freight flows to and from Russia are considerably large. Even
though capacity of the North-West sea ports is very high and increasing in the near future (e.g. increasing capacity of Port of Ust-Luga), the capacity is still not high enough and Russia needs to use the Baltic States and Finland as its transit traffic countries. Freight volumes of the North-West Russian sea ports is illustrated in Figure 7.

Figure 7 clearly shows that the Port of Vyborg is much smaller than the other four compared sea ports (1,500 thousand tons transported through the Port of Vyborg during the year 2013). Approximately 63,800 thousand tons of freight were transported through the Port of Primorsk, which had the highest freight turnover of all compared sea ports in 2013. Port of Primorsk has increased its overall liquid freight traffic considerably during the years 2002-2009. In 2002, approximately 12,400 thousand tons of liquid products were transported through the Port of Primorsk. Freight volume increased until the year 2009 in the Port of Primorsk (in the top year almost 80 million tons were transported through the port), but during the years 2010-2013 there has been
a slight decrease. Port of St. Petersburg is currently the third largest sea port, if transported freight tons are used in comparison. Freight turnover has increased quite evenly between the years 2001 and 2007 (from 36,900 to 59,600 thousand tons). After that there was a drop in the freight transportation amount to about 50,000 thousand tons in 2009, but the Port of St. Petersburg increased its throughput amount again back to about 58,000 thousand tons in 2013. Port of Ust-Luga is quite a new sea port. However, its freight turnover has increased from 7,100 thousand tons in 2007 to 62,600 thousand tons in 2013, and had the second highest throughput volume of the North-West Russian sea ports. Total summed transport volume of all reviewed sea ports has increased from approximately 37 million tons in 2001 to 202 million tons in 2013 (overall freight transported through observed sea ports has more than five-fold in 12 years).

Russia’s main export products include crude oil and oil products, natural gas, metals and raw materials. Furthermore, metals, wood and wood-related products and chemicals are exported from Russia. Import products consist mainly of consumer goods from e.g. Western Europe, machinery and vehicles (private cars etc.). In addition, pharmaceutical products, plastic, iron, steel and other semi-finished metal products have a considerable share of Russian import flows. (Karamysheva et al., 2013; Hilmola, 2011)

Transit traffic is very important for the Baltic States and Finland. It plays a large role in the whole transportation volume in these countries (more information in the following sub-chapters). Rail transport is the main transit transport mode in the Baltic States. However, road transport is mainly utilized in Finnish eastbound transit traffic (Henttu and Multaharju, 2011). Westbound transit traffic is in turn done mostly by rail through Finland (Henttu and Multaharju, 2011). Sea ports play a very large role in both eastbound and westbound Finnish, but also Estonian, Latvian and Lithuanian transit traffic. Main target country for transit traffic in the Baltic States and Finland is their neighbor country Russia. Transit traffic volume development of these countries is reviewed in the next sub-chapters.
3.3 Rail Transportation in the Baltic States and Finland

Rail freight traffic volumes along the rail network in traditional Russian transit countries (Finland and the Baltic States) are illustrated in Figure 8. Statistics include domestic and international traffic (transit, export and import).


Latvia has been able to increase rail freight volumes from 37.9 to 55.8 million tons during the observation period. Furthermore, Lithuania has increased yearly rail freight volumes along its rail network from about 29.2 to 48.0 million tons from the year 2001 to 2013. Estonia and Finland have been struggling to maintain their rail freight volumes. Estonia had its peak in 2002 (71.1 million tons), but also maintained a similar level until 2007. Estonian rail freight volumes dropped in 2008 and 2009 (52.8 and 38.4 million tons respectively). Freight volume has slightly decreased from 41.7 to 36.4 million tons in Finland. Total freight volumes of all observed countries have been increasing on an annual basis with 0.8 percent during the years 2001-2013.
3.3.1 International Rail Traffic in Observed Countries

Rail transit traffic volume development of the Baltic States and Finland is illustrated in Figure 9. Rail transit in observed countries consists mostly of oil and different oil products, coal and fertilizers (Hilmola, 2011). Data is less extensive regarding some countries in Figures 9, 10 and 12 (see e.g. rail transit traffic regarding Lithuania in Figure 9). Reason is that the author was unable to find an equal amount of data regarding all observed countries.

Figure 9 Rail transit traffic in the Baltic States and Finland (thousand tons, 2001-2012).

Two major rail transit traffic volume countries are Estonia and Lithuania. Rail transit traffic volume was more than 35 million tons in the year 2002 and during the years 2004-2006 in Estonia, but after that a major collapse in transit traffic volumes occurred, because a significant share of Russian oil and coal transit was redirected to be transported through transit countries (e.g. through Latvia) other than Estonia (see e.g. Hilmola, 2011). Furthermore, part of the flows was directed through Russia’s own sea ports (see e.g. Port of St. Petersburg, 2014). Estonian rail transit traffic volume was circa 19.9 million tons in 2012. Transit traffic volume was 19.2 million tons in 2005, but the volume has decreased to 12.2 million tons in Lithuania at the end of the year.
2012. Rail transit traffic volumes have been steadier and lower in Finland and Latvia. Transported volume has increased from 4.0 to 5.0 million tons in Finland from 2001 to 2012. A similar increase has also occurred in Latvia (from 3.7 to 4.6 million tons). Due to large decreases in transit traffic volumes in Estonia and Lithuania, the overall volume of all observed countries has decreased considerably as well from 64.6 in 2005 to 41.6 million tons in 2012. Share of international rail traffic (in transported tons) from total rail traffic in the Baltic States and Finland is presented in Figure 10. International traffic includes transit, export and import rail traffic.


Of all observed countries, international rail traffic is in relative terms on the lowest level in Finland if a comparison is made in transported tons. International rail traffic accounted for 42.4 percent in 2001, but the development has been so that the relative amount has decreased during the observation period, and it was about 37.4 percent in the year 2013. In Estonia, the share of international rail transport has been between the levels of 42.5 and 68.5 percent during the observation period. The share in 2013 was 48.6 percent. Lithuania and Latvia have the highest shares during all observed years: 68.5 and 97.9 percent in 2013, respectively. As can be seen from these shares, Latvia in particular has completely focused its rail transport strategy on serving international traffic. Furthermore, the share of international rail traffic in Latvia has constantly
increased during the last ten years. Only a very small proportion of rail freight transportation in Latvia has both a domestic starting point and destination.

### 3.3.2 International Rail Freight Turnover in Observed Countries

Comparison of rail freight turnover volumes (million ton-kilometers) in the Baltic States and Finland is illustrated Figure 11.


If freight turnover is compared, then Lithuania and Latvia have the highest volumes during the observation period. Annual rail freight turnover has increased from 14.2 (the year 2001) to 19.3 billion ton-kilometers (the year 2013) in Latvia. Rail freight turnover has changed from between 7.7 and 15.1 billion ton-kilometers in Lithuania. The figure was 13.3 billion ton-kilometers in 2013. Rail freight turnover of Finland has been the third highest during the years 2006-2013. Before that, the rail freight turnover has been quite similar with Estonia. Rail freight turnover maintained its level in Finland, whereas turnover decreased from about 10.5 to 6.0 billion ton-kilometers from the year 2006 to the year 2008 in Estonia. Turnover was 4.7 billion ton-kilometers in Estonia in 2013, which was the lowest turnover during the observation period. Freight turnover has been
rather steady between the years 2001 and 2013 in Finland, although a small reduction of volume is visible from the year 2006 to 2013. Highest rail freight volume was 11.1 billion ton-kilometers in Finland in the year 2006 during the observation period, whereas the lowest rail freight turnover actualized in 2012 with 9.3 billion transported ton-kilometers. The Finnish rail turnover increased to 9.5 billion ton-kilometers in 2013. International traffic’s percentual amount of the whole rail transport turnover is summarized in Figure 12.

![Figure 12 Share of international rail freight turnover from total rail freight turnover (2001-2013).](image)


There are no large changes in each observed country regarding the development of the share of international rail freight turnover from total freight turnover. However, the differences between observed countries are clear and have been fairly similar during the whole observation period. Share of international rail freight turnover of all the Baltic States is very high (between 72 and 98 percent during the whole observation period in all Baltic States), whereas the proportion of the international freight has been between 27 and 33 percent in Finland. The lowest share (26.6 percent) in Finland was in the year 2012. Trend has also been similar in Estonia, i.e. the lowest proportion in Estonia was in 2012 (87 percent), but the figure is still considerably high. Shares of international
rail freight turnover in Latvia and Lithuania (98 and 75 percent respectively in 2012) have maintained their levels during the last observed years.

3.3.3 Container Transportation by Rail in Observed Countries

Container transportation by rail in the Baltic States and Finland is summarized in Figure 13.

**Figure 13 Transported containers by rail in the Baltic States and Finland (TEU, 2004-2013).**

Figure 13 shows that container transportation has increased moderately in each of the Baltic States. Annual increases in each observed country are quite similar. Latvia and Lithuania have had the greatest container traffic on their rail networks during the years 2010-2013. Estonia had the lowest container traffic volumes on its rail network of all the Baltic States. Containers (TEU) transported in 2013 was approximately 62,000, 98,000 and 104,000 TEU in Estonia, Latvia and Lithuania, respectively. Percentual increase from the year 2005 to 2013 has been 460, 159 and 288 percent in Estonia, Lithuania and Latvia, correspondingly, i.e. Estonia has had the highest percentual volume increases in the container traffic by rail. If all Baltic States are observed as one
larger area, then total transported containers by rail have increased from 76,000 to 264,000 TEU containers per year. Percentual increase is 245 percent in eight years. Trend line suggests that the growth could continue in the forthcoming years.

In the future, estimation of container transport volume development by rail is somewhat optimistic in the Baltic States. The situation is fairly different in Finland. The amount of containers transported by rail in Finland was about 268,000 TEU in 2004. However, the amount of transported containers has decreased on a yearly basis (except the volume increment after the year 2006) during the years 2004-2013. There were only 42,200 TEU transported by rail in Finland in the year 2013. Percentual decrease from 2004 to 2013 is approximately 82 percent. The year 2012 is the first year, when each Baltic State transported more containers along their rail networks than Finland, although Finland was leading these statistics clearly between the years 2004-2009.

In the end, container volumes play a minor role in the whole rail transportation of each observed country. If one container weighs e.g. 20 tons, then the total yearly weight of all transported containers would be approximately 862,100 tons in Finland during the year 2012. However, the total transported tons on the Finnish rail network was more than 35.2 million tons, i.e. less than three percent of total rail freight volume was transported by containers. On the other hand, loading and unloading containers and transshipping and lifting containers from one transport mode to another creates additional possible cash flows for transportation sector companies.

Transit traffic statistics in each of the Baltic States (Estonia, Lithuania and Latvia) have increased moderately during the last decade, if container traffic is observed. However, transit traffic to Russia through Finland is mostly conducted by road transport (Henttu and Multaharju, 2011). Westbound transit traffic from Russia through Finnish sea ports is done by rail transport. This will occur in such a way that there are numerous empty rail wagons, which are transported back to Russia. If the statistics of the Baltic States will continue to increase, it means that Finland could also increase utilization of rail transport, since potential volumes are existing.
3.3.4 Rail Container Throughput’s Relative Share from Sea Port Traffic

Container throughput volumes of Finnish, Estonian, Lithuanian and Latvian sea ports is presented in Figure 14.

As is visible in Figure 14, Finnish sea ports dominate the throughput volume, if a comparison is made between the sea ports of Finland and the Baltic States. There was a significant decrease in container volume after the year 2008, when the volume was reduced from 1.22 to 0.86 million TEU. Similar, but lower reduction is visible also in other observed countries’ sea port container quantities after the year 2008. The Finnish sea port sector has almost been able to recover from the sudden volume decrease, and the amount of transported TEU was 1.12 million in the year 2013. Estonian sea ports have had the smallest container volumes of all the observed countries. Throughput was 141,200 TEU in the year 2004, but it increased to 253,100 TEU in 2013. Lithuanian sea ports’ container volume was 174,000 TEU in 2004, and 403,000 in 2013. Sea ports of Latvia have been able to have almost constant growth from the year 2004 to 2013.
Volume has increased from 151,000 to 381,100 TEU. Rail container volume share from the container throughput of sea ports is illustrated in Figure 15.

**Figure 15 Share of container rail traffic from total container throughput of sea ports (2005-2013).**


If total rail container volume is divided by total container volume of sea ports located in the observed countries, then Latvia has had the highest share of all observed countries. The share has changed between 11.9 and 29.7 percent. However, the trend has seen a decrease in Latvia during the years 2011-2013. Estonia and Lithuania have had the second highest shares after Latvia. The difference is that both Estonia and Lithuania have been able to increase the rail container traffic’s share during the whole period from the year 2005 to 2013 (Estonia has been more successful than Lithuania). Shares in Estonia and Lithuania in 2013 were 13.9 and 18.8 percent respectively. Share of container traffic by rail in Finland has experienced negative development throughout the observation period. The share was about 13.5 percent in 2005, but it has diminished to 3.5 percent in 2013.
4 POSSIBLE FACTORS INFLUENCING THE PRICE LEVEL OF TRANSPORTATION

One of the most important factors for decision-makers or customers is the price level of a certain transport mode. Other main identified factors are reliability, frequency, lead time, access, flexibility and convenience level of organizing transportation (Karamysheva et al., 2013; McGinnis, 1990; Murphy and Hall, 1995; Redman et al., 2013; Vasco, 2014). There are various aspects that could affect the price level of different transport modes, and these aspects could also change in the future. Impacts include e.g. different regulations (IMO, 2014a, b), energy price fluctuations, charges and taxes. The separate impacts reviewed in this chapter are the ones, which are assumed to affect the price level of various transport modes in BSR.

4.1 IMO’s Sulphur and Nitrogen Oxide Regulations

Sulphur regulation has possibly the largest impact for the transportation sector in BSR during the following years. Marine Environment Protection Committee (MEPC) of International Maritime Organization (IMO) made an agreement regarding a directive, which aims to decrease sulphur emissions originating from the sea transportation sector. The directive is part of MARPOL Annex VI regulations. The approved amendments include the following two terms:

- A global regulation that limits the sulphur amount in fuel to 3.5 percent. The limit took effect on 1st of January in 2012. The limit will be further reduced to 0.5 percent on 1st of January 2020.
- Stricter limit is targeting the Sulphur Emission Control Area (SECA), which includes the Baltic Sea, United States Caribbean Sea and the coast of North America. The regulation limited the sulphur level to one percent and the limit came into operation on 1st of July 2010. The limit decreased further to 0.1 percent starting on 1st of January in 2015. (Det Norske Veritas, 2009; Entec, 2010; IMO, 2014a).
The IMO Marpol 73/78 Annex VI regulation aims to decrease sulphur oxides by limiting the amount of sulphur. There are three main possibilities for sea vessels: 1) Sea vessels can use fuel, which does not contain too much sulphur (less than 0.1 percent from the start of the year 2015). 2) Sea vessels can install sulphur scrubbers. 3) Alternative sulphur free energy sources can be used (e.g. LNG or methanol). The negative aspect with low sulphur fuel e.g. marine gas oil (MGO) is the fact that it costs more than traditionally used fuels, which include more than 0.1 percent of sulphur. If the sea vessel installs sulphur scrubbers, it can eliminate and preserve the excessive sulphur content from the fuel i.e. the sea vessel can use less expensive fuel with a higher sulphur content. However, installing scrubbers will require additional investment costs. Furthermore, there is not that much experience regarding scrubbers. Maintenance costs, reliability and operational costs can vary between different types of scrubbers. In addition, installing a scrubber will take time. The scrubbers are also space-consuming with the pipes required through the vessel structure, and this could decrease the warehousing space of the sea vessel. Depending on the type of the scrubber, the preserved sulphur needs to be unloaded from the ship based on the regular time window, which means that there needs to be suitable equipment available in the sea port area. Third possibility regarding alternative sulphur free energy sources could become expensive, since installing a proper LNG system to an existing sea vessel requires high investment costs, i.e. it is more convenient to utilize LNG system in a new-built sea vessel. (Det Norske Veritas, 2009; ECSA, 2010; Holmgren et al., 2014; IMO, 2014a; Jalkanen et al., 2013; Jiang et al., 2014; Swedish Maritime Administration, 2009)

All the above-mentioned possibilities increase costs. According to literature (see e.g. ECSA, 2010; Kalli et al., 2009; Swedish Maritime Administration, 2009), these cost additions will further increase the price level of sea transportation in the Baltic Sea, since sea vessel operators will cover expense increments by their customers. Based on the literature review made by Holmgren et al. (2014), MGO will be approximately 70-80 percent more expensive than traditional heavy fuel oil (HFO). Furthermore, Notteboom (2011) estimated that 25-50 percent of total ship costs are originating from fuel costs. Another possible effect is that some sea vessels could change their routes in a way that they don’t sail in SECA anymore, which would decrease the supply of sea transportation in SECA. This could increase the price level even further.
If the price level of sea transportation increases in SECA, it could result in a modal shift from sea to inland transportation, since inland transport modes would become more attractive in comparison to sea transportation. Price levels of different transport modes play a vital role among customers. Substitute transport modes could be road and rail in SECA connected countries. In addition, short sea shipping could increase its demand on very short routes in the Baltic Sea. Basically, an efficient and environmentally less harmful inland transportation system is vitally important for SECA connected countries. Otherwise, it is possible that overall emissions actually increase, if the inland transportation creates more emissions than what can be decreased from sea transportation by the regulation. (Cullinane and Bergqvist, 2014; ECSA, 2010; Entec, 2010; Holmgren et al., 2014; Jalkanen et al., 2013; Jiang et al., 2014; Kalli et a., 2009; Swedish Maritime Administration, 2009)

Another similar regulation regards nitrogen volumes originating from the sea transportation. Aim of Regulation 13 is to narrow down nitrogen emissions, which are generated from sea vessels. It is part of the same Annex (MARPOL 73/78 – Annex IV) as the sulphur regulation, which has been described earlier in sub-chapter 4.1. The regulation is targeted to sea vessels, which use diesel engines of more than 130 kW power. In addition, engines built in 2000 or later are part of the regulation (also older engines, which underwent a major conversion in 2000 or later), i.e. engines built before the year 2000 are not part of the regulation. Furthermore, rotation speed of the engine and location of sea vessel affects the level of limitation based on the regulation. (Det Norske Veritas, 2009; IMO, 2014b)

4.2 Price Development of Fuel and Electricity

Another driving force of decision-making between different transport modes is the price of energy. Reason for this is the direct connection between energy price and the price level of the transport mode. Principal energy source of road transport vehicles is fuel or diesel. However, energy source of rail transport in Finland is mainly based on electricity, since the majority of the Finnish rail network is electrified. Occurring from this, if the diesel price level increases, but electricity price level stays on the same level, price level of road transportation increases, whereas price level of rail transportation maintains its level. This in turn improves the rail transport mode’s price level
competitiveness against the road transport. The impact is the opposite, if the price level of electricity increases in comparison with the fuel price. Development of oil price is illustrated in Figure 16.

![Figure 16 Development of Europe Brent Spot Price (dollars per barrel), on a daily basis during the time window 1988-11/2014.](image)

Source: EIA (2014)

Oil prices have changed significantly during the past fifteen years. Steady increase of oil prices began at the start of the year 2002, when Europe Brent spot price FOB for one barrel was about 17 dollars (EIA, 2014). The highest price (more than 140 dollars per one barrel) was actualized in July of the year 2008. The price decreased temporarily to about 40 dollars at the end of 2008. The price started to increase again, and it has been around 100-120 dollars per one barrel between the years 2011 and 2014. However, the price has declined to approximately 85 dollars per barrel at the end of the observation period (November 2014). This kind of increase in oil prices will naturally increase the
attractiveness of such transport modes, which are priced lower in comparison with conventionally fueled transport modes. Furthermore, since oil supply is limited, estimation regarding oil price fluctuations in the future cannot be too optimistic. Nonetheless, electricity can be produced from renewable sources i.e. particular electricity sources will never be exhausted in the long run. Finnish electricity price development is presented in Figure 17.

Figure 17 Development of total nominal electricity price (cents per kWh), if electricity demand is 35,000 kWh per year in Finland on a daily basis during the time window 1997-11/2014.
Source: Energy Authority (2014)

Figure 17 illustrated the development of the total nominal electricity price in cents per kWh. Total nominal price includes both transfer and energy prices. The reviewed price development has been actualized if the yearly electricity demand has been circa 35,000 kWh. The electricity price level decreased from about seven to 6.5 cents per kWh from the year 1997 to 2001. Electricity price has become more expensive starting from the
summer of 2001. The price level increased rather regularly to approximately 12.8 cents until the end of the year 2011. From there, the price level has fluctuated between 11.8 and 12.8 cents per kWh until the end of the observation period. (Energy Authority, 2014)

Based on the oil and electricity price review, both price levels have had a growing trend during the observation periods. The difference is that the price level of electricity has had fewer fluctuations than oil price development. In addition, the oil price level has increased relatively more. If a comparison is made between the minimum price value during the observation period and the value, which was realized at the end of observation period, then the oil price has increased from 9.1 dollars per one barrel in December of 1998 to 84.9 at the start of November of 2014. This is an 830 percent increase. Minimum price level of electricity (6.45 cents per kWh) was achieved in April of the year 2001. The electricity was 12.23 cents per kWh at the beginning of November in the year 2014. The growth is about 90 percent, i.e. electricity-based transport modes have gained a better position against the road transport during the last 15 years.

4.3 Internalization of External Costs

Another factor affecting the modal choice will be the pricing of external costs, which are e.g. CO₂ emissions, accidents, noise and congestion. Emission trading is already in force for certain industries (e.g. energy and manufacturing industries), but it is not implemented to the transportation sector (European Commission, 2014c). However, the EU aims to decrease emissions originating from the transportation sector. According to the European Commission (2014e), transportation sector accounted for 19.7 percent of total CO₂ emissions in EU-28 countries. The total amount of CO₂ emissions originating from EU-28 countries was 4.54 billion tons, whereas the transportation sector omitted about 893 million tons. It is possible that the external costs of freight transportation will be internalized in the near future. It means that companies, which are creating the pollution or other externalities, would also pay for them. Since the road transport mode creates more external costs than e.g. rail or sea transport, the price level of road transport would increase the most, which would equalize differences between separate transport modes. This would increase the attractiveness of other transport
modes in comparison with road transport. Price development of CO$_2$ emission index is illustrated in Figure 18. (European Commission, 2014c, e; Maibach et al., 2008)

![Price development of one ton of CO$_2$ during 2006-September of 2014 (ICE EUA futures – emissions index in EUR). Source: ICE, 2014](image)

One way to internalize CO$_2$ emissions from the transportation sector would be to set a price for one emitted CO$_2$ ton. This is already in force in European energy and manufacturing industries. The problem is that observing CO$_2$ pollution from the transportation sector is more troublesome than for the before-mentioned industries. The price development of one ton of CO$_2$ has fluctuated considerably during the observation period. The price is totally based on market demand, i.e. the price will increase, if demand increases and vice versa. The price changed between zero and 25 during the year 2007 and until the start of the year 2008. The higher fluctuation decreased at the latter end of the year 2008, and the price increased to almost 35 € per one ton of CO$_2$. 
The recession had a high impact on the industry starting at the end of 2008. The demand for CO₂ allowances dropped, which also affected the price of one allowance. The overall negative development has continued until the end of the observation period. Price of one allowance has thus increased during the years 2013 and 2014, but only slightly. The price level has been between 4.37 and 8.40 € per one ton of CO₂ in the year 2014. (Abrell, 2010; ICE, 2014; Scheelhaase et al., 2010; Schwanen et al., 2011)

One possibility to internalize external costs is the implementation of road charges. There are various reasons for different road charges. Some charges are targeting environmental impacts, i.e. the more the vehicle pollutes, the higher the charges are. Some charges could be implemented to maintain the road network and the relating infrastructure, if e.g. the government cannot budget for enough funding to maintain or renovate the road network. Furthermore, congestion can be decreased or avoided with a properly implemented road charge system. There are various examples of road charge systems, which are aiming to decrease congestion and emissions. Road charge system is implemented e.g. in Stockholm and London. Although road charge systems are mainly aiming to decrease the level of congestion, they have managed to decrease the level of pollution at the same time due to a decrease in private car utilization. (Beevers and Carslaw, 2005; Börjesson and Kristofferson, 2014; Eliasson, 2009; Li and Hensher, 2012)

4.4 Other Factors Possibly Affecting the Price Level of Transportation

There are EU-based weight regulations concerning road transport vehicles. These regulations are implemented to improve safety and to ensure that road network erosion is not too fast (heavier road transport vehicles wear the road surface faster). However, e.g. Finland and Sweden have applied for higher weight limitations, since road networks are in better shape and less congested in both countries in comparison to many Central European countries (e.g. France and Germany). The maximum total weight of road transport vehicle combination was increased from 60 to 76 tons in Finland in the October of 2013 (Trafi, 2014). Although the heavier trucks wear the road faster, they can additionally transport more freight with one single shipment. This increases fuel consumption, but it does not increase linearly i.e. costs per one ton can be decreased with higher weight limitations. This can increase the performance of road transport.
against its competitive transport modes such as rail transport. (de Haan et al., 2007; He et al., 2005)

Driver of a road transport vehicle needs to follow the EU-based driving time regulation. The regulation defines, how long and how many separate breaks the driver should have during his or her working day. The regulation also describes the amount of rest needed during longer time periods. Main aim of the regulation is to improve the working conditions of the road transportation sector and to improve safety. The regulation limits the amount of time when the vehicle is moving, which in turn limits the maximum throughput capacity of the vehicle. Furthermore, lead times become longer. This could increase the price level of road transport. (Regulation No 561/2006 (2006)
5 METHODOLOGY

This chapter discusses seven articles presented in Part II of this thesis. In addition, foundation of the research, data collection and data analysis methods are described.

5.1 Foundation of the Thesis

The thesis consists of seven publications. Six of these articles are published or accepted for publication in international academic journals and one in a scientific conference (25th NOFOMA Conference). All of the articles were written during 2010-2015, and most were part of larger research projects. The first three are results of the Mobile Port project (2010-2012, more information from project homepage: Mobile Port, 2012). The fourth and fifth articles are based on the Rail Baltica Growth Corridor Russia project (RBGC Russia, 2012-2014, more information: RBGC Russia, 2014), which explains the researched area from a slightly different focus (dry port concept and Rail Baltica transport corridor, including a review of statistics of North-West Russia). However, since the dry port network by itself is not a whole functioning transportation system, the Rail Baltica studies are a good complementation to the Finnish dry port research. The sixth article is a case study focusing on Estonia’s international rail transport connections, and this article was not based on a larger project. Furthermore, to add versatility and depth in the discussion of this dissertation, a seventh publication was included. This article is about patient transportation between homes and hospitals in a region of Finland, and it was part of a project, which aimed to gain information for decision-making for hospital location selection. There are naturally many differences, since patient and freight transportations have different priorities. However, there are surprisingly many similarities between these transportation processes in Finland, and this is the reason for the seventh article included in this dissertation.

Main research methodology in articles I and II is gravitational models. These models were created to estimate the optimal amount of dry ports that could be implemented in Finland. Article I represented the gravitational models. More comprehensive approach to optimize the results of gravitational models was used in article II. Methodology in article I included heuristics, but the methodology of article II is partly computer
optimized. Article III expands the Finnish dry port research made already in articles I and II. Main study method in article III was a discrete-event simulation (DES) model, which was used to estimate the optimal amount of dry ports in Finland. Article IV composes a review of transportation volume statistics in North-West Russia. Main focus is on rail transport and freight volume throughput of North-West Russian sea ports, but other transport modes are also briefly reviewed. Interview study regarding views and opinions about the Rail Baltica transport corridor was the topic of article five. Semi-structured interview was the principal methodology in article V, which was focusing on North-West Russian private companies. Estonian international rail connections were studied in article VI as a case study. System dynamics (SD) was the main methodology to research patient transportation costs in article VII.

Both quantitative and qualitative data has been included in the dissertation. However, most of the research is based on quantitative data. Analytical models, simulation models (DES and SD) and second hand data are utilizing quantitative data. The fifth and sixth articles include interview and case study based data gathering, and this data is mainly qualitative. Figure 19 illustrated the timetable regarding each article included in part II of this thesis.

<table>
<thead>
<tr>
<th>Article</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article I</td>
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<td>Article II</td>
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<td>Article III</td>
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<td>Article IV</td>
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<td>Article V</td>
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<td>Article VI</td>
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<tr>
<td>Article VII</td>
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</table>

**Figure 19 Timetable of publications. Starting from writing, and ending, when article was accepted.**

The composing of the first article was started during the summer of 2010 just after the author had finished his master’s thesis (Henttu, 2010) regarding the same subject. The article went through a double blind-review with major changes. The process was quite long and took more than one year. Article II was accepted through a double blind-review process, but the whole process took a shorter period of time (half a year). Composing of article III started at the end of 2011 as a seminar article. The full paper
was revised according to the comments from the seminar, and it was sent to a double-blind review process of a journal after the summer of 2012. The paper was improved according to major suggested changes. The process was time-consuming and there were three rounds in total before acceptance of the article in early 2013. The creation of articles IV and V started during the year 2012. Article IV was accepted after minor recommended changes (double blind-review) at the end of 2012. Article V is a seminar article and it was accepted after small suggested changes (blind-review) during the summer of 2013. The sixth article is a double blind-review journal article. The process was started in the autumn of the year 2013, when the editor of the special issue asked for abstract proposals. The article itself was submitted in the summer of 2014. It was accepted in late 2014 after four revision rounds (first round demanded major changes, but last three were minor). Article VII was accepted after the fourth revision round in the start of the year 2015. The writing process of article VII was started in the late summer of the year 2013.

5.2 Data Collection and Data Analysis Methods

Research approaches can be divided into five different classes. These are conceptual, nomothetical, decision-oriented, action-oriented and constructive approaches (Kasanen et al., 1993; Neilimo and Näsi, 1980). These are based on two dimensions: the first dimension divides the research into theoretical or empirical. The second dimension is whether the research is descriptive or normative. The articles, included in this thesis, are positioned in the research approach framework in Figure 20.
The empirical data can be classified into two main categories: these are quantitative and qualitative. Quantitative is numeric data and it can be quantified and summarized, whereas qualitative does not include numerical data and can be e.g. non-numerical data gathered with interviews or surveys. Quantitative research includes e.g. experimental methods and quantitative measures to test different hypotheses. In addition, quantitative research commonly emphasizes causal relationships between different studied variables. Quantitative data can be analyzed with the statistical approach. In qualitative research, a naturalistic approach is mainly utilized to understand the researched phenomena, but findings are not created with the statistical approach. Both quantitative and qualitative data have been gathered and analyzed in this dissertation, but the focus is more on quantitative data. Different data collection and data analysis methods and data characteristics of the included articles are summarized in Table 4. (Denzin and Lincoln, 1998; Hoepfl, 1997; Patton, 2002)
Table 4 Data collection and analysis methods utilized in the included articles.

<table>
<thead>
<tr>
<th>Article</th>
<th>Data collection</th>
<th>Characteristics of data</th>
<th>Data analysis methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Publicly available sources, interviews, emails and phone calls</td>
<td>Quantitative</td>
<td>Gravitational models</td>
</tr>
<tr>
<td>II</td>
<td>Publicly available sources, interviews, emails and phone calls</td>
<td>Quantitative</td>
<td>Gravitational models</td>
</tr>
<tr>
<td>III</td>
<td>Publicly available sources, interviews, emails and phone calls</td>
<td>Quantitative</td>
<td>Discrete-event simulation model</td>
</tr>
<tr>
<td>IV</td>
<td>Publicly available sources</td>
<td>Quantitative</td>
<td>Literature and statistics review</td>
</tr>
<tr>
<td>V</td>
<td>Semi-structured interviews</td>
<td>Qualitative</td>
<td>Semi-structured theme interviews</td>
</tr>
<tr>
<td>VI</td>
<td>A case study</td>
<td>Mainly qualitative</td>
<td>Case study</td>
</tr>
<tr>
<td>VII</td>
<td>Publicly available sources, interviews, emails and phone calls</td>
<td>Quantitative</td>
<td>System dynamics simulation model</td>
</tr>
</tbody>
</table>

Data for the first three articles were mainly gathered from publicly available sources (including e.g. Statistics Finland, 2013, 2014; Finnish Port Association, 2014). The data is quantitative by its nature. Data sources are considered to be of a high quality. However, some important data could not be obtained from these sources, and were collected with different methods. Few interviews were obtained (e.g. in intermodal terminal and sea port area) to gather the missing required data for the first three publications. In addition, e-mails, small-scale surveys and phone calls were made to gather more extensive data and to validate already gathered data. The data included in articles I-III consists of rail and road network distances between Finnish cities, cost structure of rail and road transport modes and emission amounts of road and rail transport modes. Both the cost and emission levels were converted to per ton-kilometer values.

The main research method used in articles I and II is macro gravitational models of distribution. The models are completely quantitative by their nature, and are based on numerical data concerning the populations of selected Finnish cities and distances between the chosen Finnish sea ports, dry ports, and the most important cities of consumption. In addition, cost level of road and rail transport was estimated by cost accounting method. The aim of the gravitational models was to compare relative transport costs and environmental impacts, when using the alternative amount of dry
ports (ranging from one to nine), and to examine how performance evolves with separate configurations. The models use linear integer programming to achieve an optimal distribution strategy for each setting.

Optimization of the first paper is mainly accomplished manually by using Microsoft Excel and Solver optimization module. The method was improved in article two by utilizing IBM ILOG CPLEX Optimization Studio (IBM, 2014) to optimize the whole model automatically. This approach decreased the optimization time significantly, but also allowed slightly better results due to a more comprehensive model. The models are mathematical and thus the research approach is theoretical. However, inputs of the models are empirical, i.e. the research approach of articles I and II is both theoretical and empirical. The results show, how the relative transport costs could be changed, if a dry port network were implemented in Finland. This is a normative approach, i.e. the research approach of articles I and II is both decision-oriented and constructive.

Discrete-event simulation (DES) is used as the main data analysis method in publication III. According to Robinson (2004), simulation is “*experimentation with a simplified imitation (on a computer) of an operations system as it progresses through time, for the purpose of better understanding and/or improving that system*”. Individual events occur one at a time in DES (Banks et al., 2005). Simulation is a constructive approach, where researchers can produce solutions to specific problems (Kasanen et al., 1993). An analytical or simulation model was appropriate for the research made in article III, since it was impossible to conduct experimentation with the real system regarding the Finnish transportation sector including both road and rail transport modes and almost 200 Finnish municipalities. In addition, according to Robinson (2004), a visual simulation model is a suitable way to communicate ideas and results to others. Additionally, Banks et al. (2005) point out that simulation is a very good research approach, when the aim is to experiment with new designs or policies, which was also the case with the study in article III. The article III includes more empirical inputs than articles I and II. Furthermore, the simulation model both describes the current transportation sector in Finland, but also gives insight on how a dry port network could enhance the sector. This approach can be identified as action-oriented or constructive, i.e. the article is located between these two approaches.
Data collection of article IV is based on statistics collected from official Internet websites, academic articles and research reports. Statistics regarding the same topics were gathered from multiple sources to improve the validation of information. Since the aim of article IV was a review of literature and statistics concerning the North-West Russian transportation sector, no further data gathering methods were utilized. The data is mainly quantitative including e.g. annual freight volumes of different transport modes. Data analysis method in article IV was an analysis of the gathered statistics including e.g. transportation volume statistics of the North-West Russian sea ports. The analysis is based mainly on volume development of freight transportation in North-West Russia. Since the data is gathered from literature and statistic databases, the approach is theoretical and descriptive, i.e. conceptual approach depicts article IV’s research approach.

Semi-structured interview was used as the main data gathering method for publication V. Ten interviews were accomplished in total. Two of the interview meetings were situated in Finland and eight in Russia. Finnish interviews were conducted in the cities of Kotka and Helsinki. Russian interviews were accomplished in Leningrad Oblast and St. Petersburg. The data is mainly qualitative, but a small amount of quantitative data was also gathered during the interview meetings. Quantitative data includes e.g. required lead times or frequencies for the studied transport corridor. Analysis of the article was based on the material gathered with semi-structured interviews. The data was compared with statistics gathered from official public sources. Partly nomothetical and action-oriented approaches were used in article V, since data is empirical and the results describe mainly the current situation, but also the future outlook was weighted in interview meetings.

Data gathering for publication VI was completed as a case study. The case company was an Estonian rail freight transport company. Manager of this company was interviewed. In addition, both authors of the article did a one-week long visit in Estonia. During these visits, both authors had many meetings and site visits to gather data regarding the Estonian railway sector. The gathered data is mainly qualitative, but quantitative data was also obtained during the case study. Analysis method of the article was based on gathered data. The data was analyzed and compared with a statistics review gathered from publicly available official sources. The research approach for
Data collection of the seventh article was based on interviews, phone calls, email contacts and official publicly available statistics. Part of the data was gathered from personnel working in the Finnish health district, which is the focus of the research. In addition, data was gathered e.g. from municipalities located in the health district and the Social Insurance Institution of Finland (2014). The data is mostly quantitative. Data analysis method used in the research was a system dynamics simulation model. It was created to analyze patient transportation flows between homes and hospitals inside the studied healthcare district. Aim was to find out, what is the impact between various scenarios: 1) Old hospital is renovated; 2) New hospital is built; or 3) Healthcare services are outsourced to other municipalities. The research approach is similar to what was used in articles I and II, i.e. the approach is both decision-oriented and constructive.
6 SUMMARY OF THE PUBLICATIONS

Objectives and main contributions of articles included in this thesis are described in this chapter. There are in total seven articles included in this dissertation. Six of the articles are journal articles, and one is a seminar article (publication V).

6.1 Financial and Environmental Impacts of Hypothetical Finnish Dry Port Structure

Aim of the study was to research, if the dry port network could be cost-efficiently implemented in Finland. Furthermore, possibility to decrease environmental impacts was studied. Article includes a literature review regarding intermodal transport and the dry port concept. In addition, location optimization literature regarding dry ports and intermodal terminals is reviewed. Furthermore, optimization of dry port amount and location is accomplished in the empirical part of the study. IMOs sulphur regulation and its possible impacts on BSR transportation sector are studied in the discussion.

Literature Review

Dry port research has been mainly accomplished during the last three decades, i.e. it is a fairly new concept. According to the literature review, dry port concept is defined by Roso (2009b) as: “The dry port concept is based on a sea port directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the sea port. In addition to the transshipment that a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, maintenance of containers and customs clearance are also available”. A sound connection between road, rail and sea port enables fast and reliable movement of freight between dry port and sea port, and the performance of a dry port can thus be measured by the quality of access to the sea port and the quality of the road-rail interface (Roso et al., 2009). By implementing dry ports, sea ports can enlarge their operative area in the hinterland (Lee et a., 2008). Furthermore, increasing utilization of dry ports will also increase the utilization of intermodal transport, which will lead to the decreased amount of road transport. This will again lead to an environmentally less
harmful transportation system. In addition, the congested roads and sea port access can be relieved, if less freight is transported by road.

Dry ports can be categorized by their distance from a sea port. Separate categories are close, midrange and distant dry ports (Roso et al., 2009; Woxenius et al., 2004), and each different category has its unique benefits, but there are also the similar benefits of all possible categories. Dry ports can decrease congestion on a road network, immediate vicinity of a sea port and in the sea port city. Rail operators gain more market share, but road transport shippers will also gain a wider range of logistics services. Additionally, dry ports can decrease environmental impacts, create job opportunities and regional development. (Roso et al., 2009; Woxenius et al., 2004)

Location optimization of intermodal terminals and dry ports has also been studied in various research projects. Optimization usually aims to maximize the cost-efficiency of the transportation system. Different utilized location optimization methodologies are e.g. location-allocation methodology, hub location optimization, simulation and heuristic methods (see e.g. Arnold et al., 2004; Racunica and Wynter, 2005; Rahimi et al., 2008; Sirikijpanichkul et al., 2007).

**Empirical Study, Conclusions and Contributions**

Empirical part of this article was based on gravitational models. They were created to optimize the utilization and location of dry ports. The models included Finnish road network distances between the 50 most populated cities. In addition, rail network distances between these cities were taken into account. Both road and rail network distances to the four chosen sea ports were also gathered. These are the Port of Kotka (this sea port merged with the Port of Hamina and is currently called the Port of HaminaKotka), Port of Helsinki, Port of Pori and Port of Oulu. Sea port locations were chosen in a way that they would cover the Finnish coast efficiently. Road and rail transport modes had their own cost level for one ton-kilometer. This cost level was calculated earlier by the author in his master’s thesis (Henttu, 2010). Used cost for one road ton-kilometer was 0.0506 € and for rail 0.0270 €. Due to cheaper ton-kilometer cost for rail a longer journey using both road and rail could be less expensive than a shorter unimodal road journey.
The models minimized transportation costs in the system. Transportation cost optimization was performed with Microsoft Excel Solver. The model starts with the most available number of dry ports (nine dry ports were possible in this study). Heuristic approach was then used to drop one dry port out of the system/model. The dropped dry port is the one, which has the least road and rail connections. Furthermore, additional similar models were created to compare the possibility to decrease external costs (accidents, congestion, noise and CO₂ emissions were taken into account in this study) of transportation by implementing dry ports. Used external costs per one ton-kilometer were 0.007 € for road and 0.0007 € for rail.

According to the results from analytical models, there could be up to six implemented dry ports in Finland to minimize total transportation costs in the system. If the amount of dry ports is increased further, the transportation costs will not decrease anymore, but the environmental impacts can be decreased further. Environmental benefits can be increased by adding up to eight or nine dry ports. If adding more, the benefits in pollution are very small, but the investment costs would increase considerably due to the added amount of dry ports in the transportation network. Rail sector creates a very small amount of external costs even with eight or nine dry ports. However, the road sector’s external costs cannot be decreased further, when about eight or nine dry ports are implemented, because road transportation is still needed for the initial and final legs of the transportation in the hinterland side.

Furthermore, alternative models were created to study the impacts of IMO’s sulphur regulation on Finnish dry port implemented inland transportation. The regulation could increase the cost level of sea transportation in BSR, which could lead to a situation that due to less traffic on the Baltic Sea (modal shift from sea to inland transportation could occur) some sea ports would end their operations. The models were enhanced to include only two sea ports (Port of Helsinki and Port of Kotka). According to these models, there are no high cost savings anymore available due to lower coverage of the Finnish coast. Decreased amount of sea ports increase inland transportation significantly if compared to previous models with four usable sea ports.

If implemented properly, the dry port network can improve the Finnish transportation system by increasing cost-efficiency and decreasing environmental impacts originating
from transportation. The amount of sea ports also play a crucial role in the benefits of a dry port network. With fewer sea ports, the locations of dry ports are more important, but the possible cost savings are also smaller than with more sea ports.

6.2 Optimization of Relative Transport Costs of a Hypothetical Dry Port Structure

This is a follow-up article for the previously presented article “Financial and environmental impacts of hypothetical Finnish dry port structure”. In this article, an alternative solution to optimize dry port selection (computer optimization with IBM CPLEX software, see e.g. IBM, 2014) was implemented in addition to the heuristic approach. Furthermore, results of both this and the previous article were compared.

Literature Review

Due to the characteristics of this journal, the literature review is very shortly covered in the article. The review is very similar to the previous article, i.e. the dry port concept is reviewed. Furthermore, utilization of rail for freight transportation in Finland was shortly clarified. In 2010, 85 percent of domestic freight transportation (in transported tons) in Finland was conducted with road carriers, whereas rail transport was utilized only for 11 percent. Situation is a bit better for rail transport, if ton-kilometers are compared: Road transport’s share was 67 percent, whereas rail transport’s share was 21.7 percent in Finland in 2010 (VR Group, 2014).

Empirical Study, Conclusions and Contribution

The gravitational models utilized in this article are similar than in the previous article. In this article, both the heuristic approach and automatic computer optimization (IBM CPLEX software) were used separately. Nine potential dry ports are available, when using the heuristic approach. The amount of possible dry ports was increased to include all top 50 Finnish cities by population, if they have both road and rail access.

If the computer optimized method is compared with the heuristic method, small increased costs savings were possible. However, the difference was only minimal, if compared to the heuristic approach, i.e. heuristic approach is appropriate, if the amount
of potential dry ports is limited to few, in this case nine possibilities. According to the results of both the heuristic and CPLEX optimized solutions, the most suitable amount of dry ports would be around four. Relative transportation costs can be decreased by adding more than four dry ports, but cost reductions become very slight, i.e. adding more than four or five dry ports is not sensible anymore.

If the amount of possible dry ports is increased (50 possible dry ports were tested in the article), then the utilization of software is basically compulsory, since utilizing the heuristic approach could last numerous months. When computer optimization was used, it took only a few minutes to accomplish the optimization of the model with 50 dry ports. Building of the model naturally took more time (about 2-3 hours. Building of the heuristic model took one or two working days, i.e. building CPLEX model was less time-consuming), but when the model was ready, the execution was not time-consuming. In addition, utilizing automated CPLEX optimization, the number of potential human-made errors can be eliminated. However, only small transportation cost savings were able to be achieved with a significant increase in the possible dry ports. Again, four dry ports seem to be the most optimal amount and decrease of transportation costs become low with more than four dry ports.

### 6.3 Hinterland Operations of Sea Ports Do Matter: Dry Port Usage Effects on Transportation Costs and CO$_2$ Emissions

Aim was to extend dry port research by creating a discrete-event simulation (DES) model to study the effects of a dry port network on a Finnish scale. Another objective was to research how to locate potential dry ports on a regional scale. Furthermore, research aimed to find out how to estimate the demand stability of dry ports and how chosen dry ports interact in the larger logistical system. In addition, possible environmental benefits of a dry port network were studied.

After the publication of the article, it was noticed by authors of the article that electricity prices used in this publication are not totally correct throughout the article. Used values in the model and most parts of the article are between 0.10 €/kWh and 0.20 €/kWh. However, the price of electricity is accidentally reported as 0.01 and 0.02 €/kWh in some locations of the article (see e.g. Figures 6 and 7 and Tables 5, 6 and 7). Even
though the price of electricity is mistakenly reported in some locations, the model used a more realistic price range (0.10 €/kWh and 0.20 €/kWh) during all simulation runs.

**Literature Review**

Extended literature review was obtained and updated regarding research concentrating on the dry port concept. In addition, literature and statistical review of oil price development was included, since oil price is crucial for the price level of road transport, which can be seen as the main competitive mode for rail transportation.

According to the literature review, dry port concept related research was categorized into six different topics: PPP, costs of transportation, throughput, regionalization and case studies, container management and environmental benefits. Reviewed articles are mainly focusing on two or three of these topics. Regionalization and case study is the most popular topic of dry port research. There are numerous articles, which are reporting experiences of dry port cases around the world. And due to the dry port concept’s characteristics, the regionalization is commonly studied. PPP and costs of transportation regarding dry port network implemented transportation are the second most studied topics. Due to major investment requirements regarding dry ports, PPP is taken into consideration. In addition, studies show that PPP is a usable way of investing and operating dry ports, due to more versatile co-operation between stakeholders. Dry ports are aiming to create cost advantages for customers, and due to these costs dry ports are a popular topic. Possible throughput volumes are also vital, since if dry port investment is situated in a poor geographical location, the investment is wasted. Environmental benefits are mentioned in most dry port studies, but they are not the main focus of most of the researches. Increased amount of rail transport and the same reduced amount of road transport will decrease the amount of CO₂ emissions. In addition, other external costs can be decreased and these are e.g. congestion, noise and accidents.

Price development of rail and road transport modes’ energy sources plays an important role in the future development of transportation. Price level of oil has a straight influence on the attractiveness and price level of road transport. It also has a direct influence on rail transport if diesel locomotives are utilized. In Finland, however, about
80 percent of rail network is electrified, i.e. electric locomotives are mostly used. If the price of oil becomes more expensive, it will increase the price level of road transport, which will in the end improve the attractiveness of rail transport in comparison to road transport. Long-term development of the oil price level has seen an upward trend. Increasing cost of oil can also be assumed to continue in the future due to various reasons. First of all, there is a limited supply of oil. Another reason is the fact that some principal oil exporters (e.g. USA and China) have experienced a continuous increase in the need for imported oil, which has led to a situation where these countries are nowadays actually dependent on foreign oil. At the same time, other main oil exporters (such as Saudi Arabia, Russia and Iran) have been struggling to increase their oil production volumes.

**Empirical Study, Conclusions and Contributions**

A DES model was created, which imitates freight transportation in Finland. Two different scenarios run at the same time to allow a comparison with a traditional and alternative scenario: The first one is the dry port implemented scenario. The second one is a scenario in which only unimodal road transport can be used. In addition, multiple runs were made to find out the effect of changing oil and electricity prices. Shippers can either minimize transportation costs or CO$_2$ emission amounts in the model. Location selection for dry ports was improved from earlier studies (see two previous articles) with the model. Another step forward was to take different oil and electricity prices into account and see what the effect in dry port locations and amounts is. The model collects both transportation costs and CO$_2$ emission amounts of both scenarios during the simulation runs. User of the model can change the used dry ports and see what the effect is on costs and emissions.

Simulation model can be used to find out the best locations for dry ports in different oil and electricity price scenarios. This will also help minimize investment in individual dry ports. Furthermore, by changing the prices of oil and electricity, the model can estimate how much demand changes in different cost scenarios. This can help decision-makers to invest in locations with high demand and a low variation of demand between separate scenarios.
The results of the model show that dry port network implementation could decrease both transportation costs and environmental impacts originating from Finnish transportation. There are some clear dry port locations according to the model. City locations with the highest cargo volumes and lowest variation level are the most attractive dry port locations. City of Tampere has the highest volume, but also the lowest amount of variation. Based on these results, Tampere is the highest ranked dry port location. Lahti, Jyväskylä, Pieksämäki and Hämeenlinna all have quite a high volume of freight transportation, but also very low variation. Cities of Kouvola and Lappeenranta have an average amount of volume, but high variation, which increase risks, since the price levels of oil and electricity have a large effect on these cities’ possibility to be a cost-efficient dry port. However, the rail leg between Kouvola and Kotka has a high volume in the model, since many potential dry ports are transporting freight to and from the Port of HaminaKotka. In addition, the rail leg between Tampere and Rauma has high freight volumes.

The model suggests that approximately 30-41 percent of Finnish inland transportation should be conducted through a dry port network (depending on the oil and electricity price). On the other hand, it means that 59-70 percent of inland transportation should be made by road transportation to minimize the total costs of the Finnish system, i.e. dry port implementation should be made with cautiousness to avoid poor and unnecessary investment decisions. Transportation cost of one container in the unimodal road transport scenario is between 150 and 170 € depending on the price of diesel. Cost savings related to utilizing dry ports are 8-25 € per container depending on the price of energy (both diesel and electricity).

CO₂ emissions can be decreased by up to 32-45 percent according to the model. Again, the price levels of oil and electricity are the main drivers for the accurate emission decrease. CO₂ emission amount originating from transporting one container in the unimodal road transport scenario is approximately 145 kg. This amount can be decreased by 47-64 kg down to 81-98 kg per container (32-44 percent relative decrease). However, the price level for one ton of CO₂ was low at the time of writing the article (approximately 7.6 €/ton at the end of the year 2012), which decreases companies’ efforts regarding their CO₂ emission levels, i.e. higher effects are possible, if the price of CO₂ ton would increase further. Cost savings could be between 9 to
almost 12 € per one container, if dry port implemented rail transport was used instead of unimodal road transport. This size cost savings could be possible, if the price of one ton of CO₂ would increase to approximately 180 €.

6.4 Trends of Freight Transportation in North-West Russia in 2010s

The article presents a statistical review of the Russian transportation sector. Furthermore, the objective of the article was to expand knowledge of the transportation sector of North-West Russia including mainly both the Leningrad and St. Petersburg regions. All the main transport modes are reviewed, but the main focus is on the rail and sea transport modes. Volume statistics of North-West Russian sea ports are also reviewed. North-West Russia was the main focus in the research, since it is the principal gateway between Europe and Russia.

Literature Review

Russia is one of the major trade partners of the EU. Foreign trade of Russia with Europe accounts for approximately 50 percent of the total external freight turnover of Russia. In addition, Russia has just recently become a member of the Customs Union and World Trade Organization (WTO), i.e. the Russian Federation is paying close attention on improving its competitiveness on a global scale. Furthermore, Russia actively develops its transportation system with the creation of modern transportation hubs and corridors, which also enhances the possibility for other countries to interact with Russia transport wise.

Reform of the rail sector contained the following guidelines: All freight wagons will be owned by private companies or Russian Railways’ (JSC RZD) subsidiaries. Independent tariffs will be created for JSC RZD own rolling stock. Private shipments will be used for local routes. Price level of shipments on the JSC RZD network will be based on regulated tariffs. After the deregulation of the railway market in Russia, a number of new companies appeared in the railway transport sector. JSC RZD is currently the largest player, which owns the rail infrastructure and regulates the tariffs. A high volume of smaller private railway companies owns and operates freight wagons on Russian soil. Russia has the highest volume of electrified rail tracks (43,100 km),
second longest railway network (85,200 km), third highest cargo turnover and fourth highest amount of passenger kilometers in the world.

According to the literature review, RZD holding owns a significant amount of various rail wagons, which are divided between different daughter companies of RZD. JSC TransContainer is part of RZD holding, and it is in charge of container transportation by rail. JSC TransContainer owns approximately 24,400 flatcars for container transport. Both First Freight Company and Second Freight Company own a variety of different wagons (e.g. tank wagons and mineral wagons) for freight transportation purposes. However, due to deregulation, the wagon leasing business has increased its share among private companies (other than JSC RZD) in Russia. Demand of rolling stock is high, but existing fleet is in poor condition for the most part. Customers can either procure wagons from a primary or secondary market or they can rent wagons. Renting is quite popular, since wagons are expensive, especially new wagons. Most of the new wagons in the Russian rail network are bought by wagon leasing companies. Most leased wagons during the writing of the article were tankers, semi-wagons, mineral wagons and flat cars for container transportation.

Rail transportation in Russia is strongly connected with sea transportation through North-West Russian sea ports. Approximately 46 percent of sea port throughput was transported by rail in Russia. Furthermore, this share is estimated to increase by up to 66 percent during the next two or three years, i.e. rail transportation is very important for Russian transport policy development.

**Empirical Study, Conclusions and Contribution**

If transport modes are compared in transported tons, then road transport prevails in Russia. Circa 6,790 million tons were transported by road in 1995, whereas 5,240 million tons were transported in the year 2010. Rail transport (1,030 million tons in 1995 and 1,310 million tons in 2010) and pipeline (780 million tons in 1995 and 1,060 million tons in 2010) were the second and third most used transport modes. However, if transported ton-kilometers are compared, then pipeline (1,900 billion ton-kilometers in 1995 and 2,380 billion ton-kilometers in 2010) and rail (1,210 billion ton-kilometers in 1995 and 2,010 in 2010) are the most popular modes. Road transport plays only a
minor role in ton-kilometers with 156 billion ton-kilometers in 1995 and 200 billion ton-kilometers in 2010. This indicates that road transport is used more often in short distance transportation routes than rail and pipeline. Frequency of road transport usage increases significantly due to freight distribution inside Russian cities. On the other hand, rail and pipelines are used for longer distances on average, which will accumulate more ton-kilometers.

Sea transportation sector has developed significantly during the last few decades in North-West Russia. Total turnover was approximately 40 million tons in the year 2001, if turnover of all reviewed sea ports (Port of Vyborg, Port of Primorsk, Port of St. Petersburg and Port of Ust-Luga) is summed up. In 2011, the turnover is almost 160 million tons. It is also estimated that freight volumes will increase in the near future. The actualized throughput of sea ports located in North-West Russia has quadrupled in the last ten years. Russia is also investing heavily in sea ports and infrastructure, which is related to sea ports. One example is the Port of Ust-Luga, which is situated near the Russian and Estonian border on the Gulf of Finland. The port of Ust-Luga is mainly being constructed, since the throughput capacity of North-West Russian sea ports is limited. The main container sea port located in North-West Russia is the Port of St. Petersburg. The principal problem with the Port of St. Petersburg is the fact that its throughput capacity is almost totally in use. However, some freight flows can be reconfigured to utilize the Port of Ust-Luga instead.

The Port of Vyborg was the smallest sea port with about 1,100 thousand ton throughput in the year 2011. At that time, the Port of Primorsk was having the highest throughput, and it was approximately 75,000 thousand tons. The Port of Primorsk specializes in liquid transports. The second largest North-West Russian sea port in 2011 was the Port of St. Petersburg (about 60,000 thousand tons), but it was the most versatile if different freight characteristics are compared including e.g. high volume of containers, mineral fertilizers and general products including metals and refrigerators. The Port of Ust-Luga had the third highest throughput volume in 2011 (22,700 thousand tons).

Approximately 47 percent of freight transported from the hinterland to sea ports is done by rail, and circa 24 percent of freight from sea ports to inland destinations is conducted by rail. Freight volumes between Europe and North-West Russia are estimated to increase in the near future. This creates possibilities for the local transportation sector.
A sophisticated rail transport corridor between Russia and Europe could improve the whole transportation system, since then there would be two alternative main routes (sea and rail) between Russia and Europe.

6.5 A Description of the North-West Russian Logistics Sector – Implications for the Rail Baltica Growth Corridor

Objective of the article was to study the North-West Russian private sector opinions regarding the Rail Baltica transport corridor. The utilized research method was a semi-structured theme interview and the main themes were the current situation of the North-West Russian rail transport market, decision-making processes concerning the transportation market in Russia and the opinions of interviewees regarding the rail transport corridor called Rail Baltica.

Literature Review

Literature review summarizes transport sector statistics in the Russian Federation. The first part presents and analyzes the overall transport statistics of Russia. This part also includes a short summary of the Russian railway Reform Program. The second part is concentrating on the railway market.

There are no rail corridors in use between Central Europe and Russia. Freight flows are mainly conducted by sea and road transport modes. If Rail Baltica goes ahead as it is planned, it would connect the Baltic States, Finland, Germany, Poland and Russia. Connection between Finland and Estonia would be made with short-sea shipping). If rail transport utilization could be increased between the Rail Baltica countries, it would decrease environmental impacts in the area – especially in comparison with road transport.

Transportation sector has had its ups and downs in Russian history. There was a significant decrease in Russian freight flows after 1990. The decline was a consequence of a decrease in the industry related to cargo transportation and an increase of the consumer market segment during the transition process of the Russian economy from planned to market structure in the middle of the 1990s. Almost a decade later the
transportation sector showed positive growth after the millennium. Annual growth rate of 2-3 percent was actualized from the year 2000 to 2008. Nonetheless, global crises affected the Russian transportation sector negatively after the year 2008, and negative growth followed. Russian economy is resource dependent and commodity driven. The share of oil and gas exports has increased from 50 to 67 percent from the year 2000 to 2010, i.e. Russian exports are dependent on an efficient transportation system. North-West sea ports are major trade routes between Europe, and more than 2.5 million TEUs were handled only in the Port of St. Petersburg during the year 2012. In total, more than 190 million tons of freight were transported through North-West Russian sea ports. On the other hand, negative aspects exist concerning the Russian transportation sector. E.g. transport infrastructure is partly in poor condition (if road and rail network are compared, then the road network is in worse condition), and there is a lack of carrying capacity for both road and rail transport. In addition, rolling stock is outdated for the most part and there are inefficiencies in cooperation between different transport modes in Russia. Furthermore, customs operations can be expensive, but also time-consuming.

Railroad market has played an important role in Russia mainly due to historical and geographical reasons. To improve the railway market, Russia started the railway sector deregulation process in the year 2001 with the first step of the Reform Program. European model was used, which means that infrastructure is owned and regulated by one single entity (JSC RZD). However, railway traffic is deregulated, i.e. numerous private companies are in charge of rail transportation in Russia. The Reform Program will continue to the year 2030 and it includes various changes in order to continue the deregulation process.

**Empirical Study, Conclusions and Contribution**

Empirical part of the article reveals results regarding the interviews on the following topics: rail transport in Russia, competitive transport modes, decision-making processes regarding the transportation sector in Russia and interviewees’ opinions regarding the Rail Baltica transport corridor. Empirical results are based on ten semi-structured interviews, which were accomplished mainly in St. Petersburg, but also in the Leningrad region.
Rail is the main transport mode in Russia (if pipelines are excluded; pipelines and rail transport share similar annual ton-kilometer volumes). Rail transport is both predictable and reliable. On the other hand, road transport prevails over rail on the flexibility side. It was also stressed in some interview meetings that the dry port network is poorly developed in most parts of Russia. However, there is a strong network of dry ports surrounding the St. Petersburg region and these are mainly used in connection with the North-West Russian sea ports (see e.g. Korovyakovsky and Panova, 2011). Other main weaknesses are an unclear pricing policy and high infrastructural tariffs. Tariffs are favoring long distance rail routes. Road transport is the main competitive transport mode for short distances, but sea transport is the main competitive transport mode for longer distances. However, some interviewed companies have utilized road transport for up to 3,500 km transportation legs.

Transport sector related decision-making processes are time-consuming and they include major amounts of bureaucracy. All the large decisions are made in Moscow. Smaller decisions can be decided in St. Petersburg, but decision-making in Moscow is increasing in importance all the time. The main decision-maker in the rail transport sector is JSC RZD. According to most of the interviews, JSC RZD has more decision-making power than the Russian ministry of transport.

According to the interviewees, the Rail Baltica rail transport corridor is an interesting transport sector related project, which could offer benefits for Russian customers. However, short-sea shipping connections already implemented on the Baltic Sea are believed to hinder the possibility of Rail Baltica to gain market share. On the other hand, IMO’s sulphur regulation could increase the sea transport price level, which would increase the attractiveness of Rail Baltica. Other main hindering factors are border-crossing operations and infrastructure as well as the Russian legislation, which adapts very slowly to new things. Different gauge widths in Russia and Europe were also mentioned as an important bottleneck that has to be solved.

Main factors for Rail Baltica are price, time of delivery, frequency, intermodality, safety and predefined schedule. The first three factors are the most important. Suitable delivery time for most of the interviewees would be 5-7 days between St. Petersburg
and Berlin, which would be quite easy to realize, i.e. most of the important factors can be achieved to make the corridor attractive for Russian customers.

Main strengths of the Rail Baltica rail corridor for Russian customers would be a possible shorter lead time in comparison with other transport modes (such as sea transport via the Gulf of Finland and Baltic Sea). There was some skepticism regarding Rail Baltica’s competitiveness as in price level against sea transport. Some interviewees assumed that the price level of rail transport could be too high. However, this was not seen as a very possible scenario due to IMO’s sulphur regulation, which was believed to increase the costs of sea transport in the year 2015. Rail Baltica would improve land transportation between Russia and Central Europe cost-wise, but environmental impacts would also decrease. The main opportunities of Rail Baltica would be improved connections between sea ports and the road network due to an improved rail leg. Rail transport could substitute for road transport in case the diesel price increases greatly in the near future. In addition, the rail corridor was assumed to be more attractive, when IMO’s sulphur directive becomes stricter in the year 2015.

Threads regarding the Rail Baltica rail corridor include customs procedures between different countries. Russian border-crossings were assumed to be particularly difficult to organize in a way that freight transportation is smooth. Part of the interviewees assume that rail transport would be more expensive than the sea transport alternative. Different gauge widths (Russian 1,520 mm and European 1,435 mm) along the route could be a large setback due to more expensive transportation and a longer lead time due to a change of rolling stock. Rail Baltica would also need significant investments, since the rail track should be renovated.

6.6 Border-Crossing Constraints, Railways and Transit Transport in Estonia

Transportation sector of Estonia including Estonia’s international rail connections was the focus of this study. Interest was on how transit traffic has developed in Estonia during the last few decades and what has been the main driving force for the development. In addition, rail container transport was the focus of this study. Future estimations concerning border-crossings and transit traffic in Estonia were also studied.
Literature Review

The Baltic States (Estonia, Latvia and Lithuania and other countries further East of Europe) have long served as a general cargo transit area for Russia. The total rail transport volume in Estonia has decreased during recent years. However, container transit transportation by rail through Estonia has increased its volume during the last decade from almost non-existent to nearly 62,000 transported TEUs in the year 2013. Similar progress is visible also in Latvia and Lithuania. Based on the literature review, Russian consumer market has globalized significantly during the last decade. The globalization has also made the fast growth of the sector possible (Retail trade volume has enlarged by nine times from the year 2000 to 2012 if a comparison is made in the Russian national currency). At the same time, consumption is maturing currently, and this could slow down the market growth. Online retail shopping is increasing its market share in Russia and this together with the low growth of traditional consumption possibly continue the growth of the whole consumption sector in the near future. Russia specializes in raw material exports, which means that Russia has a high demand for consumer items, which can be transported e.g. through the Baltic States or Finland.

Container market in Russia has increased significantly during the last fifteen years. Approximately 330,000 TEU were transported through the Port of St. Petersburg in the year 2001, but this increased to 2.5 million TEU in the years 2012 and 2013. During this same time window, the share of Finnish transit container traffic from the whole container market of the Gulf of Finland has decreased from 42.4 to 8.9 percent. At the same time, Estonian transit container transportation volume has increased from about 7,000 TEU to over 60,000 TEU. This increase can mainly be explained by the development of block train connections between the destinations East of Estonia. The service is rather straight-forward, since border-crossing formalities are already made before the train leaves, which eliminates the waiting time in the border-crossing area. If the developments of road and rail transport are compared from the crisis year 2009, rail transport has had higher relative volume development than road. However, road transport still dominates Estonian sea port related container transportation, but rail has doubled its market share to 20 percent during the observation period. According to the review of statistics, approximately 10 percent of Finnish hinterland transportation was
conducted by rail during the years 2008-2012. The same figure in Russia and Estonia was 25.8 and 53.8 respectively.

**Empirical Study, Conclusions and Contribution**

The research is based on a statistical review, and a case study made in Estonia. Authors of the article made two one-week visits to Estonia. Numerous meetings and short interviews were made during these visits. In addition, one deeper interview was accomplished with an Estonian rail freight company director. Besides the described methods, the authors have a long history in research observations concerning the transportation network in the Baltic States, which was also the source of data for the article.

The Estonian case company is focusing on railway freight transportation. The company owns in total 3,300 rail wagons and 70 diesel locomotives (most are made in the USA, but some are also Ukrainian, since they are needed for border-crossing operations between Russia). Total cargo volume of the company was 16 million tons in the year 2013 of which 10.4 million tons are transit traffic (highest annual rail freight volume was 42 million tons in the year 2006). Estonia is in the favorable position of being a transit rail country for Russia due to its Russian rail gauge width (1,520 mm), i.e. the same wagons can be used both on the Russian and Estonian rail network. However, Central Europe has a different rail gauge (1,435 mm), which hinders the development of rail connections between Estonia and Central Europe. The change between Russian and European gauge happens in Šeštokai, which is a small town located in Lithuania, near the Polish border. Transshipment can be made in Šeštokai, but it will increase both lead time and the price level of rail transportation between the Baltic States and Central Europe.

Even if total and transit volumes have decreased during the last eight years, container transit volume of the case company has increased during the last ten years. This is the only sector in which the case company assumes to increase its volume in the future. Other rail freight sectors will also have problems with freight volumes in the near future. There are various possible reasons for decreasing rail transport volumes between Estonia and Russia. Russia has changed the priorities of its transit traffic countries due
to different reasons (e.g. location change of Bronze Soldier could have decreased transit volumes through Estonia). In addition, global credit crunch in 2008-2009 had a major impact on the economy of Estonia and at the same in the railway sector. There were more limitations for Estonia than its neighbor countries Lithuania and Latvia in the year 2013. Additionally, Russia’s current transport policy aims at minimizing the utilization of transit countries. It has succeeded partly by investing heavily in its own sea ports located in North-West Russia. Some amount of transit traffic through the Baltic States have been redirected to go directly through e.g. the Port of Ust-Luga, which has increased its throughput capacity and realized throughput considerably in the last five years. Throughput volume of the Port of Ust-Luga was slightly less than 10 million tons in 2009, but it was increased to more than 50 million tons in the year 2013.

As was described earlier, container rail transportation is developing well in Estonia. The case company has created many international container rail connections with e.g. Russia, Ukraine, Uzbekistan and Kazakhstan. The connections between Russian destinations in particular have been very profitable. The role of the case company is only to operate trains in Estonia. Russian partners will do all the other tasks, which are e.g. marketing, getting customers and moving rolling stock in Russia. Rail connections are mainly based on a fixed schedule, but some are based on seasonal demand. According to the case company, transporting one container from Tallinn to Moscow and back will cost about 1,700 € (this was the situation at the start of the year 2014) for both road and rail. Road costs less than rail on shorter routes, but rail becomes cheaper on longer routes. However, the required capacity of the transported freight plays a large role. Smaller batches are more convenient and faster to transport by trucks. On the other hand, larger batches usually need to utilize rail, since the capacity of trucks is more limited than the capacity of rolling stock.

All the Baltic States belong to a similar railway market position. They are part of Europe, but have a geographically optimal location to serve Russia. In addition, similar rail gauge width improves the possibility to co-operate with Russia. On the other hand, utilizing rail to transport freight between Central European countries (e.g. Czech Republic or Germany) is more complicated. First of all, there are many countries between the starting point and destination, which hinders the operation of smooth transportation. Due to numerous countries located on the route, co-operation with
several railway operators and agencies would be needed. This could be improved, if one single company would be responsible for the whole route.

The main operational constraints concerning the international rail connections of Estonia are different gauge widths along the rail route, border-crossing operations, delivery time issues, low price level of road transport, unpredictable Russian market and legislation and infrastructure investments. In addition, the possible large amount of countries along the route can hinder rail transport’s smooth operation.

6.7 Transportation Costs Do Matter: Simulation Study from Hospital Investment Decision

Aim of the research was to clarify the current cost structure of patient and visitor transportation between homes and hospitals in a Finnish healthcare district. Among that, the other aim was to research how transportation costs will develop during the following decades, if the progress of population demographics is taken into account. Furthermore, different scenarios for hospital investments were created and researched. In addition, CO₂ emission volumes and prices are studied.

Literature Review

Review focuses on the progress of demographics in developed countries and simulation studies concerning healthcare. Demographics development is widened by also taking into account some large developing countries. Healthcare costs and their development are also studied in chosen countries. Finnish healthcare expenditures and age groups are reviewed, and the conclusion is that the group of 65 and older people has been and is growing. This group is estimated to grow to as large as the group of 0-18 year old people in the year 2016. This is problematic, especially for the Finnish healthcare, since older people have more visits to hospitals and medical centres than people in younger age groups on average. At the same time, personal tax rate for the citizens has increased due to a need for higher tax income, which enlarges the problem further. Higher tax income is important for the region, since total yearly hospital visits have been increasing on an annual basis, and these visits are mainly funded by tax income. Annual healthcare expenditures have increased from 7.54 billion to about 17 billion € in Finland in 16
years (from the year 1995 to 2011). In 2011, healthcare expenses accounted for nine percent of GPD, and could be assumed to increase further. Public sector (municipalities and central government) is responsible for most of the healthcare costs in Finland and thus this situation creates a major problem to be solved for the Finnish economy.

Simulation studies regarding the healthcare sector are quite common. Goal of these studies is mainly to produce the same level of service to improve the efficiency of a service process with fewer resources. Various researched healthcare topics with simulation are e.g. patient flows inside a hospital, hospital bed utilization, vehicle routing problem of material logistics and patient behavior with changing CT scanner scenarios. However, studies focusing on the transportation of patients are actually very rare. Furthermore, the authors of the article did not find any simulation studies, which would simulate patient transportation between their homes and hospitals and which would also take different transport modes into account.

**Empirical Study, Conclusions and Contribution**

Methodology of the study is SD simulation. The case in this research is a Finnish healthcare district. A city in the northerly part of the district was making a decision, whether to renovate an old northern local hospital or to eliminate it and build a new one or to outsource all healthcare services outside the northern city. Aim of the simulation model was to estimate the total costs of transporting patients living in the northern city and how these costs could evolve in the future (simulation was run until the year 2040). Another aim was to research the utilization rates of different possible transport modes (ambulance, bus, own car, taxi and train). Furthermore, the model estimates CO₂ emission volumes of the patient transportation. Required input data for the model was gathered through various sources. These include e.g. local municipality authorities, local hospitals, statistic databases and publicly available official Internet websites. Output of the model consists of once a year accumulated kilometers of different transport modes (ambulance, bus, own car, taxi and train). The model converts kilometers to yearly accumulated costs and CO₂ emissions.

Two separate demographics scenarios and three different hospital location options were adapted to the model. Population of the northerly city decreases until the year 2040 in
the first scenario. Young active population starts to move from other cities to the northern case city in the second scenario, i.e. population does not decrease or increase considerably until the year 2040. Three different options are: 1) patients use hospitals with current distribution. 2) Patients use just the northern hospital, which is located near patients. 3) Patients use only the southern hospital, which is located farther from patients.

Results show that personal car and taxi are the two most used transport modes, if yearly kilometers are compared. Personal car accumulates the most kilometers (around 151 cumulated million kilometers from the year 2012 to 2040) with scenario one and option one. Surprisingly, the second most used transport mode is the taxi with about 52 million cumulated kilometers. Bus, train and ambulance are used more rarely: 38, 22 and 3.0 million cumulated kilometers respectively.

The model estimates costs originating from different transport modes. Personal car and taxi are the most costly transport modes in the studied scenario. However, taxi is more expensive than personal car in cost comparison. Taxi accumulates circa 122 million €, whereas cumulative personal car costs are approximately 48 million €. These account for about 88 percent of total transport costs accumulated by the model. Third highest costs originate from the usage ofambulances. However, due to such major costs of taxis and personal cars, costs originating from other costs are playing only a minor role.

Traveling of patients between homes and hospitals is subsidized by the Social Insurance Institution of Finland. This is one explanation for the heavy utilization of taxis. Patients can order a taxi, which will pick them up from their homes. Taxi transports the patient conveniently with door-to-door transport to the hospital. Self-finance of one journey was 9.25 € in 2012, but it was increased to 14.25 € in 2013 (same self-finance is used also in 2014). If self-financing exceeds 242.25 € in one year, then all additional costs are subsidized without the need for self-finance share. Other public transport modes (bus and train) are also subsidized, but the self-finance share is so high, that public trains and buses are mostly cheaper than the self-finance proportion.

According to results based on the SD model, yearly transportation costs of patients and visitors will increase until the year 2033. This is the case even though it is estimated
that the population of the municipality will decrease from about 88,000 to 80,100 during the observation period (2012-2040) in scenario one. According to the statistics, older people tend to use medical services more often than younger people, and this mainly explains the increased costs. Yearly transportation costs start to decrease slowly after the year 2033. Yearly transportation costs were estimated and compared by three different scenarios: 1) all patients use the northern hospital, 2) all patients use the southern hospital and 3) patients use both hospitals with accomplished distribution. Average yearly transportation costs are 7.7 million € with real-life visit distribution among both hospitals. If all patients use the northern hospital, then yearly costs are decreased to 3.4 million €. However, if the northern hospital is demolished and all patients need to use southern hospital, yearly costs increase up to 13.9 million €.

Although transportation costs are so high that they could have an effect on the decision-making processes, the estimated CO₂ levels are rather low. Yearly CO₂ emissions would be about 670-700 tons with current patient distribution among the northern and southern hospital. If all patients would use the southern hospital (maximum transportation amount), then yearly emissions would be approximately 1,100-1,200 tons of CO₂.

Based on the results, distances to alternative hospitals play a very large role in the total transportation costs. However, transport mode selection of patients is also a very important aspect to be taken into account. Personal car trips between homes and hospitals create most of the traveled kilometers in the case location, but the taxi creates the most costs in the transportation system. These could be significantly decreased, if cheaper modes (e.g. commuter train and bus connections to and from hospitals) could be made more attractive. However, based on the results, yearly transportation costs are estimated to increase until the year 2033 even though the population is decreasing on a yearly basis. Explanation for increasing costs is the increasing average age of the population, since older people use hospital services more often than younger people.

There are different proposed solutions to decrease transportation costs. Taxi trips could be organized in a way that they would carry more than one patient per trip. Subsidy level of the most expensive transport mode (taxi) could be decreased, which would increase the attractiveness of cheaper, but not as convenient public transport modes (bus and train). Taxis could also be used together with cheaper public transport modes: taxi
could transport a patient to the railway or bus station and the patient would then continue his or her journey with public transportation. In addition, organized minibuses to and from hospitals could achieve significant cost savings, since the fill ratio of patients in one minibus could be considerably higher than if compared to one patient transported by one taxi.

6.8 Summary of the Publications

A summary of all the included publications is presented in Table 5. It includes the title of the article, objectives, method, data, connection with the thesis’ research questions, main findings and the publication’s role in the thesis.
A dry port network could increase cost-efficiency and decrease environmental impacts in Finland. There is certain minimum amount of dryports, which could be implemented. Transportation modes are minimized, then appropriate number of dryports would be around four or five. However, if externalities are eliminated, then economic dry ports would be efficiently implemented.

The results gained with the model stated that 30-41 % of inland transportation should be conducted through dry ports to minimize transportation cost. Cost saving ratio between dry and road transport modes is about 25 % per container depending on the inland district. Fuel use and CO₂ emissions could be decreased by up to 32-45 %.

The interviews stated that Rail Baltica is an interesting project. However, already implemented short sea shipping connection on Baltic Sea were believed to hinder Rail Baltica sources. On the other hand, IMO’s sulphur regulation would increase price level of sea transport, which would increase attractiveness of Rail Baltica. Most important factor for Rail Baltica are time of delivery, frequency, and reliability, safety and defined schedule.

The results show that Rail Baltica transport corridor's non-inland reaches Finland. The hypothetical Funds dry port network could achieve significant benefits, if it would be connected to Rail Baltica. This publication extends North-West Russian research from previous publications's statistics review.

Table 5. Summary of the publications.

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<th>Publication 1</th>
<th>Publication 2</th>
<th>Publication 3</th>
<th>Publication 4</th>
<th>Publication 5</th>
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<tr>
<td>Title</td>
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<td>Financial and environmental impacts of hypothetical Finnish dry port network</td>
<td>Aims was to research, if dry port network could affect the CO₂ emissions and transportation cost levels. The main difference is that the method was improved by also using computer optimisation when allocating dry port locations. The aim is to research, how dry port network could affect the CO₂ emissions and transportation cost levels. The main difference is that the method was improved by also using computer optimisation when allocating dry port locations. The aim is to research, how dry port network could affect the CO₂ emissions and transportation cost levels.</td>
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<td>Objectives</td>
<td>RQ1, RQ2, RQ3</td>
<td>Discrete-event simulation model</td>
<td>Literature and statistics review</td>
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<td>Data</td>
<td>Cost accounting, which include various data regarding rail and road transport modes. In addition, rail and road network routes, distances and locations</td>
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<td>Conclusion</td>
<td>RQ1, RQ2, RQ3</td>
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<td>RQ1, RQ2, RQ3</td>
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<tr>
<td>Materials</td>
<td>A dry port network could increase cost-efficiency and decrease environmental impacts in Finland.</td>
<td>The dry port network was optimized more efficiently. But the cost savings and decrease of environmental impacts were not significant. However, the process of the optimization is not considered.</td>
<td>The results gained with the model stated that 30-41 % of inland transportation should be conducted through dry ports to minimize transportation cost. Cost saving ratio between dry and road transport modes is about 25 % per container depending on the inland district. Fuel use and CO₂ emissions could be decreased by up to 32-45 %.</td>
<td>Freight traffic through the North-West Russian area has increased significantly during the last one or two decades. Especially the rather new sea port called Port of Ust-Luga has gained a large market share. 24 % of all traffic were researched.</td>
<td>The interviews stated that Rail Baltica is an interesting project. However, already implemented short sea shipping connection on Baltic Sea were believed to hinder Rail Baltica sources. On the other hand, IMO’s sulphur regulation would increase price level of sea transport, which would increase attractiveness of Rail Baltica. Most important factor for Rail Baltica are time of delivery, frequency, reliability, safety and defined schedule.</td>
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<td>Role in the thesis</td>
<td>Improves further the research, which was made in Publication 1.</td>
<td>A different approach was taken to improve the dry port research regarding Finnish transport network. The results are similar with Publication 1 and 2.</td>
<td>This publication widens geographical scope to North-West Russia. In addition, the aim was to study, if the Rail Baltica transport corridor could achieve freight volumes from Russia.</td>
<td>Rail Baltica transport corridor's non-inland reaches Finland. The hypothetical Funds dry port network could achieve significant benefits, if it would be connected to Rail Baltica. This publication extends North-West Russian research from previous publications statistics review.</td>
<td>Railroad traffic volumes have significant volume growths regarding their international container rail connections. This publication gives some explanations why Rail Baltica's predecessors, e.g. Finland's development of international rail traffic is compared.</td>
<td>Railroad traffic volumes have significant volume growths regarding their international container rail connections. This publication gives some explanations why Rail Baltica's predecessors, e.g. Finland's development of international rail traffic is compared.</td>
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7 DISCUSSION

The first three articles research the dry port concept with Finnish geographical scope. The first article studies the subject with gravitational models using the heuristic approach. In the second article, the approach is improved by computer optimization. The same subject is studied with a different method in the third article to have another viewpoint of the subject. The results are similar, which improves the significance of the overall results regarding the benefits of implementing a dry port network in Finland. The research focus is moved towards the rail transport corridor called Rail Baltica in the fourth article, which reviews statistics regarding the transportation sector in Russia. The aim was to study if there are enough potential freight flows in the Rail Baltica area. Since Finland is located at the northern end of the rail transport corridor, the statistics review supports the connection between the Finnish dry port network and the rail corridor, since potential freight flows exist. The fifth article continues the research, which was started in the previous article. The aim was to study the attitude of the Russian private sector towards the Rail Baltica transport corridor. Article VI is a case study focusing on research regarding the Estonian rail sector and also including international container rail connections between Estonia and its destinations. The results of this article show that profitable rail freight connections can be organized between BSR and Russia. Similar connections could also be arranged to and from Finland. All first six articles are focusing on freight transportation, whereas the seventh article is researching patient logistics between their homes and hospitals. The seventh article was added to improve the discussion of this dissertation. There are naturally numerous differences regarding patient and rail freight transportation. However, there are surprising similarities between these two different transportation characteristics. In addition, the results of the seventh article state that considerable savings can be achieved if transportation is organized efficiently.

Dry port location selection is important, since the actual investment costs could be very high. Some locations could already have part of the required infrastructure and superstructure for a dry port implementation, whereas other locations could need more investment funding. Additionally, if location is poorly selected, the dry port could not
generate enough cargo throughput to justify its existence, i.e. dry port would not be profitable. If location is appropriate, then an existing dry port will generate a major amount of volumes, and this will lead to many other benefits such as decreased congestion on the road network, decreased environmental impacts from transportation etc. In addition, payback time of the whole investment will be shorter if there is more freight throughput available. Dry port selection should be made based on possible demand and also variation if possible. Freight volume variation of a dry port is low, if demand stays unchanged or the changes occur only seldom, when the structure of the transportation system evolves or changes based on the cost-structure of different transport modes. The distinction between different transport modes can change due to fluctuations in e.g. fuel, electricity or salary costs. This can improve or worsen profitability of different routes and transport modes. If all different changes in the transportation system make significant transitions in the demand of a dry port location, then variation is high. In addition to location, the amount of dry ports on a specific area is important. It is possible that a certain area has e.g. three suitable dry port locations, but only one or two of these should be converted to dry ports. If more dry ports are implemented, the overall traffic could not be enough to create profits for all dry ports and therefore one or two dry ports would need to be eliminated. Before the elimination, all dry ports could suffer due to limited freight volumes.

Implementation of dry ports or a dry port network should not be studied or observed only locally, since transportation of freight is in many cases global, i.e. cargo is not moved only inside one country or region, but through multiple countries and possibly continents. This is also the case with this dissertation. The most probable direction for dry port related freight flows is east from Finland and the Baltic States, since the market in Russia and other emerging economies further east of Europe is considerably larger than the Finnish, Estonian, Lithuanian or Latvian market. This would increase distances between dry ports and sea ports, which would increase benefits of the whole dry port concept. With shorter distances (e.g. in the case of the Finnish dry port network without international connections) the benefits are fewer, since transshipments take percentually a longer amount of time, and they are also more expensive in percentual terms, if compared with total transportation costs. According to the statistics, transport volumes to and from Russia have grown and are also estimated to increase in the future. However, the situation in Finland and the Baltic States is not the same, since statistics
indicate that the market is staying at the same level or decreasing. This means that transit traffic has its possibilities now and in the future, and the dry port concept could play a major role in this development.

Finnish dry port network could be connected with the Russian rail network. Rail gauge width is 4 mm wider in Finland than in Russia, but it does not hinder rail transportation, and thus the same wagons can be used both on the Finnish and Russian rail network. Dry port network in Finland could be a good step to improve the Finnish transportation system, but co-operation with Russia would increase potential benefits significantly. Principal reason is the fact that cargo flows through North-West Russia are significant, if compared to flows to and from Finland and e.g. the Baltic States. The main straightforward reason for this is the fact that Russia’s population is greatly higher than the population of Finland, i.e. the consumption is on a much higher level. The population of St. Petersburg is very similar to the whole population of Finland and thus St. Petersburg could be known as the consumption center of North-West Russia. Freight volumes through North-West Russian sea ports have increased considerably during the last fifteen years. In addition, cargo flows are estimated to increase even further through North-West Russia, i.e. potential cargo flows in the rail network and dry port network in Finland and Russia is probably going to increase in the next ten or twenty years. Road transport capacity in Russia is currently almost fully utilized. If the cargo flows increase further in the near future, rail transport could be an even better alternative transport mode for freight transportation due to the available capacity in Finland and the Baltic States, but also in Russia.

If comparing the utilization of transport modes in Russia in terms of transported ton-kilometers, rail is prevailing. One reason for this are very low weight limitations for road transport. This increases the attractiveness of rail transport significantly on Russian soil. Furthermore, this increases the usability of dry ports. However, weight limits for road transport are much higher in Finland, which increases the usability of road transport against rail transport in Finland. In addition to weight limitations, there are also obligatory charges created for road transport for defined locations. This in turn increases the cost level of road transport, since transportation companies usually collect the required funding for charges from customers by increasing the freight rates.
If the Rail Baltica transport corridor is realized, Finnish dry port network could be connected to Rail Baltica via Russia or via the Gulf of Finland with a short-sea shipping connection between Finland and Estonia. There has also been discussion about whether to build a tunnel between the capital cities of Finland and Estonia, Helsinki and Tallinn respectively (Sweco, 2014). This way the Finnish dry port network could be directly connected all the way to e.g. Central or Southern Europe. Furthermore, Rail Baltica countries would have good connections to European sea ports located along the rail corridor (e.g. Port of St. Petersburg, Port of Ust-Luga, Port of Tallinn, Port of Helsinki, Freeport of Ventspils, Freeport of Riga, Port of Klaipeda, Port of Gdansk and Port of Gdynia).

There are currently functioning international rail connections between Estonia and Russia, which are operated as block trains. This is the only sector, which has been able to increase its freight volumes during the recent years in Estonia. These cost-efficient global rail connections support the assumption that the Finnish rail network could also have efficient and profitable rail connections with e.g. Russia and the further Eastern market, since the environment is very similar to Estonia. Due to similar rail gauge width, the same wagons can be used in Estonia, Finland and Russia. International rail connections through Estonia are transporting transit traffic, i.e. the Russian destinations could be known as distant dry ports, since most of the freight is transported through Estonian sea ports. Similar utilization of Finnish sea ports could work as well. The case company also has profitable block train connections with other eastern destinations (e.g. Kazakhstan and Ukraine). This indicates that not only Russian connections could be lucrative, but also other connections between eastern countries could be beneficial for rail transport.

The last included article (VII) shows that careful organization of routes and methods, and selection of transport modes and hospital locations make a large impact on the cost level originating from the transportation sector. If the organization is made carefully, significant amounts of money can be saved. The same also applies for the freight transportation sector. Inefficient organization of freight transportation can lead to a modal shift towards other transport modes, which have better lead time, price level or frequency. At the same time, current infrastructure and superstructure could be used more efficiently, which could lead to lower transportation costs, shorter lead time or
higher frequency of service. Furthermore, there are other similarities in both rail freight transportation and the passenger transportation sector. A very low amount of competition on the Finnish rail network and the possibility of the main player to also offer road transports has led to a situation where the rail transport is not often utilized to transport freight. Article VII focused on patient transportation inside a Finnish healthcare district. It was found that the most expensive transport mode, if yearly costs are compared, is taxi. This is mainly due to the fact that taxi traveling of patients is largely subsidized by the Social Insurance Institution of Finland. The public transportation would be much cheaper (price of a taxi is about 2.5 € per kilometer and price for a bus and train are approximately 0.144 and 0.219 € per kilometer in the case district) than a taxi. However, since a taxi is very highly subsidized for the patient (patient need to pay 14.25 € for one trip and the excessive costs are subsidized), it is a very popular transport mode between home and hospital in the studied district. Nonexistent or unhealthy competition in both the rail freight and patient transportation sectors has led to an expensive and partly non-logical transport mode selection. Costs of patient transportation could be easily decreased, if subsidization would be decreased. In addition, combined taxi traveling or minibus connections for a large amount of patients could decrease the costs. On the rail freight side, volumes transported by rail could be increased with more competition from the private sector. If the competition would be tighter on the rail sector, there would be more companies serving customers. This could increase the service level, but the price level could also decrease at the same time.

Another similarity can be found if a comparison is made from the external cost point of view. As it is discussed earlier in this thesis, rail transport creates fewer external costs than road transport. These are e.g. CO\textsubscript{2} emissions, noise, accidents and congestion. The difference depends on many aspects (e.g. the source of the energy). Even though rail transport creates less externalities than road, the rail transport sector needs to pay tariffs for utilizing the rail network. This is the case also in Finland, the Baltic States and Russia. However, utilization of road infrastructure is mainly free of charge excluding road charges. Nonetheless, road charges are not used e.g. in Finland. Roads are mainly maintained by tax money and a large proportion is collected from private car users. Furthermore, sea vessel and aviation fuels are tax-free. These factors could lead to unhealthy competition between different transport modes (e.g. road and rail), since
utilizing infrastructure is less expensive for the more polluting transport mode. As it was mentioned in the previous paragraph, the Social Insurance Institution of Finland subsidizes patient transportation. Since patients can use a taxi in many cases, the unhealthy competition between different possible transport modes could arise. Taxi is the most expensive transport mode (if ambulance is not taken into account), and it is also the most polluting mode. However, it is also very popular, since patients do not actually pay that much for taxi trips due to the subsidy. The difference between other transport modes is emphasized, since taxis commonly transport only one patient at a time. Costs and emissions per one patient is thus much higher if compared to e.g. a bus or train, which can transport more people at the same time. If different transport modes could be made more equal, then it could also be possible that the total price and emission levels would decrease in the whole transportation sector.
8 CONCLUSIONS

8.1 Theoretical Implications

The main research question was further divided into four sub-questions. The first sub-question is: “What kind of dry port network would optimize cost-efficiency and environmental impacts?” Based on the research made in publications I-III, dry ports could be implemented to increase cost-efficiency and to decrease emissions originating from the transportation sector. However, there is a limitation regarding how many dry ports could or should be implemented in a certain geographical area. Cost-efficiency in terms of transportation costs can be decreased considerably with up to three or five dry ports, if a dry port network is located in Finland. If more than five dry ports are implemented, transportation costs do decrease further, but by only very limited amounts, i.e. investment costs would be much higher than the revenues in a short period of time. At the same time, a higher number of dry ports can be located in such a location, which has higher freight volumes. On the other hand, transportation sector emissions can be decreased significantly by adding up to nine dry ports. Benefits become almost non-existent if more dry ports are implemented in the Finnish system. Again, environmental benefits can be improved further with a higher amount of dry ports, if the total freight volume of the area is higher and vice versa. Dry ports should be selected based on possible transport volumes and level of variation in freight volume.

Second sub-question is: “Is there enough demand and willingness to support the dry port network and the rail transport corridor?” Based on the review of statistics regarding the North-West Russian transportation sector, the transportation volumes have increased during the last two decades in the researched area. No major collapses have taken place during the last two decades considering freight volumes, which indicates that volumes will continue growing in the future. This development supports the fact that there is enough demand to justify both the Finnish dry port network and Rail Baltica. Finnish dry port network could be (and should be, when cost-efficient) of course utilized for Finland’s own national freight flows. These could, however, not be enough to justify implementation of an extensive dry port network. These aspects are very important in other geographical locations as well. There is no sense to invest in
major infrastructure projects if sufficient freight volumes do not exist. However, these volumes could be increased with the co-operation of other connected regions. Rail freight transportation between Finland and Russia should be vitalized. Finnish dry port network would create benefits to both the Finnish and Russian economies, since the dry port network could be effectively utilized for transit traffic. Since Rail Baltica is a rail corridor and the main transport mode in the dry port concept is rail transport, these could be connected together to obtain more benefits for the whole transportation system. The Finnish dry port network could be connected to Russia and the whole of Europe through Rail Baltica. This would increase the amount of possible freight volumes inside and through Finland in the forthcoming years. According to the interview study among the Russian private sector, there could be a willingness to use Rail Baltica, if the price level, frequency and lead times are suitable for the companies. In addition to the Russian connection, other eastern countries from Europe should also be taken into account, when considering possible rail transportation. Based on the results of article VI, Estonia has already established some profitable block train connections with Russia, but also with Ukraine and Kazakhstan. Connections with other eastern countries could also be beneficial for the Finnish transportation due to a higher amount of potential transportation volume and customers.

There are different factors that could have or will have an impact on the transportation sector. Different factors will have different impacts on different transport modes. Among other factors, IMO’s sulphur regulation is playing a major role in the development of the transportation network and usage of different transport modes, and is thus the main topic of sub-question 3: “Could the dry port network and the rail transport corridor improve future outlook regarding IMO’s sulphur regulation?” A result of many research studies (see e.g. ECSA, 2010; Kalli et al., 2009; Swedish Maritime Administration, 2009) is that the sulphur regulation will increase the costs of sea transport. This could lead to a modal shift from sea to inland transportation modes. Sulphur regulation has the most influence in SECA, which includes the Baltic Sea and North Sea in Europe. All the Finnish, North-West Russian, Estonian, Latvian and Lithuanian sea ports are though located in SECA, i.e. the regulation could have a major impact on the geographical scope of this dissertation. If the modal shift is from sea to inland transport, then different transport modes are road, rail and inland waterways. Road transport is the most harmful, if comparing the level of environmental impacts of
different transport modes. Due to this reason, modal shift to road could actually create more impacts than what was the situation before IMO’s strict sulphur regulation. Due to this reason, it is important that the possible modal shift is towards environmentally less harmful transport modes such as rail transport. A functioning dry port network and a rail transport corridor would definitely improve the future outlook regarding the sulphur regulation. In another way, the sulphur regulation could improve the possibility to implement the dry port network and the railway corridor, since rail transportation becomes a more competitive transport mode against sea transport, when sea transportation prices increased at the start of the year 2015. There are also other similar factors, which could affect the price level of transportation. In addition, internalization of external costs could make a substantial change to the price level of different transport modes. If the road transport sector companies will have to pay for the different externalities (e.g. congestion, CO₂ emissions, noise and accidents) in the future, the price level of road transport will increase. The price level of rail transport could also increase, but not as much due to its lower level of environmental impacts. This development would increase the competitiveness of rail transport against road transport, which in turn would improve the possibility to utilize dry ports.

Sub-question 4 is about the Finnish transportation system: “What similarities do patient and freight transportation share, and can these be exploited to improve the cost-efficiency of transportation?” Transportation system in Finland has some special characteristics. Although the rail freight sector is deregulated in Finland, there is only one major company offering rail freight transportation on the Finnish rail network during the writing process of this dissertation. There is another rail freight company, but it has only a very small share of the total volume of rail freight transportation. On the patient transportation side, the Social Insurance Institution of Finland compensates for a high share of the transportation costs of patients. This encourages passengers to use more comfortable, but more expensive transport modes such as a taxi for transportation between homes and hospitals. It is not expensive for the patient, but it will definitely be costly for the Finnish economy, if patients use more expensive transport modes, when cheaper public transport modes are available. On the other hand, the situation is similar in the rail freight sector even though characteristics and the priorities of freight and passenger transportation are somewhat different. The Finnish national railway company offers both rail and road transport modes for their customers.
Road transport is easier to organize especially for smaller transport volumes. In many cases, the national rail freight company actually offers road transport for the customers, especially if the customer wants to deliver smaller quantities of freight. This does not increase the utilization of rail transport, even though it could be cheaper in some cases, but it would definitely create less environmental impacts than road transport. With different policies and structures regarding the rail freight sector and patient transportation in Finland, utilization of rail could definitely be increased in the freight sector, but cheaper patient transportation could also be accomplished. The results in article VII suggest that considerable cost savings are possible, if the transportation would be organized more efficiently. The same also applies for the freight transportation sector. Similar characteristics can be found in different geographical locations as well. Furthermore, special characteristics could be totally different than in Finland, but they could offer an opportunity to improve the transportation sector substantially as well, if e.g. more expensive transport modes are utilized due to a monopolistic situation or subsidies.

The main research question is: “What advantages can be achieved by connecting a dry port network with a global rail transport corridor?” Depending on the location, advantages can be gained, if dry port locations are selected carefully (based on freight volumes, variation and future outlook). Location and the amount of dry ports are the main questions regarding implementation of the concept. Location should take into consideration the distance between a utilized sea port or sea ports, if the dry port serves more than one sea port. Furthermore, a more global view should be taken into account, i.e. if implementing and investing in dry ports, not only should domestic or local traffic be taken into account. There is a great potential e.g. in the east of Finland, if the Finnish dry port network is studied, since the Russian market is considerably large. Finnish dry port network could be utilized to transport domestic Finnish freight and international freight between Russia. In addition, the dry port network could be used to transport Russian export transit traffic. Instead of utilizing road transport, BSR countries could use the dry port network and rail transport corridor to transport freight between Northern and Central Europe. If properly implemented, transportation costs and emission levels could be lowered from their current level, and this is possible for other geographical locations as well. Additionally, congested areas and roads could be relieved by transporting more by railways. Due to all potential and definite changes
(e.g. IMO’s sulphur regulation, price development of energy and importance of lowering the amount of environmental impacts), the demand for rail transportation can be assumed to increase in the near future, which in turn motivates to increase the supply of rail services. These are e.g. the potential Finnish dry port network, Rail Baltica, but also further rail connections to the east such as China, Kazakhstan and Ukraine.

8.2 Managerial Implications

Based on the results of articles I-III, a dry port network could be profitable in Finland. When choosing the amount of dry ports, decision-makers should understand that there is always a maximum amount of dry ports suitable for each geographical location. If more dry ports are implemented, then the cost-efficiency of the whole system suffers. On the other hand, though, a suitable number of dry ports will increase the cost-efficiency of the local transportation system, as would be the case also in Finland. In case of the dry port concept, PPP could be one possible way to push things forward, since the whole dry port investment could be considerably expensive. On the other hand, these investments would create a positive impact on job positions in the region during the building of infrastructure, but also afterwards since the operation of a dry port requires personnel.

Articles IV-VI study the North-West Russian transport volumes, Rail Baltica and Estonian transit traffic. All the results give a signal that there were potential freight volumes during the writing of this dissertation, but also in the near future. Logistics service providers could have a chance to establish a profitable business in organizing transit traffic freight flows through the Finnish dry port network. This network could be widened in a way that the main Russian transport hubs (e.g. St. Petersburg and Moscow) could be included in the dry port network. The case study regarding Estonian transit traffic shows that profitable container block train connections can be established between Estonia and Russia. Due to a suitable similar transportation network in Finland and a suitable rail gauge width to Russia, the same kind of train connections could be feasible between Finland and the Eastern market. Furthermore, the interview study targeting the Russian private sector gave an important result, which was that Rail Baltica could definitely be an attractive transport corridor, if the price level, lead time and frequencies are at an appropriate level for Russians.
The EU aims at decreasing the amount of emissions originating from transportation by recommending the utilization of e.g. rail for medium distances. The private and public sectors of BSR could increase the utilization of rail transport for sea ports’ hinterland connections, since this is the direction towards which the EU is aiming. There could be high impact regulations for the road transportation sector due to its emission levels and this will improve the competitiveness of rail transport. It is also totally possible that customers will make their decisions more and more based on emission volumes and this can increase the competitiveness of rail transport further.

The last article studied local patient transportation flows in a Finnish healthcare district. During the research, it was found that costs originating from the transportation of patients are very rarely observed. There are major possibilities to decrease these total costs by offering alternative efficient, but cheaper transport modes for the patients. The situation could be the same in the freight transportation sector, which indicates that major cost savings are possible.

8.3 Limitations of the Study and Suggested Future Research Avenues

This thesis mainly focuses on the dry port concept and a major forthcoming rail transport corridor. As rail transport is the principal transport mode in the dry port concept and in the rail transport corridor, rail transport is also the main researched transport mode in this thesis. However, other transport modes are not ignored, since they play an important role in the whole picture. In the dry port concept, road and sea transport modes play the second largest role and they are also included in most of the publications of this thesis. Furthermore, the focus is on freight transportation, although passenger transportation is discussed and studied briefly in a smaller context (passenger transportation is studied in the seventh article). Research, which includes freight flows (Articles I-III), is based on population, i.e. more freight is assumed to be transported to and from cities, which have a higher population. On the other hand, major factories and their freight flows are not implemented in the gravitational and simulation models concerning freight flows. This approach was selected, since it was assumed to give sufficiently sharp results. In addition, the main transport mode related studied factors in this thesis are cost-efficiency and environmental impacts. Other factors are discussed briefly e.g. in article V.
The thesis has a geographical focus, which is mainly Finland, but also the Baltic States (Estonia, Latvia and Lithuania) and the Russian Federation (mainly North-West Russia). Geographic focus is a consequence of the nature of case studies made for the articles represented in Part II of this thesis. Results of the study can also be implemented in other geographical locations, but it has to be kept in mind that different factors may change in other geographic locations, and these could have an effect on results. For example, transportation costs and cost difference between different modes may fluctuate greatly in various countries due to dissimilar pricing policies and varying salary levels.

Trustworthiness of a research is traditionally described in terms of validity and reliability (Metsämuuronen, 2006). High validity means that the research measures well the phenomena that it was supposed to measure. If validity is low, then results are misleading or measuring a false event. High reliability of the study indicates that the other researcher or research group can make the same kind of study with similar results, i.e. the repeatability of the research is good. Triangulation (Mathison, 1988) was utilized in this thesis to improve the validity: data was gathered from multiple sources and it was analyzed with various different research methods. The different methods gave similar results, which increases the validity further. All the results have been presented in various seminars and conferences to allow criticism. Furthermore, the results have been shown and discussed with many different experts on the subject to improve the validity. However, since there are many data sources and methods utilized in this dissertation, the reliability could suffer. If another researcher would like to make similar research, he or she should gather quite a high volume of data from many different sources. Many of the sources are publicly available, but some part of data is gathered by e.g. interview study, i.e. most of the data can be collected easily, but part of the data collection could be troublesome. In addition, due to numerous different utilized research methods, the possibility for a mistake could rise and thus decrease the reliability. It could be assumed that validity is on a high level, and reliability has at least an average level.

Further research avenues should include more precise simulation regarding possible throughput volumes of a hypothetical dry port network in Finland. Studied freight flows represented in the articles are currently based on the population structures of Finland.
This could be improved by taking major factories (e.g. paper factories) and their transportations into focus. The model could be widened to take sea transport of the Baltic Sea into account. In addition, volumes between Russia and along the Rail Baltica rail corridor should be included in the simulation model to gain more information about possible volumes and emission decrease possibilities in the researched region. Additionally, factors other than the costs of transportation and environmental impacts should be studied more thoroughly. The importance of lead time and frequency of the service could also be important for the customers, and these could affect the selection of a transportation method.

Since the IMO’s sulphur regulations became stricter at the start of the year 2015, an interview study of its impacts regarding BSR transportation system should be made. This could be made at the end of the year 2015 or at the start of the year 2016, since then the private and public sectors would have better knowledge of the effects of the regulation. A statistical analysis of transportation flows in BSR and through BSR as transit traffic should be made after one or two years of the stricter regulation. This analysis would reveal possible modal shifts from sea to inland transportation modes. This analysis could be extended to measure how emission volumes have increased or decreased after the regulation became stricter.


References


City of Warsaw, (2011), *Private transport market stakeholders in the area of Rail Baltica*, City of Warsaw, Poland.

City of Warsaw, (2012), *The operation of the transport market and the new solutions recommended under the RBGC project*, City of Warsaw, Poland.


Entec, (2010), *Study to review assessments undertaken of the revised MARPOL Annex VI regulations. Finland, Germany, Holland, Sweden and UK*, The Shipowner Associations of Belgium, London, United Kingdom.


Henttu, V., (2010), *Financial and Environmental Impacts of a Dry Port to Facilitate Competitiveness of Two Major Sea ports in Finland*, Master’s Thesis, Lappeenranta University of Technology, Department of Industrial Management, Kouvola, Finland.

Henttu, V., (2011), *Regional Survey Study from Dry Port Concept in South-East Finland*, Research Report 230, Lappeenranta University of Technology, Department of Industrial Management, Lappeenranta, Finland.


Woxenius, J. (1998), Development of small-scale intermodal freight transportation in a systems context, Doctoral thesis for the degree of Doctor of Philosophy, Department of Transportation and Logistics, Chalmers University of Technology, Göteborg.


Part II: Publications
Publication 1

Henttu, V. and Hilmola, O.-P. (2011)

Financial and environmental impacts of hypothetical Finnish dry port structure


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Financial and environmental impacts of hypothetical Finnish dry port structure

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1. Introduction

Transportation is the only sector with increasing environmental impacts (European Communities, 2009b; UIC, 2009). The EU has taken various strategies for counteracting the pollution from transportation by introducing e.g. CO2 taxing and encouraging the use of environmentally friendlier modes of transport (European Commission, 2001). One of the main objectives of the EU is to increase the proportional share of rail transport by increasing the use of intermodal transportation (European Commission, 2001; European Communities, 2009a).

Decreasing emission amounts in hinterland transports could be achieved by using the dry port concept, which relies on the smooth and coherent operative use of inland intermodal terminals and transport equipment. Under the dry port concept the inland transportation between seaport and dry port is mostly delivered by rail instead of traditional road transport (Beresford & Dubey, 1990; Roso, 2009a, 2009b; Rodrigue, Debrie, Fremont, & Gouvernal, 2010; Roso, Woxenius, & Lumsden, 2009; Woxenius, Roso, & Lumsden, 2004). Only the final leg of transportation from/to the dry port to its final destination or from its origin is being performed by road from dry ports. Previous research has identified that rail transport is the less expensive mode of transport in comparison to road transport, especially in terms of environmental costs (e.g. Bauer, Bektaç, & Czarnecki, 2010; Chapman, 2007; Facanha & Horvath, 2006; Forkenbrock, 2001; Henttu, Lättilä, & Hilmola, 2010; Janic, 2007; Winebrake et al., 2008). As a corollary of rail being more environmentally friendly, the whole transportation system can decrease its environmental impacts by increasing the share of rail transport. Further research such as Janic (2007) and Macharis and Rongen (2004) argue that intermodal transport on the whole can be used as a cost-efficient and environmentally friendly transport mode. In addition, dry ports offer similar services like seaports, but within hinterlands. Value added transportation services at these sites could be of lower cost, offering higher flexibility, and being in proximity to final customers. In Sweden this kind of dry port network has been used increasingly during the last decade, and it has led to lower environmental emissions, and...
considerable energy savings. The current rail shuttles serving the Port of Gothenburg decrease transportation costs by 6 million Euros per year. Furthermore, CO₂ emissions have decreased by approximately 42,000 tons every year (Bergqvist, 2007, 2008; Woxenius & Bergqvist, 2010). It is possible that a comparable dry port network would improve the environmental performance of the Finnish transportation system. However, large-scale usage of dry ports in Finland is still in its infancy, and by no means can be compared to that of Sweden.

The main research method used in this research is macro gravitational models of distribution. The models are completely quantitative by their nature, and are based on numerical data concerning populations of chosen main cities (TOP50 of Finland), and distances between the chosen used seaports (maximum amount used is four), dry ports (ranging from one to nine), and the most important cities of consumption (TOP50 of Finland). The aim of the gravitational models is to compare relative transport costs and environmental impacts when using different numbers of dry ports (ranging from one to nine), and to examine, how performance evolves with different configurations. The models use linear integer programming to achieve optimal distribution strategy for each setting.

The research is structured as follows: The following Section 2 reviews the relevant literature particularly focussing on the dry port concept and studies that have researched how to choose reviews the relevant literature particularly focussing on the dry port concept. The third section describes the chosen main seaports, dry port locations and the modelling logic. The Modelling results are presented in Section 4. Following the aim of this research to investigate the possible positive impacts of implementing a dry port network in Finland in terms of transportation costs and environmental impacts, Section 5 discusses possible structural changes in Finnish sea transport and the number of used seaports as well as hinterland transport as a consequence of new sulphur emissions regulations. The conclusions and emerging further research questions are presented in Section 6.

2. The dry port concept and inland intermodal terminal location optimization

One of the largest global sources of pollution is transportation activity, fuelled by increased globalization and trade. In fact, transportation is the only sector that has not been able to decrease or even maintain its level of pollution i.e. the amount of emissions have increased every year (European Communities, 2000b; UIC, 2009). All the other sectors (energy industries, industry, household, services etc.) have lowered or at least halted the increase in their pollution levels (European Communities, 2009b). The EU has defined the dry port concept as:

“The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport. In addition to the transhipment that a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, maintenance of containers and customs clearance are also available at dry ports.”

The dry port concept is part of the intermodal transportation system. The dry port itself is an inland intermodal terminal with additional services located inland. It is directly connected by rail to a seaport or, in some cases, two or more seaports. In a dry port concept, the maximum possible amount of freight transportation is accomplished by rail between the dry port and the seaport. Only the final leg of the door-to-door transportation is carried out by road transport from and to the dry port terminal. In the most desirable situation of dry port implementation, all freight transport between a seaport and a dry port is carried out by rail. However, that is usually not possible due to capacity constraints of rail connection, and required flexibility (Roso, 2009a, 2009b).

A sound connection between road, rail and seaport enables fast and reliable movement of freight. The performance of a dry port is measured by the quality of access to the seaport and the quality of the road–rail interface (Roso et al., 2009b). The dry port offers value-added services (e.g. consolidation, storage, depot, maintenance of containers and customs clearance) to actors, which operate within the transportation system i.e. there is a whole range of administrative activities that could be moved inland by implementation a dry port.

In order to meet growing demands from shipping lines, ports are forced to respond by enlarging hinterland areas including the creation of inland terminals such as dry ports, to enhance or sustain their relative competitiveness (Lee, Song, & Ducruet, 2008). As container transport volumes continue to grow, seaports’ hinterland accessibility becomes a more critical factor for the seaports’ competitive advantage, because inland access can easily become a development constraint for a seaport (Roso, 2009b).

Because the implementation of dry ports increases the use of intermodal transport, especially rail transport, it can reduce the environmental impacts of the whole transportation system. By implementing one or more dry port solutions, it is possible to increase regional transportation efficiencies (Rahimi et al., 2008). There are differences in dry ports according to their geographical location. Roso et al. (2009b) and Woxenius et al. (2004) have categorized different dry ports according to their functions and distances from the seaport. There are three different definitions for different categories of dry ports, these are: close, medium and distant dry port. All the dry ports are located in the seaport’s hinterland areas. It is possible that dry ports serve more than one seaport. In that case, seaports share areas of their hinterland with other seaports.

All dry port categories share many common benefits. First of all, a properly implemented dry port, independent from is category, reduces congestion in the seaport’s immediate vicinity by modal shift from road to rail. Congestion is also reduced in the seaport cities and the roads connecting cities and their hinterland as road transportation considerably decreases, while rail transportation increases. Rail operators gain more market share, because more freight being transported by this mode. Shippers gain a greater
range of logistics services, thanks to dry ports. For the entire society a dry port enables lower environmental impacts, job opportunities and regional development. The most apparent benefit from an environmental perspective emerges from the modal shift from road to rail (Roso, 2009b; Roso et al., 2009; Woxenius et al., 2004).

This study aims at choosing the number of dry port installations, which offer the greatest cost savings, if cost-savings are possible. In addition, this work discusses which dry port locations should be maintained under a scenario where the number of dry ports in a system needs to be reduced. Other research work has studied how to choose the location of inland intermodal terminals. In difference to earlier research, this research used an alternative method of determining the number and location of different dry ports. A brief literature review discussing the choice of location of inland intermodal terminals follows.

Several studies about how to optimize the location of one or more inland intermodal terminals to make the transportation system more cost-efficient exist. Rahimi et al. (2008) used a location-allocation methodology (this methodology aims at minimizing truck-miles) to choose one or more optimal locations for regional inland intermodal terminals to support a seaport. Racunica and Wynter (2005) presented an optimization model, which based on the hub location problem. Agent-based modelling has been used to optimize the geographic location of an inland intermodal terminal (Aichl, van Dam, Ferreira, & Lukszo, 2007). In addition, agent-based modelling has been used to research flow of containers in container terminal (Gambardella, Rizzoli, & Funk, 2002). Limbourg and Jourquin (2009) have used the p-hub median problem to solve the optimal locations for regional inland intermodal terminals (Arnold, Peeters, & Thomas, 2004). Bergqvist and Tornberg (2008) included GIS-T (Geographic Information Systems for Transportation) in their modelling method to research the optimal location for an inland intermodal terminal in Sweden. In their study, van der Horst and de Langen (2008) analyzed coordination problems in hinterland transportation. They also investigated different procedures on how to resolve problems concerning hinterland transportation. Dekker and Verhaeghe (2008) used optimal control theory to estimate on how to expand seaports’ hinterlands. In addition, research using modelling on how shippers could optimally select the seaports has been developed by Magala and Sammons (2008). Hamalainen and Tapaninen (2008) researched transportation costs from geographical point of view. Their study found out that transportation costs have a large impact on paper mills’ profits. By using more geographically suitable locations paper mills could increase their profits. Additionally they discovered that transportation costs in the paper industry have not decreased over time.

3. Research environment

The research environment concerns Finland with its 50 largest cities by population. The concept of using population as a driving force of hinterland transportation is based on an initial analysis of transport volumes within and among 18 different Finnish counties, and the population of the respective counties. Population in the analysis of 2009 data explained approximately 75–80% of inland transportation volumes. Furthermore, four seaports and nine dry port locations were chosen (see Fig. 1 for details). The idea was to select the four most suitable seaports to support a larger dry port structure. Finland is a large country compared to its population, and has an extensive coastline with numerous seaports. The Port of Kotka is one of the most eastern ports in Finland; the Port of Helsinki is located approximately 140 km to the west of Kotka, while the Port of Pori is located on the west coast and the Port of Oulu in the north. Dry port sites were selected based on their location to serve the TOP50 cities, an appropriate access to the railway network, and preparedness for the required basic infrastructure.

The main difference between the Finnish and Swedish logistics network structure is that in Sweden there is more or less only one seaport (Port of Gothenburg), handling the majority of container traffic. In Finland there are four or five main seaports for handling container traffic (among numerous smaller ones). The main reason for using the Port of Gothenburg as the main container port in Sweden is its geographical location and the short access distance to deep seas. This study uses macro gravitational models of distribution to research, if a similar dry port network can improve the performance of the Finnish inland transport network (see also Fig. 2 for location of Finnish ports and dry port locations). The seaports (Helsinki, Kotka, Oulu and Pori) are marked with ellipses. All the other cities are used as dry ports. In addition, the seaports of Kotka and Oulu could also be used as dry ports.

It can be seen from Fig. 2 that by using the chosen ports (Ports of Helsinki, Kotka, Oulu and Pori), the coastline of Finland well

<table>
<thead>
<tr>
<th>Seaports</th>
<th>TEU vol. [2009]</th>
<th>SHARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kotka</td>
<td>545,939.00</td>
<td>35.7%</td>
</tr>
<tr>
<td>Oulu</td>
<td>153,762.00</td>
<td>10.5%</td>
</tr>
<tr>
<td>Pori</td>
<td>54,086.00</td>
<td>3.6%</td>
</tr>
<tr>
<td>Port</td>
<td>29,961.00</td>
<td>2.0%</td>
</tr>
<tr>
<td>Total</td>
<td>859,254.00</td>
<td>57.8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dry ports</th>
<th>Shortest distance to dry port as selection criterion (railway network)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kotka</td>
<td>Pori</td>
</tr>
<tr>
<td>Oulu</td>
<td>Pori</td>
</tr>
</tbody>
</table>

3.3.1. Criterion for dry port distribution - using lowest distribution cost in linear integer programming (road network).

<table>
<thead>
<tr>
<th>TOP50 Cities</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helsinki</td>
<td>583,995.00</td>
</tr>
<tr>
<td>Oulu</td>
<td>153,762.00</td>
</tr>
<tr>
<td>Pori</td>
<td>153,762.00</td>
</tr>
<tr>
<td>Port</td>
<td>153,762.00</td>
</tr>
</tbody>
</table>

Fig. 1. Modeled hypothetical dry port structure of Finland using four seaports, nine alternative locations for dry ports and 50 largest cities as consumption places. Source (TEU volume): Finnports (2010).
covered. Most of the chosen dry port locations are situated in the south, reflecting the population concentration in this part of Finland.

The rail network distances from the four seaports to the dry port locations have been gathered from the Finnish Transport Agency (Ratahallintokeskus, 2009). The distance to each dry port is calculated from the nearest seaport. Road network distances from the chosen dry port locations to the 50 largest cities have been obtained from Google Maps (2010) and ViaMichelin (2010). The populations of the 50 largest Finnish cities have been retrieved from the Finnish population register centre (Väestörekisterikeskus, 2010).

In the first gravitational model all nine dry port locations (all potential dry port cities given in Fig. 1) are included. In the consecutive models the number of dry port locations is continuously reduced by one until the model only includes one dry port location to serve the entire country. The logic for “dropping” dry port locations is based on eliminating that dry port that serves the lowest number of TOP50 cities, and has the least transportation activity (distance times population).

The first group of gravitational models considers only distances between seaports, dry ports and TOP50 cities together with the population of the TOP50 cities. In addition, two different groups of gravitational models were created. The second group of gravitational models includes the difference in total costs between road and rail transport, based on research by Henttu et al. (2010), who calculated total cost estimations for road and rail transport in the Finnish transport network. Cost estimations include internal and external costs of both transport modes. Internal costs are further divided into fixed and variable costs. External costs include accidents, noise, congestion and CO2 emissions. Estimated internal costs of road and rail transport calculated by Henttu et al. (2010) are based on various sources e.g. Finnish Transport and Logistics (2010), the Finnish Transport Agency (2010) and LIPASTO (2009). The calculation system includes exhaust emissions and energy consumption in Finland. Estimated external costs for both the road and rail transport are based mainly on calculations by Maibach et al. (2008) and LIPASTO (2009). Estimated total costs are 0.0506 Euros per ton-kilometre for road transport and 0.0270 Euros per ton-kilometre for rail transport (Henttu et al., 2010). Increasing use of

![Fig. 2. A map about chosen seaport and dry port locations. Source: Modified from OpenStreetMap (2011).](image-url)
4. Modelling results of hypothetical Finnish dry port structure

The results of the first group of gravitational models concerning relative transport costs are illustrated in Fig. 3 below. Road and rail transport are treated as equal in this group i.e. same amount of road kilometres is equal to the same amount of rail kilometres. The y-axis gives the value of relative transport costs incurred by varying the number of dry ports being used. (These are relative due to the fact that the relative costs are calculated by multiplying population and distance together). The lightest line represents relative costs between seaports and dry ports, which has a continuously increasing tendency as additional dry ports are being added into system. This means that by increasing the number of dry ports, the amount of rail transport increases. Basically, the lightest line represents the value of rail transportation costs with a different number of dry port implementations. However, the reward for this is shown as the darkest line, showing a decrease in road transport costs by adding more distribution terminals (dry ports).

The line in the upper part of Fig. 3 represents the total relative transport costs (the sum of relative costs of road and rail) with a varying number of dry port locations. The total relative costs decrease significantly when adding up to four dry ports to the system. If more than four dry ports are included the ports the total relative costs do not increase more and stabilize. By increasing the number of dry ports further than six, the relative transport costs will not decrease further – implying some sort of asymptote for transportation costs.

The results from the second group of gravitational models take the difference in costs between road and rail transport into account. Relative road transport costs are multiplied with a factor of 0.0506. Relative rail transport costs with 0.0270, respectively. These multipliers are the estimated total costs per ton-kilometre (internal and external costs) for Finnish road and rail transport calculated by Henttu et al. (2010). Because the costs calculated in the different groups of gravitational models are relative, it is important not to compare to actual amounts of the relative costs represented by the y-axis. Comparison should be made by analyzing results in terms of percentage changes. The results are somewhat similar to the previous model, if difference in total costs of road and rail transport is taken into account. The optimal number of dry ports in Finland seems to be between four and six.

The last group of gravitational models considers the difference in external costs between road and rail transport. The external costs include CO₂ emissions, congestion, noise and accidents. Relative road transport costs are multiplied with a factor of 0.007 and relative rail transport costs by a factor of 0.0007 respectively. These multipliers are the estimated external costs per ton-kilometre for Finnish road and rail transport calculated by Henttu et al. (2010). Fig. 4 shows how the external costs of the whole dry port network evolve when considering different numbers of dry ports.

In the model with only few dry ports, road transport is responsible for almost all the external costs. External costs seem to be minimal in a system with nine dry ports i.e. in a system with more than nine dry ports the environmental impacts only reduce slightly more. External costs in a system with nine dry ports are still principally caused by road transportation. This is due to road being the significantly more expensive mode of transport in terms of external costs. The external costs of rail transport remain considerably low when adding up to nine dry ports to the transportation system. From an environmental perspective a greater number of dry port terminals provides the biggest advance in environmental performance. This result differs from the results considering total costs (model group one and two) (see Fig. 3).

According to this research, by implementing dry port solutions and increasing the use of rail transport, the total relative costs of transport can be decreased. In addition, the environmental impacts of the transportation network can be reduced by using a dry port network. The models identified an optimal value for the number of dry ports in the system. If the least relative transport costs are taken into account, and most feasible number ranges from four to six inland terminals. If more than six dry ports are added to the system the environmental performance can still be improved when adding up to nine dry ports.

5. Discussion

During the year 2008 the International Maritime Organization’s (IMO) Marine Environment Protection Committee (MEPC) approved proposed enhancements to the MARPOL Annex VI regulations concerning the decrease of pernicious emissions from sea-going vessels, mainly sulphur levels. The approved amendments involve:

- A global regulation that will limit sulphur amount in fuel to 3.5 percent. The limit will take effect as of 1st of January 2012. The
These regulations are strict limitations to sulphur emissions that cannot be released into the atmosphere from sea-going vessels in countries around the Baltic and North Sea. Short sea shipping will most probably decrease its modal share. Substitute could be road and/or rail transport, and these transportation modes could significantly increase their share. Studies have concluded that road transport itself is by number of different means the most environmentally harmful transport mode. If short sea shipping decreases its modal share, then road transport will eventually increase its modal share, and the result from systems perspective is increased overall emissions (ECSA, 2010; Kalli, Karvonen, & Makkonen, 2009; Swedish Maritime Administration, 2009). According to a study from Swedish Maritime Administration (2009), under the new regulations it would be more cost-efficient to use road transport all the way from Northern Sweden to Germany. Regulations would decrease emissions of the whole transportation system; if there is no modal shift i.e. sea vessels can achieve their target sulphur levels.

These new regulations could have a large impact on the Finnish logistics sector, mainly having effect on sea transport, the number of seaports used and port throughput, but also in additional warehousing and inland logistics. One possible effect could be that small vessels would stop servicing coastal Finnish trade and might be replaced with larger vessels to create economies of scale. Economies of scale affect both transportation costs and sulphur emissions, reducing emissions per container or per tonne-kilometre. Another consequence for Finland might be that the amount of active seaports decreases. This might particularly affect seaports in the north (e.g., Port of Oulu and Port of Kokkola). In that case, the researched dry port network would not have similar benefits, because one large benefit of the researched dry port network is that it can use ports in North, South and South-West i.e. along the whole Finnish coastline. If only Southern ports are used, then the benefits could be less. It is also possible, that direct road transport from mainland Europe to and from Finland increases.

A further model was created to estimate the impact of a reduced number of seaports. In this model only two major ports in southern Finland were chosen, the Port of Helsinki (Vuosaari) and the Port of Kotka. These two seaports were chosen, because all of the Finnish seaports they have shortest access distance to the North Sea SECA line and currently handle the highest volumes of containers. The results of the model are presented in Fig. 5.

The overall advantages of implementing a dry port network reduce, if it is only based on two seaports. It seems that the number of dry ports in the model is not decisive, because relative total transport costs do not reduce with a larger number of dry ports. The main reason for this is that the rail distances are much greater than in the previous models, which considered four seaports. The decreased number of seaports increases the amount of inland transportation in general. The benefit of using dry ports with great number of dry port locations in Finland persists, if the new regulations result in a reduction of the number of seaports used for container transport.

The difference of costs between road and rail transport is taken into account, then there could be minor cost savings by using only ports of Helsinki and Kotka. However, cost savings will be less if compared to model with four seaports (Helsinki, Kotka, Oulu and Pori). If only the difference of external costs between road and rail transport is considered, then dry port network can improve environmental impacts of the transportation system considerably by using only ports of Helsinki and Kotka. Regardless, environmental impacts can be decreased more by using four seaports.

6. Conclusions

The hypothetical analytical model supports the implementation of dry ports as a strategy for inland distribution as such strategy will lead to a reduction in both, emissions and total transportation costs. According to the models analysing transport costs the ideal number of dry ports should be between four and six. However, the model measuring environmental performance proposes that even a higher number of dry ports would deliver a reduction of external costs in the transportation system. Benefits increase for a system with up to nine dry ports. These findings underline the benefits from a potential development of a dry port network in Finland. The models also show the importance of considering the specific characteristics of a country’s transportation system when constructing it. In difference to Sweden, Finland requires more seaports to support its transport system, which in return also leads to a lower number of dry ports in hinterlands.

The results show that a greater number of seaports enhances the cost-efficiency of the dry port network in Finland and the overall level of inland transportation. This is mainly due to Finland’s extensive coastline. New regulations for shipping to decrease sulphur emissions might have a significant impact and even contradictory effect on the overall external costs in the transport system, because inland transportation will probably increase its overall share in comparison to the current situation.

Further research should focus on extending the model in terms of taking different industrial sectors, such as manufacturing and raw materials, chemical factories, pulp and paper mills and mines, into account. These industry sectors usually use specific transport corridors. Considering their locations and transport volumes would be a next step in analyzing the environmental and economic impacts of implementing a dry port system. The model presented in this paper is valid for consumer goods, which follow transport patterns that are highly correlated to the population distribution.

References


Publication 2

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Optimization of relative transport costs of a hypothetical dry port structure


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OPTIMIZATION OF RELATIVE TRANSPORT COSTS OF A HYPOTHETICAL DRY PORT STRUCTURE

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Decreasing environmental emissions originated from transportation sector plays a big role in the strategies of EU. One way to decrease emissions is to shift freight transport from unimodal road transport to intermodal solutions. Dry port concept aims at increasing rail transport between seaports and inland intermodal terminals, which are called dry ports. Such a concept is in infancy in Finnish transportation network. The main transport mode used in Finland is unimodal road transport. The aim of this research is to study the effects of a hypothetical dry port structure in Finnish transportation network. The effects are researched with different gravitational models. They apply linear integer programming, and heuristics to find relative transport costs in each situation. Differences in road and rail network, and road and rail transport modes are taken into account. The results of the models argue that Finland could benefit from dry port network. Cost-efficiency of the Finnish transportation network could be enhanced by using up to five or six dry ports. In addition, by replacing road transport with rail transport the environmental impacts can be lowered considerably. However, by alternatively utilizing within wider scale dense seaport network of Finland, we could achieve even better environmental results – approach which has been neglected so far in the dry port literature.

Keywords: Dry port concept, Finnish transportation network, gravitational models, costs of transport, intermodal transport, optimization, linear integer programming

1. Introduction

Transportation is one of the major polluting sectors [1]. The difference between transportation sector and other polluting sectors is that emissions originated from transportation have risen steadily during the last decades, whereas other sectors have been able to decrease or at least stop the increase of their pollution [2, 3]. The aim of the EU is to encourage and increase the use of intermodal transport [4, 5]. One important reason for this is environmental friendliness of intermodal transport, if compared to road transport [6, 7].

Dry port concept is one way to increase the use of intermodal transport. Because the implementation of dry ports increases the use of intermodal transport, especially rail transport, it can decrease the environmental impacts of the whole transportation system. Many studies support the assumption that rail transport is environmentally friendlier mode of transport than road transport [6, 7, 13-17]. The main transport mode between seaport and dry port (inland intermodal terminal) is rail transport in dry port concept [8, 9]. The possible advantages of the concept are the decrease of environmental emissions, and improved cost-efficiency of transportation system [8, 9]. Dry port concept is still in its infancy in Finland. Based on tons being transported (domestically), road transports holds roughly 85 % share in transportation market of Finland, and railways have 11 % (year 2010). However, situation is a bit better, if tonnekms are used as then road transports have share of 67 %, and railways 21.7 %. [10-12]. The aim of this manuscript is to research, what effects a hypothetical dry port network in Finland could have in terms of relative transport costs, and literally improving railways competitiveness.

Gravitational models of distribution based on population areas in Finland are used as main research method. Models are based on populations of chosen cities, rail and road network distances between chosen seaports, chosen dry ports and chosen cities. Models are quantitative, because all the different inputs are numerical. The aim of the gravitational models is to research, how relative costs evolve by using different number of dry ports and different settings concerning choosing of dry port locations in Finland. Linear integer programming is used to find out optimal routes and locations for each setting and for each model. First model uses heuristic approach, when choosing what dry port is dropped out of the model. Other models utilize optimization software package called IBM ILOG CPLEX Optimization Studio (CPLEX) to optimize the model and choose what dry port is dropped out i.e. no heuristic decision-making is then used.
2. Research Environment and Methodology

Physical research environment includes domestic Finnish inland transportation. Different actors that are taken into account are 50 largest cities of Finland with population, different chosen seaports and different chosen dry ports. The chosen dry ports in different models are chosen from the group of 50 largest Finnish cities. Transportation between seaports and dry ports is accomplished by rail transport, whereas transportation between dry ports and the largest Finnish cities is accomplished by road transport. The difference in costs between road and rail transport in Finnish transportation network is taken into account. Henttu et al. [7] calculated cost estimations for both the road and the rail transport modes in Finnish transportation network. Relative road and rail transport costs calculated my gravitational models are multiplied with costs estimations by Henttu et al. [7], so that difference in road and rail transport in gravitational models is detected.

In our approach gravitational models start with nine different dry port cities. After that models drop one dry port out of the model, so that there are now eight different chosen dry port cities. This process is continued until there is only one dry port city left to serve the entire country. In the first model the dry port cities are dropped out by with heuristic decision-making. Logic in selecting, which dry port location “drops from the list” at each time, is relatively straight forward: dry port, which is serving the lowest amount of TOP50 cities, and has the least transportation activity (distance times population). Three other gravitational models are optimized with CPLEX, which makes decision on what dry port is eliminated.

Nine different cities are chosen according to their geographic location and attractiveness in the first two gravitational models. Chosen possible dry ports in first model are cities of Jyväskylä, Kokkola, Kotka, Kouvola, Oulu, Rovaniemi, Tampere, Turku and Vantaa. Dry port cities were selected basing on their two gravitational models. Chosen possible dry ports in first model are cities of Jyväskylä, Kokkola, Kotka, Kouvola, Oulu and Pori. These ports are chosen, because they have high capacity for intermodal transport and they cover Finnish coastal efficiently. This group is studied with both the heuristic approach and optimization software CPLEX. Both the heuristic and CPLEX optimized approaches use linear integer programming to achieve the most cost-efficient environment. Heuristic approach is used, when dry port amount is reduced. Figure 1 clarifies physical environment of two first gravitational models (upper part).

<table>
<thead>
<tr>
<th>Cities Population</th>
<th>TEUs 2008</th>
<th>TEUs 2010</th>
<th>TEUs 2009</th>
<th>TEUs Average</th>
<th>TEUs Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helsinki</td>
<td>410,804</td>
<td>371,161</td>
<td>393,965</td>
<td>393,965</td>
<td>21,9%</td>
</tr>
<tr>
<td>Turku</td>
<td>372,197</td>
<td>345,409</td>
<td>357,354</td>
<td>357,354</td>
<td>20,2%</td>
</tr>
<tr>
<td>Jyväskylä</td>
<td>178,804</td>
<td>165,868</td>
<td>181,838</td>
<td>181,838</td>
<td>10,1%</td>
</tr>
<tr>
<td>Oulu</td>
<td>35,922</td>
<td>39,074</td>
<td>38,943</td>
<td>38,943</td>
<td>2,2%</td>
</tr>
<tr>
<td>Rauma</td>
<td>30,000</td>
<td>29,643</td>
<td>30,338</td>
<td>30,338</td>
<td>1,7%</td>
</tr>
<tr>
<td>Pori</td>
<td>27,454</td>
<td>29,887</td>
<td>29,329</td>
<td>29,329</td>
<td>1,7%</td>
</tr>
<tr>
<td>Total</td>
<td>1,500,925</td>
<td>1,524,362</td>
<td>1,513,450</td>
<td>1,513,450</td>
<td>87,4%</td>
</tr>
</tbody>
</table>

Figure 1. Modelled hypothetical dry port structure of Finland using four seaports, nine alternative locations for dry ports and 50 largest cities as consumption places (upper part) and alternative hypothetical structure, where six different container sea ports are used as dry ports (lower part). Source: (TEU volume): [18]
By using the chosen ports (Ports of Helsinki, Kotka, Oulu and Pori), the coastline of Finland is effectively used. Most of the chosen dry port locations are situated in the south, because population is concentrated over there. The Northern Finland is very sparsely populated. Figure 1 above illustrates research environment only for two first gravitational models (upper part). Two other gravitational models have different settings concerning the chosen seaports and dry ports, and they are described more carefully later in this Section. Rail network distances from seaports to different dry ports are gathered from Finnish Transport Agency sources [20]. Distance to each dry port is from the nearest seaport. Road network distances from different possible dry ports to 50 largest Finnish cities are gathered from Google Maps [21] and ViaMichelin [22]. Populations of the 50 largest Finnish cities are gathered from Finnish population register centre [23].

Third gravitational model does not include any inland cities as dry ports. Only Finnish most used container seaports are used for export and import (Figure 1 lower part). Inland transportation in Finland is performed by the road transport in this model. The chosen Finnish container seaports in this group are ports of Hamina, Helsinki, Kotka, Oulu, Pori and Rauma. This group is researched only by using CPLEX.

The fourth and final gravitational model includes all the largest Finnish cities as possible dry port solutions. Only those cities are included that has railway connection. This group is the most versatile due to many possible dry port locations. This group is researched only with CPLEX. The aim of these gravitational models is to study if Finnish transportation network could achieve cost saving by implementing dry port network, which is having entirely flexible setting (optimization is allowed to make selection). Furthermore, models include different number of dry port locations to find out, what is the effect if dry port amount is decreased or increased i.e. to research, if there is an optimal amount of dry ports in Finnish transportation network according to gravitational models.

In the used CPLEX model the model is done using integer programming (various optimization methods, see [28]). The model is optimized by modifying variables $s_i$ and $d_j$. They are binary variables, which represent whether a city is using a particular dry port and whether a specific dry port is used. The model minimizes the total costs, which consists of road costs, road environmental costs, railway costs, and railway environmental costs.

In their research, Henttu et al. [7] calculated the total cost estimations for road and rail transport in Finnish transport network. Costing includes both the internal and external costs of both transport modes. Internal costs are further divided into fixed and variable costs. External costs contain accidents, noise, congestion and CO2 emissions. Estimated internal costs of road and rail transport calculated by Henttu et al. [7] are based on various sources e.g. Finnish Transport and Logistics [24], Finnish Transport Agency [25] and LIPASTO [26], which is a calculation system for traffic exhaust emissions and energy consumption in Finland. Estimated external costs for both the road and rail transport are based mainly on calculations by Maibach et al. [27] and LIPASTO [26]. Estimated total costs by Henttu et al. [7] are 0.0506 € per ton-kilometer for road transport and 0.0270 € per ton-kilometer for rail transport. Increasing use of rail transport can decrease the total costs of the transportation, because the total costs of rail transport are less than same costs of road transport. These costs are used in all groups of gravitational models.

3. Results of Gravitational Models

All the results of different gravitational models are illustrated in Figures 2-7. Relative transport costs incurred by varying number of dry ports or seaports are described in y-axis. Costs are relative, because they are calculated by multiplying population and distance with each other. They are not real costs of transportation. The aim of the relative costs is to find out different possible benefits or disadvantages. X-axis describes the number of dry ports or seaports being used depending on the model (the third model uses only seaports as terminals). Relative rail costs between seaports and dry ports are represented with the lightest line, which has continuously increasing tendency, if additional dry ports are being added into system. Possible positive tradeoff from this increase could be detected from the darkest line, in which the relative road transport costs decrease by adding dry ports. The line in the upper part of Figure 2 represents the total relative transport costs of the dry port system.

Figure 2 illustrates the results of the first group of gravitational models using heuristic approach, when choosing what dry ports are eliminated from the model. In this group, as in all other groups, the difference of costs between road and rail transport is taken into account. The relative road transport costs calculated with gravitational models are multiplied with 0.0506. The relative rail transport costs are multiplied with 0.0270. These multipliers are estimated total costs per ton-kilometer (internal and external costs) for Finnish road and rail transport calculated by Henttu et al. [7]. Cost estimations include internal and external costs i.e. models take the most important environmental impacts into account. Different environmental impacts are accidents, CO2 emissions, noise and congestion.
The first model was created mainly with Microsoft Excel. Solver of Microsoft Excel was used for linear integer programming. The model starts with settings of nine different dry ports. Solver is used to optimize the most inexpensive routes between seaports and dry ports and dry ports and 50 largest Finnish cities. After that one dry port location is eliminated from the model to research the effect of smaller amount of dry ports. Elimination is based on heuristic approach. Dry port that has the least connections is dropped out of the model. In future this city is counted as one of the consignees or consignors. This process continues until there is only one dry port left in the model. Figure 2 summarizes the results concerning the costs of the first gravitational model.

As Figure 2 shows, the relative total transport costs can be decreased by using dry port network according to the first gravitational model. Significant cost reductions can be achieved by adding up to four dry port solutions. By adding more than four dry ports in the Finnish transportation network, cost saving becomes much less i.e. according to this model, four to six dry ports in Finnish transportation network allow the most cost-efficiency for the whole transportation system. As can be seen from Figure 2, the slope of the relative total transport costs line does not become smaller evenly. The reason for this is the heuristic approach, when choosing that dry port is dropped out of the model.

Next model uses the same possible dry port cities as the previous model. Difference between these models is that next model uses optimization software CPLEX for the whole process. No heuristic decision-making is used in this model. The results are shown in Figure 3.

According to CPLEX optimized gravitational model, the relative transport costs can again be decreased. The major cost savings can be achieved by adding up to four to six dry ports. By adding more than six dry ports, costs can further be decreased, but decrease in costs becomes smaller. With nine dry port implementations, the total relative costs of road and rail transport are near each other.
Figure 4 summarized differences between two previously presented models. Both models have the same chosen possible dry ports and seaports, but the method for dropping a dry port is different. The first gravitational model uses heuristic decision-making, whereas the other useful software optimization (CPLEX).

Figure 4. Comparison of relative transport costs between two similar gravitational models with different decision-making method

Figure 4 illustrates that CPLEX optimized model is having lower costs with two and three dry ports. If models use one, five, six, seven, eight or nine dry ports, then the relative total transport costs are similar in heuristic and CPLEX optimized models. So, it seems that total software optimization does not give much benefit, if different possible dry ports are restricted to nine pieces. There is almost no difference in relative total costs between models at number of four to nine dry ports. The main difference in researching hypothetical dry port network with heuristic approach and CPLEX optimization software is the amount of work that has to be done. Both models need both road and rail distances between dry ports, seaports and 50 largest cities of Finland, and population of these cities. After collecting these input data, the heuristic approach took one to two work days to create models. CPLEX optimization was able to run in one or two hours. After first CPLEX model, the others can be run in considerably less time (new models can be created in less than five minutes). The main difference in used dry ports between these models is that one with heuristic decision-making utilized city of Kouvola between three to nine dry port networks, whereas CPLEX optimized model utilized Kouvola only with nine dry port network. CPLEX optimized model utilized cities of Oulu and Kotka instead of Kouvola.

Next results are about gravitational model that does not include any dry port solutions i.e. all intermodal terminals are container seaports, and no inland terminal is used. All the inland transportation is accomplished by road transport. Figure 5 summarizes the results of this gravitational model. Numbers at x-axis describe the number of seaports used. Different possible seaports in this model are ports of Hamina, Helsinki, Kotka, Oulu, Pori and Rauma.

Figure 5. Relative transport costs of a transportation network, which utilized only main Finnish container seaports (CPLEX optimized)
If the main container seaports of Finland are used instead of any dry ports, costs saving can still be achieved by increasing the number of seaports. According to this model, costs saving is even larger in this model. One explanation is the difference of road and rail network structure. Road network distances between different geographical locations in Finland are quite straight, whereas many rail connections between different cities are more distant than road connections.

All the Finnish largest cities are possible dry ports in the last gravitational model, if they have railway connection (not all 50 largest Finnish cities have railway connection). This model is the most versatile one with the most available configurations. The results are illustrated in Figure 6.

Figure 6. Relative transport costs of a dry port network with all 50 largest Finnish cities as possible dry ports (CPLEX optimized)

Lines in this model look very similar to the first two models. The difference is that costs can be decreased little bit more than in the first two models by using more possible dry port locations. Final Figure 7 illustrates the total relative transport cost results of all four different gravitational models.

Figure 7. Comparison of all presented gravitational models

According to both heuristic and CPLEX optimized models, the relative total costs of transport can be decreased by using limited dry port network of at most nine different chosen dry ports (Jyväskylä, Kerava, Kokkola, Kotka, Kouvola, Oulu, Rovaniemi, Tampere and Turku). By using up to four or five dry ports the relative costs can almost be minimized. By adding more dry ports, the costs savings become very small. Surprising conclusion is that CPLEX optimized model that uses major Finnish container ports excluding all inland dry ports can reduce costs significantly. The main reason could be a better attainability of the road network. Slight relative cost reductions can be achieved compared to first two models, if number of possible dry ports is increased.
4. Conclusions

Cplex software can be efficiently used to minimize model creation time. By using heuristic approach, the results can almost be optimized (at least by small number of possible variations), but creating such model takes a lot of time (one to two days). Furthermore, changing heuristic model (e.g. changing seaports, dry ports, number of seaports, number of dry ports etc.) needs much work, whereas changing Cplex model takes almost no time, once the original model is created (although learning to use the optimization software might take months).

Objective of this research was to research the effect of a hypothetical dry port network in Finland. The research has been conducted with different gravitational models that use linear integer programming to achieve the least possible transport costs. Difference between models is different methods (heuristic approach versus full software optimization), when dropping dry ports out of the models. Other difference is different possible dry ports and seaports between different gravitational models.

The results of gravitational models show that the cost-efficiency of transport system can be enhanced by implementing dry port structure to Finnish transportation network. With four to six dry ports the most cost savings can be achieved. By adding more than six dry ports, costs savings become very small i.e. gaining enough profit to cover possible investment costs of dry port (inland intermodal terminal connected to seaport by rail) will take many years with too many dry port solutions in the system. Surprising result is that unimodal road transport costs can be decreased significantly by using numerous seaports that cover the whole coastal of Finland. By using only one or two seaports, relative transport costs are relatively high. If all 50 largest Finnish cities (cities with no rail connection are excluded) are included, the total relative costs can be decreased. Decrease in costs is not much larger than in other gravitational models that have limited dry ports or seaports. It seems that by choosing possible dry port locations by heuristic approach in Finnish transportation network, the total relative transport costs can be minimized quite accurately. The main reasons for this are small number of appropriate cities that could be dry ports and centralization of Finnish population in the area of capital city.

Practicality of the results shown in this research work establishes a route for further research. For example, using numerous sea ports in decreasing overall emissions could be questionable in the future due to IMO’s strict sulphur emission restrictions of sea vessels (e.g. Entec, 2010), which are mostly harmful for Finnish shipping industry (they are taken with the most strictness from in use in northern Baltic Sea). So, this would in turn restrict the use of low volume sea container sea ports. Besides emission control, another question arises from current level of capacity in smaller sea ports, and secondly their readiness to continue investments in the future. Similar lack of capacity and willingness of investing in future concerns selected railway based dry ports of entirely “flexible” optimization model. This does not only include arrangement yards, but terminals with appropriate railway yards, railway connections, loading/unloading places and lifts for container handling.

References


25. LIPASTO. *Unit emissions of vehicles in Finland*, – http://lipasto.vtt.fi/yksikkopaastot/indexe.htm


Publication 3

Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO₂ emissions


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Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO₂ emissions

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Abstract

Decreasing carbon dioxide (CO₂) emissions is one of the most important tasks for the society in the 21st century. One possibility to decrease emissions originating from transportation is to utilize more rails instead of relying simply on road transportation. In the dry port concept an inland intermodal terminal is connected to a sea port using railways. This study analyzes impacts of dry ports in a Finnish context. We compare two different configurations: In the first one shippers drive directly to a sea port, while in the second one they use dry ports. The systems are evaluated by using discrete-event simulation. In the systems we are interested in two issues: (1) Level of CO₂ emissions, and (2) Costs to transport the goods in different configurations. We use different scenarios for future energy prices and estimate both the costs and CO₂ emission development in these scenarios. We also compare the results to a situation, where emissions are minimized instead of costs. Implications on larger scale are also discussed, for example in the Baltic Sea and North Sea area, where strict sulfur emission restrictions are seen to harm sea transport and increase concentration on small number of sea ports.

1. Introduction

European Union (EU) is paying large attention to decreasing environmental impacts originating from transportation, which is one of the most emitting sectors (Aronsson and Brodin, 2006; European Commission, 2001). Furthermore, transportation is the only sector that has increased its emissions year by year (European Commission, 2009; UIC, 2009). Its share from overall greenhouse gas (GHG) volume is one fourth and is still growing (see Stead, 2006). Result of numerous research works is that environmental impacts of transportation can be decreased by decreasing the amount of road transport and substituting it with some other transport mode, which is environmentally friendlier than road transport (see e.g. LIPASTO, 2009; Maibach et al., 2008; Van Wee et al., 2005).

The IMO Marpol 73/78 Annex VI regulations aim to reduce nitrogen oxide (NOₓ) emissions and prevent sulfur oxide (SOₓ) and particular matter emissions from sea transportation. SOₓ amounts have to be decreased radically in Sulphur Emission Control Area (SECA), which includes North Sea and Baltic Sea. SOₓ amount of fuel cannot exceed 0.10% after January 2015 (already implemented with 1.0% max. sulfur content in Baltic Sea). It should be noted that in IMO’s action plan whole world will implement low sulfur regulation of 0.5% from year 2020 onwards. Interestingly IMO has not stated any further actions to achieve the level, where e.g. Baltic Sea is demanded to be already from year 2015 onwards. It is possible that short sea shipping will decrease its modal share due to stricter SOₓ regulations e.g. in case of Finland...
and Baltic States. Reason is 30–40% higher costs of sea transport e.g. between Finland and Germany (Kall et al., 2009; in general, Delbue and Delbue, 2010). However, simulation will most probably be hindrance transportation, in form of road or rail transport. Furthermore, sulfur regulations will likely increase concentration on fewer number of sea ports i.e. most sea vessels will use southern sea ports in Finland to minimize time spent in SECA. This will lead to a direct road connection (Cullinane and Wilmsmeier, 2011), but at the same time the dry port should be able to generate enough volume (Rodrigue and Notteboom, 2012). As the cost structure for intermodal freight transport systems are highly dependent on the cost of rail and truck transport (Kim and Van Wee, 2011), it is also important to understand the feasibility of the dry port systems in future conditions. Road transportation is currently a very competitive transport mode, since it is flexible with an attractive price level. But the price level can change as the price of oil is predicted to continue to rise in the future.

One important aspect in dry ports is the regional perspective. According to Rodrigue and Notteboom (2012) the interaction between dry ports and their regional markets is a fundamental issue. It is even difficult to estimate a break-even distance for an intermodal freight transport system as many different issues impact this distance (Kim and Van Wee, 2011). Van den Berg and De Langen (2011) also argue that concentrating only in road transportation restricts sea ports change in gaining additional market share. As such it is important to correctly estimate the appropriate locations where a dry port can be located. Wilmsmeier et al. (2011) have also identified spatial directional development of intermodal terminals as an important research agenda. At the same time, there is a potential for overinvestment as many locations would like to play a crucial role in global value chains (Rodrigue and Notteboom, 2012). According to Bergquist and Wilmsmeier (2009) effective and coordinative governance and actions are needed both at a national level as well as on an EU level in order to cope with the problem of overinvestments. Government policies are needed to enable investments in ideal locations to create a good transport infrastructure.

The aim of this research is to find out the feasibility of dry ports in Finland in different scenarios. As dry ports are part of larger systems (Rodrigue et al., 2010; Roso et al., 2009) and they are influenced by many factors (Flämig and Hesse, 2011), it is also important to study dry ports more holistically in larger geographical areas. The first main research question of this study is: “How can the locations of potential dry ports be estimated on a regional scale?” We assume that the operators are interested only in lowering their own costs, but we also study the environmental impact of the potential dry port structures. The research question can also be divided to smaller research questions: “How can the stability of demand for dry ports be estimated?” and “How do potential dry ports interact in larger logistical systems?”. In addition to these we analyze the volumes for these potential dry ports. The second main research question is: “How much can the emissions of transportation be lowered by utilizing dry ports?” This is an important issue due to the need to decrease GHGs. Governmental decision-makers need to understand the environmental impact of dry port systems.

As dry port systems tend to consist of many different actors (Rodrigue and Notteboom, 2012; Flämig and Hesse, 2011; Haralambides and Gujar, 2011), it is vital to achieve buy-in from all of these individual organizations. Several studies regarding intermodal terminal locations using analytical models have been presented in the literature (see e.g. Henttu and Hilmola, 2011). However, simulation is generally regarded as a good way to achieve buy-in for complex issues (Robinson, 2004) and provides a way to enforce learning from analytical models (Banks et al., 2005). In this research the main research method is discrete-event simulation modelling, where the model simulates the Finnish transportation network. The transportation flows in the model are based on population and we provide an overview of the structure of the model. The model can be replicated to other regional systems as well to analyze potential dry port systems in other geographical areas. We use the simulation model to study different scenarios in Finland and test the networks with different cost structures. The results of the model can be used to estimate the best locations for dry ports as well as other inland terminals.

Structure of this paper is as follows: Section 2 provides a literature review concerning dry port concept, oil price, and future outlook of oil price development. Section 3 clarifies research methodology of this paper and introduces the simulation model. Thereafter, in Section 4 we analyze the results of the simulation experiment. Discussion regarding the role of CO2 emissions on overall simulated system economy is given in Section 5. And in final Section 6 we conclude our work, and provide future avenues in this endeavor.
2. Literature review

2.1. Dry port concept

Traditional sea ports have pressure to improve their competitiveness in comparison to other sea ports to maintain or increase their market share. With dry port concept sea ports can increase their service levels, capacities and storage areas in inland located intermodal terminals, which are connected to sea ports with rail link. Due to increased need of effective hinterland transport, dry ports have been studied widely during the recent years. Table 1 summarizes these contemporary research findings of dry ports. (See e.g. Bergqvist and Egels-Zandén, 2012; Cullinane and Wilmsmeier, 2011; Flämig and Hesse, 2011; Hanaoka and Regmi, 2011; Haralambides and Gujar, 2011; Henrutt and Hilmola, 2011; Ka, 2011; Korovyakovsky and Panova, 2011; Notteboom and Rodrigue, 2005; Rodrigue et al., 2010; Roso, 2008; Roso et al., 2009).

Roles of different stakeholders in dry port implemented transportation system have been studied and discussed by many authors. There are usually numerous amount of stakeholders involved in transportation network, which includes dry ports (Rodrigue and Notteboom, 2012; Flämig and Hesse, 2011; Haralambides and Gujar, 2011). The amount of stakeholders will increase, while sea port is expanding in hinterland area. This will also increase the role of communication between local and global stakeholders (Bergqvist and Egels-Zandén, 2012). Furthermore, public–private-partnership plays a significant role in dry port investments and maintenance operations due to the fact that monetary investments tend to be significant (Haralambides and Gujar, 2011). Bergqvist and Wilmsmeier (2009) point out that not only national coordination, but also EU-wide cooperation is important. Increased amount of stakeholders in the system and also the hinterland expansion considerably increase the importance of the quality of hinterland strategy by both the sea port and the dry port (Van den Berg and De Langen, 2011).

Possibilities to decrease transportation costs with dry ports is widely researched subject (Chang et al., 2008; Choong et al., 2002; Cullinane and Wilmsmeier, 2011; Flämig and Hesse, 2011; Henrutt and Hilmola, 2011; Henrutt et al., 2011). It is important that implementing dry port will lead to decreased transportation costs, if compared to current transportation costs (Cullinane and Wilmsmeier, 2011). Estimating transportation costs from dry port implemented transportation network is more complicated than estimating costs from unimodal road transport due to increased amount of variables, which have influence in total costs (Kim and Van Wee, 2011). Without transportation cost benefits, it usually is not beneficial to invest in creation of a dry port. There are also environmental benefits to be achieved by utilizing dry port (Bergqvist and Egels-Zandén, 2012; Hanaoka and Regmi, 2011; Henrutt et al., 2011; Liao et al., 2009), but these benefits are usually not enough to justify creation of a dry port without considerable internal transportation cost benefits.

Many research studies regarding dry ports are focusing in how to choose geographical location for inland intermodal terminals. Rahimi et al. (2008) developed a model, which can be used to find locations for inland ports in a way that daily

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vehicle-miles are minimized. As more inland ports are added to the model, the vehicle-miles are reduced considerably, which also decreases congestion and amount of air pollution. Furthermore, Roso (2008) focused on researching different factors, which are crucial when implementing dry ports. Ka (2011) developed an application, which utilized fuzzy analytical hierarchy process (AHP) in seeking optimal dry port locations in China. In their study, Fläming and Hesse (2011) found out that placing dry ports could increase the amount of planning conflicts, which differentiate from conflicts arising, when expanding the actual sea port. New conflicts are usually based on demand of land area and infrastructure development for the dry port.

In regionalization the sea port basically expands its actions in its hinterland area as recognizing the importance of hinterland transport. By regionalization sea port aims to improve services it is providing to customers and also to reduce logistics costs (Notteboom and Rodrigue, 2005; Rodrigue and Notteboom, 2010). There are many local and global case studies, which have researched current dry port and regionalization development in chosen geographical locations. In his study, Notteboom (2010) has focused on European sea ports. The study reveals European container port system and main hinterland corridors. Haralambides and Gujar (2011) have focused in the development of dry port sector in India. Korovaykovsky and Panova (2011) studied current development of Russian dry ports, whereas Roso and Lumsden (2010) have studied main dry ports situated in different continents. Role of development of Spanish inland terminal has also been studied by Monios (2011). Furthermore, Hanaoka and Regmi (2011) have made an overview of the main dry ports in Asia. There is also a comparison between European and North American intermodal rail systems accomplished by Rodrigue and Notteboom (2012). They found out that there are many similarities and differences due to regional and local governance and regulations regarding dry ports and rail connections.

Since dry port concept is part of intermodal transportation, management of containers plays important role. Empty container management has been studied by Choong et al. (2002). They have suggested that empty containers need to be taken into careful consideration, when managing container flows. If only loaded containers are paid full attention, but no attention is given to empty containers, it is impossible to make profits from transportation business. Choong et al. (2002) suggest that longer planning horizon encourages using more inexpensive and slower transport modes as e.g. barge, but shorter planning horizon demands faster and more expensive deliveries. Furthermore, amount and location of container storage areas have large effect on transport mode choice. Chang et al. (2008) implemented heuristic approach to research empty container sub-stations problem. Their approach allowed reduction of empty container management of 4-47%. In addition, Song and Dong (2011) utilized heuristic algorithm to minimize empty container repositioning costs. Empty container management problem has also been researched by using foldable containers instead of traditional ones (Shintani et al., 2010). Results show that repositioning costs can be decreased by using foldable containers.

Environmental benefits can be achieved by intermodal transport. In their study, Liao et al. (2009) compared CO2 emissions among two different scenarios: In the first, truck-only transportation is used for hinterland transportation, and in the second intermodal coastal shipping is used for long haulage, and road transport for final transportation leg. Results show that CO2 emission amounts can be decreased considerably by replacing road transport with intermodal transport (reduction can be up to 60%). According to Hanaoka and Regmi (2011), utilization of Asian dry ports has been able to decrease congestion and vehicle emissions. In their study, Janic and Vleugel (2012) calculated that by substituting road with rail transport on a chosen Trans-European freight transport corridor externalities could be decreased by approximately 30%.

As the review points out, dry ports are a multi-faceted problem. The issue covers many different stakeholders and public–private-partnership needs to be taken into account when considering potential dry ports. For individual shippers, the main area of interest is nevertheless actual costs of transportation. As transportation costs are highly dependent on the global oil prices, it is important to understand, how the price of oil will fluctuate in the future.

2.2. Long term development of oil prices

For a long period of time, oil prices in the world were at extremely low levels (i.e. a couple of USDs per barrel). Economic problems, abandoning Bretton Woods currency arrangement (year 1971; Sarnoff, 1980) and eventually oil crises in the 1970s changed the level of these prices, which increased up to 30–40 USD per barrel in the early 1980s. Thereafter, for two decades prices remained at relatively low levels, 15–20 USD per barrel.

However, as free trade movement spread round the world (e.g. China joining WTO in late 2001), these new emerging economies needed to fuel their energy needs with ‘old’ fossil fuels such as coal (Lin and Liu, 2010) and oil (Tao and Li, 2007). Actually these two main fossil fuels got considerable support for their usage from emerging Asian markets, and particularly from China (actually coal consumption has now more than doubled in Asia Pacific Region within previous decade, and China nowadays accounts for nearly half from the entire world consumption). Increase in the e.g. oil demand created oil bubble, which burst in year 2008 (Fig. 1 and Appendix A; please do note that oil price is 200 days moving average).

The enormous increase in oil demand created overheating in prices, and bubble burst rather rapidly: Oil price per barrel (European Brent) was having valuation of 140 USD per barrel in July 2008, but slumped down within six months to the level of 35 USD! However, this sudden decline was caused by realization of systemic crisis in the world economy, and central banks reacted strongly on this situation by providing massive amount of liquidity to the markets. This in turn has helped critical commodities to inflate their values as banks and investment community has been on the search of safety for provided liquidity (also in the case of oil, inelastic demand and limited supply play roles in the pricing, please see El-Gamal and Jaffe, 2010). It is surprising, how closely central bank credit funding (in US case QE1, QE2 and Operation Twist waves) go hand in
hand with the price of oil. End result of the extra liquidity provided is that oil prices were already in the end of year 2011 (as measured with 200 days moving average) higher than in the peak year 2008 (price peak was very sudden earlier, and high prices did not sustain that long). The robustness of this price recovery is very troublesome for transport logistics sector, especially for road transport, which is tightly tied upon oil usage.

Market price of oil is having high correlation with refined products of oil, such as diesel oil (used in trucks and partly in train traction) or heavy oil (used in ships). However, tax policies, environmental charges and refining companies operating costs and margins have occasionally higher impacts than what would oil market price changes alone indicate (e.g. shipping oil, bunker prices in year 2011; United Nations, 2012).

One major supporting factor (along with monetary policies applied) in oil pricing is its limited supply (based on both IEA, 2011 and BP, 2012 statistics indicate that oil production is slowing, especially in Middle East). This could be illustrated with long-term statistics through the difference of oil production and oil consumption in the five largest oil producers in the world as is shown in Fig. 2. Within the long observation period both USA and China have ended up in the situation, where oil imports are continuously increasing (in USA after 2005 trend has a bit changed), and these two countries could be described to be entirely dependent on foreign oil. This would be sustainable, if other countries could develop massive surpluses. However, this is not any longer the situation (supporting oil peak theory, e.g. Reynolds and Kolodziej, 2008; Maggio and Cacciola, 2009). Saudi Arabia has been struggling to increase its production volumes, while domestic consumption has considerably increased – in the end their export potential is decreasing and volumes are around 400 million tons in Fig. 2 (production minus consumption in here is export). Russia and Iran do not perform that much different in this respect; both are having problems to increase their surplus significantly (actually Russian oil export volumes in tons are not increasing based on their official statistics, mostly due to domestic direct and indirect consumption; see Central Bank of Russian Federation, 2012). If we would calculate production and consumption of these five countries together, we may identify that surplus along with them is continuously declining, and could even enter negative territory rather soon (years 2013–2014, if long-term trend continues).

Even if oil price increase has hurt (and will do so based on the scenario of this research work) national economies and especially trade balances (e.g. Sandalow, 2008), it is on the other hand very important source of governmental budgets (taxes are mostly applied on purchased fuel). Queiroz et al. (2008) illustrate that road transport, and particularly private car usage, contribute several times that of costs of road maintenance and renewal in Europe (highest gathered amount with respect of road sector costs are in Italy, France and Germany). Of course European countries are increasingly having road tolls and vign-
ette payments for all the road traffic (particularly for freight transport), but the main source of funding originates from the taxes placed on used fuel. For example, in our research environment, Finland, fuel taxes (and especially diesel) increased in the year turn of 2011–2012. This was negatively received with road freight transport sector, where diesel prices increased nearly 10%. Change was not the only one in recent years, and taxation increases only result on even higher diesel costs for oil dependent transportation sector. However, during the price hike process competitiveness has increased for more environmentally friendly, alternative power (electricity and gas) using, and energy efficient options.

3. Research methodology

This study concentrates on dry ports in a Finnish context. In Finland, competition in the railway sector has been liberated, but currently there is only one company (Finnish Railways), which provides actual transportation services. Two other companies are about to start their operations rather soon (have official permissions more or less granted; Proxion Train and Rataraiti), but of course suitable rolling stock and trustworthy customer base side is still somewhat unclear. As such, Finland can be regarded to be operated by a monopoly company in rails. Still, it is possible that the price of railway transportation is more highly correlated with road transportation compared to a situation with at least modest intra-modal competition. Other important factor in Finland is the well electrified main railway lines. The entire heavily operated railway lines in Finland are electrified and as such are operated by electric trains. These tend to have both lower emissions and lower operating costs than diesel trains. As such, in this paper we concentrate only on electric trains.

3.1. Discrete-event simulation model

In this research we utilize discrete-event simulation (DES). According to Robinson (2004, p. 4) simulation is “Experimentation with a simplified imitation (on a computer) of an operations system as it progresses through time, for the purpose of better understanding and/or improving that system”. In DES individual events occur one at a time. Usually DES utilizes servers and queues to analyze behavior of systems (Banks et al., 2005). Simulation can be said to be a constructive approach, where researchers produce solutions to specific problems (Kasanen et al., 1993). In this case, we want to analyze two different transportation systems. It would not be possible to conduct experimentation with the real system (the whole Finnish transportation sector) and as such, either an analytical model or simulation is required. As different parts of railway systems are owned by different entities in many countries (Thompson, 2003), a functional, intermodal transportation system will require co-operation from many different stakeholders. As it is vital to achieve buy-in from all of these different stakeholders, simulation is a better choice than analytical models. According to Robinson (2004), a visual simulation is a good way to com-
municate ideas to others and makes buy-in easier to achieve. Banks et al. (2005) also point out that simulations should be used, when the purpose is to experiment new designs or policies. The possibility to explore all of the different options with a visual representation makes simulation more useful for decision-making than other analytical models.

3.2. Data collection and description

The simulation model is based on earlier work of Henttu and Hilmola (2011). The model consists of 193 municipalities in Finland. The total amount of population in these municipalities is over 83% of total population in Finland. During the simulation each new transportation need represents a container, which is going to a specific city. The actual city is randomized and depends on the amount of population in the city, e.g. if 10% of the model’s population is in city A, there is a 10% change that the cargo goes to that city or leaves from that city.

When the city of the cargo is known, the model calculates whether a dry port is used or should the cargo go directly to the sea port. Eqs. (1)–(4) present the mathematical decision made in the model, while Table 2 provides the description of the variables.

The user can choose whether to minimize emissions (1) or costs (2). In the model both the emissions and costs depend almost totally on ton-kilometers (3 and 4). There are additional emissions in a direct sea port connection due to higher amount of waiting at the sea port compared to a dry port (1). On the other hand, there is additional handling cost in the dry port as the cargo needs to be shifted from road to rail (2). When each individual transportation unit makes their decision, they look through all the possible sea ports and dry ports. Thus, the cargo might use a different sea port depending it will take a direct connection or use a dry port. Eqs. (1)–(4) represented below are created by the authors of this article. Variables chosen for the computational model are based on different sources (e.g. Finnish Transport and Logistics, 2013; Finnish Transport Agency, 2013; Sahin et al., 2009; Quinet and Vickerman, 2004).

\[
TC = \sum_{m,d} C_{\text{m,d,1}} + \sum_{m,l} L_{m,l,1} \tag{1}
\]

\[
TC = \sum_{m,d} C_{\text{m,d,1}} + \sum_{m,l} CS_{m,m_0} \tag{2}
\]

\[
E_{m,l,d} = W_t \times D_{m,l,d} \times ME_t \tag{3}
\]

\[
C_{m,l,d} = W_t \times D_{m,l,d} \times MC_m \tag{4}
\]

As it can be noticed from equations one through four, there are many different issues, which impact whether a dry port should be used or not. In this paper we will analyze two situations; in first companies minimize their costs, and in second, emissions are minimized. Example of the cost components for Eq. (2) is presented in Fig. 3. There are three different routes in the figure, denoted with numbers 1, 2, and 3. Route 1 is a direct truck connection from Jyväskylä (located in the upper left corner of the figure) to Kotka (located at the bottom of the figure). In this case, the total route cost TC would be $C_{\text{truck, Jyväskylä, Kotka}}$. The route 2 and 3 are part of the total route from Jyväskylä to Kotka by using a dry port in Mikkeli (located in the right side of the figure). The route 2 utilizes a truck from Jyväskylä to Mikkeli, while route 3 is using a train from Mikkeli to Kotka. The total route cost TC for this route is $C_{\text{truck, Jyväskylä, Mikkeli+trans, Mikkeli, Kotka+CS \text{truck, train}}}$.

Many issues impact both the cost and emission calculations and these parameters are presented in Table 3.

The used truck is a semi-trailer truck with container platform (LIPASTO, 2009). Average weight of loaded container and semi-trailer combination are gathered from LIPASTO (2009), since emission amounts originating from container train and semi-trailer truck are based on the same source. The marginal cost of road and railway transport depends on many issues, but in this research we concentrate on the price of diesel and electricity. Shifting costs between rail and road are based on a case study among two Finnish logistics companies. Additional information about the cost calculations can be found in Henttu et al. (2011).
and Multaharju (2011) and Henttu et al. (2010). Both the cost (3) and the environmental calculations (4) depend heavily on ton-kilometers. With truck transportation these can easily be calculated by multiplying the amount of kilometers with the weight of the truck and cargo. In the case of train transportation, the weight is multiplied with the share of the weight of the whole train. With a 40 foot container there are 30 containers in one train and as such, the weight of the locomotive is divided with 30. Eq. (5) shows an example of the calculations of CO\textsubscript{2} emissions without using a dry port between Jyväskylä and Kotka while Eq. (6) shows the same calculations by using Mikkeli as a dry port.

\[
TE = E_{\text{truck}, \text{Jyväskylä to Kotka}} + I_{\text{train, Kotka seaport}} - D_{\text{truck, Jyväskylä to Kotka}} \times W_{\text{truck}} \times ME_{\text{truck}} + I_{\text{train, Kotka seaport}}
\]

\[
= 245 \text{ km} \times (15 \text{ tons} + 15 \text{ tons}) \times 0.044 \frac{\text{kg}}{\text{tkm}} + 3 \text{ kg} = 323.4 \text{ kg} + 3 \text{ kg} = 326.4 \text{ kg}
\]

(5)

\[
TE = E_{\text{truck, Jyväskylä to Mikkeli}} + E_{\text{train, Mikkeli to Kotka}} + I_{\text{train, Jyväskylä to Mikkeli dryport}} - D_{\text{truck, Jyväskylä to Mikkeli}} \times W_{\text{truck}} \times ME_{\text{truck}} + D_{\text{train, Mikkeli to Kotka}} \times W_{\text{train}} \times ME_{\text{train}} + I_{\text{train, Mikkeli dryport}}
\]

\[
= 113 \text{ km} \times (15 \text{ tons} + 15 \text{ tons}) \times 0.044 \frac{\text{kg}}{\text{tkm}} \times 166 \text{ km} \times 15 \text{ tons} + 30 \text{ tons} \times \frac{83 \text{ tons}}{30 \text{ tons}}
\]

\[
\times 0.0067 \frac{\text{kg}}{\text{TKm}} + 1.5 \text{ kg}
\]

\[
= 149.16 \text{ kg} + 53.13 \text{ kg} + 1.5 \text{ kg} = 203.8 \text{ kg}
\]

(6)
The DES model utilizes network-based modelling. In network-based modelling a network consisting of vertices and edges connect different parts of the model together. Distance between the locations and the average moving speed can then be used as delays in the actual DES structure. There are four different “groups” in the DES system: direct imports, direct exports, dry port imports, and dry port exports. The amount of imports and exports are evenly distributed, but the share of dry port usage depends on Eqs. (1) and (2). The simulation model calculates the share of locations willing to use a dry port and then balances the arrival table for the DES model. The four groups are presented in Fig. 4.

The simulation model combines the DES model with a graphical representation of the Finnish road and railway network. The trucks and trains follow the actual roads and railway tracks, which improves visualization over the problem domain. Example of the model during run-time is presented in Fig. 5.

The graphical user interface allows the user to make changes into the model. Most of the decisions will impact the actual structure of the network during the simulation run. As the simulation model also has the representation of the whole network embedded in a map, the user can more easily notice, what changes occur in different parts of the network, if changes are made to the decision parameters. The options of the simulation model are presented in Table 4.

The warm up period for the simulation is a relatively short one (matter of hours) as the biggest additional delays (in addition to the actual driving times) are generated when the trucks loads are batched to become a whole train load. As a full train

### Table 3

<table>
<thead>
<tr>
<th>Parameters used in the model.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average weight of container 15 tons</td>
</tr>
<tr>
<td>Container 40 foot</td>
</tr>
<tr>
<td>Average weight of truck and platform 15 tons</td>
</tr>
<tr>
<td>Weight of locomotive 83 tons</td>
</tr>
<tr>
<td>Weight of train platform 30 tons</td>
</tr>
<tr>
<td>Platforms per train 30 platforms per locomotive</td>
</tr>
<tr>
<td>Shifting cost between truck and train 35 €</td>
</tr>
<tr>
<td>Marginal cost of road transport 0.04604–0.0527 €/tkm</td>
</tr>
<tr>
<td>Marginal cost of railway transport 0.022–0.02396 €/tkm</td>
</tr>
<tr>
<td>Emissions due to waiting in sea port (truck) 15 min; 1.5 kg CO₂</td>
</tr>
<tr>
<td>Emissions due to waiting in dry port (truck) 30 min; 3 kg CO₂</td>
</tr>
<tr>
<td>Emissions of container train 6.7 g CO₂/km</td>
</tr>
<tr>
<td>Emissions of semi-trailer truck 44 g CO₂/km</td>
</tr>
</tbody>
</table>

Fig. 4. The DES models for different types of transports.
load requires 30 containers (40') and the model generates 120 trucks per hour which use up to 20 different dry ports (6 trucks for each dry port), the first full train loads require on average about 5 h (30 containers divided with 6 containers per hour). The whole simulation run used in the analysis was 1000 h and as such, the potential warp up period is almost miniscule.

4. Results of the simulation model

Model compares two different transportation scenarios in Finland. First one uses only road transportation, while in the latter one it is possible to use dry ports with hinterland rail transport. The simulation model minimizes either total transportation costs or total emissions in the latter system. Aim of the model is to find out, if there are benefits of dry ports in terms of transportation costs or CO2 emission amounts in Finnish transportation network. Price levels of electricity and diesel fuel start from levels, which are below current actual price levels in Finland (0.01 €/kW h and 0.8 €/l respectively). Road transport vehicles use diesel fuel as source of energy, and the price of diesel for heavy vehicles is almost the same as for private consumers. A small discount is possible for road transport companies due to procurement volume of diesel fuel and possibility to use summer diesel also during winter season i.e. the price of diesel fuel is about 1.4–1.6 €/l, if VAT is included. Road transport companies can deduct VAT from the diesel price. VAT excluded price for road transport companies is currently about 1.13–1.30 €/l. Price levels increase up to 100% of the starting values (up to 0.02 €/kW h and 1.6 €/l). Used trains between sea ports and dry ports are electrified.

Fig. 6 shows the optimal amount of cargo utilizing dry ports with different electricity and diesel fuel price levels (diesel fuel prices without VAT). Price of electricity affects only the scenario, which allows the usage of dry ports, since trains travelling between dry ports and sea ports are assumed to be electric trains. Price of diesel affects both scenarios, since road transport is used in both.

If electricity is expensive (0.2 €/kW h) and price of diesel is at model's minimum level (0.8 €/l), then usage of dry ports is minimized in the model (~30%). It means that approximately 30% of cargo is transported through dry ports and all the other
volumes are transported with unimodal road transport directly between cities and sea ports (this level is not even near of the current situation of Finnish sea ports, where at best 5–10% from container volumes are transported by rail). If price of electricity is minimized and price of diesel is maximized in the model, then the usage of dry ports is maximized and about 41% of freight is transported through dry port structure. According to the simulation model, 30–41% of cargo should be transported using dry ports in Finland to minimize transportation costs. Larger drops in Fig. 6 means that some large city (large cities have large cargo volumes) finds out that it is cheaper to use unimodal road transport due to changed price levels and decides to stop using dry port. This can happen, when price of electricity is expensive enough and price of diesel is cheap enough. If the price of diesel is 1.2 €/l or higher, then the usage of dry ports is almost 40% or even higher, if the price of electricity reaches its maximum possible value.

As there are no differences in the cost between imports and exports, there are no differences between the share of direct connections between imports and exports. Every location will use a direct connection for both the imports and exports. Due to this reason the share of imports and exports also does not have an impact on the results of the model. It is possible that by including information about the weight of the cargo, as well as delivery due dates, the imports and exports would differ in their profiles on the usage of dry ports.

Fig. 7 clarifies difference in CO2 emission amounts between dry port implemented transportation network and unimodal road transportation scenario. Variables are again price of electricity and price of diesel.

Results of Fig. 7 are shown as emission difference between dry port implemented and unimodal road transport scenarios as kilograms per one container. The model calculates average emission amount for one container for both scenarios. The less dry ports are used, the more road transport is utilized, and the more CO2 emissions are created in the dry port scenario. Though, dry port implemented scenario is environmentally friendlier with all different price levels for electricity and diesel. Shape of Fig. 7 is similar to shape of Fig. 6. Reason for this is that large drops in cargo using dry ports in Fig. 6 are due to some large volume cities decide to stop using dry ports, and starts using only unimodal road transport, which emits more CO2 emissions than rail transport. These drops can be seen in Fig. 7 as decreased difference of CO2 emissions between two reviewed scenarios. Every time the model chooses to drop one city out, the amount of emissions increase. Table 5 provides a summary of the results with various railway and road costs.

Minimum difference of CO2 emission between two researched scenarios is about 47 kg per one container. This difference occurs with the most expensive electricity and cheapest configuration for diesel. These settings lead to a situation, where the least number of cities use dry ports. If only sea ports are used, 145 kg of CO2 is emitted per container and as such, the dry port system provides impressive decreases in emissions. It should be noted that there exists small difference between the scenarios, where road transportation costs are ranging from medium (1.2 €/l) to high (1.6 €/l). On the other hand, the cost of railway transportation has a big difference in the scenario, where the price of road transportation is small (0.8 €/l). Due to the decreasing supply of oil it is unlikely that the price of diesel will significantly decrease in the future. Table 6 shows the cost differences of transporting a container using a dry port system instead of driving directly to sea ports.

The cost differences vary between 7.96 € to 24.80 € per container. It should be noted, that as the truckers are minimizing their costs, the dry port scenario will always have lower costs as they can also choose a direct connection to sea port, if it is
cheaper. Also, as the costs are average costs, in some cases the benefits are small ones for the truckers, but some other operators could benefit greatly. The cost differences are also linear compared to the differences in emissions, which have big steps in the differences. Fig. 8 shows the locations of the dry ports, their expected maximum demand, variation in their demand, as well as the demand for railway transports. More exact values for individual dry ports are presented in Table 7.

As it is possible to notice from Fig. 8 and Table 7, many of the dry ports have a stable demand between the scenarios (a small amount of variation). Tampere and Kouvola could work as good dry ports, which could consolidate cargo flows from other inland intermodal terminals as well. Tampere and Jyväskylä could handle over 10% of all of the cargo in the model and they have a relatively small amount of variation. Kouvola, on the other hand, has a relatively high amount of variation in

---

Table 5
Summary on the difference of CO₂ emissions (kg) with different transportation costs between the intermodal and unimodal transportation systems.

<table>
<thead>
<tr>
<th>Price of diesel</th>
<th>0.8 €/l</th>
<th>1.0 €/l</th>
<th>1.2 €/l</th>
<th>1.4 €/l</th>
<th>1.6 €/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of electricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01 €/kWh</td>
<td>61.13 kg</td>
<td>59.81 kg</td>
<td>62.43 kg</td>
<td>62.21 kg</td>
<td>63.81 kg</td>
</tr>
<tr>
<td>0.0125 €/kWh</td>
<td>57.55 kg</td>
<td>62.21 kg</td>
<td>62.95 kg</td>
<td>63.34 kg</td>
<td>63.21 kg</td>
</tr>
<tr>
<td>0.015 €/kWh</td>
<td>52.57 kg</td>
<td>61.88 kg</td>
<td>59.58 kg</td>
<td>62.66 kg</td>
<td>63.46 kg</td>
</tr>
<tr>
<td>0.0175 €/kWh</td>
<td>50.27 kg</td>
<td>57.43 kg</td>
<td>62.46 kg</td>
<td>63.12 kg</td>
<td>62.06 kg</td>
</tr>
<tr>
<td>0.02 €/kWh</td>
<td>47.00 kg</td>
<td>51.81 kg</td>
<td>60.36 kg</td>
<td>65.09 kg</td>
<td>61.98 kg</td>
</tr>
</tbody>
</table>

Table 6
Summary on the difference of transportation costs (€/container) with different transportation costs between the intermodal and unimodal transportation systems.

<table>
<thead>
<tr>
<th>Price of diesel</th>
<th>0.8 €/l</th>
<th>1.0 €/l</th>
<th>1.2 €/l</th>
<th>1.4 €/l</th>
<th>1.6 €/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price of electricity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01 €/kWh</td>
<td>13.20 €</td>
<td>15.33 €</td>
<td>18.89 €</td>
<td>21.91 €</td>
<td>24.80 €</td>
</tr>
<tr>
<td>0.0125 €/kWh</td>
<td>12.10 €</td>
<td>15.23 €</td>
<td>18.19 €</td>
<td>20.89 €</td>
<td>23.55 €</td>
</tr>
<tr>
<td>0.015 €/kWh</td>
<td>10.40 €</td>
<td>13.70 €</td>
<td>15.85 €</td>
<td>19.63 €</td>
<td>21.92 €</td>
</tr>
<tr>
<td>0.0175 €/kWh</td>
<td>9.66 €</td>
<td>12.23 €</td>
<td>15.66 €</td>
<td>18.14 €</td>
<td>20.51 €</td>
</tr>
<tr>
<td>0.02 €/kWh</td>
<td>7.96 €</td>
<td>10.24 €</td>
<td>14.02 €</td>
<td>17.66 €</td>
<td>19.54 €</td>
</tr>
</tbody>
</table>
Fig. 8. Locations for potential dry ports and their potential volumes. Map modified from OpenStreetMap, © OpenStreetMap contributors, CC-BY-SA license, www.openstreetmap.com.
demand between scenarios. Kouvola could initially become a dry port to consolidate flows from Pieksämäki, Mikkeli, and Joensuu. Even if the local operators in the Kouvola region could not benefit financially from the dry port, it would be easy so start accepting local goods in the future, if the cost structures change.

In Southern Finland Hämeenlinna and Lahti could as well function as inland terminals. The terminals connect near Kerava, which is already a major logistical center in Finland. The volumes from Kerava (6.46%) are smaller than from Tampere (13.28%) or Kouvola (11.62%), but the logistical infrastructure is already very good. The final dry port in Southern Finland, Salo, has a relatively high variation and a small amount of cargo. As such, it might not be a good location for a dry port.

In Northern Finland the sea port of Oulu could be served from three dry ports: Rovaniemi, Kajaani, and Kokkola. The individual dry ports would have relatively small volumes so the question remains whether enough cargo could be generated. It might be that serving one individual dry port in Northern Finland is not cost efficient for the sea port, but serving all three of them would be.

The previous analyses concentrated on analyzing the situation where individual actors minimize their own costs. If CO2 emissions are minimized instead of transportation costs, then the difference in price of one container between two researched scenarios evolves differently (Table 8).

If the price of electricity is maximum and price of diesel is minimum, then average transportation costs per one container are 12.57 € more expensive than the average costs in unimodal road transport scenario i.e. dry port implemented scenario is more expensive. Price difference changes linearly, if price of electricity decreases and price of diesel fuel increases. The dry port system is able to have lower costs in many cases, but this emission minimization scenario is mostly unrealistic as organizations tend to minimize their costs and can be used to understand what would be the lowest possible emissions achievable using a dry port system to the fullest.

5. Sensitivity analysis on estimate emission payments per container

Challenge with CO2 emissions in transportation is that their reduction in radical manner is not possible at transportation mode level (e.g. trucks or short sea shipping), but it is merely question of avoiding using mineral fuels and replacing them with electricity. Latter one ought to be produced with environmentally (will not produce CO2 or very low amounts) sustainable manner, like originating e.g. from solar power, wind mills, hydropower or nuclear power plants in order to have maximum utility. Railway also beats road option in a manner that it requires lower amount of land area to transport same

### Table 7
Volume of potential dry ports, demand variation between scenarios and used sea port.

<table>
<thead>
<tr>
<th>City</th>
<th>Share of cargo (%)</th>
<th>Coefficient of variation (%)</th>
<th>Sea port</th>
</tr>
</thead>
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<tr>
<td>Tampere</td>
<td>7.75</td>
<td>5.13</td>
<td>Rauma</td>
</tr>
<tr>
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<td>4.05</td>
<td>Vuosaari</td>
</tr>
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</tr>
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<td>3.83</td>
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</tr>
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<td>1.17</td>
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</tr>
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<td>0.07</td>
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<td>Kouvola</td>
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<td>Salo</td>
<td>1.53</td>
<td>20.67</td>
<td>Hanko</td>
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### Table 8
Summary on the difference of transportation costs (€/container) with different transportation costs between the intermodal and unimodal transportation systems when emissions are minimized.

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<th>Price of diesel</th>
<th>0.8 €/l</th>
<th>1.0 €/l</th>
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<th>1.4 €/l</th>
<th>1.6 €/l</th>
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<tr>
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<td>0.0175 €/kWh</td>
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<td>−6.45 €</td>
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<td>−5.35 €</td>
<td>−0.71 €</td>
<td>3.99 €</td>
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</tbody>
</table>
amount of freight transported – giving more space for forests and plants to act as world’s carbon sink (Henntu et al., 2010). This positive effect was not taken into account in our simulation experiment.

Even if long-term forecasts for emission right costs of CO2 are really high, in the emission exchange ICE-ECX (2012) their price has continued to decline. Actually it is so that CO2 emission contract prices are flirting in the lowest levels, since the trade started in year 2006. Current average contract (futures contracts) price is just slightly above 7.6 Euros per ton of CO2 emitted (in November 2012). Of course major factor for such low value is the macro economic situation in Europe (recession and in some country cases depression), but also could be assumed that implementation of emission payments on heavy industries, and the dawn of these payments in transportation sector have changed the behavior of for-profit decision makers. It could be assumed that new emission free or significantly removing technologies have been invested, but in some cases heavily polluting factories have been offshore and/or outsourced to outside of EU region. Currently within European Union area emission trading (CO2 emissions are trading at lowest point pre 2020 world).

Regional scale? As Rodrigue et al. (2010) point out, a dry port needs to have enough economies of scale to justify its existence. At the same time, shippers need to be able to operate with lower cost structure in order to utilize a dry port system (Cullinane and Wilmsmeier, 2011). In this research we provided a methodology to construct a DES simulation model, where shippers minimize their own costs and a potential dry port system emerges from the results of the model. The model is able to

Table 9

<table>
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<tr>
<th>CO2 price (€)</th>
<th>CO2 emission difference (kg/container)</th>
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<td>€7.80</td>
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6. Conclusions

In this paper the first main research question was: “How can the locations of potential dry ports be estimated on a regional scale?” As Rodrigue et al. (2010) point out, a dry port needs to have enough economies of scale to justify its existence. At the same time, shippers need to be able to operate with lower cost structure in order to utilize a dry port system (Cullinane and Wilmsmeier, 2011). In this research we provided a methodology to construct a DES simulation model, where shippers minimize their own costs and a potential dry port system emerges from the results of the model. The model is able to
give an upper bound for the potential traffic flows, which allows the decision-makers to concentrate their efforts on the most promising regions. The results of the model can be used at a regional level (if the regional area would cover multiple countries) to help devise strategies to create efficient transportation corridors. This will also help minimizing overinvestment to individual dry ports (Bergqvist and Wilmmsmeier, 2009; Rodrigue and Notteboom, 2012).

The first sub-research question: “How can the stability of demand for dry ports be estimated?” was analyzed by varying the main cost-elements (truck and railway transport costs). These are the most important cost-elements in a dry port system (Kim and Van Wee, 2011). With the help of the simulation model it is possible to estimate, how much the demand changes in different scenarios. Locations with a high volume of cargo and a small amount of variation are prime candidates for a dry port as they have enough massification even in different types of scenarios (Rodrigue et al., 2010).

The second sub-research question: “How do potential dry ports interact in larger logistical systems?” could also be analyzed with the help of the simulation model. As dry ports are part of larger logistical systems (Roso et al., 2009), it is important to understand the ramifications of individual dry ports and the connectivity of different sea ports to hinterland transportation networks. The inland terminals can also have different kinds of roles (Rodrigue and Notteboom, 2012) and it is important to understand how different locations are connected.

The second main research question was: “How much can the emissions of transportation be lowered by utilizing dry ports?” According to developed simulation model, 30–41% of Finnish inland transportation should be transported by using dry ports to minimize transportation costs of the whole Finnish inland transportation. From other angle, 59–70% of the inland transportation should be transported by unimodal road transportation, because using dry ports would increase costs. These results are similar to the findings of Roso (2007), where a dry port was able to decrease CO2 emissions by 25%. Decision-makers should also understand, that while costs might increase linearly, the potential environmental benefits of dry ports increase in steps. A small change in transportation costs can have a big impact on emissions as a cluster might start using a dry port system, when the break-even distance is broken. The break-even distance is a complex issue (Kim and Van Wee, 2011) and needs to be carefully studied by the decision-makers with advanced tools.

According to the results of this paper, by implementing dry port network in Finnish transportation context it will decrease CO2 emissions, if compared to transportation network, which utilizes only road transport. Even though CO2 emissions can be decreased by up to 45% with implemented price settings, the actual benefit in monetary terms is under one percent of total transportation costs, if one ton of CO2 is assumed to cost 20 € (currently price in exchange is 7.6 € per ton). Furthermore, total costs of transportation can be decreased by using dry port network. Average cost of transporting one container in unimodal road transport scenario is ca. 160 €. Depending on the price level of electricity and diesel fuel, transportation costs of one container in dry port implemented scenario costs 135–153 € i.e. percentual cost savings are about 4–16%.

Average amount of CO2 emissions per container in scenarios, in which only road transport is utilized, is 145 kg i.e. amount of CO2 emissions per container can be decreased using dry ports by 32% to 45% depending on the price levels of electricity and diesel fuel. Although CO2 decrease is proportionally considerable, the monetized benefit is almost non-existent with current CO2 price level (up to 20 € per ton). Situation will change, if price level of CO2 increases radically. This was illustrated within discussion section. Basically companies in high CO2 price environment could just minimize CO2 emissions and economy would follow. Explanation is coming from the connection of CO2 emissions and diesel oil used – together they will take largest part from total costs as CO2 emission costs are increasing from 20 € per ton to 60 € and especially beyond.

Currently the model has some limitations. One of the limitations is that it is based on population as there is currently no information regarding transportation flows within Finland. Secondly, there are currently no capacity limitations anywhere in the model. This tends to be more of an issue for railways, but it should be mentioned, that the railway lines used by the simulation model are currently not in full utilization. Thirdly, all of the cargo is assumed to be similar. Even if one only concentrates on containers, there will be differences in the weight of containers. Also, some containers might require a faster connection to a sea port in which case dry ports are not an option. Due to these reasons the model can only give an upper bound for the potential cargo flows. Furthermore, waiting times in dry port terminals are not taken into account, since comparison of delivery times was not aim of this research work. Adding data regarding both the weight and the delivery times could also have an impact on the differences between usage of dry ports between imports and exports, e.g. a dry port could provide more benefits for either imports or exports.

Further research includes expansion of the model to include more exact information from the cargo flows. One possibility is to use industrial production in various cities instead of amount of population. Secondly, capacity should be included in the model. This could be a maximum capacity for a dry port (containers/year) or a maximum capacity of trucks for a sea port. This is the case in some European sea ports (such as Rotterdam). Another interesting avenue for further research would be the analysis of “optimal” price for CO2 emissions. In the model the shippers could bid on the amount of emissions they are going to emit with their current transportation solution. As such, the model will reach an equilibrium price for emissions which can be gapped to a pre-defined level. This kind of analysis could be used by decision-makers to estimate how much shippers are willing to pay for emission rights. In order to reach a low carbon economy, the whole society needs to look for innovative solutions. Dry ports are one piece of the solution to reach a safer and cleaner tomorrow.
### Appendix A. European Brent prices and Federal Reserve Bank Credit (18 December 2002–1 August 2012)

<table>
<thead>
<tr>
<th>Date</th>
<th>European Brent (Dollars per Barrel, 200d)</th>
<th>Reserve Bank Credit (USA), in mill. USD</th>
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(continued on next page)
### Appendix A (continued)

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Appendix A (continued)

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<td>112.70</td>
<td>290566.00</td>
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<td>March 07, 2012</td>
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<td>286485.70</td>
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<td>2843183.00</td>
</tr>
<tr>
<td>May 02, 2012</td>
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<td>2830902.00</td>
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<td>111.30</td>
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References


Publication 4

Trends of freight transportation in North-West Russia in 2010s

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Trends of freight transportation in North-West Russia in 2010s

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Abstract: Transportation plays major role in global scale economics. Transportation volumes have increased steadily during the last decades, which increase the importance of efficient and competitive transport sector in both global and local level. Russian Railways launched Reform Programme in 2003, which aims at more competitive and private rail transport sector in Russia. The programme has led in increasing need for wagon leasing especially for small and medium sized enterprises, which are not able to fund their own rail fleet. Statistics review shows that major amounts of bulk and containers are transported by rail from and to seaports situated in North-West Russia. There are major investments in North-West seaports aiming at higher capacity levels so that Russia could import/export more freight without using other countries for transit traffic. Increased amounts of bulk and container transported through seaports also increase the demand of rail transportation in Leningrad and St. Petersburg regions.

Keywords: freight; transportation; railways; seaports; Russia; North-West Russia; statistics; Reform Programme; wagon leasing.


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Marina Karamysheva received his Master degree from Moscow State University of Railway Engineering, Moscow, Russia. At the moment, she is a Master student and applicant for PhD studies in Lappeenranta University of Technology’s Kouvola unit.

1 Introduction

The Russian Federation is the major trade partner for the European Union in monetary terms. Foreign trade of the country with Europe makes approximately 50% of the...
Russian total external freight turnover (Gorbunkova, 2009). Russia, which is already an active member of different international organisations and unions, has recently become a member of the Customs Union (between Russia, Belorussia and Kazakhstan) and the World Trade Organization (WTO). All these steps are aimed to integrate the country with the international community, obtaining more favourable conditions for penetration of Russian goods and services in foreign markets, and strengthen its positions in the world trade (Medvedkov, 2006). Development of international trade is strongly influenced by the progress in transportation technologies and vital functioning and cooperation of different modes of transport (Filina, 2009). Full membership of the Russian Federation in the WTO and other organisations will lead to increased exploitation of country’s transit potential (Medvedkov, 2006). Entrance of the country to the WTO shows as well that Russia meets all the requirements to attract long-terms investments, which can be used actively in construction and renovation of transport infrastructure and to support strengthening of international trade links (Gilbert and Banik, 2010). Implementation of new legal instruments, which correspond to the WTO trade-remedy rules, also facilitates transportation process, for instance, from custom’s side (Shadikhodjaev, 2010). To build good transport connections with foreign states and utilise transit potential in full, Russia actively develops its internal transport networks with creation of up-to-date transport hubs and corridors (Maksimov, 2009).

Aim of this article is to present the development of transportation system in the Russian Federation, especially joint development of railways and ports as vitally important transportation modes for international trade of the country. The main focus of the literature review chapter is on development of the railway sector and its cooperation with ports; and main focus in the empirical part is on St. Petersburg and Leningrad region, which have developed their transportation sector very actively during the last years. This region has also good connections to northern EU countries, and is attractive for development of EU-Russian and EU-Asia trade (Ministry of Transportation of the Russian Federation, 2012; RZD, 2012a). Region has well developed railway and marine infrastructure, and it actively participates in cooperative developments programmes with EU (Doctrine, 2001; Etelä-Karjalan liitto, 2012). For example, development of the Belooostrovskaia logistics area together with reconstruction and implementation of Ust-Luga port could be named as biggest projects in the region (Etelä-Karjalan liitto, 2012).

Ust-Luga project affects not only development of marine, but also rail transport. The aim is that new multi-purposeful seaport will have capacity up to 180 million tons of different cargo per year in 2018 (Ust-Luga, 2012). Currently, total turnover of the port is 18.9 million tons of different cargo (for first six month of year 2012) of which 14.8 million tons falls to the share of railway transport (RZD-Partner, 2012). Main types of cargo transported to the port by railways are coal, oil products.

The transport overview, presented in the article, allows better understanding of changes in Russian transport market. Furthermore, it builds trend lines and makes forecasts for further studies on the development of cooperation between the Russian Federation and European Union. Main research questions of this article are: How has rail transport and sea transport developed during the last decades in North-West Russia? What are the trends regarding sea and rail transport in North-West Russia?
2 Literature review: Russian railways and wagon leasing in Russia

Today, we are living in the century of globalisation. Companies are looking for development opportunities throughout the entire world. This also concerns transportation, logistics and supply chain management (Loppacher et al., 2011). Globalisation is strongly dependent on infrastructure, by means of which multiple market participants can interact (Esqueda, 2012). The WTO goes in line with globalisation, promotes and supports it by connecting countries in trade networks (Al-Rodhan, 2006). At the same time more and more attention is paid to green aspects in supply chain management (Pradhan and Routroy, 2012). From this point of view, railway transport is one of the most appropriate modes of transport to develop international trade and globalisation with lowest carbon dioxide emissions (Hilmola, 2012).

After deregulation of the railway market, there appeared number of different participants, of which JSC RZD is the largest. JSC RZD possesses railway infrastructure and regulates tariffs, while numerous private companies own and operate freight wagons (Husainov, 2011). JSC RZD is part of RZD holding, which is serving the market demand on railway transportation from both business and public sides and provides wide range of activities across the value creation chain in transportation of goods and passengers by the railway transport, as well as related and allied to whole transportation sector. Holding includes JSC RZD – parent company (100% of shares are hold by the State), its branches (63 units), and subsidiaries and affiliated companies of JSC RZD (158 units) (RZD, 2010a).

The Russian railway network is the first in the world by the length of electrified lines, the third by cargo turn-over and volumes of freight traffic and the fourth by passenger miles. Operational length of the Russian railways takes the second place in the world. Furthermore, Russian rail network along with the USA and Chinese trunks are among the largest railway systems in the world. In figures, the total length of the Russian rail network is 85,200 km, off which 43,100 km are electrified. The company is responsible for 42.3% of Russia’s total freight traffic (including pipelines) and more than 32.7% of passenger traffic – it carries over 0.95 billion passengers and 1.2 billion tons of freight annually across 11 time zones. There are 20,227 locomotives under its operation (instead of private ones). Geographically, Russian railways are an integral part of the Eurasian railway network and are directly connected to the railway networks of Europe and East Asia. In addition, the seaports can serve as a link in transportation chain with North America (RZD, 2010b).

Before the year 2003, Russian rail transport was ruled by the Ministry of Communication Lines of the Russian Federation. However, governmental regulation of any commercial enterprise has a tendency to deprive enterprise of needed flexibility and ability to meet challenges of the free market and perform necessary changes timely in order to prosper further (Levikov and Tarabanko, 2009). JSC RZD was established during the process of the Reform Programme by the order of the Government of Russian Federation № 585 on 18th of September, 2003 (Laisi, 2010). Reforming of the freight sector contains following guidelines:

- all freight wagons (approximately 1 million) will be owned by private companies or subsidiaries of Russian Railways
- independent tariffs on Russian Railways’ own rolling stock
• private shipments on local routes
• shipments on the Russian railways’ network based on regulated tariffs and updated tariff system.

Programme implicates that the mission of the RZD holding is effective development of transport business, competitive both on Russian and international markets, with taking into account realisation of responsibilities of national carrier and owner of railway infrastructure.

The main basis of active portfolio is freight transportation and infrastructure services, which are subject to state tariff regulation and generating the main part of the revenue and profit. In terms of steadily growing economy cash flows, which are formed by those types of business, allowed the holding to finance development of infrastructure and cover losses of passenger transportation. Subsidiary and affiliated companies of RZD are forming on the order of 25% of the revenue of the holding (RZD, 2010b).

The main part of the RZD fleet was handed over to the daughter companies of Russian Railways such as Freight One Company, The Second Freight Company and JSC TransContainer. Short description of railway wagons fleet distribution is presented below in the Table 1:

<table>
<thead>
<tr>
<th></th>
<th>JSC TransContainer</th>
<th>First freight company</th>
<th>Second freight company</th>
<th>JSC RZD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiwagons</td>
<td>0</td>
<td>82,887</td>
<td>110,000</td>
<td>-</td>
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<tr>
<td>Tank wagons</td>
<td>0</td>
<td>66,163</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cement carriers</td>
<td>0</td>
<td>11,800</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mineral wagon</td>
<td>0</td>
<td>6,233</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Covered wagons</td>
<td>0</td>
<td>16,821</td>
<td>25,000</td>
<td>-</td>
</tr>
<tr>
<td>Flatcars</td>
<td>24,376</td>
<td>6,749</td>
<td>10,000</td>
<td>-</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>549</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>24,376</td>
<td>191,202</td>
<td>150,000/173,000</td>
<td>518,700</td>
</tr>
</tbody>
</table>


Before the reformation of Russian Railways, leasing market for rolling stock was developed weakly, but since 2000s the situation changed dramatically. After deregulation, new significant players providing transportation services emerged on the Russian railway market besides JSC RZD (Shpadi, 2011).

The demand of existing rolling stock is very high, but existing fleet for the most part is exhausted. Furthermore, reduction of the working fleet realises because of faults caused by manufacturing defects and shortage of car casting (Nedosekov, 2011). Enterprises face the problem of choosing between the primary and secondary markets, when planning to purchase rolling stock. Today there exists approximately dozen of coach building companies (Abakanskyi, Altayskyi, Bryanskyi, Voronzhskyi, etc.), but demand of the primary market is not high comparing to the secondary market due to the high cost of new equipment. Prices concerning secondary equipment are much lower and depend on modification, extent of wear and executed maintenance.
Nevertheless, the size of railway fleet has continuously increased and as of the 1st of January in 2011 number of wagons exceeded 1 million (1,019,200 units). Main buyers of new rolling stock were leasing companies, which acquired more than 55% of equipment manufactured in Russian and CIS countries. Many of the leasing companies have faced financial obstacles during the recession in 2009, but in 2010 leasing market entered into new stage of development – lesser started expand their regional networks and increased their own fleet of rolling stock (InfoLine, 2011). Presently, the most reclaimed type of the wagons for leasing are tankers, semi-wagons and mineral wagons. Along the growing volumes of container transportation flat cars are also in the top priority list regarding rolling stock leasing (Gryaditskyi, 2003).

In the scenario options for development of economy of the Russian Federation it is supposed that most possible scenario for development in the next few years is scenario 2b (see Table 2), which estimates that the price for oil (Ural crude) in 2012 will decrease down to 93 dollars per barrel, subject to the stabilisation of supply and a possible slowdown in the economies of the countries – importers of oil, as well as the acceleration of cycle of increasing the base rates by central banks in the developed countries. In 2013, and 2014 in the base scenario it is forecasted, that after the increase in oil consumption the trend of moderate growth in prices up to 95 and 97 US dollars per barrel, respectively, will resume. Scenario reflects the economy’s development in the implementation of active government policies, aimed to improve the investment climate, competitiveness and business efficiency, to stimulate economic growth and modernisation, as well as to increase the efficiency of budget expenditures. In the scenario the increase in bank loans and maintaining low-key policy rate regulation are expected. GDP growth in the Russian Federation in 2012–2014 is projected at 3.5–4.6%. This means, that in connection with GDP growth, volumes of cargo transportation will grow as well. In order to handle the growth of freight transportation companies will need to have enough equipment, including rolling stock and services of leasing companies will be highly demanded (Economic Development Ministry, 2012).

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>World</td>
<td>2c–2b</td>
<td>–0.6</td>
<td>4.9</td>
<td>3.8–4.0</td>
<td>3.6–4.0</td>
<td>3.7–3.8</td>
</tr>
<tr>
<td></td>
<td>1a</td>
<td>3.4</td>
<td>3</td>
<td>3.8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>2c–2b</td>
<td>–2.6</td>
<td>2.8</td>
<td>2.7–2.9</td>
<td>2.4–2.8</td>
<td>2.4–2.5</td>
</tr>
<tr>
<td></td>
<td>1a</td>
<td>2.3</td>
<td>1.8</td>
<td>2.4</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>EU</td>
<td>2c–2b</td>
<td>–4.1</td>
<td>1.7</td>
<td>1.1–1.3</td>
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<td>0.9–1.1</td>
</tr>
<tr>
<td></td>
<td>1a</td>
<td>0.8</td>
<td>0.4</td>
<td>0.9</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>2c–2b</td>
<td>9.1</td>
<td>10.3</td>
<td>8.6–8.7</td>
<td>7.9–8.2</td>
<td>7.6–7.7</td>
</tr>
<tr>
<td></td>
<td>1a</td>
<td>7.5</td>
<td>7</td>
<td>6.8</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>CIS (without Russia)</td>
<td>2c–2b</td>
<td>–4.2</td>
<td>5.5</td>
<td>5.0–5.1</td>
<td>4.7–4.8</td>
<td>4.6</td>
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<tr>
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<td>1a</td>
<td>5.5</td>
<td>3</td>
<td>4.2</td>
<td>4.3</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Economic Development Ministry (2012)
Trends of freight transportation in North-West Russia in 2010s

Development of the sector is not limited by evolution of the leasing market only. Forecast of freight volumes for Russian rail network, which was made in the framework of the general scheme for railway transport development for years 2015 and 2020 shows that volumes of laden cargo will make up to 1,500.9 million tons per year in 2015 with average annual growth rate of 4.5%; volumes of transportation will make 1,667 million tons with average annual rate of growth of 4.4%, of which international transportation amounts about 629.8 million tons (Fedorov, 2011). Development of the infrastructure should be also established in line with development of the rolling stock fleet. Talking about satisfaction of demand on international transportation the cooperation between railways and ports should be considered as one of the most perspective way to implement international trade. Important feature in this cooperation is that railway tariffs for transportation towards seaports of the Russian Federation are much lower comparing to tariffs on inland international transportation (Nedosekov, 2011). Projects on increasing capacity of railway tracks, especially leading to ports of the Russian Federation, were included into investment budget developed by JSC RZD for years 2012–2013 (Fedorov, 2011).

Statistics shows that there are positive trends in development of cargo turnover between railway and marine transport in the Russian Federation. Railways are traditionally one of the main cargo suppliers to ports. Railways and pipelines share approximately equal amount of cargo flows, where railways supply to ports bulk cargo and oil products and pipelines – crude oil. All in all railways transport around 46% of cargo to ports (FSUE Rosmorport, 2012). JSC RZD reports that 217.1 million tons of cargo was transported by the Russian railways to ports, which is 10% more comparing to the year 2009. Strategic programs on development of the ports in Russia were also taken into account by the JSC RZD, when drawing up forecast on perspective cargo volumes. It was supposed that share of transportation towards ports will increase significantly: expected cargo volume increase is 143 million tons or by 66% compared to year 2010. The largest increase in traffic loads with railways is predicted in commercial seaports of Ust-Luga, Primorsk, Vysotsk – in the North-West Region, Taman, Novorossiysk – in southern Russia, Vanino, Vostochnyi – in the Far East region. Predicted volumes of cargo transportation by railway in connection with seaports are presented in the Table 3 (Fedorov, 2011).

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Freight transported by railways by JSC RZD in connection with Russian seaports (in million tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2007</td>
</tr>
<tr>
<td>North-West region</td>
<td>86.0</td>
</tr>
<tr>
<td>Southern region</td>
<td>64.1</td>
</tr>
<tr>
<td>Far East region</td>
<td>42.6</td>
</tr>
<tr>
<td>Total</td>
<td>192.7</td>
</tr>
</tbody>
</table>

Source: Fedorov (2011)

Modern seaport is a large transport hub, which connects different modes of transport and port’s activity is a strategic point in development of the State’s economy (Korovyakovsky and Panova, 2011). Also SWOT analysis for competitiveness of seaports of the Russian Federation made in the framework of the Development strategy for marine port infrastructure up to 2030 of FSUE Rosmorport shows, that one of the strengths for
marine ports is capability of cooperation with all modes of inland transport, including railways (FSUE Rosmorport, 2012; Shcherbanin, 2011).

3 Research methodology

Main research approach for the present work is quantitative. Quantitative data is numerical data or other types of data, which can be quantified or calculated. Using of quantitative data allows establishment of relationships between different variables after applying of different techniques of analysing and interpreting of this data (Saunders et al., 2009). Development of transportation sector can be best of all described by figures, showing dynamics in freight carriage, development of infrastructure, investments made etc. (Petrova et al., 2001). In addition, some qualitative data was used for more thorough description of the overall situation.

Qualitative information was used for literature review chapter and was gathered from the official websites of companies, which present both key participants of the Russian railway market (JSC RZD and its subsidiaries) and reflect main trends of economic development of the country (Economic Development Ministry, banks, exchanges). Qualitative data was used to describe the current processes in development of the researched sector, which are not yet described by statistics or where statistics only is not enough to elicit important changes. Furthermore, journal articles were naturally used as additional sources. Empirical part of this article is made as a statistics analysis of current transportation structure in Russia, focusing in North-West Russia by using quantitative data. Statistics were mainly obtained from the official websites of national statistics organisations, which present main social and economic indexes and reflects the current situation in the Russian Federation. In addition, many statistics were validated by using multiple sources for same data. Current study uses secondary information only, i.e., it is a literature review and statistical data.

4 Empirical part: transportation statistics in North-West Russia

Small focus is given to rail transport, but all the other main transport modes (sea, road and air) are also included in the statistics analysis. Transportation statistics are geographically targeting whole Russia at first. Focus is then moved towards North-West Russia including also specific statistics of St. Petersburg. In the end of empirical part, statistics of four North-West Russian seaports are reviewed and analysed (Port of St. Petersburg, Port of Primorsk, Port of Ust-Luga and Port of Vyborg). Statistics review is started by reviewing development of different transport mode lines (e.g., roads and railroads) in Table 4.

Length of railway lines in the Russian Federation has been on the same level between years 1995 and 2008; there was about 86,000 kilometres of railroads in Russia in 2008. Road network is by far the most extensive in Russia (if compared to other transport mode lines). In year 2008, there was approximately 940,000 kilometres of road network of which 754,000 kilometres were paved roads. Length of inner shipping lines has increased from 84 to 100 thousand from 1995 to 2008. Tramways, trolleybus and subway lines are
the shortest in Russia. There were about 2,700, 4,900 and 460 kilometres of tramways and subway and trolleybus lines respectively in 2008. Length of pipelines has increased from 210,000 km to 228,000 km from 1995 to 2008. Table 5 includes volumes of freight transport among different transport modes in the Russian Federation.

Table 4  Development of different transport mode lines in 1995–2008 (in thousand kilometres)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Public railway tracks</td>
<td>87</td>
<td>86</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>86</td>
</tr>
<tr>
<td>Roads</td>
<td>940</td>
<td>898</td>
<td>858</td>
<td>932</td>
<td>963</td>
<td>940</td>
</tr>
<tr>
<td>Roads with solid surfacing</td>
<td>750</td>
<td>752</td>
<td>724</td>
<td>754</td>
<td>771</td>
<td>754</td>
</tr>
<tr>
<td>Tramways</td>
<td>3.00</td>
<td>3.00</td>
<td>2.80</td>
<td>2.80</td>
<td>2.70</td>
<td>2.70</td>
</tr>
<tr>
<td>Trolleybus lines</td>
<td>4.60</td>
<td>4.80</td>
<td>4.90</td>
<td>4.90</td>
<td>4.90</td>
<td>4.90</td>
</tr>
<tr>
<td>Subway lines</td>
<td>0.39</td>
<td>0.41</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.46</td>
</tr>
<tr>
<td>Cross-country pipelines</td>
<td>210</td>
<td>213</td>
<td>223</td>
<td>224</td>
<td>226</td>
<td>228</td>
</tr>
<tr>
<td>Inner shipping lines</td>
<td>84</td>
<td>85</td>
<td>102</td>
<td>102</td>
<td>102</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Rosstat (2012a), The World Bank (2012a, 2012b) and UNECE (2011)

Table 5  Freight transport volumes by different transport modes (in million tons)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail transport</td>
<td>1,028</td>
<td>1,047</td>
<td>1,273</td>
<td>1,312</td>
<td>1,345</td>
<td>1,304</td>
<td>1,109</td>
<td>1,312</td>
</tr>
<tr>
<td>Road transport</td>
<td>6,786</td>
<td>5,878</td>
<td>6,685</td>
<td>6,753</td>
<td>6,861</td>
<td>6,893</td>
<td>5,240</td>
<td>5,236</td>
</tr>
<tr>
<td>Pipeline</td>
<td>783</td>
<td>829</td>
<td>1,048</td>
<td>1,070</td>
<td>1,062</td>
<td>1,067</td>
<td>985</td>
<td>1,061</td>
</tr>
<tr>
<td>Sea transport</td>
<td>71</td>
<td>35</td>
<td>26</td>
<td>25</td>
<td>28</td>
<td>35</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Inland waterways</td>
<td>145</td>
<td>117</td>
<td>134</td>
<td>139</td>
<td>153</td>
<td>151</td>
<td>97</td>
<td>102</td>
</tr>
<tr>
<td>Air transport</td>
<td>0.6</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Total</td>
<td>8,814</td>
<td>7,907</td>
<td>9,167</td>
<td>9,300</td>
<td>9,450</td>
<td>9,451</td>
<td>7,469</td>
<td>7,750</td>
</tr>
</tbody>
</table>

Source: Rosstat (2012b) and UNECE (2011)

Road transport is the most used form of transport if total weight of transported freight is compared among different transport modes. Level of road transport has maintained its volume during all the observation years until a drop in 2009. Road transport includes almost 7 billion tons of freight in all observation years except in year 2000, when a little less than 6 billion tons was transported by road transport, and in years 2009 and 2010. Second most used transport mode is rail, which has been about one billion tons in 1995 and 2000. Rail transport amount has increased to about 1.3 billion tons in 2010. Pipeline transportation is the third popular transport mode with about one billion tons of freight transported in 2010 (less than 800 million tons in 1995). Other transport modes (sea transport, inland waterways and air transport) are used much more rarely. In total, approximately 7.75 billion tons of freight was transported in the Russian Federation in year 2010. Freight transport by different transport modes in billion of ton-kilometres is presented in Table 6.
Table 6  Freight transport volumes by different transport modes (in billion ton-km)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail transport</td>
<td>1,214</td>
<td>1,373</td>
<td>1,858</td>
<td>1,951</td>
<td>2,090</td>
<td>2,116</td>
<td>1,865</td>
<td>2,011</td>
</tr>
<tr>
<td>Road transport</td>
<td>156</td>
<td>153</td>
<td>194</td>
<td>199</td>
<td>206</td>
<td>216</td>
<td>180</td>
<td>199</td>
</tr>
<tr>
<td>Pipeline</td>
<td>1,899</td>
<td>1,916</td>
<td>2,474</td>
<td>2,499</td>
<td>2,465</td>
<td>2,464</td>
<td>2,246</td>
<td>2,382</td>
</tr>
<tr>
<td>Sea transport</td>
<td>326</td>
<td>122</td>
<td>60</td>
<td>62</td>
<td>65</td>
<td>84</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Inland waterways</td>
<td>91</td>
<td>71</td>
<td>87</td>
<td>87</td>
<td>86</td>
<td>64</td>
<td>53</td>
<td>54</td>
</tr>
<tr>
<td>Air transport</td>
<td>1.6</td>
<td>2.5</td>
<td>2.8</td>
<td>2.9</td>
<td>3.4</td>
<td>3.7</td>
<td>3.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Total</td>
<td>3,688</td>
<td>3,638</td>
<td>4,676</td>
<td>4,801</td>
<td>4,915</td>
<td>4,948</td>
<td>4,446</td>
<td>4,751</td>
</tr>
</tbody>
</table>

Source: Economic Information Agency Prime (2012), Rosstat (2012c) and UNECE (2011)

If comparison between different transport modes is accomplished in ton-kilometres, then road transport plays very minor role. Most used transport mode is pipelines and second used transport mode is rail transport. Rail transport has almost doubled its ton-kilometres from 1995 (1,214 billion ton-kilometres) to 2010 (2,011 billion ton-kilometres), but pipeline has also increased its volume from 1,899 billion ton-kilometres in 1995 to 2,382 billion ton-kilometres in 2010. Amount of road transport in ton-kilometres was circa 199 billion ton-kilometres in 2010. This means that road transport is used for much shorter transport distances than pipelines and rail transport, which explains the difference between transported tons and ton-kilometres in road transport. Other transport modes are again used seldom, if ton-kilometres are compared. Both freight transportation amounts (see Tables 5 and 6) have decreased in year 2009 due to global economic crisis, but decrease was much heavier on tons than on ton-kilometres. Table 7 summarises availability of operational park of freight wagons and passenger cars.

Table 7  Availability of rolling stock in 1995–2008 (in thousand units)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational park of freight wagons (daily average)</td>
<td>368</td>
<td>464</td>
<td>499</td>
<td>512</td>
<td>526</td>
<td>507</td>
</tr>
<tr>
<td>Operational park of passenger cars</td>
<td>29.6</td>
<td>20.7</td>
<td>23.1</td>
<td>23.3</td>
<td>24.2</td>
<td>24.5</td>
</tr>
</tbody>
</table>

Source: Rosstat (2012d)

The amount of freight wagons used in Russian railway market has been increasing steadily from 1995 to 2007 (from 368 to 526 thousand units). There was a slight decrease in year 2008 with total of 507 thousand freight wagon units. The amount of passenger cars is much lower than the amount of freight wagons. There were about 29.6 thousand passenger cars in 1995 and 24.5 thousand cars in year 2008.

4.1 Transportation statistics in St. Petersburg region

Statistics concerning freight transportation related to St. Petersburg are illustrated in Table 8. Data of freight turnover in ton-kilometres is provided without rail transport statistics since it was not available.
### Table 8  Freight transportation in thousand tons and million ton-kilometres in St. Petersburg (2009–2010)

<table>
<thead>
<tr>
<th>Transport Mode</th>
<th>Freight Transportation (thousand tons)</th>
<th>Freight Turnover (mln ton-km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td>Rail transport</td>
<td>5,249</td>
<td>6,286</td>
</tr>
<tr>
<td>Road transport</td>
<td>6,905</td>
<td>7,577</td>
</tr>
<tr>
<td>Sea transport</td>
<td>9,087</td>
<td>9,016</td>
</tr>
<tr>
<td>Inland waterways</td>
<td>1,310</td>
<td>1,154</td>
</tr>
<tr>
<td>Air transport</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Pipeline</td>
<td>79,350</td>
<td>84,935</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>101,910</strong></td>
<td><strong>108,977</strong></td>
</tr>
</tbody>
</table>

Source: Petrostat (2012)

If weights of transported freight among different transport modes are compared, then clearly the most popular transport mode is pipeline in St. Petersburg area with about 85,000 thousand transported tons in year 2010, when the total transported freight volume in St. Petersburg area is about 109,000 thousand tons (pipeline account of about 78% of the total transported freight). Second most popular transport mode is sea with about 9,000 thousand tons of freight transported in or out from St. Petersburg, Road transport is third (7,600 thousand tons in 2010) and rail transport is fourth most popular (6,300 thousand transported tons) in St. Petersburg region. Comparison between different transport modes in ton-kilometres is not totally fair, because rail transport statistics could not be obtained due to lack of information. Pipelines are again the most popular transport mode in St. Petersburg with approximately 40,700 million ton-kilometres (it is about 64% of the total amount of 63,500 million ton-kilometres. It has to be noted that rail transport is not included in the total amount). Second most popular transport mode is sea with about 17,700 million ton-kilometres.

### 4.2 Seaports in North-West Russia

Seaport statistics review includes four seaports situated in North-West Russia (Port of St. Petersburg, Port of Primorsk, Port of Ust-Luga and Port of Vyborg). First seaport statistics concern Port of St. Petersburg (Table 9).

Of all the observed seaports (Port of St. Petersburg, Port of Primorsk, Port of Ust-Luga and Port of Vyborg) St. Peters burg is the most versatile in freight characteristics. Containers (21,978 thousand tons in 2011) and liquid products (15,739 thousand tons) are the most transported freight types through Port of St. Petersburg. The amount of containers has also increased considerable during the last years. In 2009, about 1.34 million containers were transported through Port of St. Petersburg, but in year 2011 approximately 2.37 million containers were transported (the increase is about 77% in two years). Furthermore, general products including, e.g., metals and refrigerators play large role in St. Petersburg (almost 13,963 thousand tons were transported through the seaport in 2011). Port of St. Petersburg is also used to transport mineral fertilisers in large amounts (approximately 6,000 thousand tons in 2011), but transportation of coal has decreased to almost non-existent in year 2011 (about...
2,183 thousand tons of coal was transported in 2010, but only 282 thousand tons in 2011. Total weight of transported cargo through Port of St. Petersburg has increased from 50,408 thousand tons in 2009 to 59,989 thousand tons in 2011. Freight turnover of Port of Primorsk is illustrated in Table 10.

Table 9  Freight turnover of Port of St. Petersburg during 2009–2011

<table>
<thead>
<tr>
<th>Characteristics of freight</th>
<th>Freight turnover in 2009 (thousand tons)</th>
<th>Freight turnover in 2010 (thousand tons)</th>
<th>Freight turnover in 2011 (thousand tons)</th>
<th>2011 in % to 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk, including</td>
<td>7,682</td>
<td>9,025</td>
<td>7,173</td>
<td>79%</td>
</tr>
<tr>
<td>Ore</td>
<td>626</td>
<td>646</td>
<td>688</td>
<td>107%</td>
</tr>
<tr>
<td>Coal, coke</td>
<td>2,471</td>
<td>2,183</td>
<td>282</td>
<td>13%</td>
</tr>
<tr>
<td>Mineral fertilisers</td>
<td>4,464</td>
<td>6,073</td>
<td>6,036</td>
<td>99%</td>
</tr>
<tr>
<td>Other</td>
<td>121</td>
<td>123</td>
<td>167</td>
<td>135%</td>
</tr>
<tr>
<td>Loose bulk, including</td>
<td>212</td>
<td>198</td>
<td>251</td>
<td>126%</td>
</tr>
<tr>
<td>Grain</td>
<td>204</td>
<td>142</td>
<td>237</td>
<td>167%</td>
</tr>
<tr>
<td>Other</td>
<td>8.5</td>
<td>56</td>
<td>14</td>
<td>24%</td>
</tr>
<tr>
<td>Timber</td>
<td>139</td>
<td>223</td>
<td>194</td>
<td>87%</td>
</tr>
<tr>
<td>General, including</td>
<td>11,649</td>
<td>12,823</td>
<td>13,963</td>
<td>109%</td>
</tr>
<tr>
<td>Black metals</td>
<td>4,081</td>
<td>4,522</td>
<td>4,662</td>
<td>103%</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>1,803</td>
<td>1,641</td>
<td>1,604</td>
<td>98%</td>
</tr>
<tr>
<td>Metal stuff</td>
<td>935</td>
<td>1,041</td>
<td>1,219</td>
<td>117%</td>
</tr>
<tr>
<td>Packaged-pieces cargo</td>
<td>710</td>
<td>862</td>
<td>893</td>
<td>104%</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>2,752</td>
<td>2,622</td>
<td>2,621</td>
<td>100%</td>
</tr>
<tr>
<td>Other</td>
<td>1,367</td>
<td>2,135</td>
<td>2,965</td>
<td>139%</td>
</tr>
<tr>
<td>Containers</td>
<td>14,543</td>
<td>19,000</td>
<td>21,978</td>
<td>116%</td>
</tr>
<tr>
<td>TEUs</td>
<td>1,343,675</td>
<td>1,931,012</td>
<td>2,365,174</td>
<td>122%</td>
</tr>
<tr>
<td>Cargo on ferries</td>
<td>276</td>
<td>451</td>
<td>692</td>
<td>153%</td>
</tr>
<tr>
<td>Liquid, including</td>
<td>15,908</td>
<td>16,339</td>
<td>15,739</td>
<td>96%</td>
</tr>
<tr>
<td>Oil products</td>
<td>15,888</td>
<td>16,299</td>
<td>15,677</td>
<td>96%</td>
</tr>
<tr>
<td>Food products</td>
<td>20</td>
<td>40</td>
<td>62</td>
<td>155%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>50,408</strong></td>
<td><strong>58,060</strong></td>
<td><strong>59,989</strong></td>
<td><strong>103%</strong></td>
</tr>
</tbody>
</table>

*Source:* Port of St. Petersburg (2012a)

Table 10  Freight turnover of Port of Primorsk during 2009–2011

<table>
<thead>
<tr>
<th>Characteristics of freight</th>
<th>Freight turnover in 2009 (thousand tons)</th>
<th>Freight turnover in 2010 (thousand tons)</th>
<th>Freight turnover in 2011 (thousand tons)</th>
<th>2011 in % to 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil products</td>
<td>74,891</td>
<td>71,831</td>
<td>70,127</td>
<td>98%</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>4,266</td>
<td>5,809</td>
<td>4,998</td>
<td>86%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>79,157</strong></td>
<td><strong>77,640</strong></td>
<td><strong>75,125</strong></td>
<td><strong>97%</strong></td>
</tr>
</tbody>
</table>

*Source:* Port of St. Petersburg (2012b)
Port of Primorsk is specialised in liquid products consisting of oil products and diesel fuel, i.e., there are no other freight types transported through Port of Primorsk than liquid products. The volume of liquid products transported in year 2011 was 75,125 thousand tons in 2011. The amount of liquid products transported through Port of Primorsk has decreased a little from year 2009, when 79,157 thousand tons of freight was transported through the seaport. Table 11 summarises freight volumes transported through Port of Ust-Luga.

### Table 11  Freight turnover of Port of Ust-Luga during 2009–2011

<table>
<thead>
<tr>
<th>Characteristics of freight</th>
<th>Freight turnover in 2009 (thousand tons)</th>
<th>Freight turnover in 2010 (thousand tons)</th>
<th>Freight turnover in 2011 (thousand tons)</th>
<th>2011 in % to 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk, including</td>
<td>8,343</td>
<td>10,042</td>
<td>13,596</td>
<td>135%</td>
</tr>
<tr>
<td>Coal, coke</td>
<td>7,771</td>
<td>8,942</td>
<td>12,417</td>
<td>139%</td>
</tr>
<tr>
<td>Other</td>
<td>482</td>
<td>1,100</td>
<td>1,179</td>
<td>107%</td>
</tr>
<tr>
<td>Timber</td>
<td>173</td>
<td>238</td>
<td>290</td>
<td>122%</td>
</tr>
<tr>
<td>General, including</td>
<td>841</td>
<td>1,051</td>
<td>1,289</td>
<td>123%</td>
</tr>
<tr>
<td>Black metals</td>
<td>680</td>
<td>750</td>
<td>963</td>
<td>128%</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>-</td>
<td>-</td>
<td>25</td>
<td>Increasing</td>
</tr>
<tr>
<td>Packaged-pieces cargo</td>
<td>1.9</td>
<td>3.9</td>
<td>-</td>
<td>Decreasing</td>
</tr>
<tr>
<td>Other</td>
<td>160</td>
<td>297</td>
<td>301</td>
<td>101%</td>
</tr>
<tr>
<td>Containers</td>
<td>-</td>
<td>0.0</td>
<td>0.5</td>
<td>Increasing</td>
</tr>
<tr>
<td>Cargo on ferries</td>
<td>998</td>
<td>445</td>
<td>1,039</td>
<td>234%</td>
</tr>
<tr>
<td>Oil products</td>
<td>-</td>
<td>-</td>
<td>6,478</td>
<td>Increasing</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,358</strong></td>
<td><strong>11,776</strong></td>
<td><strong>22,693</strong></td>
<td><strong>193%</strong></td>
</tr>
</tbody>
</table>

**Source:** Port of St. Petersburg (2012c)

Main products transported through the Port of Ust-Luga are currently bulk. Main transported bulk is coal and coke. In addition, oil products have quite large volumes, but they were started to transport through Port of Ust-Luga in year 2011. First containers were also transported in year 2011 and container volume is expected to increase significantly in year 2012 (Ust-Luga, 2012). Total tons of transported freight through Port of Ust-Luga has increased in two years from 10,358 thousand tons to 22,693 thousand tons in 2011. According to Ust-Luga (2012) and RZD-Partner (2012), the turnover of Port of Ust-Luga in first six months of year 2012 was about 18.9 million tons of which circa 14.8 million tons were transported by rail to or from the port, i.e., turnover in 2012 is estimated to increase if compared to year 2011. Freight statistics regarding the Port of Vyborg are represented in Table 12.

Of all observed seaports Port of Vyborg is the smallest in transported freight volumes, but it is also quite versatile in freight characteristics. Most transported freight includes bulk such as coal, coke and mineral fertilisers. Comparison of development of total transported freight in selected North-West Russian seaports can be seen in Figure 1.
Table 12  Freight turnover of Port of Vyborg during 2009–2011

<table>
<thead>
<tr>
<th>Characteristics of freight</th>
<th>Freight turnover in 2009 (thousand tons)</th>
<th>Freight turnover in 2010 (thousand tons)</th>
<th>Freight turnover in 2011 (thousand tons)</th>
<th>2011 in % to 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk, including</td>
<td>921</td>
<td>717</td>
<td>795</td>
<td>111%</td>
</tr>
<tr>
<td>Coal, coke</td>
<td>525</td>
<td>72</td>
<td>154</td>
<td>215%</td>
</tr>
<tr>
<td>Mineral fertilisers</td>
<td>388</td>
<td>545</td>
<td>502</td>
<td>92%</td>
</tr>
<tr>
<td>Other</td>
<td>8.3</td>
<td>100</td>
<td>139</td>
<td>139%</td>
</tr>
<tr>
<td>Loose bulk, including</td>
<td>-</td>
<td>49</td>
<td>6.0</td>
<td>12%</td>
</tr>
<tr>
<td>Grain</td>
<td>-</td>
<td>16</td>
<td>2.4</td>
<td>15%</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>33</td>
<td>3.6</td>
<td>11%</td>
</tr>
<tr>
<td>Timber</td>
<td>26</td>
<td>9.1</td>
<td>14</td>
<td>158%</td>
</tr>
<tr>
<td>General, including</td>
<td>128</td>
<td>223</td>
<td>212</td>
<td>95%</td>
</tr>
<tr>
<td>Black metals</td>
<td>31</td>
<td>68</td>
<td>41</td>
<td>60%</td>
</tr>
<tr>
<td>Metal stuff</td>
<td>26</td>
<td>15</td>
<td>18</td>
<td>122%</td>
</tr>
<tr>
<td>Packaged-pieces cargo</td>
<td>18</td>
<td>27</td>
<td>8.7</td>
<td>32%</td>
</tr>
<tr>
<td>Other</td>
<td>53</td>
<td>113</td>
<td>145</td>
<td>128%</td>
</tr>
<tr>
<td>Liquid, including</td>
<td>107</td>
<td>92</td>
<td>76</td>
<td>83%</td>
</tr>
<tr>
<td>Oil products</td>
<td>-</td>
<td>2.1</td>
<td>-</td>
<td>Decreasing</td>
</tr>
<tr>
<td>Food products</td>
<td>39</td>
<td>37</td>
<td>13</td>
<td>34%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>68</td>
<td>53</td>
<td>64</td>
<td>119%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,184</strong></td>
<td><strong>1,090</strong></td>
<td><strong>1,104</strong></td>
<td><strong>101%</strong></td>
</tr>
</tbody>
</table>

Source: Port of St. Petersburg (2012d)

Figure 1  Development of freight turnover in thousand tons in all observed seaports (2001–2011) (see online version for colours)

Figure 1 clearly shows that the Port of Vyborg is much smaller than the other compared seaports. Freight transported through the Port of Vyborg is a bit more than 1,100 thousand tons whereas about 75,000 thousand tons of freight is being transported through the Port of Primorsk, which in year 2011 had the largest freight turnover of all the compared seaports. Port of Primorsk has also increased liquid freight traffic considerable during the observation period (2002–2011). In 2002, 12,403 thousand tons of liquid products were transported through Port of Primorsk. Freight volume increased until year 2009 in Port of Primorsk (being the top year with 79,157 thousand tons turnover). There has been a slight decrease during years 2010 and 2011. Port of St. Petersburg is currently the second largest seaport. Freight turnover has increased quite evenly between years 2001 and 2007 (from 36,900 thousand tons to 59,628 thousand tons). After that there was a drop in freight transportation amount to 50,408 thousand tons in 2009, but Port of St. Petersburg increased throughput amount again to 59,989 thousand tons in 2011. Port of Ust-Luga is quite a new seaport. Its freight turnover has increased from 7,143 thousand tons in 2007 to 22,693 thousand tons in 2011. Total summed transport volume of all reviewed seaports has increased from approximately 37 million tons in 2001 to 159 million tons in 2011 (overall freight transported through observed seaports has quadrupled in ten years).

According to forecasts by FSUE Rosmorport (2012) and Fedorov (2011), freight transported through North-West Russian seaports will continue to increase in the near future. Basic variant forecasting future by FSUE Rosmorport (2012) suggests that overall freight transported through North-West Russian seaports will increase to approximately 262 million tons in 2015 and to 290 million tons in 2020. 46.6% of freight arriving in Russian seaports and 23.8% of freight dispatching from seaports was transported using rail transport. If forecasts of FSUE Rosmorport (2012) and Fedorov (2011) will realise, then the need for increased rail transport is considerable.

5 Discussion and conclusions

Road transport is by far the most popular freight transport mode in Russia, if weight of transported cargo is compared, but rail and pipeline are most used modes if transported ton-kilometres are compared, i.e., road transport is used for short distances, whereas pipeline and rail are used for long distances. These long distances include significant amount of freight transported to and from Russian seaports. Major amount of short road transports can be explained by freight distribution in city areas. All the other transport modes are used much less. The total amount of transportation (both weight and ton-kilometres) in the Russian Federation has increased steadily until year 2008, when global economic crisis started to have influence in transportation amounts. Pipeline is by far the most popular transport mode in St. Petersburg area. Pipeline has majority both in transported freight tons and ton-kilometres. Leadership of pipelines can be explained by the fact that Russia exports significant volumes of oil products. With country’s deepened integration with global economy it can be assumed that pipelines will hold leading position in the near future. Other main transport modes are rail, road and sea, if freight volumes are compared. Considerable difference between pipeline and other transport modes decrease, if transported ton-kilometres are compared. Ton-kilometres of sea transport are almost half of ton-kilometres transported by pipeline.
Having the railway transport as the second productive mode of transport after the pipelines (if transported ton-kilometres are compared) the Russian Federation is investing heavily on improving its railway sector, e.g., by privatisation through railway reform or improving wagon leasing. Bulk transportation including, e.g., coal, coke and fertilisers is playing major role in Russian transportation, which is mainly transported by railways in hinterland transports. Bulk is also transported by large shares through seaports (main bulk seaport in North-West Russia is currently Port of Ust-Luga with almost 13,596 transported tons). Other main freight types transported through North-West Russian seaports are oil products and containers. Containers are currently transported mainly through Port of St. Petersburg, but Port of Ust-Luga is increasing its container throughput. Port of Primorsk is fully specialised in oil transportation. Common characteristic among all reviewed seaports (Port of St. Petersburg, Port of Ust-Luga, Port of Primorsk and Port of Vyborg) is that volumes transported through seaports are mainly increasing. Port of Ust-Luga is actually quite new seaport, and it is investing hugely on increasing its throughput. Port of Ust-Luga is located near St. Petersburg, but it has large land areas, where it can expand. By increasing overall throughput capacity of North-West situated seaports, Russia can increase straight imports and exports, and decrease needed amount of transit traffic through, e.g., Finland or Baltic States. At the same time, Russia has enough transport facilities and constantly improving interaction between sea and rail transport modes to handle transit cargo flows coming from and to Europe in case of cargo volumes growth.

When analysing transport statistics regarding North-West Russian seaports, it is very visible that the strategy is to increase throughput of all the main seaports. This leads to increased demand of transportation services between inland intermodal terminals and seaports, i.e., there are considerable market volumes for rail and road transport modes and it is quite certain that demand will grow in the near future. Due to increasing hinterland transportation markets, quality of hinterland transportation infrastructure plays very important role. The capacity of hinterland transport modes have to cope with increasing demand, which is consequence of increased throughput of North-West Russian seaports.

Limitation of this study is the fact that all the information analysed in the empirical part of the study is based on public statistics. Opinions of seaport and railroad operators are not discussed in this study. Furthermore, statistics are mainly focusing in North-West Russia, but transit statistics with Finland and Baltic States are not analysed. Further research avenues could include updating statistics during forthcoming years to gain up-to-date knowledge of development of transport sector in North-West Russia. In addition, an interview or questionnaire study could be implemented among seaport and railroad operators, managers and other transport-related decision-makers in North-West Russia. These studies could include topics regarding North-West Russian transport trends, which cannot be studied from available statistics. In addition, transit traffic could be analysed and compared with statistics analysed in this study to gain information on how transit traffic is developing in comparison with North-West Russian transport statistics. Very interesting topic would be to research the effect of capacity increases in North-West Russian seaports in transit traffic through Finland and Baltic States.
Acknowledgements

The authors would like to thank reviewers for their constructive and helpful comments.

References


Trends of freight transportation in North-West Russia in 2010s


Publication 5


A Description of the North-West Russian Logistics Sector – Implications for the Rail Baltica Growth Corridor

A DESCRIPTION OF THE NORTH-WEST RUSSIAN LOGISTICS SECTOR – IMPLICATIONS FOR THE RAIL BALTICA GROWTH CORRIDOR

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ABSTRACT

Purpose
Purpose is to research current logistics situation of North-West Russia. Furthermore, aim is to gather private sector opinions of rail connection called Rail Baltica, which would connect North-West Russia and Central Europe through the Baltic States and Poland.

Design/methodology/approach
Data gathering was accomplished by semi-structured case interview study among North-West Russian (St. Petersburg and Leningrad areas) private logistics sector during 2012-2013.

Findings
Rail Baltica is seen as possible transport corridor by interviewed persons, if there is enough cargo available. Delivery time, frequency and price level are three main factors influencing the attractiveness of Rail Baltica route. Huge necessary investments in infrastructure, border crossing operations, different gauge widths and unclear decision-making processes are named as hindering factors.

Research limitations/implications
The scope is limited to North-West Russian private sector companies. This region is however leading one in the Russian logistics sector.

Practical implications
Understanding of overall attitude towards the project and readiness of Russian companies to use its services; main requirements for further development, together with threats and opportunities.

Social implications
The project could improve both infrastructural and environmental logistics situation in the region for both passenger and freight transportation.
Originality/value
The paper extends existing research about Rail Baltica with coverage of Russia. In earlier Rail Baltica studies transportation demand has been estimated to be endogenous (arising from the corridor countries), but actually both ends of alignment (Russia and Finland as well as Germany) play decisive role in the investment success.

Keywords: Railway corridor, Rail Baltica, investments, European Union, Russia, the Baltic States
1. INTRODUCTION

Aim of this study is to research northern dimension of Rail Baltica Growth Corridor (RBGC) having one ending in the North-West Russia. Currently, there is no such rail connection utilized between Russia and Europe, although it could be fully usable transport corridor, if major infrastructure investments are made. Most of the freight between Rail Baltica countries (incl. Baltic States, Finland, Russia, Poland and Germany) is currently transported by sea transport through the Baltic Sea (100 mill. tons), and cargo having Russian origins was in total 45.8 mill. tons (Eurostat, 2013; Karamysheva et al., 2013). An alternative transport corridor could improve the monotonous transport market and routes in the Baltic Sea Region (BSR). Due to relatively short distances in the BSR there is tough competition between short sea, road and railway transport. Thus, one Taiwanese research work showed that inside of this island one TEU transported by small container ship instead of road carrier from main container sea port to other local sea port was more than twice as expensive and took 2.5-3 times more time (Liao et al., 2011). In other empirical research works it has also been e.g. found that short sea shipping (typically RoRo) is having hard time to compete in cost wise against road transport (Morales-Fusco et al., 2012; Puckett et al., 2011), and typically only remedy has been public sector subsidy in one form or another (Morales-Fusco et al., 2012). Increased utilization of rail transport would also lead to increased environmental friendliness of the transportation activity and in the Gulf of Finland in particular (Kalli et al, 2012; Hilmola, 2012). Thus, Dekker at al. (2011) shows that in terms of CO₂ emissions rail transport is the second least polluting mode of transport ceding to container vessels. Railway transport shows lower emission figures comparing to heavy trucks: 0.043 and 0.067 kWh/ton-kilometer for railroads (electric/diesel), and 0.18 for heavy truck (Dekker at al., 2011; Friedrich and Bickel, 2001).

One possible alignment of RBGC can be seen in Figure 1. Even if hinterland transport route through Sweden and Denmark to Central Europe could sound feasible, in practice it is inappropriate for larger volumes (using either road or rail). Basically, routes starting e.g. from Tallinn or St. Petersburg will have both time and distance advantage through Baltic States and Poland. This not only to such cities like Warsaw, Berlin or Budapest, but also even to Frankfurt and Stuttgart as short sea shipping e.g. from St. Petersburg, Tallinn or Helsinki to Stockholm is having relatively high cost (much higher than same amount driven by road; see e.g. Hilmola, 2012). However, more could be done in eastern side of Baltic Sea to enhance the logistics competitiveness – if Kaliningrad region (belonging to Russia) would be more integrated (border crossing easy, like inside of European Union), in distance and time wise it would be more efficient to reach Berlin from Tallinn, St. Petersburg or Helsinki (in 1930’s actually railways were connected to Berlin through Kaliningrad or in that time, Königsberg region).
RBGC has been earlier studied at European level mainly (see e.g. AECOM, 2011; Heiland et al., 2012; Henttu et al., 2012; Himola, 2011; Laisi et al., 2011; RBGC report, 2011), but the possible Russian ending in the north has not been included in previous research works. Due to lack of research from Russian side, this study is important and adds information to the current knowledge regarding transport corridors connecting Europe and Russia. Research questions of this article are: What is the current situation of rail transport market in North-West Russia? How are the decision-making processes regarding transport market organized in Russia? Could RBGC be an effective and sensible alternative transport corridor connecting Russia and Europe?

Research methodology used in this research is semi-structured case study interview. The interviewees have high experience in logistics and they work in private sector in North-West Russia. Structure of this article is as follows: Section 2 summarizes current state of transportation sector in Russia mainly through statistical analysis. Russian railway sector is reviewed in Section 3. Following Section 4 informs about utilized research methodology and data gathering. Main findings from interviews are presented in Section 5. Discussion and conclusions are drawn in Section 6.

2. TRANSPORTATION SECTOR IN RUSSIA

History of Russian transportation sector has its own ups and downs. For example, Figure 2 presents sharp decline of cargo flows after 1990, taking into consideration that volumes of gas pipelines were not included (basically Figure 2 and Figure 3 illustrate merely domestic transports as maritime most often proceeds to foreign destination and is in Russian territory only for very short sea journey). This decline arose from the reduction in inter-industry cargo transportation (uncompetitive industrial structure) and increase in consumer market segment during the transition process for Russian economy from planned to market type in the middle of 1990s. It also should be noted that whole Soviet railway system was growing and dominating the world with its volumes (50 % from total world railway freight transports in 1988) until the very end of the former eastern bloc (Pittman, 2013). Recovery of transportation sector from the crisis of 90’s took almost 10 years. After the fall of 90’s (freight volumes declined by 54 %), positive growth came only in after year 2000. Slow growth at a rate of 2-3 % per year was observed from year 2000 to 2008, when the global
financial crisis caused another recession. (Nikolskaia, 2011) It should be emphasized that by any economic measure 90’s was very difficult decade in Russia. For example, currency (RUB) was devaluated nearly by 80% against USD in two years from Jan.1998 to Jan.2000 (more from crisis, see Chiodo and Owyang, 2002). In nominal and USD terms slump in GDP during 1998 was very strong (aftermath of Asian crisis), more than 30 %, and decline also continued in nominal terms with 27 % in year 1999 (in 2009 crisis nominal and USD terms decline in GDP was approx. 26 %; more see, Karamysheva et al., 2013). Due to these dynamic changes Russian inflation has remained to be high during previous decade time, and devaluation against major currencies has slightly continued during the years. However, Russian economy is resource-dependent and commodity-driven – and trades with huge surplus of foreign trade, and national economy does not hold any debt problems (from public side). According to the World Bank data, the share of oil and gas in total Russian export increased from about 50 % in 2000 up to 67 % in 2010 (The World Bank, 2012).

![Figure 2 Dynamics of freight transportation by means of all transport modes in the Russian Federation in 1970-2011, million tons. (Rosstat, 2013a; Rosstat, 2013b)](image)

In 2008, freight transportation activity stopped, which was exacerbated in 2009 with a decline of 21 %. Decline of industrial production in key cargo-generating sectors of economy in 2009 had a negative effect on the transport system of the Russian Federation. Volumes of commercial cargo transportation by all modes of transport (excluding pipelines) made 79 % in 2009 comparing to year 2008, while commercial freight turnover made 90 % correspondingly. The transport capacity of GDP fell by 5.6 %. Supportive measures taken by the Government such as investment of 95.4 billion RUB in different modes of transport has led to an emergence of positive traffic trends in the second half of 2009 (MED, 2012). After recession of 2009, the growth in 2010 was positive, but at a small level of 2.4 % (Nikolskaia, 2011).

![Figure 3 Transported cargo volumes by different transport modes in 2008-2011, billion ton-kilometers. (Rosstat, 2013c; Rosstat, 2013d)](image)
It should be noted here that even if Russian economy is improving all the time and trade surplus is massive, Russia is repeating similar pattern with west that its transportation section (domestic) is not any longer growing, even if GDP is strongly showing upwards movement. This could be explained with the fact that raw material price inflation together with service sector, domestic consumption through imported items and banking sector are growing in importance. However, it is still so that GDP growth is within its core totally dependent on export flows functioning, mostly through railways, pipelines and sea ports.

The freight turnover of transport in 2011 amounted to 4,915.4 billion ton-kilometers (+3.4 % to the level of 2010) (for more, see Figure 3). Freight turnover in 2012 made 4,998.1 billion ton-kilometers, which is 1.7 % more comparing to year 2011 (Rosstat, 2013c). Thus, albeit small increase, there are positive trends in transport sector of the Russian Federation in the post-recession period. Only the sea transport showed decline, but the main reason for this is that data, provided by national statistics agencies, does not include volumes transported by the vessels sailing under flags of other countries, even though they belong to Russian operators. (RBK Daily, 2012) However, maritime volumes at sea ports e.g. of St. Petersburg are staggering for north Europe (Big Port St. Petersburg, 2013): More than 2.5 mill. TEUs were handled in year 2012, and total cargo amount is well above 190 million tons. In international studies St. Petersburg has been found to be one of the most connected regions in sea transport in the whole world, even more connected than Bremerhaven or Barcelona (Kaluza et al., 2010).

According to the Russian Ministry of Economic Development, the volume of commercial transportation by all transport modes (excluding pipelines) in 2020 will reach 4.8/5.1 billion tons (127/137 % compared to 2011), the commercial turnover will make up to 3/3.2 trillion ton-kilometers (127/136 % compared to 2011), including public rail transport - 1.5/1.6 billion tons (121/129 % compared to 2011) and 2.6/2.8 trillion t-km (126/135 % compared to 2011) respectively (MED, 2013). According to Fisenko (2011), total growth of Russian transportation market together with logistics services is expected to grow from 48.5 billion in 2011 up to 150 billion US dollars until year 2015.

In spite of positive trends shown by statistics there are a lot of negative aspects in the Russian transportation sector development. Thus, various research work (Fisenko, 2011; Nikolskaia, 2011; Varnavskyi, 2004) outline poor transport infrastructure, lack of carrying capacity of road and railway transport, outdated and rundown rolling stock, non-transparent tariff system, inefficient cooperation of modes of transport between each other and with other services, i.e., customs and so on creates difficulties for further development of the sector and do not meet up to date requirements of customers. In light of international evaluations concerning infrastructure state and customs of Russia, it could be argued: (1) Customs is the weak point of the transportation logistics chains (as foreign trade flows are concerned; Arvis et al., 2007; Arvis et al., 2010; Arvis et al., 2012), not only to costs associated, but due to considerable time delay caused (e.g. seen at borders as long queues of trucks and in uncompetitive manufacturing supply chains, Hilmola and Lorentz, 2012), and (2) road transportation infrastructure state is much poorer as compared to rails (actually rails reach even standards of west; Schwab, 2011).

3. RAILWAY MARKET IN RUSSIA

Russia is the biggest country in the world in terms of geographical size, with total of 17.1 million square km, and the ninth ranked country according to population (Rosstat, 2013b).
Historically and due to geographical reasons, the railway transport is the backbone of the Russian economy. (Velichkov, 2007)

Dynamics of changes in rail freight transport reflects the general economic situation in the country and is correlated with the dynamics of GDP; respectively, operation of Russian railway transport sector was subject to recession in volumes transported in 1990s. The lowest indications were fixed in the year 1998 – 39 % compared to volumes transported in 1990 with freight turnover at a level of 40.4 %. Along with decline in freight-turnover, Russian railways also showed low indicators in technical performance comparing to foreign railways (Strategy, 2010). For example, having worse operating standards, customer-oriented US railways were far ahead of Russian railways in terms of speed of cargo delivery, time of delivery, safety etc.

Inner drivers for increasing efficiency of sector’s performance, and creation of products and services of higher quality were missing in the economic relationships in the industry as it was. Although the railway transport showed high figures in quality of operational work, satisfaction of customers with services provided was yet very low. All this has caused the urgent need to reform the industry. To improve the situation in the railway market and increase its competitiveness, decision on deregulation of the industry was made by the Government of the Russian Federation in the beginning of 2000s. (Guriev, 2008; Pittman, 2013)

In result of deregulation, JSC RZD was established in 2003. JSC RZD is a parent company in the RZD holding, which provides different services to satisfy the market demand on railway transportation services from both business and public sides. In the case of Russian Railways the European model was used for opening the railway market. This model implicates that infrastructure is owned by a single entity (JSC RZD) and is still regulated, but traffic with use of this infrastructure is carried out by number of companies – operators and owners of rolling stock and locomotives. (The World Bank, 2004) In total, the Reforming Program for JSC RZD is accounted until 2030 and includes the update of production and technical facilities, renewal of track and rolling stock, greater efficiency and increased revenues, along with higher competitiveness and motivation of railway personnel.

After 10 years since the start of the Reform Program, several changes in the industry became visible. Introduction of private ownership in the field of operating of wagon fleet created autonomous tools supporting private investments in rolling stock. The next step for the industry is creation of similar tools for infrastructure and locomotive traction sector (The World Bank, 2004). Deregulation of railway tariff system in part of infrastructure is also needed (Husainov, 2011).

Russian railways play important role in the system of international transport corridors (ITC) passing through the territory of the country (Rezer, 2010). For example, during the formation of ITC, the Trans-Siberian railway line was included in different projects of international organizations (UNECE, UN ESCAP, and OSJD) as top-priority route in connection between Europe and Asia (CCTT, 2012). In light of new ecological regulations adopted by the EU for marine transportation (e.g. IMO’s sulphur regulation) and active economic development of the North-West region of the Russian Federation the due attention should also be paid by Russia to development of additional land-based transport corridors with Europe, which could also be important for sustaining of Russian export flows of oil, gas, raw materials and semi-finished industrial goods. (RZD, 2012; VNIIZhT, 2012)
4. RESEARCH METHODOLOGY AND DATA GATHERING

Empirical data has been gathered utilizing qualitative semi-structured interview study. This method has been used, because there was no secondary data available regarding the connection of Europe and Russia with RBGC. By utilizing semi-structured interviews as data gathering method, the interviewer can skip or deepen certain questions to get more accurate data according to the specific organizational context (Saunders et al., 2009). About 150 logistics companies located in Russia were invited to take part in the interview study. Contacting was started by sending email to companies, and continued by contacting them by phone. After about 300-400 phone calls, eight interviews were settled during spring 2012. Ninth interview was accomplished in late 2012 and the tenth in the beginning of 2013. All interviews (except one) were recorded. Transcriptions were made out of all interviews, and the written documents were sent to interviewees for them to check and correct possible mistakes.

Utilized interview framework has been earlier used in RBGC project, but the framework was modified to be suitable for Russian private sector interviews. Main aim of the interviews was to gather private sector opinions towards Rail Baltica rail transport corridor, which is located in north-south direction connecting Russia, Finland, Estonia, Latvia, Lithuania, Poland and Germany. In this article we are focusing in findings regarding transport market in Russia, infrastructure, national decision-making processes and opinions and views concerning RBGC. All the 10 interviewed companies are operating in field of logistics, but they have different strategic focuses including freight forwarding, railway and road operations, customs brokering, terminal operations, manufacturing and consultancy in transport sector in North-West Russia.

5. EMPIRICAL RESULTS

All the empirical results represented in following sub-sections are based on the interviews.

5.1. Rail Transport in Russia

Rail is the main transport mode in Russia, if ton-kilometres are compared and pipelines are excluded. It is the most reliable land transport mode, and as Russia is geographically very large, it is also the most reachable transport mode in Russia. According to most of the interviewees, rail infrastructure is in good shape all around the Russia although there are some bottlenecks: Border crossing infrastructure is poorly developed (e.g. some stations are lacking rail tracks for wagon storage and inspection) and time spent in customs procedures is high. Other throughput capacity limitations are realized between Urals and Asia (whole capacity of two main lines are in full use i.e. more cargo cannot be transported between Urals and Asia). Furthermore, most of the terminals with rail connection are in poor condition, and only few terminals are modern. Furthermore, poorly developed dry ports network in Russia was discussed in some of the interview meetings.

Predictability and reliability are the main advantages of rail transport. Rail transport can be operated in any kind of weather with maintained schedule, whereas problems arise with road transport, if weather is poor. In addition, safety of rail transport is in good level and environmental friendliness is also better for rail than for road. Furthermore, congestion on road network can be decreased by utilizing rail transport particularly in St. Petersburg area and near of its surroundings. Roads are often very congested, because Port of St. Petersburg (mainly handling containers) is situated inside the city. Deregulation of railway sector has
increased the competition of rolling stock markets. Currently, due to the high competition there exist more wagons than there is capacity in Russian rail network.

Unclear pricing policy and high infrastructural tariffs were mentioned as weaknesses of rail transport in Russia. Railway tariffs are especially high for short distance transportation, but more reasonable for longer distances. Larger companies actually mentioned that tariffs could even be increased, but small and medium sized companies argued that tariffs are too high (discounts are provided, if more than six wagon units are transported by rail). One drawback of Russian tariff policy is its slow ability to evolve with the market demand e.g. currently there does not exist tariff policy for transporting semi-trailers by rail wagons.

5.2. Competitive Transport Modes

Road transport is much more flexible transport mode than rail. Furthermore, smaller batches are easier to transport by road, since the whole capacity of road transport vehicle is easier to fulfil. Rail transport is not able to react to changes in the market as quickly as road and sea transport modes. Some quality factors (e.g. time of delivery) are higher by road. Faster time of delivery by road can be in most cases explained by the fact that, when utilizing rail transport also road transport is needed in the beginning and end of the whole transportation chain. Transhipments between road and rail increase total costs of transportation in addition to increased delivery times on shorter distances. In most cases, costs per ton-kilometer are lower by rail, but the transhipment costs make rail transport more expensive in shorter distances i.e. a certain break-even distance has to be achieved to make intermodal transport cheaper than unimodal road transport. One interviewee mentioned that they have utilized road transport for up to 3,500 km transportation legs inside Russia.

Major problem of road transport in St. Petersburg region is the lack of road vehicles. It also hinders utilization of other transport modes, since road transport is needed for multimodal transport. In addition, poor infrastructure was mentioned as a large drawback for road transport. Road infrastructure is in much poorer condition than rail network infrastructure. Road infrastructure can though be developed faster and with lower investments than rail infrastructure. There are currently many large-scale investments to improve road network in St. Petersburg area. However, majority of road network investments are made near large cities, but roads connecting large cities are not getting as much investment funding and are deteriorating. Also the terminal network in and near St. Petersburg is already in good condition and it is being improved more in the near future.

In long distance freight transportation, main competitive transport modes are sea and rail. Interviewees commented that freight rates have increased faster in sea transport than in rail, which has decreased competitiveness of sea transport. In addition, infrastructure and hinterland connections of some sea ports are not meeting customer demands. Currently, regional and federal authorities of Russia are applying major amount of force to develop sea transport in the region (mainly regarding ports of Ust-Luga, Primorsk and St. Petersburg).

5.3. Decision-Making Processes Regarding Transport Sector in Russia

Transport sector related decision-making processes are very long and include major amounts of bureaucracy. Responds regarding decision-making processes varied from negative to very negative. Basically, companies can express their opinions, but they usually cannot make any influence in transport sector focused decisions by themselves. Large companies or groups of companies can have some influence i.e. the only possibility for smaller companies is to join unions or associations and make their suggestions with help of them. Furthermore, relationships with e.g. the state plays very large role in Russian decision-making processes.
Companies have to co-operate with numerous authorities, when developing transport sector projects. Furthermore, decision-making is very centralized in Moscow, but also in St. Petersburg. Larger main decisions are always made in Moscow, and trend is that decision-making will be more centralized in the near future (Moscow will increase its decision-making power even more). Decision-making processes have become faster than e.g. 10 years ago, but they are still quite slow. It is also very hard to identify the main stakeholders, which should be contacted to push decision forward.

Decision-making concerning railway sector is mainly handled by the state owned Russian Railways. Governmental bodies can implement some projects, but Russian Railways is the main decision-maker. Main reasons for strong decision-making power of Russian Railways is its ability to generate very large profits for Russia (freight side) and personal relationships between top managers among different sectors i.e. if some company would like to start some project in rail sector, it should contact Russian Railways. Some problems regarding rail sector were mentioned: Different stakeholders inside Russian Railways do not always communicate with each other. Furthermore, decision-makers of Russian Railways have only limited communication with authorities in different organizations or companies (e.g. customs duty).

5.4. Rail Baltica Growth Corridor

RBGC is seen as an interesting project, since it would develop transport market into more versatile direction by adding alternative transport corridor to compete with sea transport in BSR. This could improve the whole transport market in Russian side in price level, frequency of service and lead time level. The project could also lead to improved infrastructure not only in the actual Rail Baltica alignment, but also on the regional level by connecting areas with the transport corridor. Most of the interviewees stress that not only Germany is important to reach, but also the cities and countries south to Germany are playing major role and should be connected by rail transport corridor. RBGC is also seen as a possibility for private locomotive market in international traffic. Another point was made regarding to IMO’s sulphur regulation: The regulation will get stricter in 2015 and this will probably increase prices of sea transport. RBGC would be more important, if sea transport loses some of its competitiveness. Interviewed companies consider St. Petersburg and Leningrad region as the main cargo gate between Russia and Europe, and stress the importance of St. Petersburg as a vital transit hub. This can be seen in major investments in sea port infrastructure in North-West Russia.

Some interviewees however pointed out that current and already existing sea transport route along the Baltic Sea between Russia and Europe is very efficient and competitive. Due to this, these interviewees assume that RBGC would not be very important, if large-scale investments are demanded. Border-crossing operations and infrastructure are seen as major obstacle in cross-border rail transport. Border crossings are lacking capacity e.g. for wagon storage. Also the bureaucracy regarding customs legislation is hindering border crossings. Different gauges along the corridor were also mentioned as bottlenecks. Interviewees’ mostly shared similar opinions, when discussing about the most important factors regarding RBGC (see Figure 4).
Figure 4 The most important features of RBGC according to interviewees.

Percentual figure indicates how many interviewees mentioned the factor as an important one for them i.e. ten percent of the interviewees said that schedule is an important factor, whereas half of the interviewees stressed that price is an important factor, which is actually the most important factor, if compared to other alternatives. Interviewee could choose several important factors instead of just one. Frequency and time of delivery are almost as important for the interviewees (four out of ten stressed these factors). Safety, intermodality and scheduled services are also having importance for the interviewees. Even if price was the most important factor, interviewees assume that price could be higher, if frequency and time of delivery is better than if compared to sea transport. Comparison to competitive transport modes is crucial regarding all the most important factors: Price level should be on the same level with sea transport. Suitable delivery time would be between 5-7 days between St. Petersburg and Berlin. In addition to previously discussed factors, the containerization was selected as very important. Interviewees stressed that container transport should be available for RBGC, since containers are widely used, when transporting general cargo by railways in Russia.

6. DISCUSSION AND CONCLUSIONS

According to the interview findings, all main transport modes used in the Russian Federation are having their own local and global advantages and disadvantages. They are summarized in Table 1.

Table 1 Comparison of rail, road and sea transport modes in the Russian Federation.

<table>
<thead>
<tr>
<th></th>
<th>Railway</th>
<th>Road</th>
<th>Short sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main advantage</td>
<td>Predictability, well developed infrastructure</td>
<td>Flexibility, door-to-door delivery</td>
<td>Low prices</td>
</tr>
<tr>
<td>Main disadvantage</td>
<td>Unclear pricing policy</td>
<td>Unsound condition of infrastructure and vehicle fleet</td>
<td>Undeveloped port infrastructure</td>
</tr>
<tr>
<td>Pros</td>
<td>Great power in decision-making process, renovated rolling stock</td>
<td>Diversified cargo base</td>
<td>Well developed services in Finland and the Baltic States</td>
</tr>
<tr>
<td>Cons</td>
<td>Raw materials are the main cargo group</td>
<td>Shorter competitive distance of transportation, growing prices of fuel</td>
<td>High level of environmental pollution, growing prices of fuel</td>
</tr>
</tbody>
</table>

Main advantage of rail against road and sea transport is its very good predictability in Russia. In addition, rail infrastructure is in better shape than road transport infrastructure (also agreed in macroeconomic studies of infrastructure, like Schwab, 2011). Other advantages are
possibility to have effect in decision-making processes and largely renovated rolling stock. Main disadvantage of rail transport is its unclear pricing policy for many customers. Furthermore, raw materials are the most transported cargo by rail in Russia. Road transport is more flexible than rail and sea, and this added with ability to door-to-door services creates the main advantages for road transport. Furthermore, versatility of transported cargo expands market of road transport. Limited capacity of road transport vehicles in Russia and especially in and near St. Petersburg creates problems for the customers. Furthermore, poor condition of infrastructure outside large cities is hindering utilization of road transport. In addition, road is not as competitive as rail in longer distances, especially since fuel prices have been increasing during the last years. Sea transport in BSR is having very competitive price level, which is very hard to challenge by other transport modes. Moreover, sea transport services in Finland and BSR are well-developed. However, port infrastructure in North-West Russia is undeveloped although large funding is targeted to improve the infrastructure. Price level of fuel affects also sea transport’s competitiveness. In addition, a SWOT analysis of RBGC project was made based on the interview findings (see Table 2).

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>- Shorter lead time, if compared to other</td>
<td>- Necessity of huge investments</td>
</tr>
<tr>
<td>transport modes</td>
<td>- Long-term realization</td>
</tr>
<tr>
<td>- Lower freight rates</td>
<td>- Different rail gauges and undeveloped cross-border infrastructure</td>
</tr>
<tr>
<td>- Improvement of land transport between</td>
<td></td>
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<tr>
<td>Russia and Europe</td>
<td></td>
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<tr>
<td>- Extends variety of choices regarding</td>
<td></td>
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<tr>
<td>transport corridors</td>
<td></td>
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<tr>
<td>- Increases the competitiveness of</td>
<td></td>
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<tr>
<td>different transport modes</td>
<td></td>
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<tr>
<td>- Green aspects</td>
<td></td>
</tr>
<tr>
<td>Threats</td>
<td>Opportunities</td>
</tr>
<tr>
<td>- Not adjusted customs procedures</td>
<td>- Development of logistics infrastructure on-route</td>
</tr>
<tr>
<td>- Higher prices compared to sea transport</td>
<td>- Good connections to seaports and road network</td>
</tr>
<tr>
<td>- Development of the 1520 gauge rail</td>
<td>- High gasoline prices</td>
</tr>
<tr>
<td>transport corridor to Vienna by FSC RZD</td>
<td>- Drawbacks in Russian seaport operations</td>
</tr>
<tr>
<td>- Well-developed port infrastructure in the</td>
<td>- Introduction of the IMO’s sulphur regulation</td>
</tr>
<tr>
<td>Baltic States</td>
<td>- Tailored value-added services</td>
</tr>
</tbody>
</table>

Realized rail transport corridor could decrease lead times between Russia and Europe. In addition, freight rates could decrease due to increased competition in the transport market in BSR. Transport market would also become more versatile in means of added amount of usable transport modes. As rail transport is environmentally friendly mode of transport, Rail Baltica could decrease environmental impacts of the whole transportation (environmental friendliness is dependant of the type of locomotive and how the energy is created). Furthermore, rail transport would be good alternative for sea transport, because IMO’s sulphur regulation will increase costs of sea transport in 2015 (and this especially for Russia and Finland). Implementing RBGC would enhance rail connections to and from sea ports and between road network connections i.e. the logistics infrastructure would improve not only in rail sector, but also in sea and road sectors. The problem of high gasoline prices could be partly avoided by using electric train. However, RBGC would need major investments and long-term realization. Different rail gauges and undeveloped border infrastructure hinders the project. Furthermore, customs procedures should be more efficient to allow faster freight and passenger flows between border-crossing along the Rail Baltica route. Some interviewees also believe that rail transport could not compete with sea transport price level. Developed and
modern sea port infrastructure in the Baltic States and Finland impede the competitiveness of RBGC.

According to the interviews, Rail Baltica is seen as a possible transport corridor, if there is enough freight to be transported along the corridor. It would enlarge the portfolio of the whole transport market in BSR. There were also doubts regarding large-scale investments of constructing and renovating the rail line. Furthermore, interviewees stressed that the service should have proper price level, frequency and lead time to be competitive with other transport modes (in this case the competitive transport mode is seen as sea transport). Rail transport market has been and still is a very reliable and predictable in the Russian Federation. It is also assumed to maintain its market share in the near future. Rail transport is most suitable for long distance transports, since tariff level is relatively low on long distance transportation. Road transport is mainly utilized in shorter distances (however, not as “short” as in west). The decision-making processes regarding transport market are very long and bureaucratic and they include many national peculiarities in Russian environment. Private sector companies have only limited possibility to have influence in decision-making processes. Larger companies have better possibility, but smaller can influence on decision-making only through larger unions or organizations. Large part of the interviewees sees RBGC as an interesting and potential transport sector project. Interviewees are a bit sceptical about the funding of large-scale investments regarding the project, but they believe that connection could be efficient for freight transport between Russia and Europe. It would be a good alternative for the current sea transport in the Baltic Sea.

If talking about development of international rail corridors, Woodburn et al. (2008) mention that they are successful and competitive to sea transport only when services provided on them do not suffer from different limitations and barriers. At the same time Dekker et al. (2011) assume that even though nowadays rail transport is less competitive comparing to road mode, without proper innovations railroads may lose their competitive advantages, while severe requirements to road transport will enhance its development and result in e.g. significant decrease in environmental pollution. Puckett et al. (2011) argue that frequency of services nowadays is playing more and more important role in choice of transport mode, as transportation of goods has shifted from single dispatches to large consolidated cargo flows.

The research is limited mainly to freight transport i.e. passenger transport was not discussed in the interview meetings. In addition, all the interviewees are from private sector, and no sea transport company was interviewed. Geographical focus of this study is in North-West Russia (St. Petersburg and Leningrad Oblast).

Future research avenues should include similar interview rounds in public sector organizations, since they are very important decision-makers on planned, but uncertain large-scale investment projects. Deeper interview or questionnaire study could be made to research in order to clarify possible transport volumes along the RBGC from and to Russian markets in the northern end of the Rail Baltica alignment.

ACKNOWLEDGEMENTS

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Russian module was initiated in the early 2012. We hold gratitude for provided research funding, which has made possible different studies from the topic.
REFERENCES


Karamysheva, M., Henttu, V. and Hilmola, O.-P. (2013), Logistics of North-West Russia and Rail Baltica: Standpoints of Private Sector, Lappeenranta University of Technology, LUT School of Industrial Engineering and Management, Research Reports 3, Lappeenranta, Finland.


RBGC report (2011), Private transport market stakeholders in the area of Rail Baltica, City of Warsaw, Poland.


Publication 6

Border-Crossing Constraints, Railways and Transit Transports in Estonia
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Border-crossing constraints, railways and transit transports in Estonia

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North-East Europe has served as a general cargo transit area for Russia and other emerging economies of the East for decades. Typically, this activity was initiated with road transport, but after some years of operation, border-crossings became problematic and in some cases even impossible to conduct. Volume of transit transport was therefore severely constrained. As one remedy to sustain transit traffic, the Baltic States have implemented container trains to eastern destinations. Even though, overall transit traffic through Estonia has decreased mainly due to the increased volumes of Russian seaports, the container transit traffic has increased steadily. Volumes were really minor a decade ago, but have increased from several thousand containers up to above 50,000 TEU in 2013. This has enabled hinterland transport and incoming container volumes in the port of Tallinn to develop. This research work analyzes not only second hand data regarding Estonian general cargo transit, but also includes case study visits. The case company has established many international container train connections. Container transit traffic has an optimistic future outlook in Estonia. However, the main operational constraints are related to gauge widths, border-crossing operations, delivery time issues, low price level of road transport, unpredictable Russian market and legislation and infrastructure investments.

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1. Introduction

North-East Europe has served as a general cargo transit area for Russia and other emerging economies of the East for decades. Even though the total rail freight volume of Estonia has decreased in recent years, container transit transportation by rail has increased, not only in Estonia, but also in the other Baltic States. At the time of the study, the Estonian railway company reported transporting nearly 62,000 containers (TEUs) cross-borders per annum (in the year 2013), and public information from Latvia and Lithuania confirms that their volumes are substantial as well. Latvian Railways (2012) reported that in the year 2012 they have carried 111,117 TEU by rail (showing doubling in a five year period). Based on the Statistics Lithuania (2013), Lithuanian international railway volumes were roughly 75,000 TEU in the year 2012 (showing rather similar growth with Latvia). It should be noted that former Soviet economies have grown substantially in the recent decade, and the Russian retail sector is one of the most important in Europe. For example, in sales of new cars, Russia is nowadays larger than France, and lacking just slightly behind Germany (Oica, 2013). Furthermore, the capital of Moscow has been listed as one of the most expensive cities in the world for years.

There are many possible constraints that Estonian container transit traffic faces currently or could face in the near future. Direct rail line between Estonia and Central Europe is not used due to different

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1.1. Global retail trade development

Global retail trade has been under tremendous change in the last ten to fifteen years. New markets have emerged, and retail trade growth is mostly located in Asia, and particularly today in China (Ben-Shabat, Moriarty, Rhim, & Salman, 2014). In Europe, it has been Russia, which was in a similar favorable position earlier. Domestic and local retail chains held market dominance in Russia during the early 2000s (Lorentz, Hakkinen, & Hilimola, 2006), but nowadays the market has internationalized considerably by the entrance of French, German and Turkish retailers (Lorentz & Loureiro, 2011; Roberts, 2005). Based on All-Keany’s Global Retail Development Index, Russia was very favorable for retail market expansion in the early 2000s, and had the number one rank in ALL-Keany’s 2004 study (All-Keany, 2004). In the following years (until the year 2009) ranks were still very high, varying between two and three. However, position dropped to rank ten in the year 2010 study (Ben-Shabat, Moriarty, & Neary, 2010), and was as low as rank 26 in the year 2012 (Ben-Shabat, Moriarty, Rhim, & Salman, 2012). This all reveals that the retail sector has grown considerably during the recent decade, and consumption is maturing. Based on Russian Federal State Statistics (2014a), retail trade has grown by nine times in Russian national currency (RUR) terms from the year 2000 to 2012, while wholesale trade has recorded tenfold growth. Despite that the Russian retail market is maturing, its sales volumes are increasingly less dynamic than before. On the other hand, online retail is growing within significant terms (Ben-Shabat, Moriarty, & Nilforoushan, 2013). This all means that the consumption base will remain high in the forthcoming years, and will even show some growth. As Russia specializes in raw material exports, it means that the import of consumer items with containers will show growth for years to come.

This is good news for neighboring countries located within the main container routes such as all three Baltic States and Finland (Hilimola, Taparainen, Perk, & Säynätalo, 2007). However, most of the Russian container volume is currently handled within the Port of St. Petersburg, which is located on the European side on the coast of the Baltic Sea.

1.2. The Russian and East European container market

Russian and further the eastern consumer and container market has grown substantially over the years, mostly because of a growing consumer sector. In Fig. 1 this is being illustrated with container handling growth within the Port of St. Petersburg, which was in the year 2001 at the level of 330,000 TEU and eleven years later has grown up to 2.5 million TEU. Over the years, Finnish transit container amounts were firstly growing rather consistently until the crisis year of 2009, when half of the demand just disappeared. Transit volumes have recovered a bit thereafter, but only within very limited extent. Share of Finnish transit containers at the main seaports has more than doubled in the observation period up to 2012. In reality, this number could be even lower, since railway statistics and seaport statistics differ a bit in the Estonian case (railways carry return empty containers). As could be noted, recession and the global crisis in the year 2009 had very small effects on container volumes. Actually, Estonia recorded the lowest decline in transit volumes from all three countries within the Gulf of Finland. This is rather typical for a niche strategy, when a valuable and unique set of service offering is being developed and delivered to markets. On comparison, depicted volume developments of container transportation by road and rail transport modes are illustrated in Fig. 2 – much lower growth trajectory is apparent by road after the 2008–2009 crisis and clear downturns in 2002 and 2009. Overall, truck transport still dominate in the seaport related logistics, but the market share of railways from all containers handled at seaports has more than doubled in the observation period up to 2015.

Railway transport shares of total hinterland transportation were collected and examined from the time period of the previous five years (in the case of Russia, only four years were available), and this examination reveals significant differences between the three countries in question (Estonia, Finland and Russia). From Finland we could not find reliable and publicly available data from import transit container by rail to Russia, but total sum in tons from transit import cargo was available at the Statistics Finland (2013). This amount was summed together with the Finnish Customs (2013) data from road transit transport to find out the total market of hinterland transport modes. (some seagoing transshipment also takes place, but it could not be considered as hinterland). This estimation gives 10% share for rail transport in the five recent years (2008–2012). In reality, container volumes could be even lower than this amount. In Russia, aggregate share of railways on seaports imports from the last four years was 28.5%. Only Estonian market shares of rail are calculated from transit container amounts, but this country holds an exceptional share, which is 53.8% in the last five year period.

Actually, Estonian railway share has increased above 60% in the year 2012. In reality, this number could be even higher, since railway statistics and seaport statistics differ a bit in the Estonian case (railways carry transit containers typically more than what seaports actually report to have handled themselves). This analysis further supports the assumption that the niche market of railway container transports is the key reason for the robust performance of Estonia in the recent years. In the case of Finland, transit transportation is too dependent on road transport, which is known to be a much higher cost alternative, which will be hurt the most in the case of economic crisis. Railways are considered to be in much better shape infrastructure wise also in the Russian environment (Schwab, 2013), and railway reforms have made the sector increasingly more market oriented, lower cost and a real alternative for road transport in a country of long distances (see e.g. Läsi, 2013; Läsi & Panova, 2013; Henttu & Karamysheva, 2013).

Research work is structured as follows: Case study research method is being introduced in Section 2. Our case study findings are reported in Section 3. Discussion follows in Section 4. Finally in Section 5, we conclude our study and propose avenues for further research.

2. Methodology

Three traditional research strategies based on Hirsjärvi, Hurme, and Sajavaara (2004) are experimental research, survey research and case study. Case study was selected as the main methodology for this article, since it gathers detailed data regarding a certain subject (Hirsjärvi et al., 2013).
Furthermore, case study has been used especially with logistics research (Eisenhardt, 1989; Hilmola, Hejazi, & Ojala, 2005). Case study presented in this article is based on two one-week visits by the authors in Estonia. Visits included many short interviews among the top management of Estonian transport sector companies. In addition, transport related meetings and observations during the visits have been used as a source of data for this article. Material and document gathering, as well as previous research by the authors provide data for the detailed single case study presented in this article.

This particular case was selected, since container transit traffic has shown high volume increases during the recent years in Estonia (similar trend has also occurred in other Baltic States). However, total volume of rail transport in Estonia has decreased from its highest level during the recent years. As a country, Estonia is good for this case study, since it is

Fig. 1. Container handling at seaports (St. Petersburg in total, Finland and Estonia transit containers; all in Twenty feet Equivalent Units), and share of Finland and Estonia from eastern container flows in the period of 2001–2013.

Fig. 2. Containers transported through Estonia with railways and road transport during the period 1997 to 2013 (index in 1997 is 1.00).
quite similar with other countries such as Latvia, Lithuania and Finland, if researching transport related topics regarding transit traffic to and from Russia. Estonia has for a long time been one of the main transit countries between Central Europe and Russia. However, there are many trials which could affect efficient governance of an intermodal transportation. These are e.g. different rail gauges between the Baltic States and Central Europe, unpredictable Russian legislation and competing transport modes.

Case study was expanded with an extensive expert interview from a railway company (Commercial Director) dealing with cross-border activity from Estonia to the East. This company was chosen, since they have a long history of operating Russian rail transit traffic. Interview itself was conducted in November 2013 at company headquarters. Theme interview with the case company expert was completed within a semi-structured form (see e.g. Saunders, Lewis, & Thornhill, 2009; Chaurri & Gronnaug, 2010; Yin, 2011), where the main themes of the interview were Company background, Transport market, Transit traffic, Intermodality, Infrastructure, Rolling stock, Green aspects and International railway corridors such as Rail Baltica. Researcher took notes from the interview, and also recorded it. After the meeting, the entire interview was documented, and in the following month's the interaction with the interviewee consisted of checking interview findings and technical data. This interaction with the case company was felt to be important as numerous technical aspects needed further clarification and misunderstandings would have been possible without checking and re-checking of the situation concerning the present and past. However, to ask exact questions and to know the developed situation in Estonia, the authors have done years of research in this country and in the Baltic States in general. Even during November 2013 one-week visit, the researchers visited Estonian seaports and had meetings with different logistics research branch actors of the country. A similar one-week visit was completed by the other author of this research work in March 2014, and meetings during that week also consisted of the top management of different logistics companies to discuss topics such as container transportation and intermodality.

Part of the data for this article has been gathered as an extensive literature and statistics review. Literature review includes mainly journal articles and official Internet sites, whereas the statistics review is mainly focusing on official statistical databases accessed through the Internet. We have presented and depicted the current situation in Section 1 and partially in this section through second-hand statistics.

3. Research findings

3.1. The case company

Case company owns in total 3300 rail wagons, which include flat wagons for container transport and open wagons for other transportation purposes. Flat wagons are in modern shape, but open wagons are mainly old. The company transported about 16 million tons of freight by rail in 2013. Approximately 65% of the total volume is transit traffic (10.4 million tons, and most of this transit is oil through Estonia to other European countries). Trains are moved with diesel locomotives (company does not own any electric locomotives). Most of the locomotives are made in the USA and they are about 25–30 years old. These locomotives are quite reliable with low maintenance costs and relatively low fuel costs, if compared to Ukrainian locomotives owned by the company. Ukrainian locomotives are however important, since they are needed, when operating in border-crossing points within Russian territory. They are important simply for the reason that Russia does not allow locomotives with USA origin to enter their region i.e. Ukrainian locomotives are needed for operations with Russia. Table 1 summarizes the main figures of the company.

There are in total three border-crossing points for rail transportation in Estonia (see Fig. 3). Locations are named as Narva, Koidula and Valga. Narva and Koidula are located at the Russian border (Narva in the North-East and Koidula in the South-East of Estonia), whereas Valga (in the South of Estonia) is located at the Estonian border next to twin town Valka, and it offers access to Russia through the Russian Pskov region. Koidula is the newest border-crossing point. The whole Estonian rail infrastructure is in good shape, since all the main rail lines have been renovated recently. Border-crossing points, railway network and main roads of Estonia are illustrated in Fig. 3.

Transit traffic volume has been decreasing during the last decade. However, container transit traffic has been able to increase its share in the case company. This is the only sector that has been able to increase its market volume during the last decade. Future outlook is the same i.e. case company assumes that container transit will increase its volume, but the company will have problems in other rail freight sectors.

Russian legislation has had its own effects in decreased transport volumes. Transit traffic from/to Russia through Estonia had a major impact and the volume decreased significantly in the year 2007. Highest cargo throughput of the company was approximately 42 million tons of freight transported by rail in 2006, but the volume decreased to about 25–26 million tons in years 2008 and 2009. Total transported rail freight was circa 20 million tons in 2013. Case company estimates that rail freight volume will maintain its current level of 20–25 million tons p.a. within the forthcoming years. Political dispute with Russia regarding the Bronze Soldier statue location change in the capital of Tallinn was estimated to be one of the main reasons for decreased transit traffic (also global credit crunch in 2008–2009 played its role). There were still more limitations regarding cross-border transportation for Estonia than for its neighboring countries in 2013. Another important factor regarding transit traffic in Estonia concerns Russian transport policy regarding its own seaports. Transit traffic’s future is partly threatened, since Russia has been and is having a significant focus in increasing the throughput of its own seaports situated in North-West Russia (these are Port of St. Petersburg, Port of Vyborg, Port of Ust Luga, Port of Vyborg, Port of Primorsk and Port of Bronka). Furthermore, the aim of Russia is to maximize throughput volumes of its own seaports and this is challenging for traditional transit countries such as the Baltic States and Finland. A good example is Port of Ust Luga (Russia, port next to Estonia). Its throughput volume was less than 10 million tons in 2009, but the throughput was increased to more than 50 million tons in 2013. And due to decreasing transit volumes after 2007, this is extremely troublesome for Estonia.

Estonia has the same rail gauge width (1520 mm) with Russia. In addition, Finnish 1524 mm width can be used with the same wagons and locomotives. However, Central European countries have a narrower gauge width (1435 mm), which basically means that the same wagons and locomotives cannot be used in Estonia and e.g. in Germany or Poland. Freight of wagons therefore needs cargo transshipment at the station. A small town called Seitsikai in Lithuania is situated in a location, in which Russian and European rail gauge widths are both presented and it acts as main transshipment point. This location could be used by the case company to make the change of locomotives and wagons. However, it increases lead time and the costs of the whole operation, which in turn decreases the attractiveness of rail transport against competing transport modes (these are e.g. road transport through the main road called “via Baltica” and sea transport on the Baltic Sea).

Decisions concerning infrastructure are not made by the case company. This creates problems, since a major amount of infrastructure costs are paid by the company. Most of the infrastructure costs are directed towards passenger transportation infrastructure, although

| Table 1 Main figures of the main case company in 2013. |
|------------------------|------------------------|
| Rail wagons            | 1300                   |
| Locomotives (diesel)   | 70                     |
| Transp cargo volume    | 11.6 million tons       |
| Total cargo volume     | 16 million tons         |
| Highest cargo volume in 2006 | 42 million tons      |

only a minority of investment money originates from passenger trans-
portation. If e.g. electrification would be decided to be increased along
the Estonian rail network, most of the investment funds would be gath-
ered from the freight sector and this would decrease the attractiveness
of electrification in the case company.

3.2. Container rail transportation

Main transported freight types are currently general cargo and spare
parts. However, containers can include almost anything. Container sec-
tor is doing very well in Estonia (trend has been similar in all Baltic
States). According to our case study findings, Russian consumer market
and containerization has affected container transportation amounts of
the Baltic States.

The company has co-operation with different countries including
e.g. Russia. These international co-operations are mainly container
train connections, which have mostly been working very well. Russian
partners especially have been very productive, since there is a fixed
schedule container train between the capitals of Estonia and Russia
(Tallinn and Moscow). This has increased the company’s container
transport volume significantly (the train departs three times per
week). Furthermore, the container train between Moscow and Tallinn
has been easy to operate, since Russian partners in Moscow are mainly
responsible for marketing and gaining customers for the corridor. They
have also been very efficient on these matters. Estonian company is only
operating the train in Estonia i.e. business has been easy to operate
from the case company’s side. However, due to long and very deep
co-operation with rail companies in different countries, the case
company is very well aware of their operations. Case company’s
partner in Moscow is currently building a new intermodal terminal
near of Moscow i.e. investments are made at the Russian end rail
transportation chain. Another Russian container train connection was
started in 2013 and it is to that of Kaluga (three trains a week, important
industrial district for truck, car and electronics production, where nu-
merous foreign companies are present; part of programs and foreign
collaboration to develop Russian industrial capability, see Pakhomov,
von Cramon-Taubadel, & Marat, 2013). This connection, among all the
other container train connections, has increased container transport
by rail in Estonia. Other container trains connect Estonia with Ukraine,
Uzbekistan and Kazakhstan. Some container train connections are sea-
sonal, e.g. container train between Tallinn and Yekaterinburg, Russia is
operated on a seasonal basis. Sea freight price level clarifies whether
the train or sea vessel is used for transportation purposes of freight
(the cheaper is usually preferred).

Case study findings show that price level of Tallinn–Moscow leg is
somewhat the same for both road and rail transport (approximately
1700 € from Tallinn to Moscow and back; distance from Tallinn to
Moscow is roughly 1000 km with both road and rail). This is not surpris-
ning as road transports in Russia is having low cost (Notteboom, 2011
gave estimate of 40% lower rates as compared to Central Europe), at
railways raw materials (oil, coal, construction materials and iron) are
dominating within freight mix (Karazynsheva, Henttu, & Hilmola, 2013)
and average freight lead at rails is between 1500 and 1600 km (Russian
Federal State Statistics, 2014b). In addition, a study of AT Kearney
(2010) proposes that road transport in Russia is less expensive on legs,
which are below 1000 km in distance. Rail becomes less expensive
against road with longer routes. Cost of freight transportation by the
Russian rail network is based on freight tariffs, which are determined
by the Federal Tariff Service (these tariffs are updated regularly and they are at least covering net costs). If the volume of transported freight is high, then road transport cannot be utilized, since there are not enough trucks available on Russian soil. However, smaller quantities are more convenient and faster to transport by truck, since only full container trains (57 units) are transported between Tallinn and Moscow (consolidation and creation of a full train takes time). Delivery time for a single shipment could take up to ten days, if consolidation is taken into account. It will take approximately 2.5 days for the train to reach Moscow from Tallinn. Longer time horizon is especially troublesome for container transport due to container renting prices.

3.3. Main hindering factors on border-crossing points

Since the Baltic States and Russia have a different gauge than Poland, change of wagons and locomotives has to be made on the border of Lithuania and Poland. This decreases the attractiveness of rail transport between Eastern and Central Europe. Change of rolling stock on the Lithuanian and Polish border will increase lead time of transportation, increase costs (transshipping to another train creates more costs) and will make the organizing of rail transport more complicated.

Case company had a project, in which the case company and other participating organizations tried to establish a connection between Estonia and Central Europe. Most of the main matters were agreed (e.g. tariffs) and many meetings regarding the subject were held. There were partners on the whole rail line. However, border-crossing issues were so troublesome that the project never went to a stage that would have an actual train moving along the corridor. There were no scheduled train connections between Estonia and Central Europe during the time of writing this article (year 2014).

3.4. Other issues regarding rail transportation in Estonia

Cargo volume in Estonia is too low to operate rail transportation profitably, which means that Estonia needs its neighbor countries to increase cargo levels on the domestic rail network. Finland is an important partner for Estonia. The problem with Finnish customers is that they demand regular trains and they also want to transport semi-trailers or trailers. However, there are not enough wagons for trailer transportation in Estonia. The company could invest in appropriate wagons if demand would be high enough. Transshipment issue on the Polish and Lithuanian border from the Russian to European gauge and vice versa hinders the situation further. Decent equipment for transshipping containers from one wagon to another exists in Soljtoki. Since the Finnish market is mainly a trailer market, things become more complicated. Transshipping containers is easier with existing equipment than transshipping trailers.

In addition, there have been some location-specific problems regarding international container train connections. Administration of Kiev (Ukraine) decided what road transport company will be used on the final leg to transport freight to the customer located in Ukraine. Price level of these companies can be more than the actual market price, which decreases the attractiveness and profitability of the container train. In Uzbekistan, customers are using containers provided by the case company, but consignee in Uzbekistan demands significantly higher fees for short-term storage of containers (price could be as high as five dollars for 1 h, whereas a normal fee would be around two dollars for one day). This again affects the container train price level and thus attractiveness. However, the case company has not had similar problems with Russian container trains.

4. Discussion

All Baltic States are in a similar railway market position – they all belong to the European Union, but have a geographical position to serve well the growing Russian consumer markets with the same railway gauge width. Furthermore, used rolling stock favors this direction as wagons and railway engines fulfill Russian standards. Together with a competitive distance to reach Moscow and other large consuming and industrial centers has resulted in a situation, where railway transport is having a very strong tendency to grow. This has benefited the transportation logistics sector (in all Baltic States). It is also notable that mostly used intermodal unit in the Russian logistics market is container, not a semi-trailer. This helps railways considerably, since it is easy to carry freight with a standard transportation fleet and loading and unloading equipment is widely available. What is a surprising finding in this research work, is the price level of railway transports vs. road. As road enjoys very lucrative diesel prices (nearly tax free) in Russia, its cost competitiveness is high (also noted by Notteboom, 2011). Railways in cross-border transports are typically forced to use diesel oil as interoperability is ensured only with diesel traction, and this means that energy input does not bring that much benefit for railways. Actually, payloads in rail transport are better in Russia than what is the situation with road, but for general cargo and containers this does not matter that much. Containers are light weighted and weight is seldom above legislative requirements.

Railway transport through cross-borders starting from Estonia is in a troublesome position for the Central European direction. For example, transporting containers to the Czech Republic or Germany would require collaboration between five countries and five railway companies as well as railway network agencies. Matching capacity, schedules and lead time requirements has so far been poorly organized. However, attempts have been made. In addition, interoperability with regard of technical railway gauge width between Lithuania and Poland is an issue. It could be assumed that this situation remains until the Rail Baltic corridor investment of the Baltic States is agreed and constructed (AECON, 2011; Baltic Times, 2014). The plan is to have European gauge width up to Tallinn. Furthermore, administration and management of this corridor is planned to be given for a single company, where possibly neighbor countries (like Finland or Poland) could be acting as minor owners. This arrangement could overcome all current constraints, which prevent container transports on rail to grow in the Central European direction. However, as highlighted in this research work, semi-trailers are commonly used units for general cargo transports in EU, and these are troublesome for railways. Special loading places and wagons are needed. Either internal European transport logistics should transform itself more towards using containers, or otherwise these specific investments should be completed. Whatever the case is, it creates a considerable delay for railway volumes to grow towards Central Europe.

As was identified in this research work, competition is not necessarily in eastern logistics markets between road and rail, but against container transports at sea (also reported in (Yes), 2007; Ivanova & Hilmola, 2009; Notteboom, 2012). Eastern destinations are difficult to reach, regardless of the entry direction (e.g. through European Union main seaports and routes, through the Black Sea or through the Asian side of Russia). In recent years, container transport capacity at sea has been on oversupply. In addition, long routes and complex supply chains have gained cost competitiveness (United Nations, 2013). This results in a situation, where transportation chains having Baltic States origin are having a hard time to compete against others. It is so that even transports from China to Moscow are sometimes having a lower cost using extremely long sea routes instead of a shorter railway connection through the Trans-Siberian railway section. This research verifies earlier research findings in this regard. It could also be assumed that as the transportation fleet oversupply within seas declines in the forthcoming years, it leads a much better situation for hinterland based transportation chains (freight rates already slightly grew in the year 2012; see United Nations, 2013). In the year 2014, the largest sea container operator Moller-Maersk revised its profitability outlook and started a share buyback program for the first time in its 110 year company history (Mikkelsen & Jensen, 2014). This is a strong indication that the container shipping market is slowly recovering.
Regarding the future development of international railway routes, this research reported that major trans- and inter-national routes and destinations are in demand. Uzbekistan and Kazakhstan are in the implementation and operation stage already. Seasonal container routes are also implemented according to the demand. This is a rather surprising development, and illustrates that logistics development is really a bottleneck in the wider Eurasian area (e.g. noted in Logistics Performance Index of World Bank, or Logistics Costs in various studies; Arvis, Saaslavsky, Ojala, Shepherd, & Anasuya, 2014; Rantasila, 2013). For example, it would be hard to imagine seasonal connections gaining ground in the European Union area.

5. Conclusions

5.1. Implication for managerial practice

Main operational constraints regarding the Estonian rail transit sector are different gauges along the rail route, border-crossings operations, delivery time issues, low price level of road transport, unpredictable Russian market and legislation and infrastructure investments. Even though the gauge is changed already on the Lithuanian and Polish border, it will affect the Estonian rail transport sector, since it has a major effect on possible transit traffic between Estonia to Russia or Central Europe. Similar situation concerns every country, which have transportation flows with countries, which have a different rail gauge. There are other similar hindering factors e.g. signaling systems, which are different in many locations. Furthermore, if freight would be transported by rail between Estonia and Central Europe, there would be many different countries along the route. This could probably lead to a situation where more than one rail company would be used, which in turn would increase the challenges of organizing the whole transportation chain (systems hence have to be complicated with numerous actors involved in the process). In addition, border-crossing operations between countries could take time, which would lead to increased lead time along the whole route. To solve all of these problems, very efficient governance should be implemented. If the governance is not efficient, the whole rail freight market could diminish, since there are alternative options for the customers (sea and road transport).

In addition, it is risky to focus on only transit traffic to and from Russia through Estonia, since the Russian market and legislation could change very quickly. It means that a very lucrative business could diminish significantly in a very short period of time, if legislation or taxation changes to unfavorable direction regarding the business. Changes in legislation are usually very difficult to predict. This factor could affect all countries, which have transportation flows to or from Russia. Neighboring countries probably have the most issues with legislation changes, but they can also affect farther countries, which are operating on transit, export or import traffic with Russia. Infrastructure investment decisions regarding the Estonian railway network are made by the owner of the rail network i.e. case company of this article does not make these decisions although the funding is based largely on the case company’s revenue. Similar problems could arise in other countries, where the financier of investments and decision-maker of investment decisions are different organizations or companies. One solution could be to create a company or organization to make these investments. This company could include personnel from different rail operators, public sector and transport organizations, which are important for the decision-making. There is a large market potential for rail transport companies in Estonia due to possibly increasing volume of transit traffic. However, different aspects could hinder the operation of railway traffic through Estonia. These are e.g. different gauges and numerous countries, which should be passed if the destination of the cargo is in Central Europe. In addition, lead time, frequency and price level expectations of customers should be met by the operator of the service.

5.2. Contribution to scholarly knowledge

Intermodal transport is typically discussed in the context of developed countries and from environmental aspects. However, in emerging countries, like that of Russia (Panava, 2011; Panaya & Koryzjakovsky, 2013) and India (Haranambides & Gujar, 2011) railways do play an important role in the transportation chains and intermodal solutions are demanded due to precision, capacity and predictability. In addition, costs are an important issue, but they are seldom significantly below road transport costs. Consumer demand, especially in the retail sector within emerging markets, has developed so favorably that sustainable transportation logistics solutions are in great demand. According to results of this research work, competition is interestingly not within transportation modes between road and rail, but against long distance and time consuming deep sea container transportation chains. We may assume that in the forthcoming years an oversupply of sea container transportation capacity shall level off, and it means that railway based solutions shall gain more and more market share, especially in the research context of this study. What was really encouraging concerning this intermodal route, was the robust growth outlook, not only based on statistics, but also from the opinions raised inside of the main railway actor of this route. Economic environment has been difficult after the 2008–2009 global credit crunch and economic hardship, and it seems that rail based solutions have clearly taken the market share. This could be seen from the second hand analysis done from the competing transit market actor of Estonia and Finland. In the latter country, rail based intermodal solutions have not gained ground for different reasons, and it could be clearly detected that transit container volumes have declined to a much lower level to what they were in the pre-crisis environment.

Future research avenues could include a more extensive case study among not only Estonian, but also among other Baltic States (Latvia and Lithuania), since transit traffic plays a very important role in the rail transport sector of all Baltic States. Furthermore, all of these countries have a significant role in the transportation chains reaching the east. Linking this together to a new TEN-T transportation network of the European Union (TEN-T, 2014) would also be interesting as TEN-T sees Poland and the Baltic States as one of its primary investment areas to develop railway infrastructure now and in the forthcoming decade.

References

Ben-Shabat, Hana, Mortarity, Mike, & Nilforoushan, Parvin (2011). The 2011 Global E-Commerce Index — Online Retailing in Focus and going from strength to strength; New York etc, USA: A.T. Kearney Publications.


Publication 7

Transportation Costs Do Matter: Simulation Study from Hospital Investment Decision

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