Cost Benefit Analysis IWW Saimaa

Socio-Economic Cost Related to Different Transport Scenarios

M4traffic AB

This report is conducted by M4Traffic AB, the traffic analysis company, and commissioned by the Finnish Waterway Association and in co-operation with the Finnish Transport Agency

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Background and summary

IWW transport does have plenty of unused capacity even in Finland. At the same time the Finnish Government and the local authorities are doing planning for future rail, road transport infrastructure capacities. Also, the heavy producing industries are implementing their environmental strategies.

There have not been any public studies concerning the social costs for the different transport modes in Finland. The social costs include: emissions, accident costs, infrastructure maintenance costs etc. FWA ordered a CBA analysis from a Swedish specialist, consulting company in order to get a neutral and highly professional opinion on the societal costs of the different transport modes. The results can be used by the governmental authorities, local planning authorities and by the industries. The results will also be communicated to the political decision makers.

The Baltic Sea Region with its growing transport volumes especially between East and West and its insufficient road and rail infrastructure needs innovative and pragmatic solutions to cope with future requirements. Rivers, canals and also the Baltic Sea have huge capacity reserves, whereas road and rail infrastructure are (at least in some parts of the Baltic Sea Region) overloaded. However, inland waterway transport (IWT) does still not play a role in the transport system commensurate to its potential.

The Saimaa Lake and Canal area are the only inland waterways in Finland where there is cargo transportation. This inland waterway connection to the sea is vital for the area.

Over the years many studies e.g. on bottlenecks, potential cargo volumes, development have been conducted on the Saimaa Lake and Canal areas. There are plans for significant improvements at the Saimaa Lake and Canal area, which needs noteworthy investments from the state and regions as well as from the shipowners.

The Finnish Waterway Association as an advisor and a promoter of the use of inland waterways (sea-lake) when appropriate wanted to bring another perspective to these earlier conducted studies. The social-economic impacts of different transport modes have not been studied in this extension at the Saimaa Lake area. This study will support the decision-making on investments by assuring the cost-efficient and environment friendly use of inland waterways in certain routes and with certain cargo.

The assignment and the work consist of a cost benefit analysis (CBA) of a typical freight transport between Joensuu in Finland and Dusseldorf in Germany. The calculations are based on actual transport volumes of pulp between the two cities, information from the Finnish Transport Agency and on guidelines from the Swedish Transport Administration. The assumptions in the calculations are based on studied effects of actual transports by truck, train and ship. For the different types of vehicles, standardized values regarding fuel consumption, wage costs for crews, loading/unloading costs, etc have been used, which makes the analysis comparable with other CBA's. In general, all emission-values as well as the costs and times for loading and unloading are Finnish, transport-costs regarding trucks and trains are Swedish and for ships the transport costs are based on European traffic.

The time span the calculations cover, are until 2062, hence the same year as the current agreement regarding the Saimaa Canal ends. The calculations are based on today's knowledge and parameters, which of course may differ in the future as research progresses and new parameters might develop, for example due to electric powered trucks or ships. During the calculation period, the values regarding emissions are incremented by 1,5 % per year according to existing guidelines. The underlying factor being political decisions regarding reducing emissions. Also, diesel prices are incremented during the calculation period. The rest of the calculation values are assumed to be in line with the inflation, which is standard in CBA.

The costs presented below are the total costs summarised during the calculation period and presented as net present values. The net present value makes comparison between the alternatives possible.

Six different transport options and one sub alternative are included in the analysis and compared to each other:

- *Alternative 1* Direct vessel – General cargo ship 2 500 dwt and 3 200 dwt
- *Alternative 2a* Truck (Carelian route) - RoRo ship 9 500 dwt -Truck
- *Alternative 2b* Truck (Carelian route) - Passanger ferry ship -Truck
- *Alternative 3* Truck (Carelian route) - General cargo ship 4 500 dwt -Truck
- *Alternative 4* Train (Carelian route) - General cargo ship 4 500 dwt -Train
- *Alternative 5* Truck (Savo route) - General cargo ship 4 500 dwt -Truck
- *Alternative 6* Train (Savo route) - General cargo ship 4 500 dwt -Train

Regarding alternative 1, the increase in ship size occur after 5 years, and is a result of the proposed investments in the Saimaa Canal with the prolonging of the lock chambers with 11 meters and the raising of the water level with 10 centimetres, which allows for the increase in ship size. This also requires investments by the ship owners in larger ships, investments that are included in the time-based cost used in the calculations.

The analysis covers the socio-economic costs that society values and can put a price on. This can be compared with a business calculation/analysis that include only the costs that the company considers essential. The socio-economic analysis takes a greater grip and tries to include the costs that are not covered by the business analysis. Evaluation of emissions is one such example.

For this CBA, the socio-economic costs related to the different transport scenarios are calculated. This, in the end, allows for a comparison between all different scenarios to see which alternative that has the lowest total socio-economic costs.

The result of the estimated total socio-economic costs associated with the different alternatives can be seen in table 1 below.

Table 1: Comparison of the estimated costs for the different alternatives. Alternative 1 has the lowest total cost and is therefore the best alternative from a socio-economic point of view.

Alternative:	**A1** Direct vessel	**A2a** Truck + RoRo	**A2b** Truck + Ferry	**A3** Truck + GC[1] ship	**A4** Train + GC ship	**A5** Truck + GC ship	**A6** Train + GC ship
Distance cost [MEUR]	72,2	257,2	727,4	247,9	90,5	254,4	96,5
Time-based cost [MEUR]	60,7	198,8	499,8	205,3	73,8	209,7	77,2
Loading and unloading [MEUR]	191,6	175,5	51,9	229,2	242,3	229,2	242,3
Emissions [MEUR]	22,4	38,8	80,3	33,6	11,7	34,3	15,3
Infrastructure cost [MEUR]	-	6,9	21,4	6,9	16,9	7,1	18,3
Accident cost [MEUR]	-	11,3	35,3	11,3	-	11,6	-
Fairway dues and port costs [MEUR]	4,1	29,7	40,3	32,4	3,7	32,4	3,7
Total social-economic costs [MEUR]	**351,7**	**718,2**	**1 456,3**	**766,6**	**438,9**	**778,6**	**453,3**

[1] GC=General Cargo

The calculated results show that Alternative 1 – direct vessel, has the lowest total socio-economic costs and therefore can be considered the best alternative for the society. The total costs associated with other logistic solutions are, as can be seen, are clearly higher. The fact that the total socio-economic costs are lowest for this option indicates that it may be beneficial for the society to try to influence carriers to choose this transport mode.

Looking at the distance-based costs, these show the advantages of the ship's cost effectiveness regarding bulk transports, especially over long distances. Ships are very fuel efficient per tonne transported, which contributes to the low costs. Compared for example with the transport alternative using a "direct" truck transport (alternative A2b), the distance-based costs associated with this alternative are about 10 times higher. It is only the alternatives with the combination of train and ship that have about the same distance-based costs.

Regarding the time-based costs, the need for staff per tonne transported is also more efficient using the direct vessel alternative, as more tonnes per person is transported using ships compared to trucks. Also, with the direct transport, loading and unloading costs are lower compared to the alternatives using several different transport modes.

However, the alternative with direct vessel transport is affected by the fact that the Saimaa Canal will be closed for one month each year due required maintenance of the Canal and harsh winter conditions. This non-valued effect most likely affects the attractiveness of this alternative, as this situation needs to be handled in some way. Also, to obtain the level of total costs presented in Table 1, the investments mentioned above need to be made in the Saimaa Canal, as well as new larger ships are needed, in order to increase the maximum vessel size to 3 200 dwt.

From the results it can also be seen that the alternatives that use rail transport in Finland and Germany (Alternative 4 and 6) are preferable to the alternatives where trucks are used. The railway alternatives also have the lowest emissions, see table 2 below. This is due to the railway transport is powered by electricity (how the electricity has been produced is not included). Also, the ships used between Kotka and Lubeck in these alternatives (GC) have a larger cargo capacity meaning fewer vessels are needed.

Table 2: Emissions associated with each alternative

Alternative:	**A1** Direct vessel	**A2a** Truck+ RoRo	**A2b** Truck+ Ferry	**A3** Truck+ GC ship	**A4** Train+ GC ship	**A5** Truck+ GC ship	**A6** Train+ GC ship
CO2 [tonnes]	278 024	548 787	1 213 574	486 153	143 530	495 967	200 122
NOx [tonnes]	6 298	7 276	11 426	5 857	3 251	5 931	3 582
VOC [tonnes]	180	208	328	168	93	170	129
SO2 [tonnes]	180	134	96	93	93	93	93

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1 Introduction

The assignment and the work consist of a cost benefit analysis (CBA) of a typical freight transport between Joensuu in Finland and Dusseldorf in Germany. The calculations are based on actual transport volumes of pulp between the two cities. Different transport options are included in the analysis and are compared to each other. The options/transport modes included in the analysis are:

- Shipping
- Road
- Rail
- as well as combinations thereof

This report aims at describing the socio-economic costs that arise when the goods are transported from Joensuu to Dusseldorf for different transport modes.

This socio-economic analysis covers the costs that society values and can put a price on. A business calculation/analysis includes only the costs that the company considers essential, while socio-economic analyses take a greater grip and try to include the costs that are not covered by the business analysis. Evaluation of emissions is one such example. Traditionally, a CBA compares a comparative alternative with an investigation option and make use of investment costs as a factor. This is to determine if it is profitable to make a certain investment or not. For this CBA, the traditional methodology is dropped and instead the socio-economic costs related to the different transport scenarios are calculated. This, in the end, allows for a comparison between all different scenarios to see which alternative that have the lowest costs.

The report and the work are part of the ongoing EMMA project:

EMMA - "**E**nhancing freight **M**obility and logistics in the BSR by strengthening inland waterway and river sea transport and pro**m**oting new intern**A**tional shipping services". EMMA is a 3-year project (1.3.2016-28.2.2019), part-financed by the Baltic Sea Region Programme using available funding from the EU´s European Regional Development Fund (ERDF). The Finnish Waterway Association as a project partner in the EMMA project in the mandator of this study together with the Finnish Transport Agency.

1.1 Purpose

The purpose of the investigation is to compare the socio-economic effects between the different transport options to see which of the transport options is preferable from a socio-economic point of view.

1.2 Methodology

The analysis is based on the total annual transport volumes of pulp, transported from Joensuu to Dusseldorf. The calculations are further based on information from the Finnish Transport Agency and on guidelines from the Swedish Transport Administration. The Swedish parameters and information are taken from the report "Analysis Method and Socio-economic Costs for the Transport system", developed by the Swedish Transport Administration (ASEK 6).

As described above the traditional methodology for a CBA, where two alternatives are compared to each other, is dropped. Instead the socio-economic costs are calculated separately for the different alternatives. The total cost for the alternatives can thereafter be compared and the alternative with the lowest total cost is the most advantageous. In the calculations, no investment costs have been assumed.

In addition to the calculated results, non-valued effects are also described. These effects are expected to affect the different options, but they cannot be priced.

The different transport alternatives have been calculated using Microsoft Excel.

1.3 Report layout

The report begins by presenting the parameters that have been used in the calculations. First, the common parameters, which apply to all options, are presented. Then, the specific parameters, which relates to specific modes of transport are explained. Thirdly, the transport options and routes that have been selected for this calculation are presented. In the last part the results and non-valued effects are presented.

2 Prerequisites

This chapter describes the identified valued effects in the socio-economic analysis as well as the parameters used in the calculations. First, the valuable effects are described and then the parameters used for calculations are explained. The parameters are divided into mutual parameters and specific parameters for truck, ship and train.

There are six different transport alternatives and one sub-alternative that will be investigated. These alternatives will be described in detail in chapter 3 but the overall picture of the various options is shown below. As can be seen in the figure below, the types of transport arrangement consist of ships, trains and trucks, as well as combinations of the different modes.

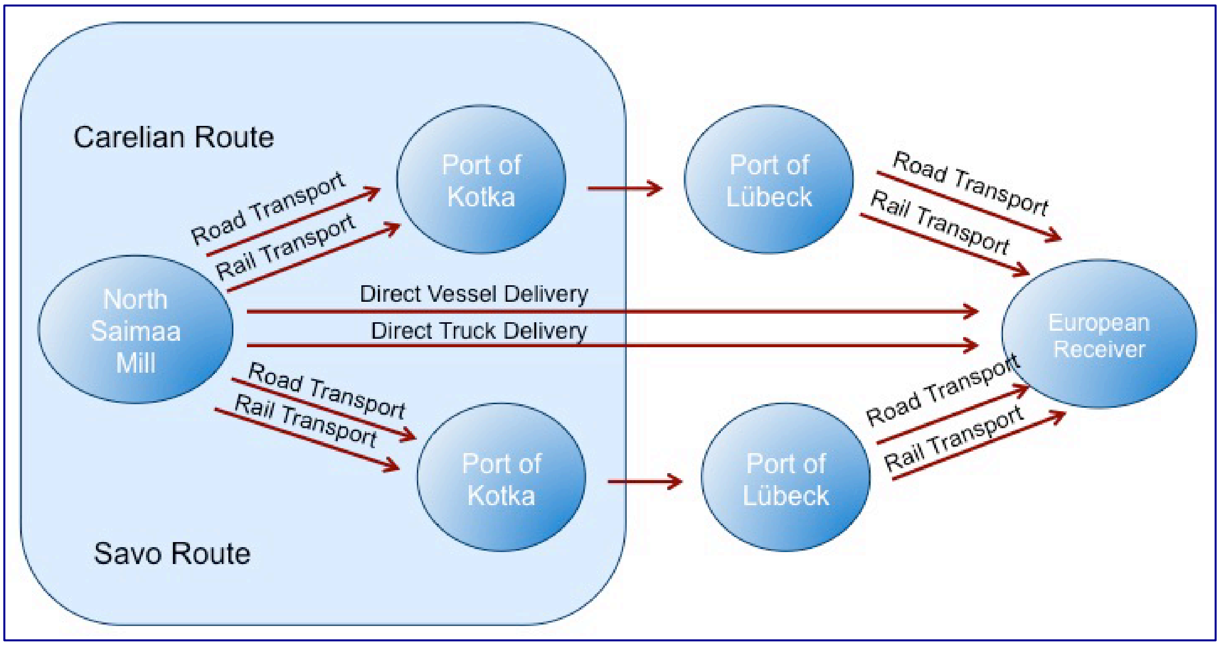

Figure 1 Different transport alternatives

2.1 Identified valuable effects

The effects that are calculated are the same, as those recommended for socio-economic calculations by the Swedish Transport Administration, these are:

- Transport costs
  - a. Distance based (fuel costs and other distance-based costs such as maintenance etc.)
  - b. Time based, including wages, maintenance, insurance, capital costs etc.
- Loading and unloading costs
- Emissions
- Infrastructure costs ("wear and tear")
- Accidents costs
- Fairway dues and passage costs

The transport costs incurred for the carriers; loading and unloading costs, the fairway dues and passage costs used in this analysis are based Finnish values. While the costs of emissions, infrastructure and accidents are affecting the society.

2.2 Transport volumes

The calculations are based on actual transport volumes of pulp between Joensuu and Dusseldorf. The total demand is 200 000 tonnes of pulp for the starting year of the calculations.

According to Paper Advance, the long-term development of pulp demand in Europe has increased by approximately 0.6 % per year over the last 30 years (Paperadvance, 2017).

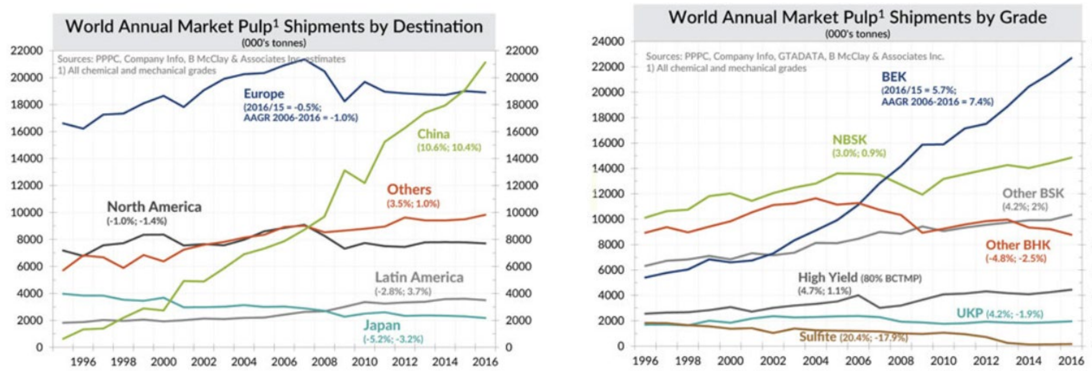

Figure 2. The annual development of the pulp shipment has graded for different markets around the world over the last 30 years (citation here).

According to Figure 2 the total demand for pulp have generally increased. However, the European market has varied over time and during the last 10 years there have been a declining demand. For the last five years there have been no significant change in the market in Europe regarding the demand for pulp. Since the calculation of socio-economic effects is done over a longer period, it is more relevant to use the long-term development instead of the development the last few years. Therefore, the transport need will increase with 0.6% annualy due to assumption of the increased transport demand described earlier. It is a simplification to use an even annual increment. In reality, the increase will occur gradually, for example, when investments in the paper mills are made. But since it's not known when the investments will be made, it is better to use an annual increase.

2.3 Investment cost

The analysis focuses on the socio-economic effects associated with the different transport modes to establish which mode, or which combination of modes that have the lowest total socio-economic costs. It has been assumed that no investment in infrastructure is needed. However, for the option of larger ships serving the Saimaa Canal and lake area, investments need to be made. The comparison in the end gives a hint of how large these investments can be for this transport alternative to still be beneficial. One should also point out that this sum only relates to the analysed pulp transport, and that there are other transports that also would benefit from an investment in the Canal. The sum presented for this alternative is therefore not exactly equal to the maximum possible investment cost.

2.4 Mutual parameters

Table 3, below, lists the mutual parameters for the calculations. These values are the same regardless of transport alternative. Examples of the mutual parameters are the calculation period, which specifies the period for which the effects are calculated and the exchange rate, used to convert costs in Swedish kronor to the euro. Additional parameters that are mutual to the different transport options are values of different emissions. The emission values below apply to the opening year and are thereafter increased by 1.5% per year according to calculation assumptions used in Sweden.

Table 3 Mutual calculation parameters

Mutual parameters		Unit	Source
Calculation period	2020-2062	year	The Finnish Waterway Association
Price level	2010	year	Requested by the client
Exchange rate	9.5	SEK/EUR	Average value 2010 according to www.valuta.se
NOx	282	EUR/tonnes	Table 57 (Liikennevirasto, 2012)
VOC	30	EUR /tonnes	Table 57 (Liikennevirasto, 2012)
SO2	345	EUR /tonnes	Table 57 (Liikennevirasto, 2012)
CO2	37	EUR /tonnes	Table 57 (Liikennevirasto, 2012)
Diesel price 2014	0.60	EUR/L	Table 14.4 (Trafikverket, 2016)
Diesel price 2040	0.74	EUR/L	Table 14.4 (Trafikverket, 2016)
Diesel price 2060	0.772	EUR/L	Table 14.4 (Trafikverket, 2016)

The emission ratings from the Finnish Transport Agency which have been used in the calculations, are substantial lower than the Swedish values, see Table 4. These values have a significant impact on the results.

Table 4 Comparison between Swedish and Finish emission values

Emission	Finnish value [2010]	Swedish value [2014]	Unit
NOx	282	9 053	EUR/tonnes
VOC	30	4 526	EUR /tonnes
SO2	345	3 053	EUR /tonnes
CO2	37	120	EUR /tonnes

2.5 Transport specific calculations parameters

In this section, the specific parameters for truck, ship and train are presented. In the end of each part, a summary will be presented in tabular form where the sources are reported.

2.5.1 Truck

Below are the conditions and assumptions made regarding transport arrangements, where transports are carried by truck. Each truck has a total length of 18 meters and net weight 22 tonnes. The truck is assumed to consume 0.4 litres diesel/km.

Operational transport cost

- Distance based 0.36 EUR/ vehicle-km excl. fuel. (service, reparation and other distance-based costs such as capital cost etc.)
- Time based, including wages, insurance, tax. Total cost of 30.3 EUR/vehicle-h. The time-based values are calculated on effective transport time.

Loading and unloading costs

It takes in average 1 hour to load and unload a truck and the cost is 1.9 EUR/tonnes. The driver is assumed to be present while loading and unloading the truck, which means that the time costs are affected, and the loading/unloading time is therefore added in the total time in time-based cost.

Emissions

Emission factors regarding road traffic include the following climate gases and air pollutants shown in Table 5:

Table 5 Emission factors truck

Emission factor truck		Unit
NO_x	7.3	g/km
HC	0.21	g/km
SO_2	0.00000354	kg SO2/l diesel
CO_2	2.4	kg CO2/l diesel

Infrastructure cost

Truck transports are assumed to entail costs in terms of road wear. These costs, in the calculations, are assumed to be 0.02 EUR/vehicle-km according to socio-economic analysis of heavier vehicles on the European road network, which consist mainly of highways.

Accident cost

Traffic safety costs for road traffic consist mainly of costs relating to dead, severely injured, care costs and costs for production losses due to traffic accidents. This cost is 0.03 EUR / vehicle-km for trucks.

Fairway dues

In Germany there are tolls for truck traffic, which will be a cost to the carriers. It has been assumed that the trucks used in transportation are environmentally rated, giving a mileage cost of 0.14 EUR / km.

Summary

In Table 6 below, the parameters related to truck transports are presented.

Table 6 Cost linked to truck

Prerequisites linked to Truck		Unit	Source
Distance based (excl. Fuel)	0.36	EUR/vehicle-km	(Trafikverket, 2016)
Fuel consumption	0.4	l/km	(Trafikverket, 2016)
Time-based- salary	22.6	EUR/vehicle-km	(Trafikverket, 2016)
Time-based- insurance, tax, capital cost	7.7	EUR/vehicle-km	(Trafikverket, 2016)
Load/unloading truck	1	h	(Koskinen, 2017)
Load/unloading truck cost	1.9	EUR/tonnes	(Koskinen, 2017)
Emission NO_x	7.3	g/km	(Trafikverket, 2016)
Emission HC	0.21	g/km	(Trafikverket, 2016)
Emission SO_2	0.00000354	kg SO2/l	(Trafikverket, 2016)
Emission CO_2	2.4	kg CO2/l	(Trafikverket, 2016)
Infrastructure cost	0.02	EUR/vehicle -km	(Trafikverket, 2016)
Accident cost	0.03	EUR/vehicle -km	(Trafikverket, 2016)
Fairway dues Germany	0.140	EUR/vehicle-km	(DB Netz AG, 2017)

2.5.2Ship

Below are the conditions and assumptions made regarding transport arrangements, where shipments are done by ship.

Fuel consumption
The fuel consumption for all ships used in the different alternatives are based on data provided by the FWA and its partners.

Operational transport cost
The operational transport costs depend on the capacity of the ship and therefore both distance-based and time-based cost vary depending on the ship size assumed in the different alternatives. Five different vessel types are used in the calculations. Distance-based cost includes fuels and maintenance and is based on the fuel consumtion. The time-based costs include wages, insurance, capital cost etc. All time-based costs are based on a previous conducted R&D project performed by M4Traffic on behalf of the Swedish Transport Administration. The cost for different ship can be seen in Table 8.

Loading and unloading costs
Loading and unloading in the harbour, both time and cost are included in the parameters. The costs depend on the vessel type and the port in question. The different costs can be seen in Table 8.

Lastauskustannus varmaankin riippuu enemmän laivatyypistä kuin laivan koosta ja satamasta jossa lastataan- ja tai puretaan

Emissions
Emission factors have been collected from ASEK and include effects from vessel traffic. Table 7 below lists the emission factors used.

Table 7 Emission factor

Emission factors

NOx	0.07	kg NOx/kg MDO
VOC	0.002	kg VOC/kg MDO
SO2	0.002	kg SO2/kg MDO
CO2	3.09	kg CO2/kg MDO

Infrastructure cost
Ship transports are assumed to entail no costs in terms of wear and tear.

Accident cost
Regarding accident costs for shipping, these are not included in this calculation and explained later in the section Non-valued effects.

Passage costs, fairway dues and port costs
The Saimaa Canal passage costs are 10 000 EUR/Ship for the 2 500 dwt ships and 11 000 EUR/ship for 3 200 dwt ships. These costs cover the round trip the Baltic Sea – Joensuu – Baltic Sea hence these costs have been halved in the calculations. The costs include both the Finnish and Russian part of the Canal.

In the Kiel Canal, the fairway dues are 2 910 EUR/ship (2 500 dwt) and 3 256 EUR/ship (3 200 dwt) respectively and are for a one-way journey.

Fairway dues for arriving and departing Kotka are according to current legislation. For the RoRo ships, the fee is ca 13 100 EUR/ship, for the ferry ca 11 000 EUR/ship and for the general cargo ship ca 3

800 EUR/ship. After 10 callings at Kotka, the maximum fairway due is reached, and no more fees must be paid for the rest of that year (Finlex, 2018).

The port costs regarding the different ports included in the calculations are listed in the table below.

Summary

In the Table 8 below, the parameters related to ship transports are summarised.

Table 8 Summary Ship

Prerequisites linked to Ship	General cargo 2 500 dwt	General cargo 3200 dwt	RoRo 9 500 dwt	Ferry 500 dwt	General cargo 4 500 dwt	Unit
Fuel consumption ship*	11.25	11.25	52.73	148.9	17.38	kg/km
Distance based (incl. fuel costs)	3.24	3.82	106.69	162.66	32.65	EUR/km
Time-based- salary	102.06	110.12	139.34	188.65	96.80	EUR/h
Time-based- insurance tax. capital cost	54.63	66.62	252.15	512	68.27	EUR/h
Loading/unloading cost Kotka /Lübeck	-	-	7.2	0.96	10.0	EUR/tonnes
Loading/unloading cost Joensuu	10.0	10.0	-	-	-	EUR/tonnes
Loading/unloading cost Düsseldorf	10.0	10.0	-	-	-	EUR/tonnes
Saimaa Canal passage and port costs (one-way)	5 000	5 500	-	-	-	EUR/ship
Fairway dues in Kiel Canal	2 910	3 256	-	-	-	EUR/ship
Fairway dues Kotka*	-	-	850	-	700	EUR/ship
Port costs Düsseldorf*	3 900	3 900		-	-	EUR/ship
Port costs Lübeck*	-	-	5 000	-	6 500	EUR/ship
Port costs Kotka*	-	-	4 700	-	10 000	EUR/ship
Port costs Helsinki*	-	-	-	1 130	-	EUR/ship
Port costs Tallin*	-	-	-	750	-	EUR/Ship

* Input delivered by the FWA

2.5.3Train

Below are the conditions and assumptions made regarding the transport arrangements where shipments are made by train. The load capacity of the train used in the calculation is 64 tonnes per wagon and a train set is assumed to have 22 wagons. A small part of the railway in Finland, used in this calculation on the Savo route, is not electrified; hence diesel-powered trains are needed there. The total unelectrified length is 182 km. The Carelian route is all electrified.

The rail in Germany has access to electricity according to a train map (Büker, 2017).

Operational transport cost

- Distance-based costs include fuel, maintenance etc. For electric powered trains the cost is 0.009 EUR/tonne-km and for diesel-powered trains it is 0.0010 EUR/tonne-km.
- Time based costs, including wages, maintenance, insurance, capital costs etc. are 0.43 EUR/tonne-h for both electric and diesel-powered trains.

Loading and unloading costs

Loading or unloading time is assumed to be 6 hours per train and the cost is 2.6 EUR/tonne. The train driver is assumed to be present at loading and unloading the train, which means that the time costs are affected, and the loading/unloading time is therefore added in the total time in time-based cost.

Emissions

Emission costs are assumed to occur only for diesel-powered trains according to the calculation conditions used by the Swedish Transport Administration. They include the climate gases and air pollutants presented in Table 9 below.

Table 9 Emission factor diesel train

Emission factor diesel train

NOx	0.46	g/net tonnes-km
VOC	0.04	g/net tonnes-km
Particles	0.009	g/net tonnes-km
CO2	31.8	g/net tonnes-km

There are no explicit emission values for electrified trains.

Infrastructure cost

Infrastructure costs are the fees trains pay for using the infrastructure and these fees are depending on the country. The Finnish track fees are 3.83 EUR/train-km and the German 2.58 EUR/train-km. It has been assumed that the fees paid cover the wear and tear of the infrastructure.

Accident cost

Accident costs for trains are not included in this calculation and is discussed more thoroughly in the section Non-valued effects.

Summary

In Table 10 below, the parameters related to train transports are summarised.

Table 10: Cost linked to train

Prerequisites linked to train		**Unit**	**Source**
Distance based -Electricity (incl. Fuel)	0.009	EUR/tonne km	(Trafikverket, 2016)
Distance based -Diesel (incl. Fuel)	0.010	EUR/tonne km	(Trafikverket, 2016)
Time-based- electricity	0.43	EUR/tonne h	(Trafikverket, 2016)
Time-based- Diesel	0.43	EUR/tonne h	(Trafikverket, 2016)
Load/unloading time	6	h/train	(Koskinen, 2017)
Load/unloading cost	2.6	EUR/tonnes	(Koskinen, 2017)
Emission NOx	0.46	g/net tonnes km	(Trafikverket, 2016)
Emission VOC	0.04	g/net tonnes km	(Trafikverket, 2016)
Emission Particles	0.009	g/net tonnes km	(Trafikverket, 2016)
Emission SO2	0.00002	g/net tonnes km	(Trafikverket, 2016)
Emission CO2	31.8	g/net tonnes km	(Trafikverket, 2016)
Track fees Finland	3.83	EUR/train km	(Liikennevirasto, 2017)
Track fees Germany	2.58	EUR/train km	(DB Netz AG, 2017)
Accident cost	-		

3 Transport scenarios

In Figure 3 below, an overall description of various transport alternatives is shown. In total, socio-economic effects will be calculated for six alternative transport options and one sub-alternative. These are described more detailed later in this chapter. All alternatives will only be calculated one-way direction, from Joensuu to Düsseldorf.

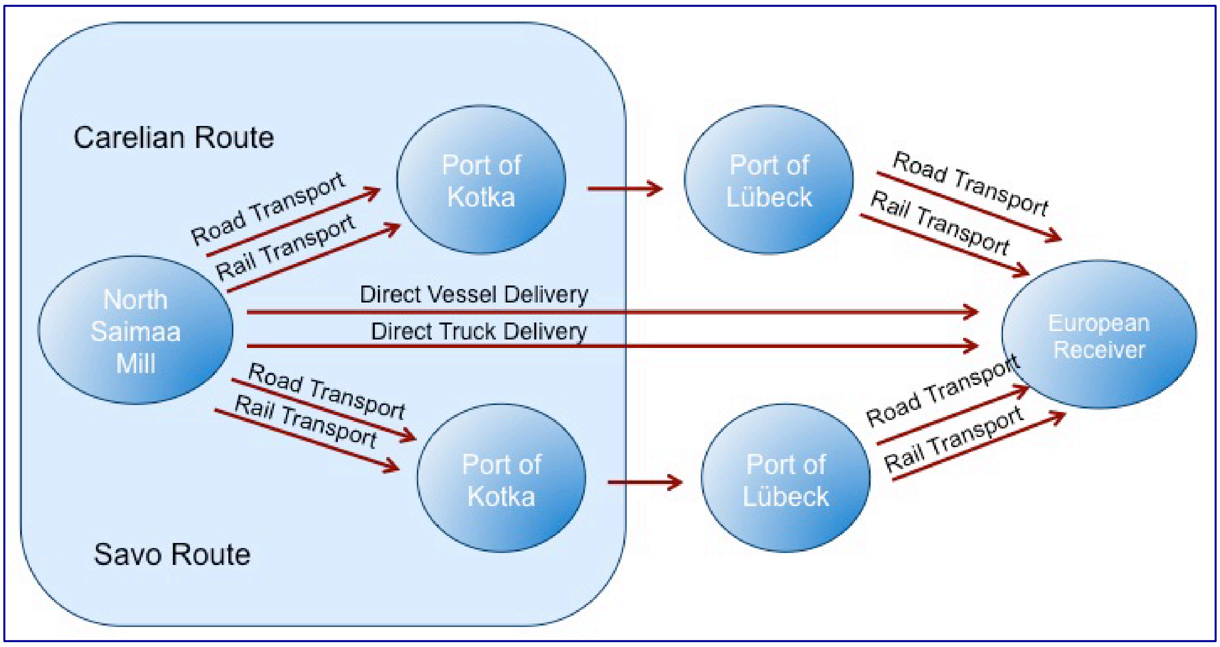

Figure 3: Different transport alternatives

The socio-economic effects are calculated on condition that all trucks, trains and boats used for transport are fully loaded. Calculations are made for the number of transport units required to transport the annual transport volumes. This means, for example, that the number of trucks needed per year is calculated by taking the annual transport requirement (200,000 tonnes for the opening year 2020 and then an annual increase of 0.6%) and divided it with the load capacity of each truck. The same applies to trains and ships. This is obviously a simplification as in reality transports will not always be fully loaded. In reality, the products will for example be co-loaded with other products, especially this holds for ship shuttles. However, these simplifications are required to make the calculations not too extensive. The prerequisites apply to all modes of transport, which means that the comparability of the various options remains.

The different transport alternatives are:

- *Alternative 1* Direct vessel – General cargo ship 2 500 dwt and 3 200 dwt
- *Alternative 2a* Truck (Carelian route) - RoRo ship 9 500 dwt-Truck
- *Alternative 2b* Truck (Carelian route) - Passanger ferry ship-Truck
- *Alternative 3* Truck (Carelian route) - General cargo ship 4 500 dwt -Truck
- *Alternative 4* Train (Carelian route) - General cargo ship 4 500 dwt -Train
- *Alternative 5* Truck (Savo route)- General cargo ship 4 500 dwt -Truck
- *Alternative 6* Train (Savo route) - General cargo ship 4 500 dwt -Train

3.1 Alternative 1 – Direct vessel delivery

Shipping from Joensuu to Düsseldorf. The first part of the route goes from Joensuu to the Baltic Sea, via the Saimaa Canal and lake area. Thereafter the ships go via the Baltic Sea through the Kiel Canal to the North Sea. South of Rotterdam, the ships connect to the Rhine River for the final part of the route to Dusseldorf. The total travel time is 114 h and the distance are approximately 2 600 km.

Figure 4: Alternative 1 direct vessel delivery.

This alternative is affected by the limitations regarding the ship size in the Saimaa Canal. For the first 5 years the current limitation of 2 500 dwt is used. From the year 2025 and onwards the limitation will be 3 200 dwt due to improvements in the canal.

2020-2025 Current limitation of ship size 2 500 tonnes
2026-2062 Future limitation of ship size 3 200 tonnes

In total, there will be 103 ships (2 500 dwt) year 2020 and 80 ships (3 200 dwt) year 2026 to accommodate the transport need. Thereafter the transport need will increase with 0.6 % annually due to the assumption of the increased transport demand described earlier.

3.2 Alternative 2 – Truck transport from Joensuu to Düsseldorf

Truck transports will be calculated for two options. Both involve part of the shipments going to sea by ferry or on RoRo vessels.

Option a- Trucks take the trailers from Joensuu to Kotka via the Carelian route. The trailers will be pulled on board a RoRo-ship (9 500 dwt) by a port tug master and transported to Lübeck. A new truck will pick up the trailer in Lübeck for transport to Düsseldorf where the goods will be unloaded. Approximate 800 km /14 h with truck and 1 300 km/44 h with RoRo-ship from Kotka to Lübeck. In total, 9 091 trucks and 27 ships (9 500 dwt) are needed to accommodate the transport need the first year.

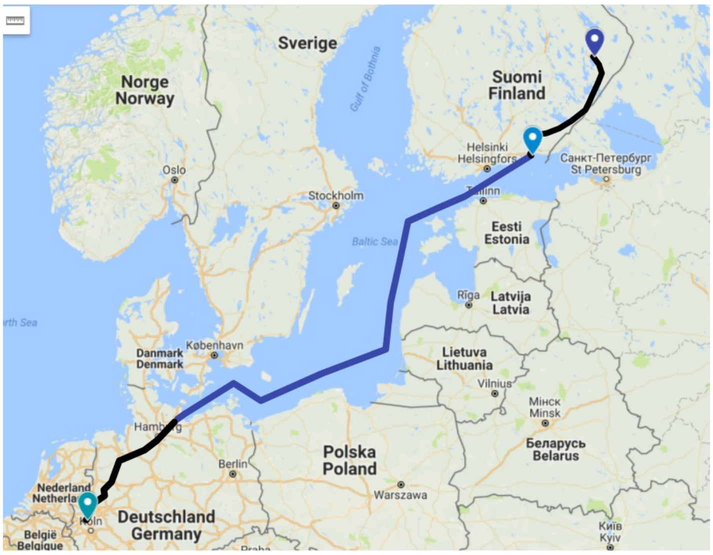

Figure 5: Alternative 2a Truck transport via RoRo vessel to Lübeck.

Option b- The truck takes the trailers from Joensuu to Helsinki. The truck and trailer will be transported to Tallinn with Passanger ferry. The truck will thereafter drive via Estonia, Latvia, Lithuania and Poland to the destination Düsseldorf where the goods will be unloaded.

Approximately 2 500 km/38 h with truck and 90 km/2 h with ferry. In total, there will be 9 091 trucks and 96 ships (passanger ferry) to accommodate the transport need the first year.

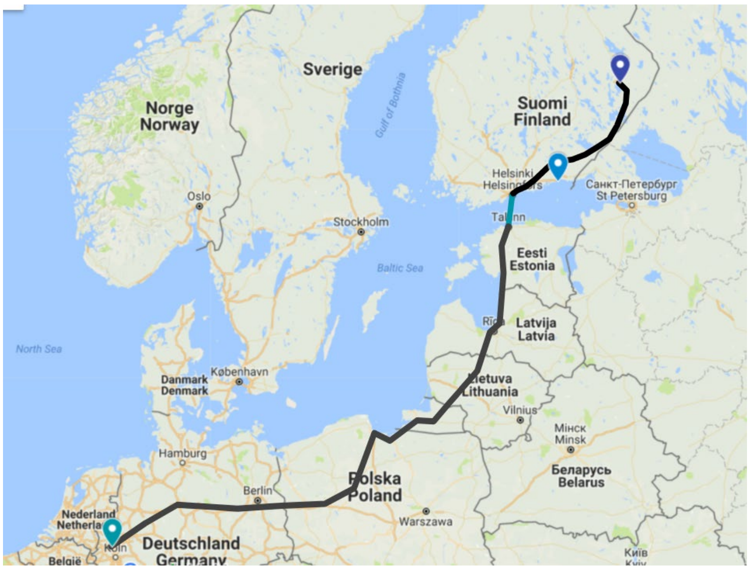

Figure 6: Alternative 2b, truck transport via passanger ferry to Tallinn.

3.3 Alternative 3 – Truck (Carelian route) and ship transport

Truck transport from Joensuu to Kotka, via Carelian route (east of Saimaa). There after a General cargo ship (4 500 dwt) will transport the goods to Lübeck. Reloading to truck transport from Lübeck to Düsseldorf.

Approximately 800 km/14 h with truck and 1 300 km/68 h by general cargo ship. The sailing time for the general cargo ships is significantly longer compared to the RoRo vessels used in alternative 2a. In total, there will be 9 091 trucks and 57 ships (4 500 dwt) to accommodate the transport need the first year.

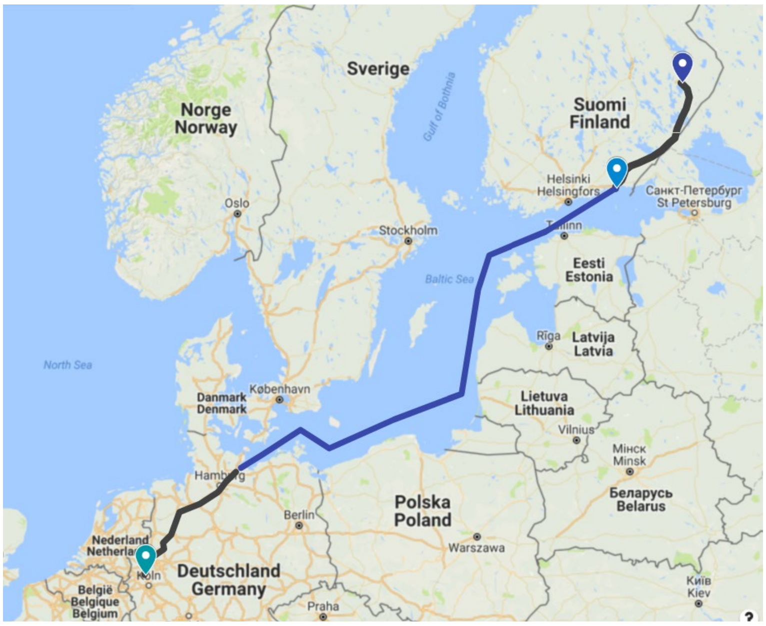

Figure 7: Alternative 3, truck transport via Carelian route

3.4 Alternative 4 – Train (Carelian route) and ship transport

Train transport from Joensuu to Kotka, via Carelian route (east of Saimaa). Reloading to shipping from Kotka to Lübeck with General cargo ships of 4 500 dwt. Reloading to train transport from Lübeck to Düsseldorf. In this option all rail transport takes place on electrified railways. Approximately 770 km/12 h with electrified train and 1 300 km/68 h by general cargo ship. In total, there will be 142 trains with 3125 wagons and 57 ships (4 500 dwt) to accommodate the transport need the first year.

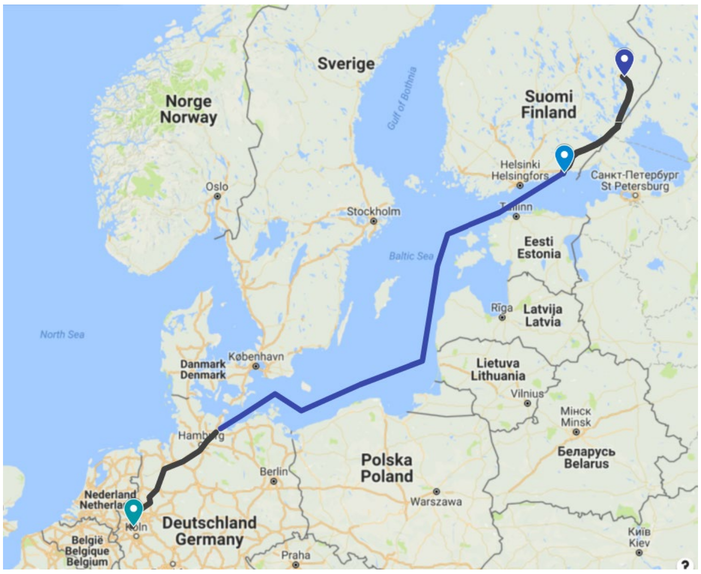

Figure 8: Alternative 4, train transport via Carelian route

3.5 Alternative 5 – Truck (Savo route) and ship transport

Truck transport from Joensuu to Kotka via Savo (west of Saimaa). Reloading to shipping from Kotka to Lübeck with General Cargo ship of 4 500 dwt. Reloading to truck transport from Lübeck to Düsseldorf. 830 km/14 hours by truck. In total, there will be 9091 trucks and 57 ships (4 500 dwt) to accommodate the transport need the first year.

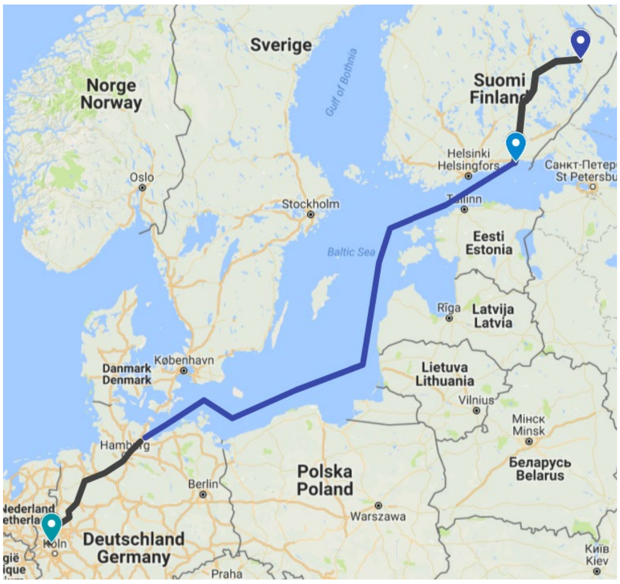

Figure 9: Alternative 5, truck transport via Savo route

3.6 Alternative 6 – Train (Savo route) and ship transport

Train transport from Joensuu to Kotka via Savo (west of Saimaa). Reloading to shipping from Kotka to Lübeck, general cargo ship of 4 500 dwt. Reloading to train transport from Lübeck to Düsseldorf. In this alternative part of the railway in Finland is not electrified which means that this part needs diesel-powered trains. It is also assumed that the train set can be switch between electrical- and diesel operation. Approximately 635 km/10 h with electrified operation and 182 km/3 h with diesel operation. In total, there will be 142 trains with 3 125 wagons and 57 ships (4 500 dwt) to accommodate the transport need the first year.

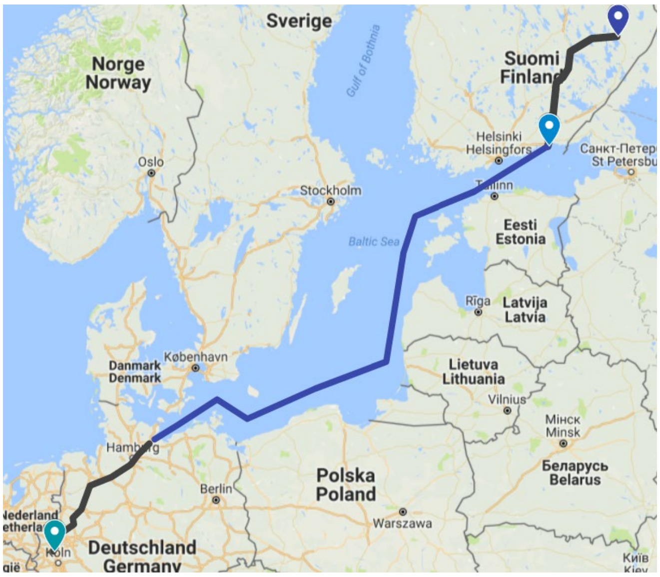

Figure 10: Alternative 6, truck transport via Savo route

4 Results

This chapter presents the effects calculated based on the conditions described above. Effects that have not been calculated, but are expected to affect the different options, are also described (chapter 4.2).

4.1 Valued effects

Based on the above-mentioned conditions, the calculation results are summarized below. First a summarized table of all alternatives regarding total costs and emission results during the calculation period. Thereafter the alternatives are commented separately.

As can see in Table 11, Alternative 1 – direct vessel, has the lowest summarized socio-economic costs and therefore can be considered the best alternative of the once studied.

Table 11 Summary of alternatives result

Alternative:	**A1** Direct vessel	**A2a** Truck+ RoRo	**A2b** Truck+ Ferry	**A3** Truck+ GC ship	**A4** Train+ GC ship	**A5** Truck+ GC ship	**A6** Train+ GC ship
Distance cost [MEUR]	72,2	257,2	727,4	247,9	90,5	254,4	96,5
Time-based cost [MEUR]	60,7	198,8	499,8	205,3	73,8	209,7	77,2
Loading and unloading [MEUR]	191,6	175,5	51,9	229,2	242,3	229,2	242,3
Emissions [MEUR]	22,4	38,8	80,3	33,6	11,7	34,3	15,3
Infrastructure cost [MEUR]	-	6,9	21,4	6,9	16,9	7,1	18,3
Accident cost [MEUR]	-	11,3	35,3	11,3	-	11,6	-
Fairway dues [MEUR]	4,1	29,7	40,3	32,4	3,7	32,4	3,7
Total cost [MEUR]	**351,7**	**718,2**	**1 456,3**	**766,6**	**438,9**	**778,6**	**453,3**

Note that the calculated costs presented in Table 11 have not been discounted; only summarised. This means that the total utility from an investment cannot be directly compared with the total costs. However, this gives a hint of which alternative is the best for the society to invest in.

Emission results

In Table 12 the total emissions during the calculation period is shown for the different alternatives. Alternative 4, with electrified railway combined with General Cargo ship has the lowest emissions.

Table 12 Emissions

Alternative:	**A1** Direct vessel	**A2a** Truck + RoRo	**A2b** Truck + Ferry	**A3** Truck + GC ship	**A4** Train + GC ship	**A5** Truck + GC ship	**A6** Train + GC ship
CO2 [tonnes]	278 024	548 787	1 213 574	486 153	143 530	495 967	200 122
NOx [tonnes]	6 298	7 276	11 426	5 857	3 251	5 931	3 582
VOC [tonnes]	180	208	328	168	93	170	129
SO2 [tonnes]	180	134	96	93	93	93	93

Alternative 1 - Direct vessel

This option has the lowest socio-economic costs and is therefore considered best from this point of view. The largest costs arise due to loading and unloading the vessels. However, compared to the other alternatives, the loading and unloading costs are relatively low since it is a direct delivery without transhipments on the route.

The operational costs of this alternative are low and vessel transport is well suited for transporting heavy freight volumes longer stretches.

However, this alternative requires that investments are made in the Saimaa Canal to be able to use the 3 200 dwt vessels that are assumed in the calculations from year 2025 and onwards.

Alternative 2a - Truck (Carelian route) - RoRo ship 9500 dwt-Truck

Truck transports included in this option contribute to high operational costs. Many trucks are required to transport the requested volumes and the cost per tonne of freight transport becomes higher than for both trains and ships. The costs are mitigated by the fact that a relatively large part of the route goes by sea with a RoRo vessel.

Alternative 2b - Truck (Carelian route) - Passanger ferry ship-Truck

This alternative has the highest socio-economic cost because the pulp is transported by truck almost the entire route. Loading and unloading costs are low since the trucks drive onboard the ferry by them self and no extra equipment is needed.

Alternative 3 - Truck (Carelian route) - General cargo ship 4500 dwt -Truck

This alternative is similar to alternative 2a. The only different is the ship used between Kotka and Lubeck. In alternative 2a a RoRo-ship is used while this alternative uses a General Cargo ship. The difference in total costs between the two alternatives is small and arises from the different ships being used.

Alternative 4 - Train (Carelian route) - General cargo ship 4500 dwt -Train

This alternative is the second best when it comes to the total socio-economic costs. Compared to Alternative 1, the loading and unloading costs are higher since this alternative includes transhipment between the trains and ships. Also, the operational costs are higher in this alternative. Emission costs are low as large part of the transport uses electric powered trains, which have no operating emissions.

Alternative 5 - Truck (Savo route)- General cargo ship 4500 dwt -Truck

This Alternative corresponds to Alternative 3. The difference is in the route in which trucks travel in Finland between Joensuu and Kotka. In this option, the route is via Savo, which is marginally longer than the Carelian rout used in Alternative 3.

Alternative 6 - Train (Savo route) - General cargo ship 4500 dwt -Train

Similar alternative as option 4. The difference lies in the railway used in Finland. In this alternative, the route goes through Savo, which is a slightly longer route than the Carelian route used in alternative 4. The Savo route also partly lacks electrification. On the stretches without electrification, the trains must be powered by diesel engines, leading to higher emission costs and higher slightly higher time-based costs.

4.2 Identified non-valued effects

Below are non-valued effects identified during the calculation work.

Saimaa Canal
The Canal will be closed for 1 month a year due to ice. This means, in turn, that transports will not be able to go on the Canal, which affects the effectiveness of alternative 1. During this month, one might be forced to have another transport solution or to store pulp. If the pulp is stored, storage space and additional handling costs will be required. Instead if different transport solutions are used, costs probably will occur due to the changed conditions. It is, most likely, more efficient and cheaper to use the same transport solution during the entire year.

This non-valued effect is probably the one with the greatest impact on the transport choice. It is hard to value this effect in monetary costs, but it is considered to be significant.

Train
Electrified railways are emission-free in the calculations in accordance with the method. However, this might underestimate the climate effect depending on how the electricity used is produced.

Accident cost
For the truck transports accident costs are being calculated according to the method, which is based on vehicle kilometres. For ships and trains there are no available values regarding this type of cost. The reason for this is probably due to lack of relevant data since there are few accidents for these types of transport. Accident costs regarding ships and trains are therefore being considered a non-valued effect where the actual costs are underestimated for the scenarios.

Roundtrips
The calculations are made for one-way transports from Joensuu to Dusseldorf. If any of the transport alternatives can attract transport volumes for the return trip, this will affect the total costs for the return trip. But since the transport demand in the opposite direction is not known, the effects have not been calculated. If any of the alternatives are more suitable for return-trips, this alternative has advantage over the others.

Value of goods
For the transport buyer, the travel time of the goods is of importance since capital is tied up in the goods. This means that a shorter transport time from Joensuu to Dusseldorf is preferable. Of the studied alternatives, Alternative 2a and 2b has the shortest transport time of approximately 70 hours including resting time for the truck drivers. In the other alternatives the transport time is nearly twice as long due to lower average speed and longer transhipment times.

Regulations on the Rhine
There are no fairway dues or other fees for ships on the Rhine however it is requested that the sea-going vessels comply with Rhine Vessel Inspection Regulations (RVIR). A specific certificate will be issued to the ships that use the river. To get the certificate, the ships must meet certain requirements. For example, installations of specific equipment like radar and AIS (Automatic Identification System). This might lead to an extra investment cost in Alternative 1, which is the only alternative where ships use the Rhine.

4.3 Summary/conclusion

The results from the socio-economic calculation show that Alternative 1, with direct vessels from Joensuu to Dusseldorf, is the most advantageous. This applies both to the total costs as well as the costs that affects society in terms of wear and tear, accident costs and emissions. The fact that the total socio-economic costs are lowest for this option indicates that it may be beneficial for the society to try to influence carriers to choose this transport mode.

Even when studying the costs incurred for carriers in terms of transport costs, fairway dues and loading and unloading costs, alternative 1 is best and should therefore be the most attractive transport mode for the carriers. However, there are also non-valued effects related to this alternative, which might affect the attractiveness of this alternative. The one with the greatest impact is probably the fact that the Saimaa Canal will need to be closed for a month due to ice. This means that one will need to choose a different transport mode during this month or to store the pulp before shipping when the Canal is reopened. It is hard to value this effect, but it is considered significant and will add a “cost” to Alternative 1.

From the results it can also be seen that the alternatives that use rail transport in Finland and Germany (Alternative 4 and 6) are preferable to the alternatives where trucks are used. These alternatives also have the lowest emission costs. In the calculations the Finnish values have been used regarding the emissions. These values are significantly lower than the Swedish values, which means that the costs of emissions will be lower in relation to the other costs. If the Swedish values regarding emissions had been used, the emission costs would increase for all alternatives. Since the emission costs would increase proportionally to the relation between the Finnish and Swedish values, the alternatives with the lowest emission costs would also have the lowest actual increment. This means that alternative 4 and 6 would be better compared to the other alternatives. Since the emission costs are relatively low even in Alternative 1, this alternative would still have the lowest total socio-economic costs.

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