Comparison of transport methods for plastics from Belgium to Sweden

Alternatives, costs, environmental impacts and price of transport services

Bachelor's thesis in TIEPL - Industrial management and production engineering

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Comparison of transportation method for plastic goods from Belgium to Sweden
A look at environmental cost and price of transportation

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Abstract

In this work the C02 emission and cost has been determined for transport of plastic scrap from Antwerpen, Belgium to Smålandsstenar, Sweden. Boat, rail and truck transports have been investigated as well as combinations of these transport modes. The CO2 emission both for transport and for electric power generation as well as the cost has been determined through literature searching as well as in interviews with transport companies.

It was found that the train transportation was the one giving lowest CO2 emission. Boat transport also turned out to be rather environmentally friendly as well. Regarding the cost, it turned out that it was fairly equal, in the range of 18000-24000 kr per container.

Keywords: train, truck, boat, transport, CO2 emission, freight, intermodal

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Carl Thiringer, Göteborg, June 2021

Contents

1
Introduction

1.1 Background

Around the globe there is a global wish to lower carbon emissions because it is a contributing factor to global warming. By absorbing some of the heat from the sun and keeping it from leaving the atmosphere, the earth gets warmer[1]. CO2 from the usage of fossil fuels is one key factor for the increased CO2 in the atmosphere.

There is also not infinite amount of fossil fuels to extract, which also has lead to a strive towards reducing the usage of fossil fuels. One sector that today releases the second most carbon emissions, after energy production, is the transport industry [2] where companies have started to look in to solutions such as electrical vehicles, biofuels, hydrogen, shorter transports, and so on [3]. In the US the green house gas emissions from the transport sector is even larger than the one for the electricity production [4].

Due to the impacts of fossil fuel, EU put up a target to reach 10 percent of transport driven by renewable energy in 2020 [5], but this number has been updated to be 14 percent in 2030 instead [6]. One company that is working in the transport sector, and for which this thesis has been done is Ultrapolymers, and according to them more and more companies are starting to focus and invest in processes that gives a lower environmental impact because this will probably generate "Goodwill" for the company.

Due to the impact of plastics on our environment, for instance in [7], the plastic industry is under extra much scrutiny, and have to work to hard to reduce their impact on the environment in whatever way they can [7]. One possibility, without removing/reducing the usage of plastics, is to lower carbon emissions by lowering the emissions from transports.

Today, there are a huge amount of gods transports made by trucks, more than 42 millions 2020, and abroad about 381000 transports are made annually [8]. Even if trucks are starting to become less polluting, freight trains are at the moment better for the environment [9]. It is however unclear which logistical, environmental and economical consequences such a transition from an ordinary fossil fuel based transportation will bring. If it would be the case that there are logistical and economical up sides, or limited downsides, even more companies would be interested in rethinking their transport strategy in this way.

This report will be based on Ultrapolymers Nordics operation. Ultrapolymers Nordic is a subsidiary of Ultrapolymers which is Europe's largest polymer distributor. Which means that they have a portfolio of different plastics and polymers from different manufacturers, and sell and deliver their products to other manufacturing companies (https://ultrapolymers.com/). Ultrapolymer Nordic have a number of customers in Jönköpings län where the majority of plastics are sold. Ultrapolymers is owned by Ravago, which is a Belgium-based plastic producing company.

1.2 Purpose

The purpose of the report is to compare the different transport options of plastic goods from Belgium, in this case specifically from Antwerpen to Jönköpings län. The options which will be investigated are by truck, by rail and by boat. The aspects that will be compared are the environmental aspects (energy and CO2 equivalents) and economical aspects, but also the logistical solution. One important step to reach the purpose of the report is to map and analyse the economical and the environmental impact of the transport systems.

1.3 Research questions

In order to come to a conclusion about the current and future routes and flows both needs to be examined with stating the following questions.

- How does the flow look like today in terms of volumes and stakeholders involved.
- What are the alternative route setups?
- How does the cost structure look like today and can be in future setup.
- What are the environmental impacts of today and suggested future setups.
- What are the effects of different alternatives?

1.4 Scope and limitations

There is today a lot of goods in Ultrapolymers network that could be moved from road to other modes of transportation. This report will however only look at one specific case. That is when plastic goods is transported from Antwerpen to industries in Smålandsstenar in Jönköpings län with focus on Ultrapolymers Nordics customers in the area.

This work will not look at what happens to containers after the plastic polymer transport has been made. However, an important issue in transportation is indeed the imbalance of goods sent and goods received. This means that containers arriving full can, if there is nothing to refill them with, leave empty, which is a waste of money and is unnecessarily effecting the environment. However, according to Ultrapolymers Nordic, this is more of a problem when the trucks are coming to Sweden, due to an imbalance in transport needs, with a higher need in the southward direction. Only CO2 and no other greenhouse gases will be treated.

1.5 Layout of report

After the introduction a theory Chapter follows introducing the energy and environmental aspects. After that follows Chapter 3 where the method used is described. After that, the analysis chapter follows where the different transport routes are investigated. Finally before the conclusion comes, Chapter 5 presents the comparison of the different transport paths.

2
Theory

2.1 Environmental impacts of transportation

In the atmosphere there are a lot of different gases, some of these are called Greenhouse gases, and one important of these is carbon dioxide, CO2. The greenhouse gases absorb some wave lengths of the heat radiation that is about to leave earth. The heat in the gases is redirected towards earth in a different wave length and is then absorbed again and again to retain even more heat. Because of the greenhouse gases, the heat radiation is retained in the atmosphere until the wavelengths are so long that they cannot be absorbed anymore, and the remaining heat is sent out in to space. The greenhouse effect is necessary for all life in earth and without it the earth would be approximately 30 degrees colder than it is today [11]. The greenhouse gases work a bit like a blanket that keeps the earth at a stable and warm enough temperature.

C02 is a dominating greenhouse gas, ans also the one that is most frequently mentioned. In order to quantify environmental impact on the global warming/greenhouse gas in the atmosphere, environmental impacts of various kinds can be quantified using the term CO2 Equivalents [12]. Different greenhouse gases do not affect the atmosphere to the same amount. Methane has for instance an 20-80 times stronger greenhouse gas effect than CO2, depending on which time horizon that is utilised, in [13] the value of 86 is given for the effect over the coming 20 years and 25 over the coming 100 years. To be able to calculate and compare the different gases a unit of measure is needed. That is why the unit CO2-equivalents is used when comparing the damage done by the different gases. Basically everything is converted to how much CO2 that is required to affect the environment the same way. Since different Greenhouse gases have different life expectancy, as the example above shows, the environmental impact differs a bit from CO2 depending on for how long time that is considered. That is why the usual time CO2 equivalents is counted, is 100 years.

When the amount of greenhouse gases in the atmosphere increases, the greenhouse effect increases as well. It can be compared to putting another blanket on top of the earth, which leads to increasing global temperatures. This rise in average temperature across the earth is called Global Warming and is the main source of climate change. [11]

There are many reasons for the increase of Greenhouse gases in the atmosphere. One is deforestation (less trees that can take up CO2) and another is the agricultural sector which both cause great emissions of greenhouse gases. But the biggest factor, and most important to this study, is the burning of fossil fuels. Fossil fuels are made up of remains of old plants and algae. These plants and algae has captured CO2 from the atmosphere through the photosynthesis millions of years ago. The dead plants and algea have during millions of years been buried and have through the years been turned in to coal, gas and oil. When the oil is pumped from the ground and burned, old CO2, which haven't been in the atmosphere for a very long time, is released back in to the air. The living plants on the surface can't compensate and take up the huge increase in the amount of CO2 in the atmosphere from the burning of fossil fuels, which leads to more greenhouse gases in the atmosphere, and with that a higher temperature on earth.

2.2 About modes of transportation

In todays society transport of people and goods are an essential part of how the society works. There are a number of ways to transport goods and people, such as by trucks, busses, cars, ships, aircrafts to mention some. The focus so far has been mainly on price and time for the transportation, and for people also the comfort is an important issue. Safety is also an important issue. During the last decades there has been an increasing interest for the environmental impact as well. In the beginning, when the oil crises in the 1970-ies took place, the worry was the price increase and the issue of having a guaranteed energy supply [14]. Also the fact that the fossil fuels are limited was an important issue. However, lately the discussion has been turning more and more over towards the global warning caused by greenhouse gases.

A truck is the most flexible solution and therefore the one which is least likely to cause severe problems in the supply chain. Boat will likely not cause any problems either, unless there is a strike at the port in Gothenburg, which isn't entirely unlikely and has happened before. Train is by far the most likely to encounter problems with only 82.9 percent of trains arriving on time in 2020 [15]. This number is the highest since at least 2013 and is the lowest since 2013 is 73.2 percent, and that happened in 2018, [15].

Furthermore, due to the easiness of using trucks, they can be ordered on short term need basis, which simplifies the transport planning. If transferring the transport of the plastic goods to trains and ships there is a need for more long term planning. Since one of the bigger problems for trains is their unreliability and their sensitivity to other disturbances, it means that an non arguably necessity for the future, in order to increase the competitiveness of train transports, is to build more railways in order to increase the capacity on the tracks, which should lead to access to more trains and more trains on time [16].

2.3 Energy usage in transportation

2.3.1 Energy relations

The unit for energy is Joule $[J]$ or WattSecond $[Ws]$ where W is the unit for power, and their relation is

$$Energy = \int Pdt \tag{2.1}$$

Often energy is expressed as kWh instead of Joule and the relation is

$$1kWh = 3600kWs = 3600000Ws = 3600000MJ = 3.6MJ \tag{2.2}$$

2.3.2 Energy in transport

In order to make a comparison between the impact of various transport ways, it is convenient to recalculate the energy needed to transport 1 ton of goods 1 km. As an example, a Nissan Leaf (an electric car) needs with a weight of 1,7 tonnes consumes 0.16 kWh to drive 1 km [17], which as will be noted later is approximately 3 times more than what is needed to transport 1 ton 1 km on railway.

There is a wide spread of information regarding the energy needed to transport goods. The source selected to be used in this work for railway transport was a report from [18] and the energy need is measured to be 0,09 MJ/tonne-km. This results in an energy consumption that is 4,5 MJ/container-km, assuming 25 ton of load and 25 tons of wagon weight.

The following energy usage in BruttoTonKm for the three types of transportations that will be used in this thesis, truck, train and ships are presented in Table 2.1.
The value for the truck transport was taken from [19]

Table 2.1: Energy transport consumption per Bruttotonkilometer.

	Energy kWh	Energy MJ
Truck	0,05	0,19
Train	0,025	0,09
Boat	0,078	0,281

A comment regarding the energy consumption from trains is that it varies strongly with the type of transport. In [20] the consumption is 34 Wh/tonkm for a high-speed transport train (130kpm) down to 11.6 Wh/tonkm for an iron ore train.

2.4 CO2 emission

2.4.1 Direct CO2 emission

When it comes to trucks, these are today in principle almost all combustion engine driven, mainly diesel is used as fuel. The same goes for boat transports. Also train transports can be driven by fossil fuels, in for instance the USA, this is common, but also in parts of Europe, for instance Denmark, it is not uncommon either.

According to Transportstyrelsen [21] the 2020-2024 target for cars in average is 95 g CO2/km and for vans 146g CO2/km. A car has a weight of 1-2 toms meaning 48-95 g/CO2/km. According to [22] the emission relation for diesel is 2.6 [kg CO2/liter of fuel] which means that a very modern low fuel-consuming car that uses 0.04 l of diesel for 1 km emits 104 g /CO2, so the 95g CO2/km in average is an ambitious goal.

A long-haul truck can take about 23.5 ton payload and consumes about 0.3 l/km and thus emits 780 g CO2 per 23.5 tonnes transported goods per km. 1L diesel of diesel has an energy content of 38 MJ, meaning 11.4 MJ/km for the whole truck and 3.1 kWh, giving per netto ton-km 132 Wh/km, and 65 Wh per km per brutto-ton (the weight of the truck included). This number i slightly higher then the one given in Table 2.1, but in principle very similar.

If the train is diesel drive, than, of course, there is a direct CO2 emission as well. In Europe the railways are usually electrified, however, in the USA there are a large amount of track-km that are not electrified. However, in [9] it is found that the fuel consumption transporting goods using diesel trains is 67-75 % times lower than using trucks per ton-km.

2.4.2 Indirect CO2 emission

Another aspect that is important is where the energy for transporting the goods comes from. Unfortunately, a lot of it comes from fossil fuels. Also power sources operated by renewables, such as water, sun, wind, have CO2 emissions, related to manufacturing of the power plants. This means that for each kWh electricity used there will be a CO2 emission. This emission depends on the country the electricity is generated in. Norway and Sweden has a very low CO2 emission per kWh electricity while Germany and in particular Estonia have very high values of CO2 for the produced electricity.

So, for trains running on electrified tracks, which is the typical situation in Europe, and in this work as well, no direct CO2 emission occurs, however, electricity is consumed. The same is true in the future for electrically driven truck and ship transports as well. In Table 2.2 the CO2 equivalent per MJ and kWh is presented, taken from [10]

Table 2.2: CO2 emissions for some fuels used for electric power generation, [gCO2 eq/kWhJ and gCO2 eq/MJ

	gCO2 eq/kWhJ	gCO2 eq/MJ
Coal	820	2952
Gas	490	1764
Nuclear	12	43
hydro	24	86
Wind	12	43
Solar	45	162

This electricity has to be generated, and depending on the country of generation, the CO2 emission very strongly. In Norway they are extremely low, while in countries with little hydro power as well as other renewables, and even more so if they lack nuclear power generation, the CO2 emission can reach equivalents as high as using fossil fuels directly. In Table 2.3 the CO2 emission per produced kWh for a number of countries is given.

Table 2.3: CO2 emissions per produced kWh for some different countries [gCO2 eq/kWh]

	[24]	[31],2016	[31],2019
Germany	485	456	338
Belgium	188	172	167
Denmark	316	231	126
Sweden	16	12	8
Estonia	1020	924	891
France	66	60	52
Netherlands	479	491	390
Norway	-	-	19

2.5 CO2 emission estimations

The CO2 data for road transport also varies in various sources. According to [23] road transport releases 62g CO2 / tonne-km and sea transport releases 10g CO2 /ton/km. The value for the truck transport is a bit higher than the previously estimated one in Chapter 2, but anyway believed to be a better choice to pick.

When measuring the emissions from train transport it has to be considered which country the train is traveling through. The values selected was the [24] values from

Table 2.3

2.6 Other costs related to transportation

Apart from the cost of the energy to drive the transportation there are also substantial costs for the infrastructure, the driver as well as for the vehicle. Insurances, taxes, are further costs related to the transportation. The energy is typically diesel or electricity, however, petrol, natural gas, biogas and in the future likely more and more hydrogen [25].

The infrastructure costs vary from transport to transport [26]. Much transport enabling infrastructures such as roads, railways, waterways, airports etc have been subsidised by governments. In order to have funds for re-investments and maintenance, as well as for depreciations for earlier costs, fees are put on the various transports. For trains, track fees of various cost structures are imposed, and for trucks there can be road tolls as well as costs on the fuel to cover infrastructure costs. For ships there is typically a fee for entering and leaving ports, as well as a fee for using a pilot, also in this case for departing or arriving from/to a harbour. Out on open sea, there are today no fees. In inland waterways, i.e. channels/rivers, there are of course also fees.

There is continuously a vivid discussion concerning if the various means of transportation cover their real costs, in addition to what the real costs are. As mentioned in Section 2.2, train transports are today more complicated and riskier than moving goods by truck which is why there has to be some financial incentives to speed up the change. Increasing the fee to use the road by a truck would make it more expensive to move goods by truck and could make even more companies look at changing to a less environmentally burdening transport option.

In [27] it is claimed that the trucks do not pay their costs. Regarding this issue, it is of course possible for politicians to either punish (through for instance environmental fees) or promote, through various subsidies or other benefits, to support the infrastructure for a certain kind of transport. According to [28], only 20 % of the cost of the railway is covered by fees, and the rest covered by the state in Sweden. According to [29] sea transports cover their costs.

Loading and deloading is a cost that in contrast to the other ones has been less subsidised and in this report a general cost of 2000 kr for all reloadings, i.e between truck and boat (which was the information given by Schenker), between train and truck, as well as train and ship, has been used. The cost for doing the initial loading and final de-loading of the goods has been omitted in this report, assuming that it is always the same.

3
Methods/Case set-up

3.1 Analysis methodology

Since there are three different modes of transportation that will be compared, information regarding their energy consumption and CO2 emissions had to be collected. For each of the alternative, the various parts of the trip is determined. The length and type of transport is found. Then the energy needed as well as the CO2 emission for each part is calculated and summarised. Finally also the cost for the different transport routes is established. To compare the different modes this report will look at the cost and emissions of moving one container that weights 25 metric tonnes from Antwerpen to Smålandsstenar. Both the current emissions and possible future routes is counted by measuring the distance and using the numbers from [23] and [18]. When the energy consumption and environmental impact and cost is calculated from the different scenarios, these can be compared to the current situation.

3.2 Transport route

Today the transport is made by truck all the way from Belgium to Sweden, which is a distance of 1100 km.

The assumed way a railway transport will travel is 25 km in Belgium, 230 km in the Netherlands, 512 km in Germany, 333 km in Denmark and 222 km in Sweden. When counting the combined route going through Gothenburg the train will only travel 184 km in Sweden and when stopping in Malmö it is counted as only going 16 km in Sweden.

3.3 Alternative future scenarios

This study investigates transport of plastic scrap to Trioplast in Smålandsstenar which only lies a couple hundreds of meters from the railway, but which currently have no way of receiving goods by train. It would seem unlikely that it would be "worth" to build new infrastructure, (for example a branch line from the main railway) but a limited study about this might be done, and thus only existing routes have been considered. So various combinations fo trucks, railway and sea transport utilising existing infrastructure will be investigated in Chapter 4

How one or several possible reloads might look like and in what kind of container or truck the goods would moved, are examples of aspect that need to be studied.

3.4 Primary data

Some key information is collected at meetings with Ultrapolymer and with Scandibulk. During the meetings the CEO of Ultrapolymer Nordic was present, along with one or two more employees. It was in these meetings were some information regarding the routes were collected.

The cost of some alternatives was given by Scandi Bulk, Ultrapolymers Nordic and Schenker by e-mail. Because of fluctuating prices in the transport sector they are a close approximation of the price, but will serve as the basis for comparison.

3.5 Secondary data

The majority of the data comes from earlier research, both in regards to cost and emissions. The data comes from for example Delft [18] and from other Thesis works at Chalmers [30] and KTH [23], see Chapter 2, Theory. This data was found by using research databases.

3.6 Model for CO2 and cost

In order to count the emissions and the cost of transport two different models are created to get an accurate result. The numbers are collected form Chapter 2 and also from this Chapter and are put in an Excel document where cost and emissions from all the different routes are calculated. The cost and emissions are counted per container, which is how much one truck carries today.

3.6.1 Overall description of model

In a separate Excel document, every indata have been stored and used in different ways. The emissions have been calculated by multiplying the weight of the container, and truck, with the distance and with the emission data of the specific vehicle. For the trains it also has to be considered in which country the train is driving in. That is because of the difference in CO2 from the different energy sources.

Calculating the cost is a bit more complicated. In addition to the numbers given by Scandi Bulk, Ultrapolymers and Schenker, a similar model as for emissions has been used. Unfortunately there isn't a number cost/ton*km because different aspects have to be considered with each transport method and route. Each of these calculations will be presented in the corresponding chapters. But in the end it can be summaries as Weight * Distance * Cost per ton*km + Fixed costs.

3.6.2 Input data

First, the distance is measured using google maps to get as close as possible. The emission data from is taken from [23] and [18]. According to Ultrapolymer, 25 tonnes per container is an appropriate value to use.

3.6.3 Transportation prices

According to Ultrapolymers a typical price is 18000 - 19000 kr per truck transport from Antwerpen to Smålandsstenar depending on the current price situation.

In [32] the price for transporting of gods with trucks managing 21 tons was determined, and it was found that the price per ton and km was 0.56 kr/ton/km. Their assumption was that this type of truck operated 130 000 km during a year including the fixed costs, driver cost and the variable cost for a total cost of 0.56 kr/km/ton. Using this data the transportation cost for moving one container the whole way with truck was 25 * 0.56 * 1104 = 15400. However, a larger emphasis was given on the price given by Ultrapolymers and accordingly the lower range price was used, 18000 kr.

Schenker provided a price approximation for transporting a container usin a truck in the range of ca 50-200km of 1.14 kr /ton/km. This number has been used for all shorter truck transports in this report.

The cost for moving one container by train the whole way given by Scandibulk was 19000 kr. This approximation was given for the case when a train was going directly from factory to factory, which are located 1322 km apart.

The cost of shipping by boat through Gothenburg came from two sources. From Scandibulk we got the price 15250 for moving a container from Belgium to Gothenburg. From Schenker we got that it costs 2000 kr per container for handling in Gothenburg harbour.

4
Analysis of route selections

The present transportation takes place using truck the whole route from Belgium to Sweden. In figure 4.1 the present route can be seen. Each truck brings a load of 25 tons of plastic scrap from Antwerpen to Smålandsstenar, going on motorways the shortest route (according to Google Maps) via Öresundsbron and the Rödby - Puttgarten ferry.

4.1 Present route

Figure 4.1: The present transportation route, conducted by truck all the way

4.1.1 Setup

Today the goods is transported using trucks from door to door. This solution is the least complex and the most reliable because it is not likely that the trucks are late. Each truck carries one 25 tonnes container and it requires a lot of trucks to move the needed volume. Every transport is bought at the current price and is sent to the location. The current price can vary depending on the current supply of available trucks and demand of transport.

The route begins in Antwerpen and goes through Belgium, the Netherlands and Germany until it reaches Puttgarten where it takes a ferry across to Rödby in Denmark. From there it continues across Denmark and over the Öresund bridge to Sweden. From there it goes straight to Smålandsstenar.

4.1.2 Result

Here the price figure given by Ultrapolymer, as mentioned in 3.6.3, of 18000 kr was used. In this route no reloading was needed so the price ended up in 18000 kr per container.

Based on the value of CO2 per ton per km, 62g CO2/ton/km the CO2 emission is found to be 2126 kg for the 1104 km of transport of the 25 ton container plus 6 ton for the truck. Then an additional 5 kg CO2 for the ferry between Puttgarten and Rödby.

4.2 Alternative route 1: Rail Antwerpen - Malmö

4.2.1 Setup

In figure 4.2 a transport alternative comprising rail transport from Antwerpen to Malmö, and from there truck to Smålandstenar, is presented. Using a direct line from Antwerpen to Malmö and transport by truck to the factories. Operators include for example Green Cargo. Unfortunatley it was not possible to get an answer from Green Cargo about how much this would cost. Instead, the train cost for the transport all the way from Antwerpen to Smålandstenar, given by Scandibulk, was used, but shortened to only go from Antwerpen to Malmö. Then the truck transport price of 1,14kr/ton km given by Schenker was used.

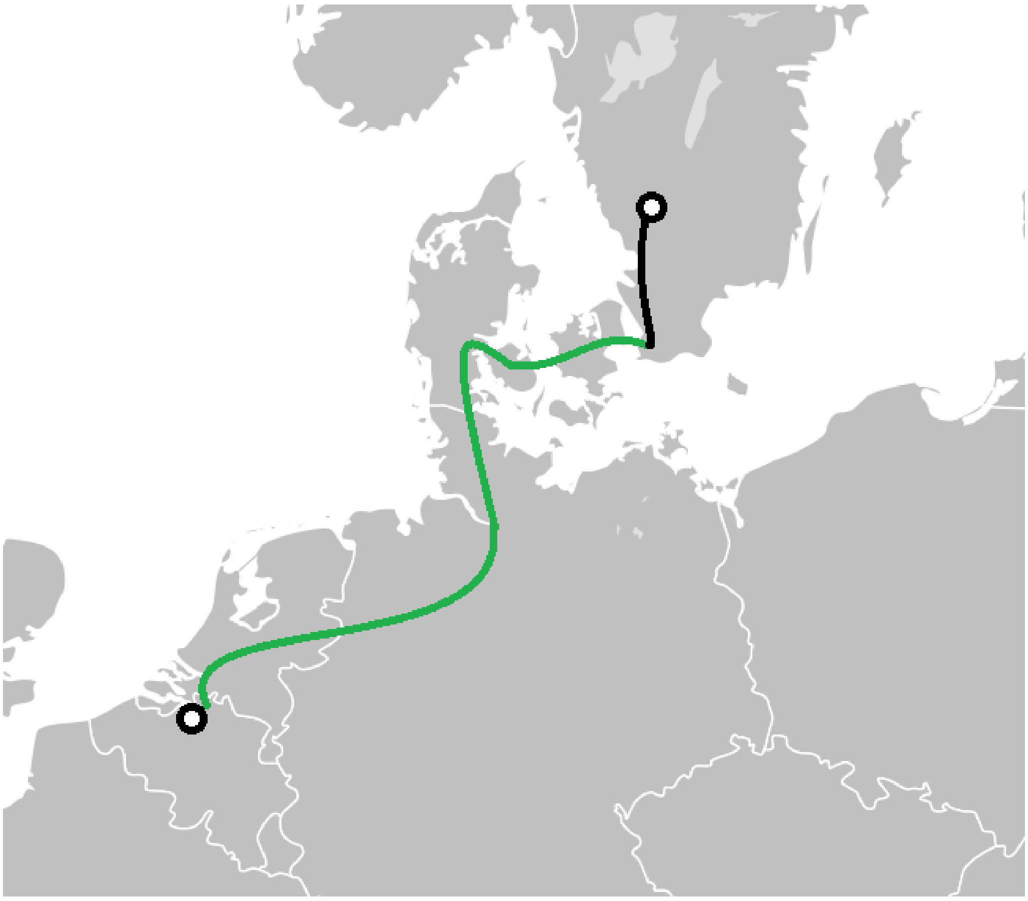

Figure 4.2: Transport alternative, train Antwerpen-Malmö and then truck Malmö-Smålandsstenar

4.2.2 Result

The train price estimation is scaled to only go to Malmö instead of Smålandsstenar (1116 km instead of 1322 km), giving the price of 16077 kr. Then the truck price for 200 km becomes 200 * 1,14 * 25 = 5700 kr. A cost of 2000 kr was added for the handling in Malmö when reloading. The total price was calculated to be 23777 kr.

The train travels 25 km in Belgium, 230 in the Netherlands, 512 km in Germany, 333 km in Denmark and finally 16 km in Sweden. Using the data from table 2.3 the CO2 emission is found to be 438 kg. The CO2 emissions from the truck transport is found as 203 km * 31 tonnes * 62 g per CO2/ton/km = 390 kg CO2. This gives in total 828 kg CO2.

4.3 Alternative route 2: Rail Antwerpen - Smålandsstenar

4.3.1 Setup

In figure 4.3 a transport alternative with train all the way from Antwerpen to Smålandsstenar is depicted.

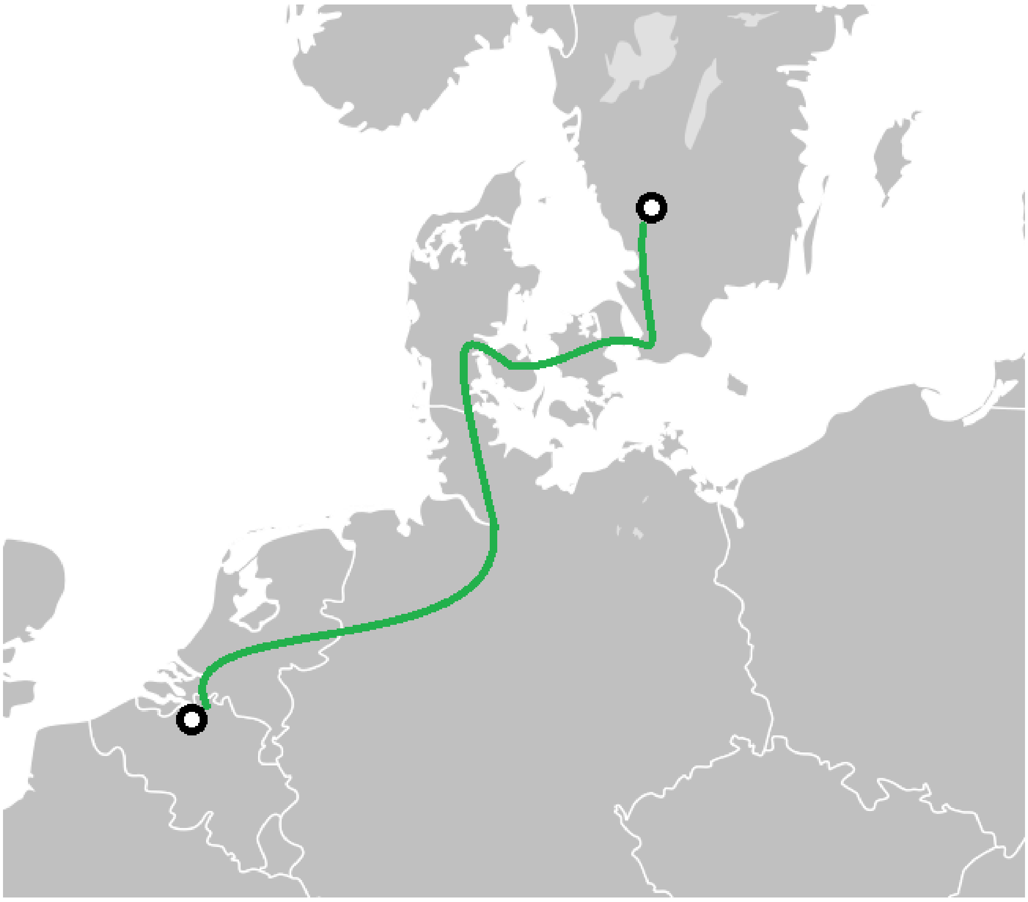

Figure 4.3: Alternative with rail transportation all the way from Antwerpen to Smålandsstenar.

Using the same route as before but hiring a new rail transport company to ship the goods even closer to the factories. This hypothetical unloading point is located approximately 3 km south of Trioplast/Smålandsstenar center. This route is currently not electrified and would today probably run on diesel. Since there does not currently exist a terminal which would be able to receive containers this report will be using a future scenario where both an electrified rail and a terminal exists in order to show the probable best case scenario for the environment.

Building new infrastructure at the factories would help to get the train closer to the factories. One condition for the new route "Trains to factories" is that a combi-terminal is build in the southern part of Smålandsstenar. Here the train can be unloaded and the goods can be taken the last few kilometers to the factories by truck. Although no official source, according to Ultrapolymers, there is a discussion at Gislaveds kommun to build one of these terminals at that place. Another option is to build it at a place directly at the factory to receive trains there. This requires much more specific infrastructure and probably can't be used by others if needed.

4.3.2 Result

The price information of the train transport was, as previously mentioned, given by Scandibulk, and was 19000 kr per container. In addition to this price another 2000 kr per container is used as handling is added representing the final distribution to the factory. This equates to a price of 21000 kr per container.

The CO2 emission was the second lowest in the investigation done in this report. The train travels 25, 230, 512, 333, 222 km in Belgium, The Netherlands, Germany, Denmark and Sweden respectively, giving emissions of 447 kg of CO2.

4.4 Alternative route 3: Boat Belgium - Göteborg

4.4.1 Setup

In figure 4.4 the next route is presented, which is utilising a boat from Belgium to Göteborg with truck transport from Göteborg to Smålandsstenar.

The boat could leave from from different ports in Belgium, either Antwerpen, Ghent or Zeebrugge, and then to Göteborg and finally truck from there. It was decided to use Ghent, since many botas seemed to leave from there. In the discussion with the various companies it turned out that there is a bit of a drawback to use Göteborg harbour since it is considered as an unreliable harbour, although lately it seems like a very long union conflict has started to approach an end. Another drawback is that Göteborg harbour is also an expensive harbour.

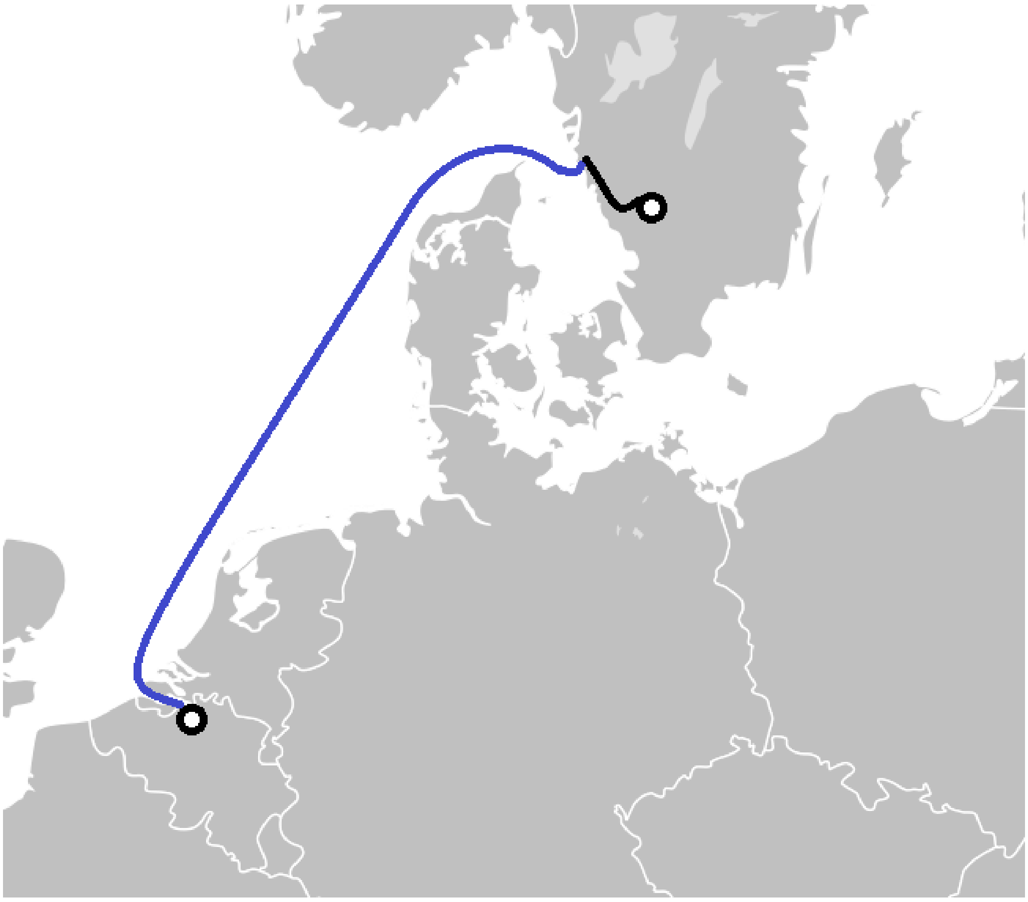

Figure 4.4: Boat transport from Belgium to Göteborg and then truck to Smålandsstenar.

4.4.2 Results

The price for the shipping of the container from Belgium to Göteborg was given by Scandibulk and was 15250 kr. The reloading price of 2000 kr per container was again used. Finally the truck price per ton km that was given by Schenker was 1,14 kr/ton km. With a distance of 150km the total truck price is 1.14 * 25 * 150 = 4288 kr. The total price thus becomes 21538 kr.

The boat trip was 1000 km times the CO2 emission per ton km from [23], 10 g CO2, gives 250 kg CO2 emission per container. Adding the CO2 emissions from the truck of 150 km * (25 + 6) ton * 62g = 300 kg. The CO2 emission was fairly low, 550 kg of CO2.

4.5 Alternative route 4: Combined Sea-Rail Antwerpen - Göteborg - Vaggeryd

4.5.1 Setup

In figure 4.5 the last route is presented.

Using the same route as before, although the factors when choosing the best transport could be different from the previous scenario, the goods are moved to a freight train and transported to Vaggeryd. This is a Service Göteborgs Hamn calls "Railport Scandinavia". The containers can be stored at Vaggeryd until the are moved to the factories. The train leaves every day. A benefit is that it is a very short truck route and that the infrastructure is there. again a drawback is that Göteborg harbour is expensive and has historically been unreliable.

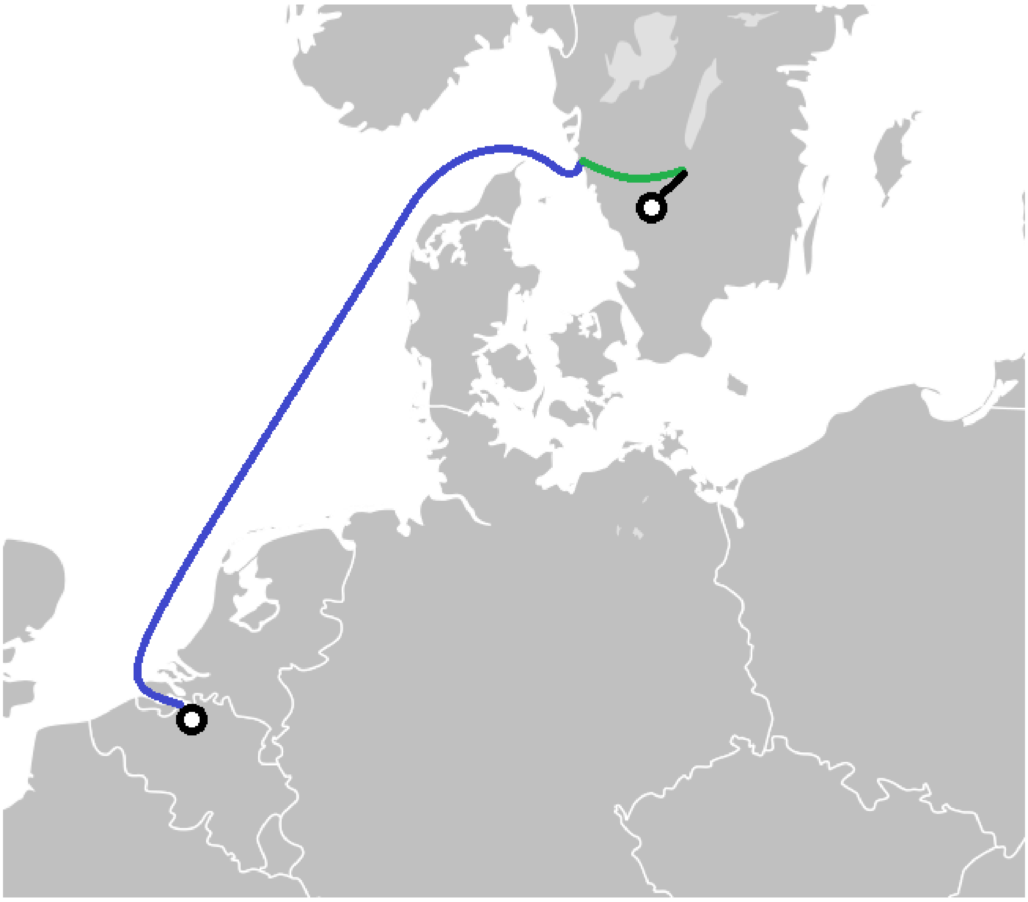

Figure 4.5: Boat Belgium to Göteborg, then railway to Vaggeryd and finally truck to Smålandstenar.

4.5.2 Results

The price for the boat trip is the same as in the previous alternative route, 15250 kr. The price for reloading in the harbour and reloading at the combiterminal in

Vaggeryd is set to 2000 kr per container for each reload. The price for the train part is calculated by the distance, 184km, and scaled from the from the price given from Scandibulk, giving a price of 2690 kr. Finally the truck cost was 65 km * 25 ton * 1,14 kr /ton km = 1852 kr. This gives a total price of 23792 kr.

The CO2 emission from the boat part is once again the same as the previuos route, which is 250kg CO2. The train is this time only traveling in Sweden and can then be more easily calculated with as only 184 km * (25 ton + 23 ton) * 5 g CO2/MJ * 0,07 MJ/ton km = 3kg CO2 per container. Truck emissions was given by 65 km * (25 ton + 6 ton) * 62 g CO2/ton km = 125 kg CO2 per container. In total this gives the lowest amount of CO2 of only 378 kg for one container transport.

5

Comparisons

So what are the effects of different alternatives? The truck alternative provides a low risk, hassle free and easy solution. However as shown, it is the worst solution for the environment, and will continue to be so.

The boat alternatives provides a middle way. It is much better for the environment than the truck and cheaper than rail. It is slightly more complicated because of more actors/connections.

5.1 Resulting price

As was found in this investigation, and presented in figure 5.1, the prices are somewhat similar. Going from approximately 18000 to 24000 kr per container. The prices given and calculated are presented in Table5.1.

Table 5.1: Resulting price for the various alternatives

Route	Price (kr)
Present route	18000
Rail Antwerpen - Malmö	23700
Rail Antwerpen - Smålandsstenar	21000
Boat Belgium - Göteborg	21538
Combined Sea-Rail Antwerpen - Göteborg - Vaggeryd	23792

It should once again be said that these prices can vary from day to day and are not set in stone. The price for a delivery by truck have been at least 21000 kr in some cases as well.

Figure 5.1: Price of transporting one container of plastic goods using the various alternatives.

What this shows is that the price approximations are too close to solely base a decision on this report. It can however be shown that the prices of transport are similar enough, so that it can't be the only argument used when deciding mode of transportation.

5.2 Environmental impact

In figure 5.2 the resulting CO2 emissions are presented.

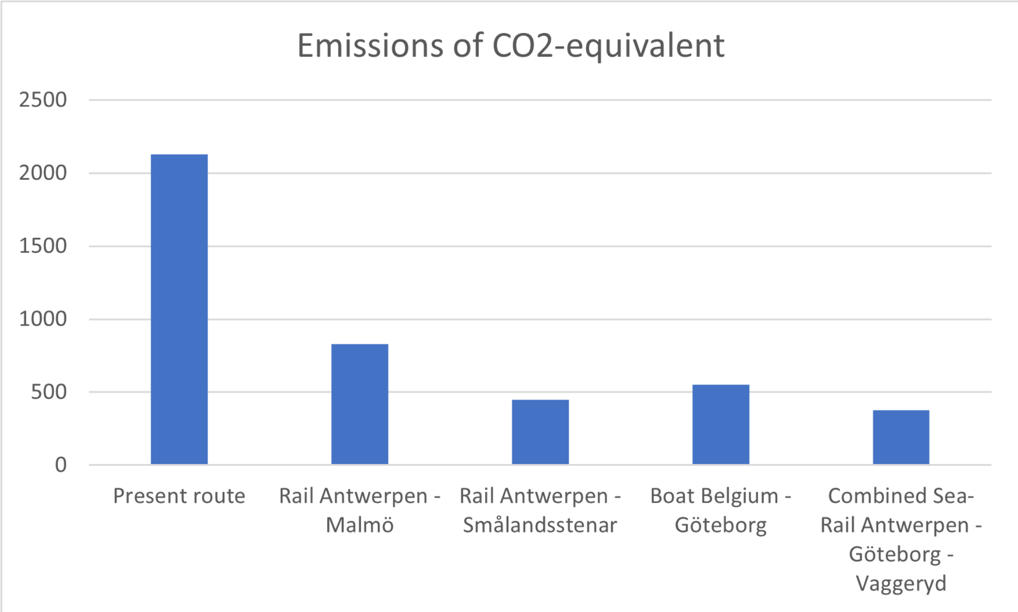

Figure 5.2: CO2 emission for transporting one container of plastic goods using the various alternatives.

In Figure 5.3 the CO2 emissions split into the various transport means is presented

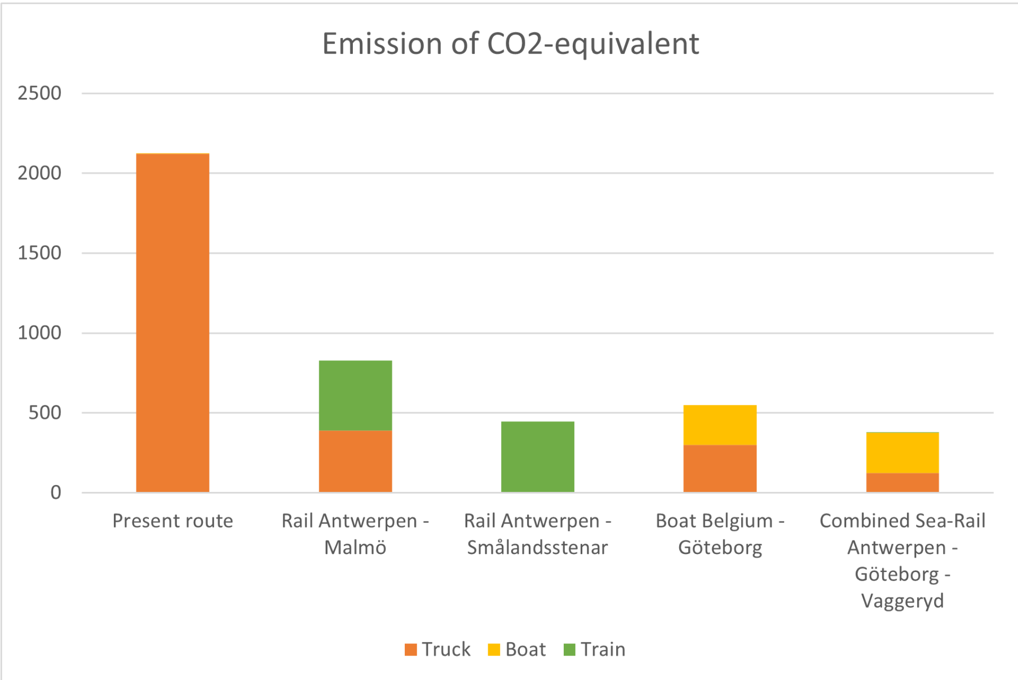

Figure 5.3: CO2 emission for transporting one container of plastic goods using the various alternatives, separated into the different transport means.

It is clear that transport by truck causes the most CO2 emission, which means that todays solution by far the most impact on the environment. As seen in the graphs, it releases more than four times as much CO2 compared to some of the other alternatives. It can also be seen that a big part of the emissions from the boat or train alternatives comes from a truck driving the first and last distances to and from the factories.

Worth mentioning is that the CO2 emissions when generation electricity using powerplants are on their way down rapidly, see Table 2.3. So it is just a question of time before the rail alternatives will outcompete the boat alternative.

5.3 Other aspects

The differences in transportation times is not entirely clear, however a time of two days for every route seems plausible. The time is important because of the investment value tied up in the transport. The less time moving, the less goods is in transport and that leads to less money tied up in goods.

6
Conclusion

In this thesis work, it is investigated how a transport of plastics could be made in alternative ways and the resulting consequences in terms of CO2-emissions and price. The focus is on CO2 emissions, however, costs are also treated. Today, the transport of plastics is made using trucks, that transports the plastics directly from factories in Belgium up to Småland. This is a very convenient transport mode, where only a truck transport company, including driver is involved and a robust system, since trucks are very flexible in case of 'transport path disturbances'.

Four alternative routes were investigated where parts of the whole trip was replaced with boat and train transport. The first alternative was rail from Belgium up to Malmö, where then truck transport is used for the last part. The second alternative was to replace the whole truck transport with train transport instead. The third was to use boat all the way to Göteborg from Belgium and then truck the last part, and the last alternative was the same as the third one, with the difference that train was used from Göteborg to Vaggeryd, where the last part was made with truck. Worth mentioning is that route two requires an investment regarding the train access at the factory in Smålandsstenar, while the other do not require any new infrastructure investments.

The cost structure today comprise of Ultrapolymer buying a container transport where the price can vary (depending on the daily price situation) and in this report a price of 18000 kr has been used.

It was found that all four alternative transport routes reduced CO2 emissions and the most favorable one was the combined sea and rail route, with only a small amount of truck transport. Sea transport turned out to be the least CO2 emitting alternative. The reason why using train for the whole distance was not the most favorable one, is due to that the ship transportation could take much goods for a limited fuel usage, but also since today, electricity is generated in great extents from fossil fuels. In the future, and already today in Sweden, electricity will to a great extent come from non-fossil fuels and it is likely that train will become the more favorable way from a CO2 point of view. So, with decreasing CO2 equivalent for generating electricity from power plants as the trend today is, train transports will further reduce the negative impact on the environment.

Regarding cost, all alternative routes showed a slight decrease in cost, the highest was when boat, rail and truck was used, 23792 kr.

A suggestion of future work more detailed cost and CO2 calculations could be done.

More sizes of boats could be investigated, as well as using trains with higher or lower top speeds.

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