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Original Article

New environmental demands and the future of the Helsinki – Tallinn freight route

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Abstract The environmental friendliness of short sea shipping has been justified in Europe by the ensuing lower congestion at hinterlands and unneeded large-scale infrastructure investments on roads and railways. However, the attractiveness of short sea shipping is about to change. This is because of increasing environmental regulations (International Maritime Organization (IMO) sulfur regulation in the Baltic Sea and planned CO_2 emissions trading) and increased world market oil prices. In this research, we analyze this potential change using data envelopment analysis on the existing transportation chain alternatives in the Helsinki (Finland) – Tallinn (Estonia) short sea route (chains using either roro, ropax or container ships). The analysis also includes the planned railway tunnel between the two cities. On the basis of our findings, the current truck and semi-trailer-based transportation is challenged by containers, irrespective of how they are carried (ship type). In the long term, for reasons of emissions and oil independency, the possibility of tunnel construction would make it vital to have container ship operations available along this route. The forthcoming change is not radical, but rather evolutionary and long term oriented.

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Introduction

The vast majority of world trade travels by sea, almost 90 per cent by volume and 70 per cent by value (IHS Global Insight, 2009; IMO, 2012). This presents a challenge for landlocked nations who must use hinterland modes of transportation to reach the maritime transportation network at major seaports. At the other extreme, there are island nations who must rely almost exclusively on the sea for their global trade needs. Although Finland is not an island, the shortest route for trade coming from or destined to Western and Central Europe is over the waters of the Baltic Sea. In 2012, maritime transport (measured in tons) carried almost 90 per cent of Finnish exports and 80 per cent of the imports arriving in the country (Finnish Customs, 2013). Railway transport could gain a higher share of the market in terms of trade in the Eastern direction (Russia, Ukraine and Kazakhstan), since the Finnish railway network is compatible with the Russian standard. Unfortunately, cumbersome tariff practices have resulted in declining volumes (Hilmola and Lorentz, 2012).

Finland is currently almost entirely dependent on seaports and routes for its foreign trade. According to conventional wisdom, this dependence should result in high efficiency, quality, flexibility and cost standards. The future, however, holds significant threats to the historic trading system of Finland, namely, the new sulfur oxide emission regulations for the Baltic Sea (see analysis from Greece, Tzannatos, 2010) and CO_2 payment schemes that increase the price of oil. The sea transport industry will need to transform itself as the current system of sea transport will become more expensive than hinterland modes of transport (rail or road). The end result may be for companies to prefer an intermodal transport system that uses extremely short sea legs to move trucks and semi-trailers (STs) from one landmass to another.

From the perspective of export trade, often considered one of the engines for economic growth, it is important that a country maintain inbound flows as well in order to achieve a high enough backhaul capacity utilization in ships and containers (Notteboom and Rodrigue, 2008). Thus, if a country is able to attract import transit with containers to serve neighboring countries and regions, then it may increase the cost efficiency of its own export trade. In the case of Finland, this would entail transit traffic from Russia and other Eastern European economies (Hilmola *et al*, 2007). Another external factor to be considered in transportation costs is the increasingly tight environmental regulations. Most Finnish shipping routes serve as feeder traffic to larger hubs in Germany, Sweden and The Netherlands. Increasing oil prices (connected to environmental regulations such as sulfur oxide restrictions) will raise fuel prices and thus the costs of goods to non-hub markets like Finland (United Nations, 2012). Long distance, ocean traffic is relatively easy to optimize regarding costs with lower steaming speeds; however, this is not possible in the case of short sea shipping where ships are barely able to reach the lowest scale levels (see emission curves in

Walsh and Bows, 2012). Previous research has found that short sea shipping (typically roro) faces cost disadvantages against road transport (Liao *et al*, 2011; Puckett *et al*, 2011; Morales-Fusco *et al*, 2012). The typical remedy has been public sector subsidies in one form or another (Morales-Fusco *et al*, 2012). Earlier studies also show that in shorter distance raw material transportation, railways have the upper hand on the shipping alternative (railway network is also more proximate than, for example., Great Lake transport in North America), if numerous emissions and their costs are taken into account (McIntosh, 2013).

Most of the seagoing trade is carried in containers and this sector has experienced the fastest growth. In 1990, 28.7 million twenty-foot equivalent unit (TEU) containers moved across the seas. By 2008, this figure had risen to 152 million TEUs (Rodrigue, 2010). For Finnish industry and its retail sector, there is a significant preference for the use of trucks and STs over containers. Traffic on the Helsinki – Tallinn route, the main interest of our research, illustrates this preference. According to Hilmola (2011a, b), there were only two connections between Tallinn's Muuga terminal to Helsinki's Vuosaari in 2009–2010 (ship frequency of one or two per week). The situation was somewhat better before the global credit crisis; between early 2000 and 2008, numerous container connections served this route. The reasons behind the change are unclear. One explanation could be the massive investments in ropax ships and the resultant competition among vessel operators on this route, however, the situation may prove difficult to change. At present volumes, container-based transport commands an extremely low market share in the Helsinki – Tallinn route. Sundberg *et al* (2011) estimated that the share may be as low as 0.4 per cent. On the basis of their longitudinal data, container transport has been at very low levels for a long time. International comparisons show that the efficiency in Scandinavian (including Finland) and Eastern European container ports is relatively low (Wang and Cullinane, 2006).

The larger scale use of containerized transport is possible as increasing amounts of traffic on the Helsinki – Tallinn route are based on STs having their origin or destination in Central and Eastern Europe (for example, Poland or Czech Republic; Tapaninen and Räty, 2012). The official long-term development plans for both the cities, Helsinki and Tallinn, cite improvements in the volume of container traffic as a goal of future development; however, they also call for pre-feasibility studies (both technical and economic) for a railway tunnel connecting the two locations (Keinänen and Sakkeus, 2012). On the basis of the above discussion, this research aims to evaluate the possible future of the Helsinki – Tallinn transportation route, taking into consideration emissions and related environmental regulations.

This research is structured as follows. In the next section, we analyze the transportation environment, primarily through secondary statistics on Estonia and Finland (also concerning the seaports of Tallinn and Helsinki). In the section after that, the research methodology is described, including the introduction of the data envelopment analysis (DEA) efficiency evaluation model. DEA has been successfully implemented in past related research, for example, on port efficiency (for example, Wang and Cullinane, 2006; Wu *et al*, 2010). In this section, the performance of alternative transportation chain options in a particular input – output area (using measures in the model) is also explored. As the railway tunnel option does not yet exist, the assumptions behind its development are explained further. The empirical DEA model results are described in the following section, first without the railway tunnel option and then with the tunnel option included in the analysis. The penultimate section offers a discussion of the results, mostly through the future perspective of developing container usage, container ships and a railway tunnel on this short route. In the final section, conclusions are offered with consideration of avenues for further research.

Research Environment: Unitized General Cargo in Finland and Estonia

Owing to their peripheral location and thin transportation flows, all of the smaller countries in Northern Europe (for example, Finland, Sweden and Estonia) have built their transportation logistics sectors similarly. In the general cargo segment, trucks and STs are the basic and dominant transportation mode, whereas containers are used mostly for intercontinental transportation needs. Statistics provide further evidence of the use of trucks and STs (or trailers): (i) in Sweden during the year 2011, the total volume handled in seaports was 2.62 million units (Ports of Sweden, 2012), (ii) in Finland during the same year, seaports handled 0.9 million units (Finnports, 2014) and (iii) in Estonia, the handling volume was 0.42 million units (Statistics Estonia, 2014). In all of these countries, the volume of containers handled was lower (see Figure 1 concerning Finland and Estonia), if TEU are converted to forty feet equivalent units (FEU) (corresponds STs then with dimensions). The most common reason given for favoring trucks and STs in regional, and within trade area transport is better customer service, convenience and precision, but not necessarily low cost (Woxenius and Bergqvist, 2011).

In this research, the interest is in short sea shipping between Finland and Estonia, namely, the seaports of Helsinki and Tallinn. Despite the Tallinn seaports' dependence on raw material transports (transit export of Russia and other Eastern countries), the general cargo segment plays an important role for Tallinn as well. In Helsinki, the bulk cargo segment is so small that it could be argued that it only serves general cargo. Helsinki is also the largest truck-based general cargo seaport in Finland (Hamina – Kotka is largest by container

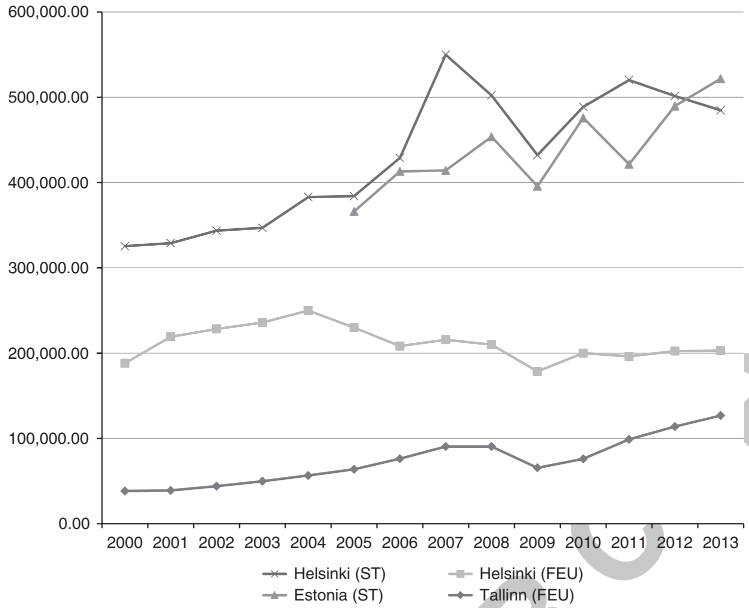

Figure 1: Container handling (FEUs) in Helsinki (Finland) and Tallinn (Estonia) seaports during the period of 2000–2013 as well as truck and ST handling in Helsinki and Estonia.
Source: Finnports (2014), Statistics Estonia (2014), Tallinn Sea Port (2014).

volumes). Figure 1 illustrates the situation in Helsinki and Tallinn further (trucks and STs are shown from Estonia in general because of statistics availability problems at the city level). In both of these seaports, truck and ST traffic continues on a growth path (long and medium term). Container transport is prospering in Tallinn due functioning railway connections to east, like Moscow. In contrast, Helsinki has experienced problems with container volumes for years. Volume began to decline in 2004 after modest increases in 2000 (Merk *et al*, 2012). Even if container volumes are on the decline, it is doubtful whether this is going to be the future of STs. The tight coupling of passenger flows (cars and passengers) together with STs in the ropax vessel concept is the most significant line of argumentation for this growth. It is difficult to offer the required frequency and short lead time that are significant factors in shippers' decision making (Brooks and Trifts, 2008) without this transportation segment. During the year 2011, 7.3 million passengers were transported between Helsinki and Tallinn. This includes 1 million passenger cars and 0.25 million trucks and STs. The forthcoming tightening of environmental regulations favors shorter sea journeys because of the minimization of the total costs (for example, the sulfur regulation becomes effective from the year 2015 onward, with later implementation of

CO_2 emission trading for sea freight transports for the whole European Union (EU) area) (Kalli *et al*, 2009; Tzannatos, 2010; DNV, 2012).

Although trucks and STs still dominate in both Finnish and Estonian seaports, the growth rates for container traffic are similar or higher. During the global credit crisis (2009), container handling volumes in both countries experienced a very serious decline (Figures 2 and 3). There was also a minor correction in 2005. Volume growth for STs has roughly mirrored container traffic except for 2011 (because European financial crisis internal European volumes were low, but Russian consumption continued and container volumes continued old trajectory). Containers follow trends in international trade and the global macro-economic situation more closely than truck and STs, because of the use of these containers in intercontinental transportation logistics. Container logistics experience longer transportation chain delays and exhibit larger inventory pipelines in the process. Both of these factors contribute to swings and demand slumps in this sector.

One transportation option discussed between the Helsinki and Tallinn has been the building of a railway tunnel under the seabed. The proposal is mostly

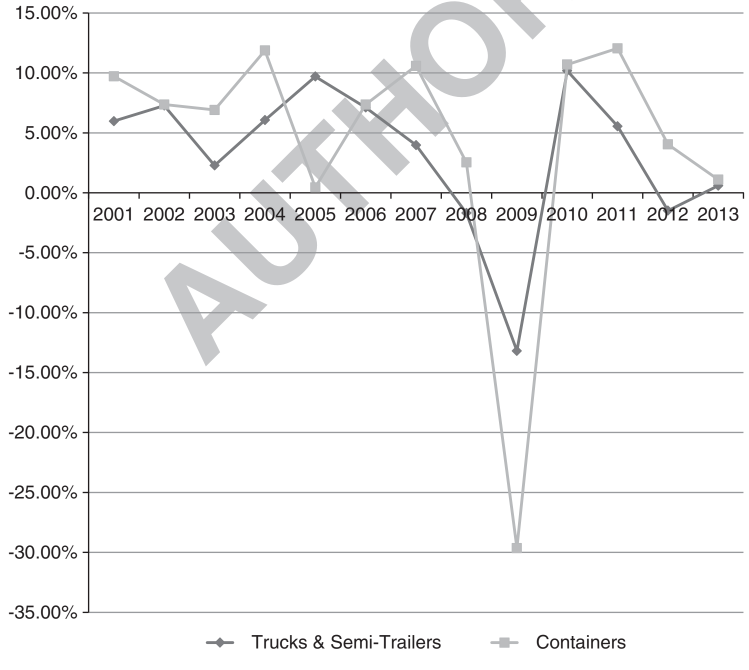

Figure 2: Annual changes of unitized general cargo in Finnish seaports during the period of 2001–2013. *Source*: Finnports (2014).

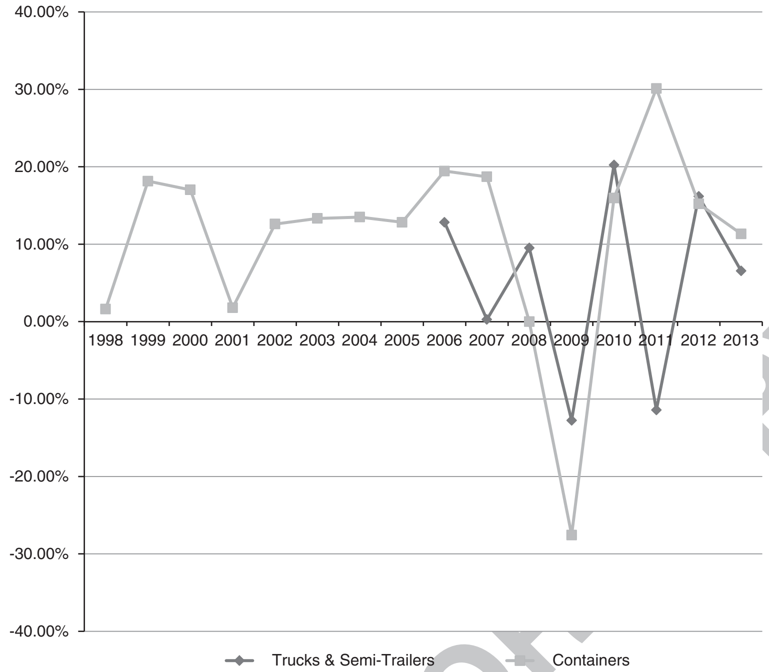

Figure 3: Annual changes of unitized general cargo in Estonian seaports during the period of 1998–2013.
Source: Statistics Estonia (2014).

motivated by the example of the Channel Tunnel between the United Kingdom and France and the ongoing discussions within Europe regarding three major tunnels projects: (Hilmola and Ketels, 2012) (i) Fehmarnbelt serving Germany and Denmark (currently in the feasibility study and lobbying stage), (ii) the Brenner railway tunnel (or axis), currently in early construction phase, which is going to be operational between Italy and Austria (BBT SE, 2012) and (iii) the soon to be opened (2016) Gotthard railway tunnel between Italy and Switzerland (AlpTransit Gotthard, 2014). Even if the Channel Tunnel was not originally a financial success, its major financial loss during the first decade of operations (until the haircut of debt in 2007) was caused by now identified factors (Crumley, 2010). These factors include poorly designed and engineered tunnel plans and requirements, cost overruns at the construction phase (also delayed construction project) and loss of passenger growth (caused mostly by a loss of tax free sales) within the channel route (Anguera, 2006; Chang and Ive, 2007; Crumley, 2010). The Channel Tunnel example illustrates clearly the effect of price competition between channel sea ferries and the tunnel: The greatest beneficiaries from evolved situation and tunnel implementation have actually been shippers and passenger customers, who have enjoyed significant fare reductions over the years (whatever mode they ended up using). Interestingly, the company managing the Channel Tunnel, called Eurotunnel, is now the new owner of ferry ships operating within the channel as well (purchased in an auction from the bankrupted SeaFrance, see Wright, 2012).

The Channel Tunnel has been a success in terms of freight transport, in particular unitized freight. Market share is well above estimates given before the construction decisions made in the 1970s and 1980s; in absolute terms, freight traffic has been in line with expectations (Anguera, 2006). Currently, after debt restructuring and operational re-engineering, the Eurotunnel is now profitable and even pays small dividends to its shareholders. On the basis of the most recent news, the Channel Tunnel is going to be operated by Deutsche Bahn after 2016 for the Berlin – London route (Jasper and Webb, 2013). Owing to the experience gained from tunnel construction in Europe, we suggest that in the long-term prospects for the Helsinki – Tallinn railway tunnel under the Gulf of Finland are improved.

Research Methodology

Data for this study was gathered as part of an externally funded research project commissioned by the cities of Helsinki and Tallinn. These cities exercise considerable influence over the seaports in the respective areas. In the case of Helsinki, the seaport is city owned. The seaport in Tallinn is currently state owned. The project concentrated on gathering and modeling the performance of various transportation chain alternatives operating between these two cities. The physical distance between this seaport pair is short. Given minor variations in distance based on the terminal used, the distance of 84 km provides a reasonably accurate estimate from a short sea shipping operations point of view. From a transportation network perspective, Estonia represents an important link for the capital region of Finland. The seaport of Helsinki is the leading roro/ropax seaport in Finland; truck and ST handling volumes are larger than all of the other seaports' volumes put together (Merk *et al*, 2012). Estonia also offers the shortest sea-crossing distance to the European continent. The closest alternative through the Helsinki seaport is Stockholm, which represents an additional 400 km of sea journey. In the following paragraphs, we first analyze the currently available short sea shipping options and enlarge the evaluation to take into account a railway tunnel option.

In order to evaluate the currently existing short sea shipping alternatives at the Helsinki – Tallinn route, a DEA model was developed, as shown in Figure 4.

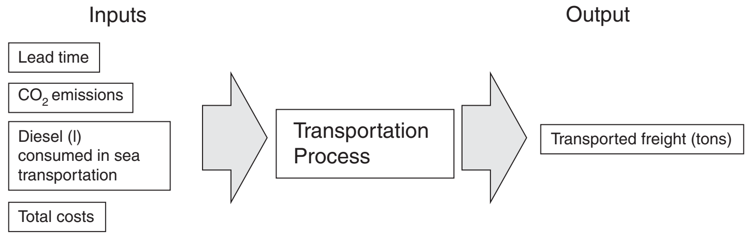

Figure 4: Used DEA models in this study – input-focused model with four inputs and one output.

This efficiency evaluation was not completed as part of the externally funded research project, but is based on the data collected.

Data was collected from primary and secondary sources. Lead time and total cost data was gathered through subject matter expert interviews with sea vessel operators and seaports. Diesel oil consumption at sea is based on technical databases (VTT Lipasto, 2011; Defra, 2012) and takes into consideration short sea shipping operations as well as ship utilization levels. Data on CO_2 emissions was derived from a combination of technical databases and site visit interviews. Hinterland operations and processes differ considerably between shipping alternatives. In some cases (like container ships and trains), hinterland loading and unloading arrangements could contribute from 10 per cent to more than 30 per cent of the entire transportation chain's CO_2 emissions (depends on ship size and utilization of the ship). In roro and ropax operations, placing a ST in a ship with a truck is a very simple and short lead time operation. Further, the contribution of this activity to CO_2 emissions is very marginal, a few per cent at best of the entire transportation chain emissions profile. Our approach to gathering CO_2 emission and fuel/energy consumption data is relatively close to the method by Haralambides and Gujar (2012).

Table 1 shows the estimated costs of the various transportation options considered. The total cost column includes the following: sea freight, bunker surcharge, cargo charge of the seaport, estimated fleet holding costs and possible driver-related costs during the sea journey. It is surprising that the lowest short sea shipping costs for a distance of 84 km are €494.3 per transported unit (€5.88 per km). This is more than three times higher than the basic road transport charge for a truck and ST. The maximum cost estimate is more than €650 (€7.9 per km).

It should be noted that during the time of the study, oil prices were rather high resulting in high bunker charges. Both the bunker surcharge and cargo charge of the seaport are driven by transported tons. FEU containers are priced higher than STs as they have a higher average freight load. We estimated that a transportation fleet derives half of its value from new purchases with an

Table 1: Four inputs (I) and one output (O) used in DEA efficiency evaluation – Utilization of ship and freight train is 50 per cent.

	Total costs (I)	*Diesel (I)*	*CO_2 (I)*	*Lead time (I)*	*Tons (O)*
Roro: STs with cabin	642.8	90	245 026	5	13.9
Roro: STs without cabin	494.3	71.8	196 623.7	6	13.9
Roro: FEU on platform with cabin	661.3	83.8	230 822.2	5	16.7
Roro: FEU on platform without cabin	512.8	65.6	182 440.5	6	16.7
Roro: FEU on mafi roll trailer	512.8	64.2	179 951.2	6	16.7
Ropax: STs with cabin	579.8	107.9	292 548.5	3.5	13.9
Ropax: STs without cabin	538.1	86.9	236 803.8	4.5	13.9
Ropax: FEU on platform with cabin	598.3	100.9	276 457.4	3.5	16.7
Ropax: FEU on platform without cabin	556.6	78.2	216 114.4	4.5	16.7
Ropax: FEU on mafi roll trailer	556.6	76.3	212 261.5	4.5	16.7
Container ship (500 TEU): FEU	560.5	32.9	102 988.4	72	16.7
Container ship (1000 TEU): FEU	560.5	23.5	77 897.2	72	16.7
Railway tunnel: FEU ON FLATCAR	475.8	0	69 745	18	16.7
Railway tunnel: STs with cabin	524.8	0	61 147	18	13.9

economic use time of 15 years. A similarly conservative approach was used for driver salaries (including direct and indirect costs) which were at 50 per cent of the typical Finnish salary level. This is a realistic assumption as drivers are typically from the Baltic States, Poland, Russia, Belarus or Ukraine. In all of these countries truck drivers earn significantly lower rates than in Finland.

Both diesel consumption at sea and CO_2 emissions demonstrate considerable differences between the short sea shipping alternatives (Table 1). These results are similar to earlier studies such as Walsh and Bows (2012). Container ships are devoted only to the transport of cargo stored in boxes, while ropax operations also serve passengers, who need services (for example, catering, hospitality and tax-free retailing) or trucks together with STs (roro and ropax). Thus, container operations consume a much lower amount of diesel oil and produce lower amounts of CO_2 emissions than other alternatives. A downside of container operation is the required lead time for transport. In this case, lead time is equal to 3 days. On the basis of the data from interviews and site visits, 1 day is spent at sea with 1 day at both sides of the Gulf of Finland for hinterland operations. The other extreme in terms of lead time are the ropax operations where a ship will spend only 2 hours at sea. This, of course, has its trade-off with much higher diesel consumption and CO_2 emissions.

Our estimates regarding roro and ropax ship emissions are in line with previous research in the field. Walsh and Bows (2012) have argued (note that similar findings can be found from Tzannatos, 2010) that roro ships emit from 63 to 219 per cent more CO_2 than container ships. Note that emissions in Table 1 include hinterland operations that balance the significant difference of sea transport operations between container ships and roro/ropax. CO_2 emissions and diesel consumption of roro and ropax options are extremely high in this short sea route, but it should be remembered that even in the continental traffic their emissions are nearly equivalent to road transport (Nieuwenhuis *et al*, 2012).

Utilization of the ship cargo space is one major factor, which has an impact on CO_2 emissions and diesel consumption. On the basis of earlier research on Northern European short sea shipping (for example, Styhre, 2010) and expert interviews, we have chosen as a base case 50 per cent ship utilization. This is a bit higher than Styhre (2010) gave as a general estimate. This is increased within the DEA analysis up to 80 per cent. In terms of CO_2 emissions and the diesel oil consumption of sea operations, we have assumed that ships consume the same amount of fuel regardless of the load; fuel consumption data was taken from the VTT Lipasto (2011) database where it is assumed that 80 per cent utilization exists for roro/ropax and 65 per cent for container ships. It is also assumed that environmental load is spread evenly to different amounts of unitized cargo carried by the ship. This estimation practice can be justified because of the use of ballast water in roro and ropax ferries as they need to enter fixed ramps at seaports and this requires the same load on the ship (whether the load is actual cargo or not). Since container ships are assumed to have such low utilization levels in technical databases, we have increased diesel oil consumption linearly with added weight to correspond to an 80 per cent utilization of ship capacity.

In Table 1, the hypothetical alternative of a railway tunnel was modeled based on earlier research projects and empirical knowledge concerning railway freight transports and its loading and unloading operations. In our cost estimates, we started with transportation costs, added loading and unloading costs, and then added organizational overhead and profit margin. In addition, we have included a tunnel usage fee of €125 per ST or FEU container. Taking these items together in Table 1, results in a price estimate for a ST and FEU that appears to be in line with the current Channel Tunnel fares, if scaled up according to the longer distance between Helsinki and Tallinn (Eurotunnel, 2012).

We have assumed that actual transportation is completed in the tunnel with electrical traction, which does not directly require any diesel fuel consumption. CO_2 emissions are taken from the technical database and also include loading and unloading operations. Lead time is an estimate based on our earlier experiences with railway operations.

As could be noted from Table 1, the freight amount inside the FEU containers and STs differs in this research. This is due to the fact that on average, during the years 2003–2011, FEU containers handled in Finnish seaports had a weight of 16.69 tons, whereas STs had 2.84 tons less cargo inside. One reason for this difference is because nearly all Finnish short haul logistics relies on the truck and ST combination, while containers are used in continental trade. In general, trucking is a small- and medium-sized enterprise (SME)-driven business and overinvestment is still the norm. Entrepreneurs tend to take all sized deliveries to be transported as fixed costs are so high (due to expensive transportation fleet investment).

Typically in DEA models, correlations between input and output factors are undesirable. It is assumed that the used inputs will lead to desired output and that these are input – output relationship dependent. This is not entirely the case in this study. Diesel consumption at sea (liters) is highly correlated with CO_2 emissions. In this research, the CO_2 emissions calculation also takes into account emissions from hinterland operations on both sides of the Gulf of Finland. In our model, two other inputs, lead time and total costs, are not correlated to each other nor to the other two inputs in the model. Surprisingly, the very short lead time of ropax vessels does not result in significantly higher prices as compared with the other options considered (no trade-off). This may be due to the high handling volumes involved.

From a DEA method perspective, we have chosen to use constant returns on scale (CCR) (see Charnes *et al*, 1978). As our output has only two possible values and the differences between these two numbers are relatively small, we could assume that scale economies were constant. The other alternative would have been to use a variable return on scale (having abbreviation of BBC), which uses the non-linear scale economies function to measure efficiency. In this case, STs with their lower freight weight in terms of output would have received slightly better treatment than in the CCR condition. Of course, it is a matter of open debate, which of these two approaches is more accurate. The CCR is the original evaluation method and since the differences in this research were quite marginal (between the different options), it was decided that this method would be used throughout.

As a caveat, the evaluated amount of transportation chain options is 14 which is three times below the total amount of inputs and output used in this research work. This is the limit recommended by Raab and Lichty (2002). As our alternative options are only one less than the recommended limit, we do not consider this as a major problem. Of course, it should be noted that the following analyses are subject to variance, and results may not be entirely robust.

The following DEA efficiency evaluation was completed with an ordinary 0–100 per cent scale as well as the super-efficiency scale (where highest performers could have received substantially higher than 100 per cent performance). Using this approach, we are able to better detect the differences of transportation chain options. Typically in transportation and service sector models, efficiency differences are rather marginal among the good and best performers and it is hard to judge, which option is the best performing one (Goto and Tsutsui, 1998; Keh and Chu, 2003; Jain *et al*, 2008; Savolainen and Hilmola, 2009). The super-efficiency scale provides an opportunity for greater detection of difference as variance grows between options and the highest performing is clearly detected. This scale is a two-staged process where the ordinary frontier is at first estimated and then the highest performing options are removed from the data and the frontier is again calculated (Xue and Harker, 2002).

Empirical Data Analysis of Proposed DEA Model at Helsinki–Tallinn Route

Even if container ship lead times are extremely long in comparison to the other shipping options in the short sea route from Helsinki to Tallinn, this low performance does not appear significant in DEA model results (Figure 5), when the railway tunnel option is not taken into consideration. Other positive factors for container shipping include low environmental harm (CO_2), low diesel oil consumption (per FEU) and more competitive pricing. These results suggest that even if no change is implemented in total transportation lead time (in

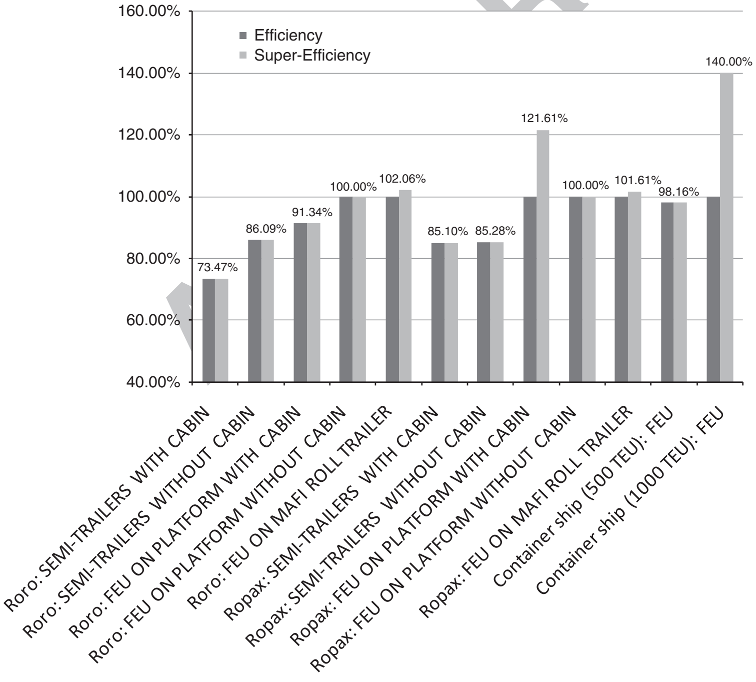

Figure 5: DEA model efficiency evaluation results (one stage CRS, super-efficiency values shown), where diesel consumption and CO_2 emissions are based on a sea vessel utilization level of 50 per cent.

hinterlands or at sea), then this connection should use the largest ship possible (in order to reach an efficiency frontier). However, smaller ships of 500 TEU are only 1.84 per cent per cent points from a frontier, making it a viable option as well.

Other best performing options include roro and ropax vessels where a container is used in freight transport. In roro, it is most efficient to have an FEU container either on a ST platform or in a mafi roll trailer (this saves loading time and time spent in the seaport areas). Ropax FEU could be loaded together with a truck cabin. This option allows for faster handling at the seaport and provides overall competitive pricing of operations.

All options become more equal in performance (Figure 6), if the utilization rate of a ship is increased up to 80 per cent (from freight side) and the cargo weight of STs is increased to the same level as FEU containers (20.5 per cent or 2.84 tons more cargo). Increasing cargo in STs will have a direct impact on freight costs as the bunker fee and seaport handling fees increase (both are ton based). We have assumed that fuel consumption and CO_2 emissions are not affected by this small weight increase. On the basis of our analysis of simply increasing

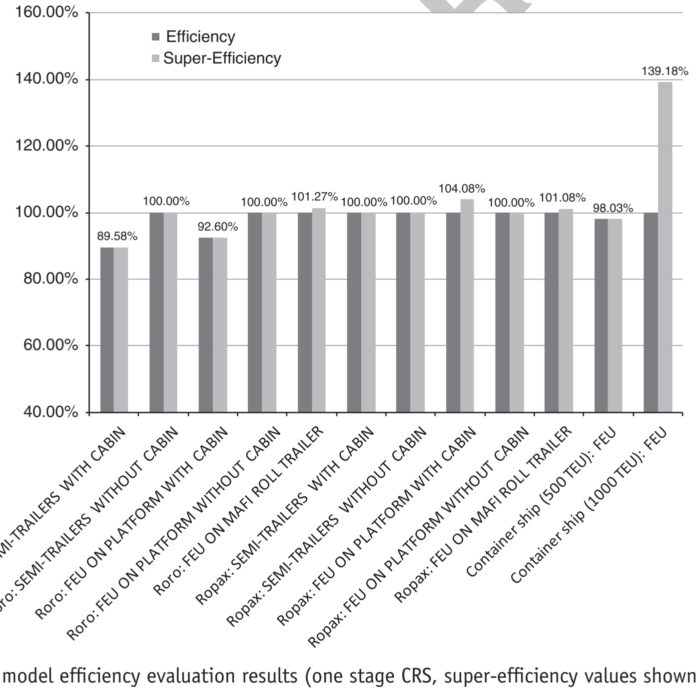

Figure 6: DEA model efficiency evaluation results (one stage CRS, super-efficiency values shown), where diesel consumption and CO_2 emissions are based on a sea vessel utilization level of 80 per cent as well as with an assumption that STs carry an equal amount of freight with FEU containers.

the utilization rates of ships (80 per cent) or adding cargo weight on STs, we have arrived to the conclusion that the latter change is much more powerful and significant for DEA efficiency analysis results. However, it should be noted that the 'with cabin' options in roro shipping was not within the frontier. In other words, this option was not deemed efficient.

When the railway tunnel option is brought into the analysis (Figure 7), the dominance of a larger container ship option diminishes. This is because the railway tunnel transportation option with FEU containers on flatcars shares a similar performance profile to a container ship. In fact, it is slightly better in all areas. Therefore, a container ship still compares favorably with the roro and ropax option, but when the railway tunnel is implemented, then freight volumes will most probably move to railways from container ships. As the ST option has slightly higher total costs as well as lower output tons, its performance was surprisingly below 95 per cent. In fact, efficiency is very unstable in the railway tunnel option. It should be noted that a ropax ship loaded with an FEU container with a truck cabin has a super-efficiency score above 120 per cent (Figure 7).

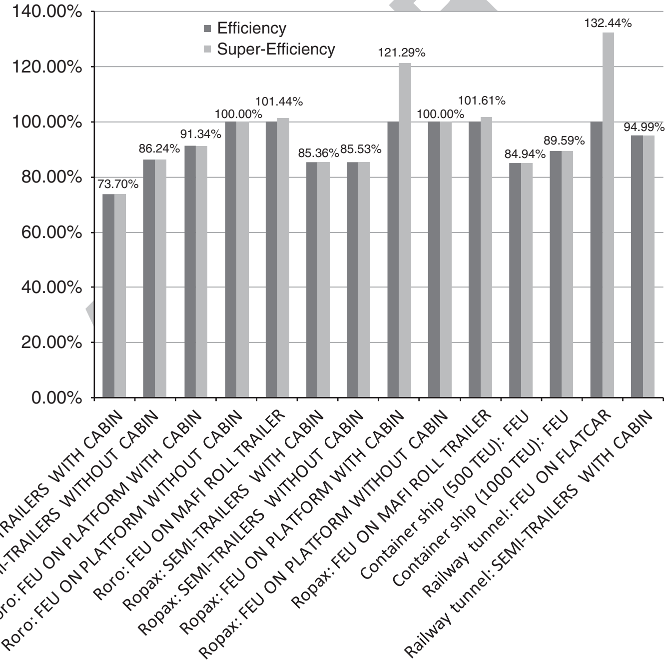

Figure 7: DEA model efficiency evaluation results (one stage CRS, super-efficiency values shown), where diesel consumption and CO_2 emissions are based on a sea vessel and train utilization level of 50 per cent and the evaluation also includes hypothetical railway tunnel options.

On the basis of these results, the tunnel will not take the whole market at once, but appears to have its own important cargo group to be served and would complement the ropax vessels (and time sensitive cargo).

As utilization of sea vessels and length of a train (corresponds to railway environment higher capacity utilization) are increased up to 80 per cent and ST weights are simultaneously increased to the level of FEU containers, the situation comes to resemble that shown in Figure 6, however, the situation has its own peculiarities (Figure 8). We have assumed that unloading on other side of the Gulf of Finland is unnecessary as a railway would proceed through the tunnel on toward a final destination in Central Europe. In other words, there would be no change of transportation mode at the end of the tunnel. This decreases the required lead time for the Helsinki – Tallinn route (our estimate is from 18 hours to 12 hours) and decreases the total costs (unloading costs plus its share from added overheads and profit margin). The situation depicted in Figure 8 shows that container ships lose their competitive advantage and their use might become

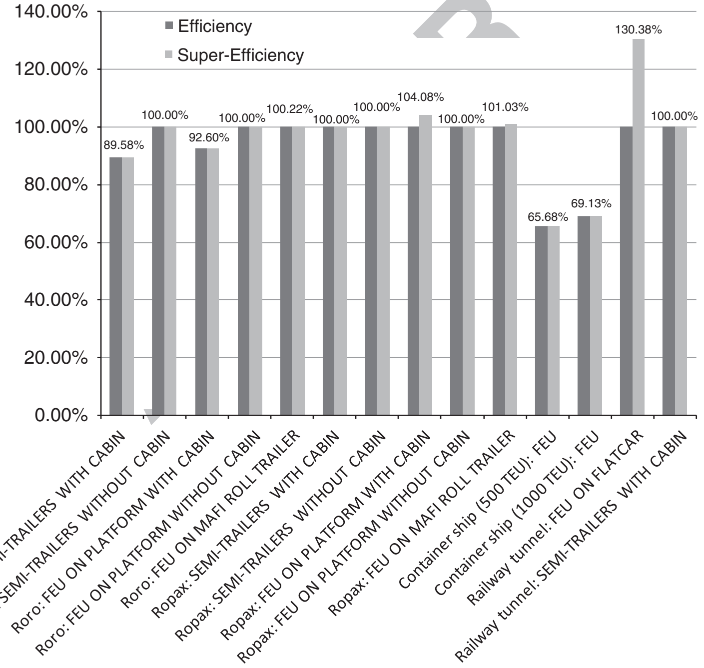

Figure 8: DEA model efficiency evaluation results (one stage CRS, super-efficiency values shown), where diesel consumption and CO_2 emissions are based on a sea vessel and train utilization level of 80 per cent as well as with an assumption that semi-trailers carry an equal amount of freight with FEU containers. Efficiency evaluation also includes the hypothetical railway tunnel option.

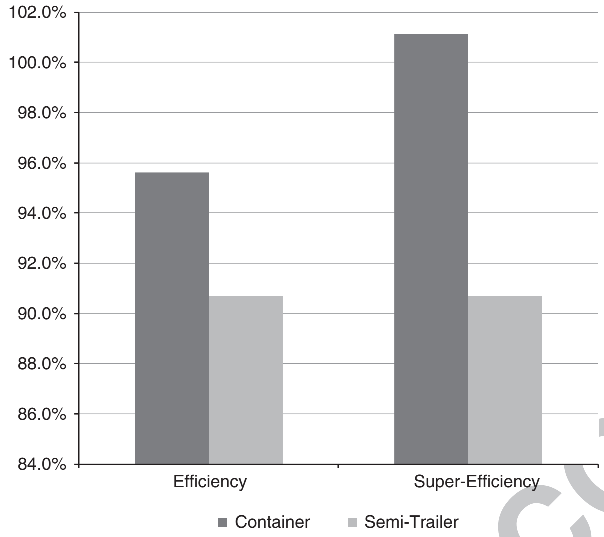

Figure 9: Efficiency and super-efficiency averages of all different models used in research work for containers ($n = 52$) and STs ($n = 28$). Both differences are statistically significant (efficiency at level of 0.05 and super-efficiency at level of 0.01).

minimal. Again, under this scenario a large number of other transportation chain options make the frontier. Only roro ships in some cases are below the frontier.

One of the findings so far has been that containers should be favored over STs. Therefore, we built a database that incorporated all scenarios presented earlier (Figures 5–8) plus two additional scenarios: (i) railway tunnel unloading operations omitted and (ii) railway tunnel scenario with only utilization increased. These two additional scenarios were not presented in Figures 7 and 8. When this data set is split (80 observations) between ST or container, the model yields the results in Figure 9. The container dominates average efficiency outcomes, calculated either from efficiency or super-efficiency numbers. This difference is not extremely large, but it is apparent. This situation holds especially in the super-efficiency models, where container-based transportation chains take the lead.

Discussion

The purpose of this research was to look into the future and evaluate different alternatives for the Helsinki – Tallinn transportation chains. On the basis of our analysis, it is now possible to discuss transformation in these chains. One major change that could take place because of the pressure from higher oil prices and requirements to reduce CO_2 emissions is the increasing use of containers in the transport operations. The current *modus operandi*, which relies mainly on ropax ships and STs with a cabin, is far from optimal (CO_2 emissions and fuel economy). However, we do not believe in major discontinuous change and feel that an evolutionary process is more likely. Thus, the change is likely to progress from ropax to ST to container and the use of container ships will change from marginal to mainstream. It should be noted from the case of the Eurotunnel, which has been operational for nearly two decades between the United Kingdom and France that ships still hold a considerable market share of the overall channel traffic. Of course, the importance of ships has declined, but they remain a viable alternative. Even if all of the technical and construction process issues had not existed, the UK – France experience shows that shipping lines are able to fiercely compete for markets and for sustained periods of time. It should be noted that ships are being re-engineered to respond to new conditions and the capacity utilization of ships is reaching new levels.

On the Helsinki – Tallinn route, the most challenging area for improvement in container transportation is the cost and time dimension. We may assume that in a cost sense the railway tunnel as well as container ships could operate at the required efficiency level (or even lower than what was estimated in this research because of a lack of volume). This efficiency would provide scale economies from the operations. The time issue is more difficult issue to address and has been shown to have a significant influence on shippers transport mode use decisions in inland versus short sea shipping context (Brooks and Trifts, 2008). Currently, ropax chains are able to offer very short lead times with competitive pricing encouraging fuel inefficiency and greater CO_2 emissions. Therefore, we would argue that the dominance of ropax ships on this route is much longer term oriented than in the case of Eurotunnel where the railway tunnel was able to offer a much shorter distance as compared with shipping lines. In the case of Helsinki – Tallinn, this is not the case, since both have the same distance.

On the basis of the efficiency evaluation findings, we have built a roadmap for the Helsinki – Tallinn transportation chain transformation (Figure 10). In the coming decade, the major change will be the return of containers and container ships on this short sea shipping route, a development scenario aligned with global trends (Notteboom and Rodrigue, 2008). These together lay the foundation or opportunity for the railway tunnel investment. Containers are cheaper to transport by rail over longer distances (as compared with STs). This is mostly attributable to better cargo versus tare weight lower pricing of rolling stock investments, and the ease of loading and unloading. For this change to become viable more demand for long-distance cargo transport is needed for this shipping route. Signs of increased demand are already visible with more cargo

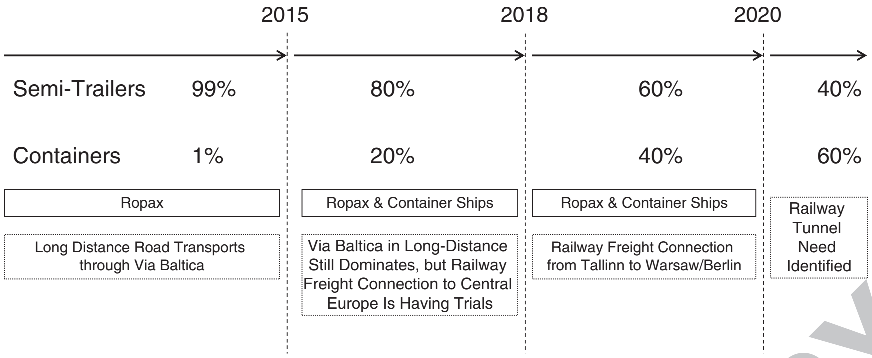

Figure 10: Roadmap for the upcoming changes in the transportation chains operating between Helsinki and Tallinn (with market shares of STs and containers and the dominant transport modes).

volume with a destination or origin in Central European nations such as Poland or Czech Republic (Tapaninen and Räty, 2012). This evolution will enable the use of containers and eventually encourage the use of railways onward from Tallinn to Central Europe (and vice versa). In Figure 10, we identify 2015 as the turning point, because of the implementation of the enforced sulfur regulation for the Baltic Sea. This new regulation should increase the popularity of short sea shipping routes to/from Finland and hinterland operations should grow considerably. For 2018, we estimate that CO_2 emission payments will be implemented in the shipping sector within the EU. There is also a possibility that some kind of system will be implemented through the IMO in a world-wide setting (United Nations, 2012). Both changes increase the likelihood of using container ships, containers and a railway connection on the route.

There are several caveats for this probable scenario. First, there is a higher cost of railway freight trains in terms of access fees from infrastructure use in the Baltic States. On the basis of Thompson (2008), these costs are already one of the highest in the EU, and correspond to an extra cost of nearly €230 per ST transported on a train on the Tallinn – Warsaw route (Hilmola, 2013). Previous research suggests that the increased use of containerization in shipping depends on inland transport systems characteristics (Notteboom and Rodrigue, 2009). Lack of capacity in terms of rail infrastructure may plague the Baltic Sea Region in the future (Ojala *et al*, 2013). Second, technological advances in terms of fuel efficiency and emissions may offset the decreasing viability of currently dominant transport modes and prevent the suggested scenario becoming a reality (Ojala *et al*, 2013). Third, the development of demand for transport services on this route is difficult to forecast. The scenario depends on the future economic growth and the viability of the manufacturing sectors in Finland.

In 2020, demanding environmental regulations and higher oil prices should make the railway tunnel and other rail infrastructure investment viable (Ojala *et al*, 2013).Other changes noted in the transportation chains should further support this option. The tunnel's construction would likely take a decade to complete, therefore, this alternative would not be in use until the late 2020s or possibly 2030 at the latest. This future scenario is naturally a sum of different factors and depends very much on the political will of neighboring countries, but within the EU.

Conclusions

As has been illustrated in this research, Northern European transport chains are still based on road transports for European continental logistics. The most viable short sea shipping alternatives support this practice. Unfortunately, these trucking-based transportation chains have very poor performance in terms of CO_2 emissions and fuel efficiency. The situation is not as one-sided as it is elsewhere in the world. Ropax ships offer very short lead time service with reasonable freight prices. Our findings suggest that this strength will remain, and that ropax ships yield to more STs who will yield to containers. Transition in transportation chains will be evolutionary with container ships offering higher frequency operations on this short sea route and slowly creating a necessary condition for modal shift (Brooks and Trifts, 2008). Although the change toward the environmentally friendly transportation chains will be evolutionary rather than revolutionary, it will take place within the next decade as environmental regulation and higher oil prices force adjustments. This development also requires more demand than is currently generated by Finnish – Estonian traffic alone. New links and networks beyond this region need to be formed. This will happen in a context where sulfur regulation on the Baltic Sea become effective and shipping in the EU area is made liable for its CO_2 emissions.

The challenge for the container transport side is improving lead time. This is particularly the case in container ship-based transportation chains. It remains to be seen how ropax operators will react to the coming changes; one option to save fuel and reduce CO_2 emissions is to operate at a slower speed (United Nations, 2012). Halving the already very short lead times would not do much harm for ropax operators, as container ships are still underperformers in this area with roughly 6–7 hours total lead time performance. Some authors argue that container ships offer the best possibilities for improvement in energy and environmental efficiency (Sames and Köpke, 2012). Hinterland operations and their development in terms of lead time are also on the agenda in the future, but it is open for debate whether this issue can be solved.

For further research, we envision DEA models being developed in a scenario-based fashion. This is because of the fact that energy efficiency, operations and transportation chains could evolve in entirely different directions within a decade. Major events on the route could also transform the development considerably. These include the possibility for lower or more demanding environmental regulations and the future of oil prices. Different scenarios should be identified through a multi-disciplinary expert group established for this purpose. The DEA model data values for each transportation chain could then be developed with contemporary knowledge from the future state of each alternative. These scenarios would thereafter need to be evaluated for efficiency, which in turn would produce more alternative paths for the development of this northern route.

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