Measurement of Green Corridor environmental impact performance
- A2A logistic corridor concept

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Baltic Sea Region
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FOREWORD

This report was produced integrated with the Bothnian Green Logistic project. A draft of this report was available for comments from the BGLC project members during 4st of June 2013 to 24th of June 2013. In the same period a representative for each model, the NTM model and the EcoTransIT model, was asked to comment the draft. The comments have been assimilated to the report when appropriate.

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SUMMARY

GENERAL

The development of Green Transport Corridors originates from the European Commissions´ intentions to develop a transport policy that meets the challenge of environmental concerns and climate change while increasing the competitiveness. Basically Green Transport Corridors aims for efficient and smooth transport solutions that minimize environmental impact.

Green Transport Corridors are characterized by the following: sustainable logistics solutions with documented reduced environmental and climate impact; high safety; high quality and efficiency; integrated logistics solutions with an optimum utilization of transport modes; harmonized rules with transparency for all stakeholders; a concentration of national and international freight in relatively long distances; efficient and strategically located transfer points and adapted and supporting infrastructure; a platform for development and demonstration of innovative logistics (information systems, collaborative models and technology).

The aim for this study is to gather basic material to suggest how to measure the performance of Green Transport Corridors. A measurement of Green Transport Corridor performance has been carried through for the A2A logistic corridor concept. It is a new transport corridor concept connecting the Atlantic Ocean with the Adriatic Sea through northern Norway, via Sweden and Poland to Italy. The hypothetical transport case is 1000 tonnes of fish transported by train or truck in combination with a ferry crossing over the Baltic Sea, from Bodö in Norway to Gdynia in Poland.

Two different tools, the NTM model and the ECOtransIT model extended version, were used for the calculations and they are freely accessible from the Internet. Both the tools were developed to measure environmental impact of transports. The parameters energy consumption, CO_2, NO_X, SO_2, PM (atmospheric particulate matter) and NMHC (non-methane hydrocarbons) have been calculated for transport combinations of train and boat as well as truck and boat. The impacts of transshipment, shorter transport distance; electrification of rail and size of trucks has been elaborated in this study.

CONCLUSIONS

Result from calculations of the A2A logistic corridor concept example indicate that the combination of train and boat is much more energy effective than the combination of truck and boat, at least 40% more effective when using the NTM model and its background features, and as much as 70% more energy effective when using the ECOtransIT model and its background features. If the entire railway would be electrified the outcome from calculations indicates that energy consumption would decrease with 35% in the NTM model and 52% in the ECOtransIT model for the train/boat combination.

The calculations indicate that the CO_2 e (GHG) emissions are much lower and the NO_X emissions are higher for the combination of train and boat than truck and boat for both models. Emissions of SO_2 are inconclusive in this study, differences in presentation and default assumptions needs to be further examined.

For a transport combination of train and boat, shortening the transport distances where ferry and diesel trains are used indicates the best environmental effect for both models. For the transport combination of truck and boat, both models show that shortening the distance for truck transports indicates the best effect on energy consumption and emissions of GHG, while shortening the ferry distance indicates large decreases on emissions of NO_X and SO_2. Both models indicate very small differences between the size of trucks (load capacity).

When using a specific calculation model it is important to pay attention to the special features of that model to be able to interpret the outcome, for example how the results are presented (well to wheel (wtw), well to tank (wtt) or tank to wheel (ttw)), if terminal handling is a general part of the transport or if it is possible to choose where and how it is performed, which emission classes for trucks are used and energy consuming and emission values used per km for different vehicles and for different areas (flat land, hilly land) and countries.

Bothnian Green Logistic Corridor

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For future measurement of Green Corridor performance different types of measuring are suggested. For specific transport chains the calculation tools NTM model and ECOtransIT model are useful. It would be positive if they can move towards each other in characterizing transport values. For monitoring a general overall methodology, gathering statistic information through member states is suggested.

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CONTENT

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The Green Corridor concept originates from the European Commissions´ intentions to develop a transport policy that meets the challenge of climate change while increasing the competitiveness in EU, and it was introduced in the EU freight logistics action plan in 2007 (2).

Sweden has been in the forefront of developing the Green Corridor concept, from 2008 by the work of the government Logistics Forum, and 2010-2012 through a governmental assignment to Swedish authorities to develop the Green Corridor concept. Green Corridors are characterized by (2):

- sustainable logistics solutions with documented reduced environmental and climate impact, high safety, high quality and efficiency
- integrated logistics solutions with an optimum utilization of transport modes
- harmonized rules with transparency for all stakeholders
- a concentration of national and international freight in relatively long distances
- efficient and strategically located transfer points and adapted and supporting infrastructure
- a platform for development and demonstration of innovative logistics (information systems, collaborative models and technology).

Measuring Green Corridor performance is of interest to many different actors. When arranging a specific transport chain the freight owners, forwarders and operators have an interest making the trip as efficient and environmentally friendly as possible. The EU, the governments and planning authorities have an interest in prioritizing investments correctly and eliminate bottlenecks to improve the transport possibilities.

Measurements are needed to be able to follow the development of the corridor, to make sure investments and activities are giving presumed results, and that transports are developing in a positive way. In case of general development an aggregated form of index per transport corridor would be very useful.

In the Bothnian Green Logistic Corridor (BGLC) project measuring of green corridor performance is an activity in the third work package (wp3). This activity aims at finding and using key performance indicators (KPI) to measure Green corridor performance. Two known models was tested in order to calculate KPI-effects and comment the results. The A2A logistic corridor concept, described below was used as a test stretch.

In 2012 the Swedish transport administration initiated a study about criteria to measure Green Corridor performance. Two aspects indicated a good performance, the enabling services (infrastructure, organization, ICT etc.) and the operational services. The study is focused on the later part, environmental emissions and energy consumption for different solutions. A tool for measuring, the NTM model, was developed (16).

In parallel, the project SuperGreen that was launched in 2010 has been in operation, assisting the Commission with developing the Green Corridor concept. The purpose of the project is to promote the development of European freight logistics in an environmentally friendly manner. The 3-year project is a Coordinated Action supported by the European Commission (DG-TREN) in the context of the 7th Framework Programme (17).

Within the SuperGreen-project a literature review of different projects and models were carried out to find appropriate KPI:s. Best practices of logistic projects and experiences from other sectors of society was elaborated on. Among these examples are the Swedish green corridors and the NTM model (18).

The SuperGreen-project arranged four regional workshops around Europe, and reached a final set of recommended KPI: s. A distinction between KPI: s for infrastructure and operation was determined, and operational KPI:s were chosen for calculating different transport chains effect on green corridors. Because of low statistical values the results are not aggregated to a single number for a corridor but instead presented in intervals. The partners decided

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that the best tool alternative was the EcoTransIT, if possible the extended version with more details. Transport chains in six transnational transport corridors were measured (19):

- The Brenner Corridor is relevant for transports from Sweden (Malmö/Trelleborg), through Germany to Italy(Palermo) and Greece(Athens);
- The Cloverleaf Corridor is mainly passing through United Kingdom (Glasgow – Liverpool - London) through Channel Tunnel to France and Germany (Duisburg), with a branch link to Ireland (Dublin);
- The Nureyev Corridor is mainly a short sea shipping corridor in the Baltic Sea, but rail-road connections Moscow-St Petersburg and Klaipeda-Minsk are also included. The largest ports along the route are Kotka, Helsinki, St Petersburg, Gothenburg, Hamburg and Rotterdam;
- The Strauss Corridor includes trade routes from Rotterdam to Black Sea (Rotterdam – Duisburg – Vienna – Bratislava – Budapest – Belgrade - Constata), and also the branch Paris – Frankfurt;
- The Mare Nostrum Corridor stretches along Mediterranean and Black Sea routes, focusing on the ports of Odessa, Constanta, Bourgas, Istanbul, Athens, Trieste, Gioia Tauro, La Spezia, Genoa, Marseille, Barcelona, Valencia, Algeciras and Sines;
- The silk way connecting the Far East and Europe, refers to the deep sea service Shanghai – Le Havre/Hamburg and rail link Beijing – Duisburg.

Table 1. Results from SuperGreen benchmarks for corridors. The results have been achieved by using EcoTransIT tool world web emission calculator, self-reported figures from interviewees and literature review. Source: Supergreen, Deliverable D2.4, Benchmarking of Green Corridors, Version 2, ID: 02-40-RD-2011-14-0-1 (19)

Corridor name	**Mode of transport**	**CO2** *(g/tkm)*	**SOx** *(g/tkm)*	**Cost** *(€/tkm)*	**Average speed** *(km/h)*	**Reliability** *%*	**Frequency** *x times/year*
Brenner	Intermodal Road Rail SSS	10.62-42.11 46.51-71.86 9.49-17.61 16.99	0.020-0.140 0.050-0.080 0.040-0.090 0.050-0.120	0.03-0.09 0.05-0.06 0.05-0.80 0.04-0.05	9-41 19-40 44-98 23	95-99 25-99 60-95 100	26-624 52-2600 208-572 52-520
Cloverleaf	Road Rail	68.81 13.14-18.46	0.091 0.014-0.021	0.06 0.05-0.09	40-60 45-65	80-90 90-98	4680 156-364
Nureyev	Intermodal SSS	13.43-33.36 5.65-15.60	0.030-0.150 0.070-0.140	0.10-0.18 0.05-0.06	13-42 15-28	80-90 90-99	156-360 52-360
Strauss	IWT	9.86-22.80	0.013-0.031	0.02-0.44	-	-	-
Mare Nostrum	SSS DSS	6.44-27.26 15.22	0.092-0.400 0.22	0.003-0.200 -	17 -	90-95 -	52-416 -
Silk Way	Rail DSS	41.00 12.50	- -	0.05 0.004	26 20-23	- -	- -

SSS= Short sea shipping, DSS=Deep sea service, IWT= Inland water transport

For each transport corridor 6-16 transport chains were identified. Interviews were held to collect data used for the calculations, for example load factor and empty trip factor, for most of the transport chains. It is noted that the interview process was very difficult and time consuming (19).

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1.2 A2A-ATLANTIC TO ADRIATIC LOGISTIC CORRIDOR CONCEPT

In the BGLC-project (wp4) a new logistic transport concept has been developed. A new intermodal shuttle connection for a train/boat service connecting the Atlantic coast to the Adriatic Sea via the Baltic Sea is aiming to start in the end of 2014. The service should be tailored to the temperature and time sensitive sea food industry (20).

Figure 1. A2A logistic corridor concept. Source: BGLC, Brochure: A2A-Atlantic to Adriatic New intermodal shuttle connection (20)

A possible schedule for the service has been drafted below.

Table 2. Draft A2A logistic corridor concept. Source BGLC, Brochure: A2A-Atlantic to Adriatic New intermodal shuttle connection (20)

Train 1	Train 2	Train 5	Boat				Boat	Train 2	Train 4	Train 6
08:45	18:00			Departure	Bodø	Arrival			07:50	16:20
09:30	I			Departure	Fauske	Arrival			07:10	I
13:00	I			Departure	Mo i Rana	Arrival			04:00	I
I	I				Mosjøen				I	I
22:15	06:20			Arrival	Trondheim	Departure			19:00	23:55
					Transshipment					
		08:00		Departure	Trondheim	Arrival		11:30		
		22.50		Arrival	Hallsberg	Departure		20:40		
		00:10		Departure	Hallsberg	Arrival		19:20		
		07:00		Arrival	Karlskrona	Departure		12:30		
			09:00	Departure	Karlskrona	Arrival	07:45			
			19:30	Arrival	Gdynia	Departure	21:00			

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CHAPTER 2
METHOD

This work was performed from August 2012 to May 2013 by Maria Öberg, research engineer/PhD-student, with support from Senior lecturer Charlotta Johansson and Professor Kristina L Nilsson, from Luleå University of Technology (LTU), Sweden. LTU is a partner in the BGLC-project and implementing partner of activity 3.6 Measuring of Green Corridor performance.

The research method has been formed in an interpretative way, meaning the research is done in a process where theory and empirical results is continuously evaluated for the choice of further steps. This leads to an accumulation of knowledge (21). This approach is also known as grounded theory, where the scientifically gathered data is the fundamental input for theory building.

Transport corridor

In consultation with the leaders of wp3 and wp4 in the BGLC-project it was decided that the new A2A - Atlantic to Adriatic logistic corridor concept would be used as an example in measuring Green Corridor performance. As a first step Bodö-Gdynia was chosen to elaborate on, being a part of the BGLC-projects area.

Transport case

The A2A logistic corridor concept is still on a planning stage, but there is an aim for starting up fish transports as a first step. Therefore a hypothetical case of 1000 tonnes of fish to be transported from Bodö to Gdynia was used.

Calculation models

There are several calculation models in use around Europe, in different projects and contexts. The SuperGreen-project, a Coordinated Action supported by the European Commission (DG-TREN) in the context of the 7th Framework Programme, has looked into many different models and *"…..the partners decided that the best alternative was to go with EcoTransIT….."* (19). It is not explained why this model was chosen, nevertheless by applying it in their project in six different transport chains it becomes an interesting reference object to relate to.

The NTM model is developed with strong support from the Swedish transport administration. Some project partners are already aware of and involved in this model.

The two models, EcoTransIT and NTM, have been chosen for testing to measure Green Corridor performance. By choosing two models the results can be compared and the differences commented.

Calculation examples

Transports by train and boat as well as by truck and boat in the A2A logistic corridor concept are calculated. The results show energy consumption and emissions from the transports.

Elaborations

When performing the calculations there were certain assumptions that needed to be made, like points of transshipments, actual transport route, and chosen vehicle. The effect of these assumptions on the outcome, the importance of for instance choice of route, came up as an interesting elaboration. Also noticing that almost the entire railway infrastructure in Norway is not electrified, the effects of electrification would be interesting to illuminate.

2.1 NTM MODEL

The NTM calculation model is a tool to get information on energy consumption and environmental effects of transports. The interface is excel, and the model intends to be simple and user-friendly, and thus give approximate values. The NTM calculation tool used in this study is available for free on the Swedish Transport Administrations website, in Swedish (2). If there is a need for more detailed knowledge, access to detailed methods, data and library can be required through a user account. Assumptions, specifications and uncertainties with this model are presented within the tool. There are detailed instructions in the tool how to carry through a calculation. These instructions have been followed in this study.

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The development and improvement of the NTM tool is carried out by working groups in NTM, the network for transport and environment, which is a non-profit organisation, initiated in 1993 and aiming at establishing a common base of values on how to calculate the environmental performance for various modes of transport. The network has 173 members, with a Swedish emphasis, but also large international transport companies, consultants and academia are members. At the moment four working groups are going on: goods and logistics, travel, transport procurement and fuels (24).
The working groups are open for all members. The Handbook on Emission Factors for Road Transport (HBEFA) is an important background source (5).

2.2 ECOTRANSIT MODEL

The ECOtransIT calculation model is a tool to get information on energy consumption and environmental effects of transports. The website is available in seven languages: English, German, French, Italian, Spanish, Dutch and Swedish. On the website it is possible to choose standard or extended version of calculation. A more detailed and customised calculating requires a user account. In this study the extended version of the calculation model, available for free at the website was chosen, where it is possible to let the transport be divided into specific parts with different modes of transport, load factor etc. It is described how to use the model in the websites “first steps”. These instructions have been followed in this study.

Rail management Consultants Gmbh (RMCon/IVE mbH), Institute for Energy and Environmental research (ifeu), Heidelberg and Öko-Institut, Berlin have developed the ECOtransIT tool. The project partners are found in an industry driven platform founded in 2013, and they are: DB Schenker, Germany; Schweizerische Bundesbahnen (SBB), Switzerland; Green Cargo AB, Sweden; Treniitalia S.p.A, Italy; Société Nationale des Chemins de Fer (SNCF), France; GEODIS logistics, France; Hapag-Lloyd, Germany; Gebruder Weiss, transports and logistics; International Union of Railways (UIC); Europe. It is open for new partners from all transport modes.

The scientific partners are Institute for Energy and Environmental Research (ifeu), Heidelberg and INFRAS Bern. The Handbook on Emission Factors for Road Transport (HBEFA) is an important background material among for example data from the Assessment and Reliability of Transport Emission Models and Inventory Systems (ARTEMIS) and the Ecoinvent database. Development of the software is made by IVE mbh Hannover. A methodology and data update report is available on the Internet (22) (23).

CHAPTER 3
MEASUREMENT

When using a calculation model certain assumptions are needed. In this section general assumptions are presented. Other choices made for each specific calculation model are referred to in the text regarding that model.

Electrification - rail

Theoretically, electric locomotives can be used where the railway is electrified, but in practice operators overall planning often affect the switch between diesel and electric locomotives. The present status is that the railways used for this logistic concept are not electrified in Norway, but they are in Sweden. Switching to electric locomotives in this case is assumed to occur in Storlien, close to the border between Sweden and Norway, as soon as it is possible to switch from diesel to electric locomotives.

Length and weight - rail

According to the draft for the logistic concept the following assumptions were made. Two shorter trains (load capacity 500 tonnes each) are used for transports Bodö-Trondheim. For Trondheim-Karlskrona a medium long train is used (load capacity 1000 tonnes).

The railway lines may have limitations in allowed train weight, length and loading gauges. Along the Nordlandsbanen and Meråkerbanen the biggest climb is 19 parts per thousand, which means appropriate

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locomotives must be chosen. General maximum train weight is 1000-1200 tons, and the maximum train length is 600 m (13)

Truck size
In EU the maximum allowed weight for a truck is 40 tonnes and maximum length is 18,75 m. Sweden together with Finland, Netherlands, Denmark (trial) and parts of Germany (trial) allows trucks at a maximum weight and length of 60 tonnes and 25,25 m (3).

Distances and routing
The same routing has been used for both models. For railway the routing Bräcke-Ange-Storvik is assumed as a first choice, since it is 52 km shorter distance than Ånge-Sundsvall-Gävle-Storvik. For road there are many alternatives between Stjördal and Karlskrona. Even if the A2A logistic corridor concept is closest to the routing Storlien-Sundsvall-Gävle-Västerås-Örebro-Mjölby-Eksjö-Emmaboda, the first choice is via Trondheim-Elverum-Karlstad-Jönköping-Växjö. Since it is 46 km shorter it seems more reasonable to use, and has therefore been the routing for calculation of truck transports.

There is a small difference, around 100 meters, between the distances used for train transport in the two models as well as for truck transports in the two models. In the NTM model the distance is an input made by the person who is performing the calculations. In the ECOtransIT model the nodes are determined using a map, and the program itself calculate the distance. The procedure is described below for each model. The differences have been considered to be small, so no additional calculations were performed.

Capacity - boat
The boats navigating Karlskrona – Gdynia are Stena vision and Stena spirit, both Ropax ferries, combining freight and passenger travels, with a freight capacity of 1,900 lane meters.

Load factors and empty trip factors
Default options are used for load factors and empty trip factors for both calculations models.

Table 3. Default values in NTM model and ECOtransIT model for load factors and empty trip factors for train and truck

Calculation model	Load factor			Empty trip factor	
	Train	Truck	Boat	Train	Truck
NTM	50%	60% (international truck trailer)	80%	No information	No information
ECOTransIT	60%	60%	57%	50%	20%

Empty trip factor=km empty/km loaded

Thermal transports
Additional CO_2 g/tonkm because of thermal transports are not included in the general calculation tools but it is found to be around 30% for truck and ferry transports and 40% for train and ship (container ship and feeder) transports (10). It has to be added to the calculations below.

Well to wheel
Well to wheel means the chain of producing fuel or similar and use it in a vehicle. It does not incorporate emissions from production of the vehicle itself or building of infrastructure (23). The result of calculations of emissions and energy consumption from the NTM and ECOtransIT models are presented in the form of well to wheel (wtw), or broken down to well to tank (wtt) and tank to wheel (ttw).

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3.1 NTM MODEL

The extent of the transportation route is A2A - Atlantic to Adriatic corridor. The system is divided into links and nodes in the NTM model, and then distance and weight are quantified. For each link the type of vehicle or vessel for the transport are chosen. For nodes, types of terminal are chosen.

Distances

Google maps are used as a tool to derive distances by road and boat, but distances by train is not provided. The distances by road have been manually adjusted, routes in city centers have been removed, due to passing freight transports mainly avoid city centers.

Information about the rail network is not very accessible for someone without special knowledge. Besides distance information is electrification and maximum permissible axle load valuable data to choose the correct vessel for the transport in the calculation model. The Swedish transport administration and the Norwegian national rail administration have information on their websites for each track. The Norwegian information includes distance and electrification, but not maximum permissible axle load. There is variation in the Swedish information, some tracks have limited information and some has information about distance, electrification and maximum permissible axle load. If the actual transport route only concerns parts of the track, then there is need for extensive information which requires some knowledge what to search for in the websites. In the Swedish transport administration and Norwegian national rail administrations websites respectively, it is available in a document called network statement (1,2). These statements contain other information that also might be needed for planning the transport such as allowed vessel profile and traffic control systems etc.

Regarding the route through Norway this web-based information was used since the both Nordlandsbanen and Meråkersbanen are entirely part of the concept (1). Maximum permissible axle load for Nordlandsbanen was confirmed by contact with the Norwegian national rail administration (13). For the route through Sweden it was chosen to request an account for the database BIS (rail information system) at the Swedish Transport Administration (4). It is possible that established transport companies already have the necessary information, which simplifies the use of the calculation model.

Table 4. Road information for A2A logistic concept

Route	Distance (km)	Main Roads
Bodö-Fauske	53	Rv 80
Fauske-Stjördal (outside Trondheim)	620	E6
Stjördal – Karlskrona (via Storlien- Sundsvall-Gävle-Västerås-Örebro-Mjölby-Eksjö-Emmaboda)	1167	*E14, E4, 50, 32, 47, 31, 28*
Alternative route Stjördal – Karlskrona (via Oslo-Gothenburg)	*1156*	*Rv 3, E6*
Alternative route Stjördal – Karlskrona (Via Trondheim-Elverum-Karlstad-Jönköping-Växjö)	*1121*	*Rv3, 61,26*

Rv=Riksveg

Table 5. Boat information for A2A logistic corridor concept

Route	Distance (km)	Comment
Karlskrona – Gdynia	300	Distance for passenger travels, but the ferries are combined for passenger and freight.

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Table 6. Railway information for A2A logistic corridor concept

Railway	Distance (km)	Electrified	Maximum permissable axle load (tonnes)
Nordlandsbanen (Bodö-Hell-Trondheim)	726	-	22,5
Meråkerbanen (Trondheim – national border at Storlien)	100*	-	22,5
Mittbanan (Storlien – Bräcke)	233	x	22,5
Norra stambanan (Bräcke-Ånge)	30	x	22,5
Norra stambanan (Ånge-Storvik)	266	x	22,5
Alternative route via Mittbanan/ Ostkustbanan (Ånge-Sundsvall)	*94*	*x*	*22,5*
Alternative route via Mittbanan/Ostkustbanan (Sundsvall-Gävle)	*217*	*x*	*22,5*
Alternative route via Mittbanan/Ostkustbanan (Gävle-Storvik)	*37*	*x*	*22,5*
Godsstråket genom Bergslagen (Storvik – Frövi-Hallsberg)	218	x	22,5
Godsstråket genom Bergslagen (Hallsberg – Mjölby)	95	x	22,5
Södra stambanan (Mjölby-Alvesta)	175	x	22,5
Kust-till-kustbanan(Alvesta-Emmaboda-Karlskrona)	131	x	22,5

** 71 km Hell-riksgränsen*

The railway between Emmaboda-Karlskrona has been reconditioned and re-opens in 2013 (2). Upgrading and electrification of the rail link to the port of Karlskrona will be completed in 2013 (2).

Terminals

Terminal handling refers to when transshipment is needed between freight carriers, or when the load carrier is moved to a direction other than the direction of travel (6). Terminal handling is assumed in Trondheim, with transshipment between trains according to the draft concept, and in Karlskrona for transfer between train and boat. Ferry crossing Karlskrona-Gdynia cannot be done by train, but trucks can use the ferry. In Hallsberg load carriers are assumed to remain on the train. Transport by truck does not have to be transshipped in this example.

The size of the terminal needs to be rated as small, medium or large. No guidelines for sizing terminals are available in the calculation program. However the rating is based on a Swedish perspective where for instance Hallsberg terminal is rated as large. It is one of the largest intermodal terminals in the Nordic and handles approximately 60,000 TEU annually (6). Brattöra with railway/port terminal close to Trondheim is the largest goods node for transport between Trøndelag, Østlandet and Nordland in Norway. In 2008 over 100.000 TEU annually were handled, meaning about 1 million tons goods annually over the railway terminal (1). It is also regarded as a large terminal. Terminal handling is needed both in Karlskrona and in Gdynia for transshipment between train and boat. Karlskrona is assumed to be a small terminal handling 1.5 million tons goods annually (8), and Gdynia a large terminal handling around 13 million tons goods annually (7) and over 600 000 TEU annually (11).

Electrification - rail

The model assumes rail transport driven mainly by electricity from renewable energy sources, "green power" (6). It is applicable for Swedish rail transport, but there can be a substantial difference between countries. For instance emissions of g CO_2/kWh from trains in Poland can be 100 times higher, due to coal-based electricity production (6). The best is of course to know the electricity mix used.

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Truck trailer - road
There are different vehicles to choose from in the model. An international truck trailer with a load capacity of 26 tonnes is the first choice, since the transport is international. Regarding type of motor, a weighted average between Euro 1-5 has been used, produced by NTM.

Calculation train/boat and truck/boat
The results show that the combination of train and boat transports in the A2A logistic concept example only need 60% of the energy consumption used in a combination of truck and boat according to the NTM model (262 478 kWh for train/boat and 433 359 kWh for truck/boat, see tables below). The emissions from train/boat transports are only around 20% of the GHG emissions for truck/boat (24 482 kg CO_2 e for train/boat and 110 444 kg CO_2 e for truck/boat, see tables below). On the other hand SO_2 emissions are around 50% higher (212 017 g for train/boat and 106 984 g for truck/boat, see tables below), and the NO_X emissions 10% higher, for train/boat than truck/boat (758 837 g for train/boat and 691 197 g for truck/boat, see tables below).

Table 7. Parameters for calculation in NTM-model, train/boat.

Link/Node	Weight (tonnes)	Distance (km)	Vehicle/terminal
Bodö-Trondheim	1000	726	Short dieseltrain (500 tonnes)
Trondheim	1000	0	Railway terminal large
Trondheim-Storlien	1000	100	Medium dieseltrain (1000 tonnes)
Storlien - Hallsberg-Karlskrona	1000	1148	Medium electric train (1000 tonnes) SE
Karlskrona	1000	0	Port terminal small
Karlskrona-Gdynia	1000	300	Ropax (2000 lm)
Gdynia	1000	0	Port terminal large

Table 8a. Results from NTM-model on the A2A logistic concept for train/boat, based on parameters in table 7 regarding energy consumption, GHG and NO_X.

TRAIN/BOAT	Energy		Global		Regional	
Link/Node	**Energy wtw absolute (kWh)**	**Energy wtw relative (kWh/tkm)**	**GHG wtw absolute (kg CO_2 e)**	**GHG wtw relative (g CO_2/tonkm)**	**NO_X ttw absolute (g)**	**NO_X ttw relative (g/tonkm)**
Bodö-Trondheim	128077	0,18	9016	12	494394	0,68
Trondheim	14567	-	1056	-	2836	-
Trondheim-Storlien	12474	0,12	878	9	48153	0,48
Storlien - Hallsberg-Karlskrona	48726	0	487	0	0	0
Karlskrona	16442	-	1270	-	3582	-
Karlskrona-Gdynia	42192	0	11774	39	209872	1
Gdynia	14947	-	1155	-	3256	-
Total	**262478**	**0,1**	**24481,7**	**10,8**	**758836,8**	**0,3**

wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

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Table 8b. Results from NTM-model on the A2A logistic corridor concept for train/boat, based on parameters in table 7 regarding SO_2, PM and NMHC.

TRAIN/BOAT	Regional		Local			
Link/Node	**SO_2 ttw absolute (g)**	**SO_2 ttw relative (g/tkm)**	**PM ttw absolute (g)**	**PM ttw relative (g/tonkm)**	**NMHC ttw absolut (g)**	**NMHC ttw relative (g/tonkm)**
Bodö-Trondheim	88131	0,12	12897	0	12897	0
Trondheim	2	-	24	-	16	-
Trondheim-Storlien	17168	0,17	1256	0	1256	0
Storlien - Hallsberg-Karlskrona	0	0,00	0	0	0	0
Karlskrona	2	-	30	-	20	-
Karlskrona-Gdynia	106714	0,36	5336	0	3557	0
Gdynia	2	-	27	-	18	-
Total	**212017,1**	**0**	**19542,4**	**0,0**	**17746,6**	**0,0**

ttw=tank to wheel, PM=atmospheric particulate matter, NMHC= non-methane hydrocarbons

Table 9. Parameters for calculation NTM-model truck/boat

Link/Node	Weight (tonnes)	Distance (km)	Vehicle/terminal
Bodö-Stjördal	1000	673	International truck trailer (26 tonnes)
Stjördal-Karlskrona	1000	1121	International truck trailer (26 tonnes)
Karlskrona-Gdynia	1000	300	Ropax (2000 lm)

Table 10a. Results from NTM-model on the A2A logistic corridor concept for truck/boat, based on parameters in table 9 regarding energy consumption, GHG and NO_X.

TRUCK/BOAT	Energy		Global		Regional	
Link/Node	**Energy wtw absolute (kWh)**	**Energy wtw relative (kWh/tkm)**	**GHG wtw absolute (kg CO_2 e)**	**GHG wtw relative (g CO_2/tonkm)**	**NO_X ttw absolute (g)**	**NO_X ttw relative (g/tonkm)**
Bodö-Karlskrona	391167	0,22	98670	55	481326	0,27
Karlskrona-Gdynia	42192	0	11774	39	209872	1
Total	**433359**	**0,2**	**110444,2**	**52,7**	**691197,3**	**0,3**

wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

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Table 10b. Results from NTM-model on the A2A logistic corridor concept for truck/boat, based on parameters in table 9 regarding SO_2, PM and NMHC.

TRUCK/BOAT	Regional		Local			
Link/Node	SO_2 ttw absolute (g)	SO_2 ttw relative (g/tkm)	PM ttw absolute (g)	PM ttw relative (g/tonkm)	NMHC ttw absolut (g)	NMHC ttw relative (g/tonkm)
Bodö-Karlskrona	270	0	2569	0	1642	0
Karlskrona - Gdynia	106714	0,36	5336	0	3557	0
Total	**106984,4**	**0**	**7905,0**	**0**	**5199,5**	**0**

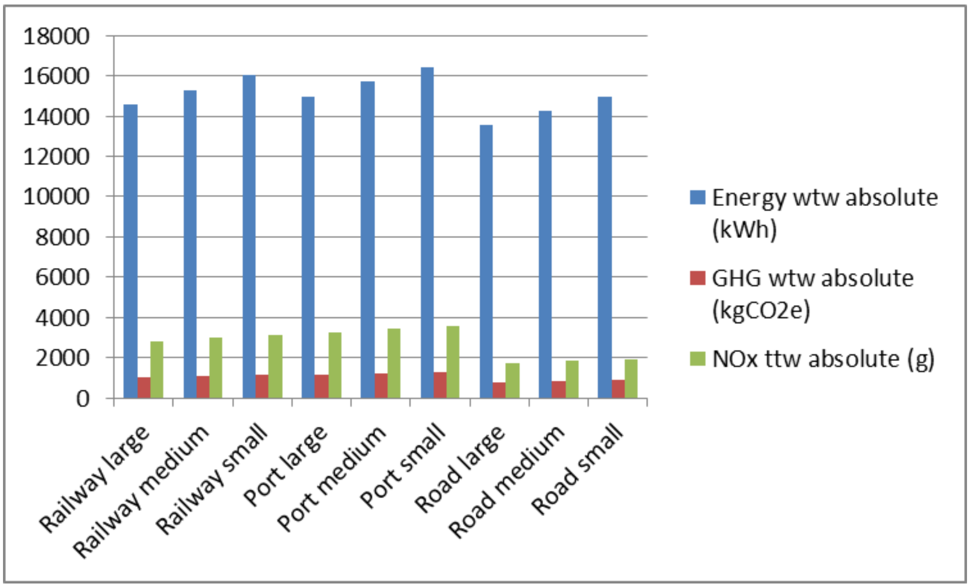
ttw=tank to wheel, PM=atmospheric particulate matter, NMHC= non-methane hydrocarbons

3.1.1 ELABORATIONS NMT MODEL

For analyses in the elaborations the most relevant KPI:s for each issue have been used. The perspective has been global and/or regional, since the elaborations regards the entire concept and is not studied in a local context.

Transshipments

Transshipping 1000 tonnes of goods in different types of terminals shows that road terminals generally gives the lowest energy consumption and emissions of GHG, NO_X and SO_2, followed by railway and ports. Larger terminals in all transport modes are anticipated to be more efficient than smaller terminals.



wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

Figure 2. Results from NTM-model, example of energy consumption and emissions of GHG and NO_X for transshipment of 1000 tonnes of goods in different type of terminals. (Calculation performed as a part of this study).

In this case terminal handling in the combination of train and boat transports are quite a large part of the total energy consumption, almost 20%. Terminal handling is also quite a large part of the GHG emissions, close to 15 %.

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Table 11. Results from NTM-model on the A2A logistic corridor concept, energy consumption and emissions of GHG, NO_X and SO_2 for transshipment in relation to the total impact in the combination of train and boat transports, based on table 8a and 8b.

TRANSSHIPMENT IN % OF TOTAL	Energy	Global	Regional	
Transport mode	**Energy wtw absolute kWh (%)**	**GHG wtw absloute kg CO_2 e (%)**	**NO_X ttw absolute g (%)**	**SO_2 ttw absolute g (%)**
Train/boat	17,5	14,2	1,3	0,0

wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

Transport route distance

If the transport routes can be shortened the effects on energy consumption and emissions are diminished. The magnitude of the effect depends on type of vehicle used.

Energy consumption is largest for truck trailer, then diesel trains, ferry and the least energy consuming electric trains. There is a considerably difference between diesel trains and electric trains, where diesel trains are much more energy consuming. Emissions of GHG are large for trucks, but also noticeably large for EU electric trains. This probably due to assumed energy mix used as described earlier. Emissions of NO_X are largest for dieseltrains and ferry. Emissions of SO_2 are largest for ferry, and dieseltrains. Trucks have almost no SO_2 emissions. Swedish electric trains have no emissions of either SO_2 or NO_X.

Table 12. Results from NTM-model on energy consumption and emissions of GHG, NO_X and SO_2 for transport of 1000 tonnes of goods a distance of 100 km with different vehicles.

ROUTE EFFICIENCY/ 100 KM-1000 TONNES	Energy	Global	Regional	
Type of vehicle	**Energy wtw absolute (kWh)**	**GHG wtw absolute (kg CO_2 e)**	**NO_X ttw absolute (g)**	**SO_2 ttw absolute (g)**
Internationell truck trailer (26 tonnes)	21804	5500	26830	15
Swedish truck trailer (40 tonnes)	20167	5065	24815	14
Short dieseltrain (500 tonnes)	17641	1242	68098	12139
Medium dieseltrain (1000 tonnes)	12474	878	48153	17168
Short electric train (500 tonnes) EU	7400	3034	5106	8954
Short electric train (500 tonnes) SE	6000	60	0	0
Medium electric train (1000 tonnes) EU	4244	1740	2929	5136
Medium electric train (1000 tonnes) SE	4244	42	0	0
Ferry RoPax [2000 lm]	14064	3925	69957	35571

wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

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If the distance in the A2A logistic corridor concept example is shortened 100 km, about 5% of the total distance, this saves energy and emissions in a range of 0- 33 %, depending on type of vehicle used and which parameter (energy consumption, GHG, NO_X or SO_2) being measured.
For the transport combination of train and boat, shortening of the distances where ferry and dieseltrain transport are used, would give the best effect. The ferry distance stands for a large part of the emissions of GHG and SO_2 in the train and boat combination.
For the transport combination of truck and boat, shortening the distance for truck trailer transport would give the best effect on energy consumption and emissions of GHG. Shortening the ferry distance would provide large decreases on emissions of NO_X and SO_2.

Table 13. Results from NTM-model on the A2A logistic corridor concept, impact on energy consumption and emissions of GHG, NO_X and SO_2 with a shorter transport distance of 5%. based on table 8a, 8b, 10a,10b and12.
wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

SHORTER DISTANCE 5%	Energy	Global	Regional	
Calculation example (transport mode shortened)	**Energy wtw absolute kWh (%)**	**GHG wtw absloute kg CO_2 e (%)**	**NO_X ttw absolute g (%)**	**SO_2 ttw absolute g (%)**
Train/boat (short diesel train)	-6,7	-5,1	-9,0	-5,7
Train/boat (medium diesel train)	-4,8	-3,6	-6,3	-8,1
Train/boat (medium electric train, SE)	-1,6	-0,2	0	0
Train/boat (ferry)	-5,4	-16,0	-9,2	-16,8
Truck/boat (international truck trailer 26 tonnes)	-5,0	-5,0	-3,9	0
Truck/boat (ferry)	-3,2	-3,6	-10,1	-33,2

Electrification rail
If the entire rail in the A2A logistic concept would be electrified, it implies large positive environmental effects. The effects of all rails being electrified have been calculated in the model. The parameters for the train/boat option in table 3 are used, but the entire rail is assumed to be electrified and short and medium electric trains with Swedish energy mix are assumed to be used in Norway.

The outcome indicates a large environmental effect of electrification. In this example energy consumption would decrease with 35% (169 762 kWh calculated in table below, compared to 262 478 kWh in table 8a showing todays´situation), GHG emissions with 38% (15 066 kg CO_2 e calculated in table below, compared to 24 482 kg CO_2 e kWh in table 8a showing todays´situation), NO_X with 71% (216 290g calculated in table below, compared to 758 837 g in table 8a showing todays´situation) and SO_2 with 50% (106 718 g calculated in table below, compared to 212 017 g in table 8b showing todays´situation).

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Table 14. Results from NTM-model on the A2A logistic corridor concept, all rail electrified in the combination of train and boat transports, based on table 7.

TRAIN ELECTRIC/BOAT	Energy	Global	Regional	
Link/Node	**Energy wtw absolute (kWh)**	**GHG wtw absolute (kg CO_2 e)**	**NO_X ttw absolute (g)**	**SO_2 ttw absolute (g)**
Bodö-Trondheim	43560	436	0	0
Trondheim	14567	1056	2836	2
Trondheim-Storlien	4244	42	0	0
Storlien - Hallsberg-Karlskrona	48726	487	0	0
Karlskrona	16442	1270	3582	2
Karlskrona-Gdynia	42192	11774	209872	106714
Gdynia	14947	1155	3256	2
Total	**169732**	**15065,5**	**216289,6**	**106718,4**

wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

Size of vehicle (truck trailer).
In the calculation example international truck trailers with a load capacity of 26 tonnes were chosen. Within the model there is an option of a Swedish long-distance truck trailer with a load capacity of 40 tonnes. Lengths are not available information in the calculation model. If a truck with higher capacity is chosen, this implies more efficient transports due to less number of vehicles. On the other hand larger and heavier trucks needs more fuel.

By using the parameters for the truck/boat option in table 5 but changing to a Swedish long-distance truck trailer with load capacity 40 tonnes the effect of size of truck can be indicated.

The outcome indicates very small differences between the two types of trucks. Using larger trucks indicates slightly lower emissions for the calculated distance and amount of freight.

Table 15. Results from NTM-model on the A2A logistic corridor concept, transport of 1000 tonnes, comparing swedish long distance trucks with a load capacity of 40 tonnes with international truck trailers with a load capacity of 26 tonnes.

TRUCK 40 TONNES/BOAT	Energy	Global	Regional	
Link/load capacity	**Energy wtw absolute (kWh)**	**GHG wtw absolute (g CO_2)**	**NO_X ttw absolute (g)**	**SO_2 ttw absolute (g)**
Bodö-Karlskrona /40 tonnes truck	361788	90870	445175	250
Bodö-Karlskrona /26 tonnes truck	391167	98670	481326	270

wtw= well to wheel, ttw=tank to wheel, GHG=greenhouse gas

3.2 ECOTRANSIT MODEL

The extent of the transportation route is A2A - Atlantic to Adriatic logistic corridor concept.
The routing can be confirmed directly on the Google maps or via city district, railway station, harbour, airport or zipcode in the ECOtransIT model. The sections of the transport are described through via locations. Then calculation

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results are available in table and graphs. It is optional to show well to tank (wtt) and tank to wheel (ttw) parts of the energy consumption and emissions of GHG, NO_X, SO_2, NMHC and PM.

Type of cargo
The type of goods needs to be specified as heavy, light or average. In this study average was chosen.

Terminals
When defining type of cargo and weight also cargo handling can be defined as bulk, liquid or other. Cargo-handling in terminals or transfer points are then considered in the calculations.

Truck trailer - road
There are different vehicles to choose from in the model. For this calculation a truck with a gross weight of 24-40 tonnes and emission standard Euro-V are used.

Boat - type
Between Karlskrona and Gdynia the chosen type of ship is sea ship. The default settings for sea ship are BC intra-continental (<35 k dwt) and it was used for the calculations. It is more a short sea shipping barge than a ferry, but the model itself does not provide for a ferry solution between Karlskrona and Gdynia. Ferries are considered to be parts of the land transport chain in the EcoTransIT model, where ferry routing can be selected. But in this case if ferry routing is selected, the model uses the land route anyhow, since ferry is not an option in this specific route.

Distances
Origin and destination of the transport are determined by using the Google maps directly in the tool. The destination can be typed in and searched. An optional number of via locations for the transport makes the route description.

For the train transport nine locations were chosen along the route from Bodö to Gdynia to get the correct routing. The locations were Trondheim, Storlien, Bräcke, Ånge, Frövi, Hallsberg, Mjölby, Alvesta and Karlskrona. After pressing the button for calculation, it is possible to look at the chosen route in Google maps in the ECOTransIT tool to be sure correct route is used in the calculation. To avoid short truck transports to and from ports etc. it can be added that on-site rail track is available. In this example this had to be done manually by using the coordinates of the ports. Perhaps the tool reflect todays situation where the rail link to the port of Karlskrona is not yet electrified so it is not possible to go all the way to the port with an electrified train transport.

For truck transports six locations were chosen between Bodö and Karlskrona. They are Trondheim, Elverum, Karlstad, Jönköping, Växjö and Karlskrona.

Table 16. Routing for calculation ECOtransIT model train/boat for the A2A logistic corridor concept

Distance [km]	**Carrier**	**Origin**	**Destination**
725,83	Train [diesel]	67.2803556 / 14.404916	TRONDHEIM
105,22	Train [diesel]	TRONDHEIM	63.316084 / 12.099118
2,50	Train [electrified]	63.316084 / 12.099118	Storlien gr
236,08	Train [electrified]	Storlien gr	BRAECKE
30,98	Train [electrified]	BRAECKE	ANGE
476,58	Train [electrified]	ANGE	FROEVI
69,46	Train [electrified]	FROEVI	HALLSBERG-ASSL
96,26	Train [electrified]	HALLSBERG-ASSL	MJOELBY
176,05	Train [electrified]	MJOELBY	ALVESTA
131,62	Train [electrified]	ALVESTA	56.1619 / 15.6016
334,45	Sea ship	56.1619 / 15.6016	54.5358 / 18.5293
Summary: 2385,01			

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Table 17. Routing for calculation ECOtransIT model truck/boat for the A2A logistic corridor concept

Distance [km]	Carrier	Origin	Destination
713,30	Truck	67.2803556 / 14.404916	Trondheim
371,11	Truck	63.4305149 / 10.3950528	Elverum
258,54	Truck	60.9550859 / 11.7466839	Karlstad
239,88	Truck	59.3791363 / 13.5008041	Jönköping
134,89	Truck	57.7826137 / 14.1617876	Växjö
112,71	Truck	56.8790044 / 14.8058522	Karlskrona
334,45	Sea ship	56.1619 / 15.6016	54.5358 / 18.5293
Summary: 2164,88			

Calculation train/boat and truck/boat

The results show that the combination of train and boat transports in the A2A logistic corridor concept example only need 30% of the energy consumption used in a combination of truck and boat (189 764 kWh for train/boat and 574 194 kWh for truck/boat, see tables below). The emissions from train/boat transports are only around 25% of the CO_2 e (GHG) emissions for truck/boat (36 tonnes for train/boat and 138 tonnes for truck/boat, see tables below), and 40% of the SO_2 emissions for truck/boat (84 kg for train/boat and 201 kg for truck/boat, see tables below). On the other hand NO_X emissions are around 15% higher for train/boat than truck/boat (524 kg for train/boat and 451 kg for truck/boat, see tables below).

Table 18. Results from ECOtransIT-model on the A2A logistic concept for train/boat based on parameters in table 16.

Transport mode	Energy (kWh)	CO_2 (tonnes)	CO_2 e (tonnes)	NO_X (kg)	NMHC (kg)	SO_2 (kg)	PM (kg)
Train (wtt)	34705	4,520	5,591	18,498	13,399	38,005	2,833
Train (ttw)	141424	26,853	26,986	430,108	40,490	0,178	11,841
Sea ship (wtt)	2775	0,351	0,393	1,467	1,286	3,487	0,185
Sea ship (ttw)	10190	2,845	2,873	73,914	2,704	42,273	6,208
Intermodal transfer (wtt)	60	0,002	0,002	0,009	0,002	0,003	0,010
Intermodal transfer (ttw)	611	0	0	0	0	0	0
Total	**189764**	**34,6**	**35,8**	**524,0**	**57,9**	**84,0**	**21,1**

wtw= well to wheel, ttw=tank to wheel

Table 19. Results from ECOtransIT-model on the A2A logistic corridor concept for truck/boat based on parameters in table 17.

Transport mode	Energy (kWh)	CO_2 (tonnes)	CO_2 e (tonnes)	NO_X (kg)	NMHC (kg)	SO_2 (kg)	PM (kg)
Truck (wtt)	127658	17,9	22,3	74	54	154,5	9,3
Truck (ttw)	433572	109,7	112,2	302	4	0,7	4,1
Sea ship (wtt)	2775	0,4	0,4	1	1	3,5	0,2
Sea ship (ttw)	10190	2,8	2,9	74	3	42,3	6,2
Total	**574194**	**130,8**	**137,8**	**451**	**62**	**201,0**	**19,8**

wtt= well to tank, ttw=tank to wheel

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3.2.1 ELABORATIONS ECOTRANSIT MODEL

For analyses in the elaborations the most relevant KPI:s for each issue have been used. The perspective has been global and/or regional, since the elaborations regards the entire concept and is not studied in a local context.

Transshipment

In the extended version of the model transshipment handling can be chosen as bulk, liquid, other or no transshipment at all. An amount of energy is assumed for the transshipment type and then country specific energy factors are used to calculate energy consumption and emissions (23).

In the A2A logistic corridor concept example the effects of transshipment in the combination of train and boat are negligible, only 0,4% of the energy consumption. It is however not possible in this version to adjust how many transshipments anticipated or which type of terminals. It is considered as a general part of the transport.

Transport route distance

If the transport routes can be shortened the effects on energy consumption and emissions are diminished. The magnitude of the effect depends on type of vehicle used. For trucks default settings for Euro classes are used.

Energy consumption is largest for truck trailer, and then diesel trains and the least energy consuming are ferry and electric trains. Emissions of CO_2 e are large for trucks, somewhat lower for diesel trains and considerably lower for electric trains. Emissions of NO_X are largest for short diesel trains and heavy trucks. Emissions of SO_2 are largest for ferry, and trucks. Electric trains have very low emissions of SO_2.

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Table 20. Results from ECOtransIT-model, transport of 1000 tonnes, energy consumption and emissions of CO_2 e, NO_X and SO_2 per km for different type of vehicles.

TEST DISTANCE 1000 TONNES Type of vehicle	Distance (km)	Energy wtw (kWh/km)	CO_2 e wtw (tonnes/km)	NO_X wtw (kg/km)	SO_2 wtw (kg/km)
Bräcke-Karlskrona (train electrified/ 500 tonnes)	956,24	48,87	0,000209	0,00063	0,000209
Bräcke-Karlskrona (train electrified/ 1000 tonnes)	956,24	31,80	0.000105	0,00042	0,000209
Bodö-Trondheim (train diesel/500 tonnes)	725,0	173,05	0,041379	0,56414	0,047862
Bodö-Trondheim (train diesel/1000 tonnes)	725,0	112,60	0,026206	0,36690	0,031172
Bodö-Trondheim, truck 24-40 tonnes, Euro-V	713,30	308,47	0,074303	0,20608	0,085378
Bodö-Trondheim Truck 40-60 tonnes, Euro-III	713,30	290,76	0,068695	0,53274	0,080471
Bodö-Trondheim Truck 40-60 tonnes, Euro-V	713,30	287,14	0,068695	0,17805	0,079350
Karlskrona – Gdynia, Sea ship	334,45	38,77	0,009765	0,22539	0,136822

wtw= well to wheel

If the distance in the A2A logistic corridor concept example is shortened 100 km, about 4-5% of the total distance, this saves energy and emissions in a range of 0- 16 %, depending on type of vehicle used and which parameter (energy consumption, GHG, NO_X or SO_2) being measured.
For the transport combination of train and boat, shortening of the distances where diesel train transport are used, would give the best effect on energy consumption, CO_2 e and NO_X. Shortening the ferry transport would give the best effect on lowering the SO_2 emissions.
For the transport combination of truck and boat, shortening the distance for truck transport would give the best effect on energy consumption and emissions of CO_2 e. Shortening the ferry distance would provide large decreases on emissions of NO_X and SO_2.

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Table 21. Results from ECOtransIT model on the A2A logistic corridor concept, impact on energy consumption and emissions of GHG, NO_X and SO_2 with a shorter transport distance of 4-5%. based on table 18, 19 and 20.

SHORTER DISTANCE 5% Calculation example (transport mode shortened)	**Energy wtw kWh (%)**	**CO_2 e wtw tonnes (%)**	**NO_X wtw kg (%)**	**SO_2 wtw kg (%)**
Train/boat (500 tonnes diesel train)	-9.1	-11,6	-10,8	-5,7
Train/boat (1000 tonnes diesel train)	-5,9	-7,3	-7,0	-3,7
Train/boat (1000 tonnes electric train)	-1,7	0,0	0,0	0,0
Train/boat (ferry)	-2,0	-2,3	-4,3	-16,3
Truck/boat (24-40 tonnes truck, EURO V)	-5,4	-5,4	-4,6	-4,2
Truck/boat (ferry)	-0,7	-0,7	-5,0	-6,8

wtw= well to wheel

Electrification rail

If the entire rail in the A2A logistic corridor concept would be electrified, it implies large positive environmental effects. The model accepts the choice of electrified train even if it is not in reality electrified, but when looking into the results in the part showing distances and carriers, the program has still used diesel train where the rail was not electrified.

To elaborate on this, a test distance for short (500 tonnes capacity) and medium long (capacity 1000 tonnes) electrified trains are used from table 20. The energy consumption and emissions of CO_2-equivalents, NO_X and SO_2 are calculated per km distance. This is then used in calculations of the energy consumption and emissions in the A2A logistic corridor concept, if electric trains could be used where diesel trains are operating today.

The outcome indicates a large environmental effect of electrification. In this example energy consumption would decrease with 52% (91 233 kWh calculated in table below, compared to 189 764 kWh in table 18 showing todays´situation), CO_2 e emissions with 90% (3,6 tonnes calculated in table below, compared to 35,8 tonnes in table 18 showing todays´situation), NO_X with 85%(76,4 kg calculated in table below, compared to 524 kg in table 18 showing todays´situation) and SO_2 with 45% (46 kg calculated in table below, compared to 84 kg in table 18 showing todays´situation).

Table 22. Results from ECOtransIT-model on the A2A logistic corridor concept all rail electrified in the combination of train and boat transports, based on table 16 and 20.

Transport mode 1000 tonnes	**Distance (km)**	**Energy wtw (kWh)**	**CO_2 e wtw (tonnes)**	**NO_X wtw (kg)**	**SO_2 wtw (kg)**
Train 500 tonnes	725,83	35471	0,152	0,457	0,152
Train 1000 tonnes	1324,73	42126	0,139	0,556	0,277
Sea ship	334,45	12965	3,266	75,381	45,76
Intermodal transfer	-	671	0,002	0,009	0,003
Total	**2385,01**	**91233**	**3,6**	**76,4**	**46,2**

wtw= well to wheel

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Size of vehicle (truck)
In the calculation example a truck 24-40 tonnes, EURO V were chosen. Within the model there are options of other gross weight on trucks. Lengths are not available information in the calculation model. If a truck with higher capacity is chosen, this implies more efficient transports due to less number of vehicles. On the other hand larger and heavier trucks needs more fuel.

By using the distance for the road part of the truck and boat combination, and the emission data from table 20, the effects of size of trucks for the A2A logistic corridor concept can be indicated.

The outcome indicates very small differences between the three types of trucks except for emissions of NO_X, which is much higher for the heavier trucks when they have the emission class EURO III. Otherwise using larger trucks indicates slightly lower emissions for the calculated distance and amount of freight, especially for the emission class EURO V.

Table 23. Results from ECOtransIT-model on the A2A logistic corridor concept, transport of 1000 tonnes, comparing trucks with a gross weight of 24-40 tonnes (Euro V) with heavier trucks with a gross weight of 40-60 tonnes (Euro III and V), based on table 17 and 20.

TYPE OF TRUCK 1000 TONNES	Distance (km)	Energy wtw (kWh)	CO_2 e wtw (tonnes)	NO_X wtw (kg)	SO_2 wtw (kg)
Bodö-Karlskrona/24-40 tonnes truck Euro V	1830,43	564632	136,0	377,2	156,3
Bodö-Karlskrona /40-60 tonnes truck Euro III	1830,43	532216	125,7	975,1	147,3
Bodö-Karlskrona /40-60 tonnes truck Euro V	1830,43	525590	125,7	326,0	145,2

wtw= well to wheel

CHAPTER 4
DISCUSSION AND CONCLUSIONS

4.1 DISCUSSION

Performance according to the NTM model and the ECOtransIT model
Direct comparisons between the NTM and ECOtransIT models are not really suitable since the used versions of the models are meant to be easy and somewhat blunt using many default settings. They should however still be indicative of the effects. For a more precise calculation both models offers more detailed versions, where default settings can be changed for actual values.

Result from both models show that the combination of train and boat is much more energy effective than the combination of truck and boat in the A2A logistic corridor concept example. There is quite a large difference, though, in how much more effective. The NTM model gives a result of 40% more effective and ECOtransIT model 70%. One part of the explanation is connected to terminal handling; almost 20% of the energy consumption for the train combination in the NTM model is due to terminal handling, while it is regarded negligible in the ECOtransIT model. Another part of the explanation is that energy consuming values for trucks are considerably higher for the ECOtransIT

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model than the NTM model, referring to the table 12 and 20. This leads to a larger difference between train and truck transports for the ECOtransIT model.

The CO_2 e (GHG) emissions are much lower and the NO_X emissions are higher for the combination of train and boat than truck and boat for both models. The emissions from train/boat transports are for the NTM model only around 20%, and the ECOtransIT model only around 25%, of the CO_2 e (GHG) emissions for truck/boat transport. The NO_X emissions from train/boat transports are around 10% higher for the NTM model, and around 15% higher for the ECOtransIT model, than truck/boat. The larger emissions of NO_X originate from the use of dieseltrains.

There is however a discrepancy regarding emissions of SO_2. The NTM model results in 50% higher emissions with the train combination, while the ECOtransIT model shows that it is 60% lower emissions of SO_2 for the train combination. The ECOtransIT model presents results in wtw (well to wheel) for all parameters, splitted into wtt (well to tank) and ttw (tank to wheel). The NTM model presents the results for NO_X and SO_2 only in tank to wheel (ttw). Almost all SO_2 emissions from trains are in the well to tank part (wtt). For NO_X it is the opposite, almost all emissions from trains are in the tank to wheel part (ttw). From ferry transports SO_2 emissions are almost entirely originating from the tank to wheel part (ttw). If the well to wheel part of the SO_2 emissions in the ECOtransIT model is disregarded, the SO_2 emissions will be about the same for the train combination and the truck combination and thus reduce the difference between the models. Still, there is a considerable discrepancy. The SO_2 emissions are very differently valued per km in the different models, looking at the table 12 and 20. The SO_2 emission value (g/tonkm) for diesel trains in NTM is about five times higher than in the ECOtransIT model. The SO_2 emission values (g/tonkm) for the ferry transport are about three times higher in the NTM model than the ECOtransIT model For trucks (24-40 tonnes, EUROV) in the ECOtransIT model SO_2 emission values (g/tonkm) are over 500 times higher than trucks in the NTM model(26 tonnes international trailer, average EURO class). It is probably connected to default settings. The background data report available for the ECOtransIT model (23) states that the sulphur values are derived from contents in the fuel in line with valid legislation. For EU the value was 10 ppm, but in some countries it can go up to 2000 ppm.

If the distance in the A2A logistic corridor concept example is shortened 100 km, about 5% of the total distance, this saves energy and emissions in a range of 0- 33 % in the NTM model and 0-16% in the ECOtransIT model, depending on type of vehicle used and which parameter (energy consumption, GHG, NO_X or SO_2) being measured.
For both models, shortening of the distances with ferry and dieseltrains, would give the best effect for a transport combination of train and boat. For the transport combination of truck and boat, shortening the distance for truck transports would give the best effect on energy consumption and emissions of GHG. Shortening the ferry distance would provide large decreases on emissions of NO_X and SO_2.

If the entire rail in the A2A logistic corridor concept would be electrified, both models imply large positive environmental effects. The outcome from the two calculation models indicates that energy consumption would decrease with 35% and 52% respectively, GHG emissions with 38% and 90% respectively, NO_X with 71% and 85% respectively and SO_2 with 45% and 50% respectively. The large decreases in energy consumption, CO_2 e and NO_X are results from the ECOtransIT model. The effects are smaller for the NTM model. One reason is that terminal handling is a constant part of the energy consumption and emissions in the NTM model. Another reason is connected to default values. The values of energy consumption for electric and diesel trains are quite similar between the models, but considering the values of emissions of CO_2 the difference between diesel trains compared to electric trains are considerably larger in the ECOtransIT model than the NTM model, as presented in table 12 and 20.

In the calculation model different types of trucks can be chosen for the transport. Both models indicates very small differences between the size of trucks. Emissions might vary, though, due to the trucks emission class. That can be specifically chosen in ECOtransIT model, while an average between EURO I-V is used in the NTM model.

Tested transport chain in A2A logistic corridor concept in relation to the results from SuperGreen
It is interesting to comment the outcome from the calculations from the two models, also in relation to the results from the SuperGreen project, where ECOtransIT model was used for calculation emissions from transport chains in six corridors. Related to the results from the Supergreen project, the results from the calculations in this study seem

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plausible. The term added for thermal transport is relevant in size and it shows that actual type of transport is important.

Again, there is a discrepancy between the models regarding emissions of SO_2, which is assumed to have emerged from different base assumptions. Amount of SO_2 in g/tkm is directly available in the NTM model, but it is rounded off to zero without decimals. Therefore it has to be calculated from the absolute values presented in the results from the calculation, similarly as for the ECO transit model.

The train/boat combination is less energy consuming in the ECOtransIT model than in the NTM model in this example. Despite that, it gives rise to more emissions of CO_2/tonkm. This indicates that different energy mixes are used in the two models.

Table 24. A2A transport logistic corridor concept, 1000 tonnes of fish transport Bodö-Gdynia, calculated with NTM model and ECOtransIT model in relation to results from the Supergreen project, calculated with ECOtransIT tool.

Corridor name	Mode of transport	CO_2 (g/tonkm)	Thermal addition * fish transports, CO_2 (g/tonkm)	SO_X (g/tkm)
Brenner	Intermodal	10.62-42.11		0.020-0.140
	Road	46.51-71.86		0.050-0.080
	Rail	9.49-17.61		0.040-0.090
	SSS	16.99		0.050-0.120
Cloverleaf	Road	68.81		0.091
	Rail	13.14-18.46		0.014-0.021
Nureyev	Intermodal	13.43-33.36		0.030-0.150
	SSS	5.65-15.60		0.070-0.140
Strauss	IWT	9.86-22.80		0.013-0.031
Mare Nostrum	SSS	6.44-27.26		0.092-0.400
	DSS	15.22		0.22
Silk way	Rail	41.00		-
	DSS	12.50		-
A2A logistic corridor concept/fish transports	**Train/boat NTM**	**10,8**	**3,8**	**0,093 g SO_2 (ttw)/tonkm**
	Truck/boat NTM	**52,7**	**15,8**	**0,051 g SO_2 (ttw)/tonkm**
	Train/boat ECOtransIT	**14,5**	**5,1**	**0,035 g SO_2 (wtw)/tonkm** *0,017 g SO_2 (ttw)/tonkm*
	Truck/boat ECOtransIT	**60,4**	**18,1**	**0,093 g SO_2 (wtw)/tonkm** *0,020 g SO_2 (ttw)/tonkm*

SSS= Short sea shipping, DSS=Deep sea service, IWT= Inland water transport, ttw=tank to wheel, wtw=well to wheel
**Thermal addition used: 35% for train/boat and 30% for truck/boat*

Interpreting results from calculations

Results from the calculation example with NTM model and ECOtransIT model show that they indicate similar environmental effects. Still, when using a specific calculation models it is important to pay attention to the special features of that model to be able to interpret the outcome, for example how the results are presented (well to wheel (wtw), well to tank (wtt) or tank to wheel (ttw)), if terminal handling is a general part of the transport or if it is possible to choose where and how it is performed, which emission classes for trucks are used and energy consuming and emission values used per km for different vehicles and for different areas (flat land, hilly land) and countries.

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Updates and transparency
The values used in the models are very important for the outcome. Therefore transparency in background information for the calculations is needed. Background information should be easily found and accessed by the users. Updates are important, like for instance considerations of the new sulphur directive.

In the ECOtransIT website the background information report is easily accessed in Internet. Assumed values are gathered in one report, which is regularly updated. For the NTM model you have apply for a log in account to get access to a library and, as it seems, different background reports on the topic.

User friendliness
If actors from different organisations are supposed to use the calculation models it is important that they are self-communicative. There can be individual opinions of what is user friendly or not. Specifically noted when this study was carried through was that the ECOtransIT model has, by the use of Google maps, rationalised the input of distances in a very convenient way. Electrification of the railway is also a known attribute included in the model (23).

Use of results
There are many actors with diverse interest of measuring Green Corridor performance. The goods owners and operators might want to know that the chosen transport chain is environmentally friendly. That aim includes some kind of comparison, between modes of transport or routes or vehicles etc. Authorities might want to know if the overall emissions from transport are decreasing in the corridor.

The ECOtransIT model and NTM model both can be of help for evaluating specific transport chains. It should be valuable for operator, goods owners etc. It is more problematic, however, with this type of calculation tools to find an overall aggregated performance, an overall monitoring. The SuperGreen project aimed for aggregating transport chains into indexes for entire corridors but due to statistical problems decided to present results for the measured parameters in intervals instead (19).

Key performance indexes (KPI: s) and limit values
The KPI:s used in the calculations are focusing on environment. It is highly important since the aim for the corridors are to be “green”, but other KPI:s are also needed. The Green Corridor concept is about environmentally friendly and efficient transport corridors. Other proposed KPI:s from the SuperGreen project are cost, average speed, reliability and frequency (19).

Using limit values for chosen KPI: s could be a way of steering towards more green and efficient transport corridors. In case of using limit values it is necessary to agree upon a specific calculation tool or model to be able to measure KPI: s in a similar way. This small study is an example of where assumptions and default settings made in different tools do affect outcomes. Translating results from one model to another is not preferred, as the risk of making mistakes is obvious, especially when the tool is used in a detailed manner to relate results to KPI limit values.

One or several calculation models
There could be either one accepted and widely used model, or several locally adjusted models, or both in parallel. The best option would be to have a model, broadly accepted, that could measure geographically specific, but still in a comparable way for different corridors. It would encourage the concept of Green corridors as seamless transnational corridors in Europe. On the other hand, a world calculation model is at risk of being to general, not fully catching the regional disparities.

The version of the NTM model used in this study has a clear Scandinavian perspective (terminal size, energy mix etc), while the version of the ECOtransIT model has a world perspective, with easily maneuvered maps which makes the transport corridors easily extended across country borders.

If it seems difficult to agree upon one single model in all of Europe, one solution could be to agree upon using a certain tool within a geographical area. The Baltic Sea area might be a suitable area.

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European perspective
From a European monitoring perspective statistics should be consistent and overall comparable. Regarding for example carriage of goods and passengers by sea, statistics are collected by Eurostat through a directive of the European parliament and Council (25). The member states have to provide statistic information. In Sweden this is done through a national authority, Transport analyses. The administrative agency Statistics Sweden is normally producing the statistics, from inquiries and questionnaires etc. When information is gathered directly from companies, law normally states participation in inquiries in these cases. Statistic variables are described in the directive, as well as a structure for collecting the data, a result from a three-year study concerning the feasibility and the cost to Member States and to the respondents of collecting the information. This resulted in a structure where some ports are selected to answer certain areas of information and other ports are selected for other areas of information.

Statistics on freight transports in EU are also harmonised for railway and truck transports.

The Green Corridor concept is quite similar to the trans-European transport network initiative (TEN-T), where large consolidated transport corridors are being developed in a core network over Europe. It should be of interest to the European Union how the TEN-T core network is developing generally. In this aspect progress for TEN-T transport corridors could be merged with Green Corridor development and statistics for chosen KPI:s could be asked for, similarly to the sea example above, but specifically for these corridors.

4.2 CONCLUSIONS

Result from calculations of the A2A logistic corridor concept example indicate that the combination of train and boat is much more energy effective than the combination of truck and boat, at least 40% more effective based on the NTM model and its background features, and as much as 70% more energy effective based on the ECOtransITmodel and its background features. If the entire railway would be electrified the outcome from calculations indicates that energy consumption would decrease with 35% in the NTM model and 52% in the ECOtransIT model for the train/boat combination.

The calculations indicate that the CO_2 e (GHG) emissions are much lower and the NO_X emissions are higher for the combination of train and boat than truck and boat for both models. Emissions of SO_2 are inconclusive in this study, differences in presentation and default assumptions needs to be further examined.

For both models, shortening of the transport distances where ferry and dieseltrains are used, indicates the best effect for a transport combination of train and boat. For the transport combination of truck and boat, shortening the distance for truck transports indicates the best effect on energy consumption and emissions of GHG. Shortening the ferry distance indicates large decreases on emissions of NO_X and SO_2. Both models indicates very small differences between the size of trucks.

When using a specific calculation model it is important to pay attention to the special features of that model to be able to interpret the outcome, for example how the results are presented (well to wheel (wtw), well to tank (wtt) or tank to wheel (ttw)), if terminal handling is a general part of the transport or if it is possible to choose where and how it is performed, which emission classes for trucks are used and energy consuming and emission values used per km for different vehicles and for different areas (flat land, hilly land) and countries.

For future measurement of Green Corridor performance different types of measuring are suggested. For specific transport chains the calculation tools NTM model and ECOtransIT model are useful. It would be positive if they can move towards each other in characterizing transport values. For a monitoring perspective a general overall methodology, gathering statistic information through member states is suggested.

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