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Calculation tools for the documentation of the environmental performance of freight transport alternatives: a comparative analysis

Tim-Ole Böhm

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Preface and acknowledgements

This Master thesis represent the last assignment to complete my studies in Logistics at Molde University College from August 2010 until June 2012.

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Abstract

Emissions of CO_2, SOx, NOx, HC and PM produced by freight transporting vehicles are contributing to a large extend to the problem of air pollution and other environmental related problems. Consumers, producers and politicians getting more and more aware of the problem of GHG emissions, together with a rising understanding that a change is needed. Especially in urban areas all modes of transportation are not only an issue of pollution but also of human health and other direct and indirect impacts on the environment as e.g. acid rain. For these reasons, both customers and authorities have a rising interest to know the "carbon footprint" of products and services. To measure the emissions for transportation, as a central part of the supply and value chain, emission calculation tools exist. These emission calculation tools are existing beside many other emission calculation tools for private house holds, private and commercial energy consumption, emission for production of goods and travelling. These tools are the major part of the free in the Internet existing tools, where the calculation tools for the emission of transportation representing the smallest group. In order to evaluate the calculation tools, to measure the emission caused by freight transportation, within made limitations, three of these tools have been chosen for a deeper analysis (with chosen limitations) with regards to the data background they have, the outcome they produce and to what extend these tools have a right to exist and can beconsidered useful.

The analysis contains a comparative case study with two different cases. One case from the Norwegian transport industry, the name of the company has been anonymised, and a constructed case. The constructed case considers important restrictions to fulfil the requirements of an on the one hand relevant setting for the transportation industry and on the other hand to produce the most comparable outcome. The aim of the analysis is not to compare different modes of transportation, but the emission calculation tools itself. The findings of the literature research and the case analysis have been used to map the analysed emission calculation tools with regards to their background and relationship between each other and between databases. In the end of this Master thesis, based on the analysis made, conclusions are drawn and recommendations for further analysis are given.

Key words: Emissions, transportation, emission calculation tools, case study, analysis.

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List of Abbreviations

CBDR – Common but Differentiated Responsibility

CO_2 – Carbon dioxide

ECA – Emission Control Area

EEA – European Environment Agency

EU – European Union

GHG – Greenhouse Gases

HC – Hydrocarbon

HSFO – High Sulphur Fuel Oil

ICAO – International Civil Aviation Organization

IMO – International Maritime Organisation

LSFO – Low Sulphur Fuel Oil

MARPOL – International Convention for the Prevention of Pollution from Ships

MEPC – Marine Environment Protection Committee

NM – Nautical Mile

NO_x – Nitrogen oxides

OECD – Organisation for Economic Co-Operation and Development

PM – Particular matter

SO_x – Sulphur oxides

SSS – Short Sea Shipping

TEN's – Trans-European Networks

UNCTAD – United Nations Conference on Trade and Development

UNFCCC – United Nations Framework Convention of Climate Change

1. Introduction

Since the early last century the world's population almost tripled and with it the need and consumption of energy and natural resources, some of them are already marginal goods like oil and water. Simultaneously, the demands of the population are growing and countries like China and India are developing and generating wealth and new needs for consumer goods. Between 2003 and 2011, the worldwide output of goods and services grew with average 2.28 %[1] per year (UNCTAD 2011). This continuous development over the last decade has had influences on the worldwide trade as well, only in 2011 the worldwide trade increased after the down peak in 2009 by 14 % (UNCTAD 2011). In the EU freight transport grew by 30 % over the last decade. All the traded goods have to be produced and transported, mainly by sea; general cargo with help of the standardized container, bulk commodities with bulk carriers and tankers. More than 95 % of the global trade in 2002 (Pisani 2002) was transported by seagoing vessels, but also by air, rail and road. The production and the transportation of goods consume energy and create pollution. The transport industry is responsible for 31 % of all energy consumption and 23 % of the Greenhouse Gases (GHG) emission in the EU (European Investment Bank 2008). Noise pollution, emissions to sea, air pollution and the greenhouse effect, just to mention a few of them, all represent harms to the environment and the health of human beings and animals (Knörr 2008). The most focused substances with regard to air pollution and the greenhouse effect are inter alia: carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbon (HC) and different kinds of particular matter (PM) (National Association of Clean Air Agencies 2011). The language regime in this Master thesis will use GHG as an overriding term for the above-mentioned emissions, when not one or several emissions are explicit mentioned.

Thus, the policies in the transportation industry focused more and more on the environmental impact of transportation. One of the drivers behind the efforts to make transportation greener and more environmental friendly is a secular monetary reason. The impact on human health, materials, ecosystems, flora and fauna are causing considerable environmental costs. (Bickel, Schid et al. 2005) These costs are rarely included in the price for transportation. Anyhow, cargo owners want to know more and more what impact

[1] Authors calculation based on the UNCTAD Trade and Development Report 2011.

the transportation of their goods has on the environment and the key word *sustainability* became more important for customers throughout all industries. Being a “green label” company can create benefits and can be a competitive advantage for these companies. Furthermore, politicis on national and supra-national level (UN, EU) are the driving force behind the change by implementing rules and restrictions for pollution and commit countries around the world in order to raise awareness of the subject and at the same time set measurable, realistic goals in order to reduce emissions and pollution. The Kyoto protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is to be considered the most powerful; the international treaty to reduce the emission of GHG is ratified by 183 states and commits them to reduce the GHG emissions by up to 26 % (UK) by 2020. (Bauer, Bektas et al. 2010; Karim and Alam 2010)

Another example in which also environmental issues are part of the motivation of politics are the TENs, the Trans-European Network project of the European Union which is partly one of the tools to get the transportation of goods from the road to rail and waterways. This is based on an assumption that transportation on waterways and rail is overall always better for the environment and has less impact on it.

This assumption is not a general truth, as concerning the overseas traffic; one has to consider the haul distance of the shipment and the kind of emissions. Shipping as a transportation mode is “greener” with regards to the CO_2 emission and if the shipping leg is not much longer than the alternative road transportation distance, cf. (Hjelle and Fridell 2012). Levin and Sund cite 2010 in their paper “Green fright – Every penny counts” van Klink and van den Berg, 1998, who state that inter-modal[2] transportation needs a minimum of 500 km in Europe to be competitive from an economic point of view with regular road transportation (Levin and Sund 2010). This might lead to a lower interest of shippers to use an inter-modal transportation including transportation by ship (on sea or inland waterways) rather than using the pure road transportation. Anyhow, there are different reasons to be found for intermodal transportations.

One of them is that nowadays the supply chain from the producer to the customer rarely consists only of one mode of transportation rather than the need to shift the transportation mode, to the inter-modal transportation mode. This fact raises the complexity to calculate the emissions from transportation. In addition the inter-modal transportation mode needs

[2] Inter-modal transportation, the use of more than one mode of transportation when shipping goods.

nodes and facilities to change from on to the other mode, the energy consumption and emission of these facilities (terminal) are not considered in most of the calculation tools. (Levin and Sund 2010)

Another challenge of calculating emissions from transport is the different external preconditions of gathering the data for different transportation modes, as well as the different kinds of energy sources used. There is a difference with regards to emissions if the energy a train uses is coal or electricity, and if it uses electricity how the electricity is generated. Furthermore the life cycles of the different transportation units differ dramatically, and consequently the time needed to implement higher emission standards. While it needs a relatively short time for trucks, the life cycle for a ship is in average about 20 years and therefore it takes much more time to implement new and higher emission standards.

The focus of the author will be to compare known calculation tools to measure the environmental impact of different transportation modes. Furthermore, the reliability, accuracy and significance of these calculating tools as well as their degree of utility in reality will be part of this thesis at hand. The goal is to evaluate the potential need for these calculation tools and their utility for the transportation industry. Additionally the data background (databases) and the relation between the databases and tools will be mapped and compared. Furthermore two different approaches for the calculation of emissions will be discussed, the bottom-up approach and the top-down approach. The top-down approach describes the way to calculate emissions based on e.g. fuel consumption. The bottom-up approach is gathering emission data by measuring the exhausted emission in a specific area e.g. tunnel measurements.

To achieve that goal two cases are used for this paper to make the different calculation tools comparable. One case is from the Norwegianindustry and describes the transportation situation in two different real life settings of a Norwegian producer of oils for human consumption in the middle of Norway. Another case is a constructed setting by the author with chosen parameters, which allow a comparison with regards to relevant problems as the similarity of the transportation length of the haul for the road and sea transport as well as the problem of the load factor and utilization of the transportation box.

1.1 Green Transport

The need for a change in the mindset concerning the climate change gets more and more in focus not only for the private house holdings but also for the producing industry and the transportation industry. A green image can be a competitive advantage and can result in economical advantages. On the one hand the environmental cost for the society by pollution on a macro economic level and on the other hand the savings for companies and private persons on a micro economic level. For private persons, green transportation means to use public transport and alternative transportation modes, for companies, greener transportation means to invest in alternative and innovative technologies to fulfil law regulations, e.g. the Euro norms for vehicles (Euro 5, from 2013 Euro 6 norm) in road transport, cf. (Hjelle and Fridell 2012), or for the international shipping regularities on supra-national level as the MARPOL act of the IMO.

Besides, there is also a quite obvious reason for the need of lower emissions and that is an economical reason. Emissions are following energy consumption and the most used energy source for transportation are oil-based products. Regardless what product in particular a truck, train, airplane or vessel uses, it based on oil, and oil is a marginal good with a continuous rising price. Therefore, control of emission means control of consumption and thus control of costs. Reducing emissions means reducing spending for a transportation company, if this emission reduction is a result of reduced usage of fuel. In other words, beside the better image and an advantage to generate new customers by having a “green label” as a company, it helps the company to save money by choosing the right mode of transportation for their shipments.

1.2 Structure

The purpose of this Master thesis with the title “Calculating tools for the documentation of the environmental performance of freight transport alternatives: a comparative analysis” at the University College Molde is to analyse the background and the use of different emission calculation tools for the transport industry in form of a comparative case study. This Master thesis includes an overview about the topic with an introduction and will further on give a definition of the calculation tools that are going to be analysed as well as limitations and boundaries of the topic in the first part. In the second part, the methodology and research theory is reviewed. Based on the relevant theory the research questions are developed, as well as the relevant theory of case studies, in particular the comparative case study approach is discussed. Furthermore, the different kind of generated and used data will be elucidated and reviewed. The third part contains the relevant literature review for this Masters thesis. Afterwards in part four, the analysis part, the different cases will be used to analyse the different calculation tools and their outcome with regards to the defined parameters. The findings will be discussed and evaluated to answer the research questions from part two. In the end a conclusion and recommendations for further analysis will complete this Master thesis.

1.3 Definition of calculation tools

The definition of the calculation tools for the documentation of the environmental performance of freight transport alternatives for this thesis is made by the author to clarify which tools will be analysed and to distinguish them from similar tools and programs. The analysis tools discussed in this thesis are consisting the following:

- Having an interactive interface for the end-user.
- They are measuring the emission for freight transportation.
- They are net based or in-house solutions.
- The tool is measuring the emission of at least one of the main gases as CO_2, SO_x, NO_x, HC and PM for different types of transportation (air, sea, land) and measuring the emission in weight/distance.
- The calculation is based on energy consumption and distance.
- The tools are calculating and comparing the emissions and energy consumption for a transportation of an exact amount of goods.

These parameters are chosen to exclude non-relevant calculating tools from research as tools for the calculation of the energy consumption and emission of housings, plants, air transport and passenger transportation.

1.4 Limitations

The paper will focus on the transportation modes road and sea and will exclude air transportation and will cover rail transportation only with a short side view. This has several reasons. First of all there is the amount of data and the limited time for this paper, secondly the importance of the different transportation modes with regards to the shipped amount per year per mode. The European Commission stated the following regarding the modal split in freight transportation in the EU (July 2011):

“The modal split of freight transport gives the shares of different transport means measured in tonnekm[3]. Between 2000 and 2009, the modal share of road inland freight transport in the EU increased from 73.7 % to 77.5 %. In contrast the modal share of rail transport fell to 16.6 % in 2009, and the share of inland waterways to 5.9 %.”(Eurostat 2011)

These figures show that the major parts of the shipped goods are transported by road, that road transportation is still growing and that the shift to more environmentally friendly modes has still not happened. The relatively small share of 5,9 % for transportation by ship results from the fact that it only counts the pure inland waterway shipments and exclude the Short Sea Shipping (SSS) and the ferries used for the inter-modal transportation. In other words the indirect share of transportations using a vessel seems significant higher. Rail and air playing a more important role in the transportation of passengers than for freight, especially airfreight is mainly used for oversea transportation of high value goods due to the high costs of air transport.

Furthermore this Master thesis will clearly focus on freight transportation and exclude passenger transportation and will restrict the analysis to the European Union and Scandinavia.

[3] Tonne/km or Tonne-km = describes the transportation of a payload of one tonne for one kilometre.

2. Methodology

In the second chapter the research methodology used for this Master thesis will be mentioned. Some authors describe research as a movement from the known to the unknown, as a voyage of discovery (Dhawan 2010). Another definition of research is:

"(…) a systematic way to collect information and get knowledge out of it with a methodology so that the derived knowledge can be used to make decisions" (Sachdeva 2009 p. 2).

To make a clear research some definitions and differentiations have to be made as well the clarification that research has a theory, but is made in the real world and therefore research methodology and methods can differ considerably. *Method* is the techniques for gathering evidence and the various ways of proceeding in gathering information. *Methodology* is "the underlying theory and analysis of how research does or should proceed, often influenced by discipline [as well as] "an epistemology" is a theory of knowledge. It is the theory that decides what can be observed" (Sachdeva 2009 p. 9).
Bryman and Bell (2011), investigating the topic of business research in their book "Business Research Methods" and making further differentiations with regards to the different possible research approaches. They classify the *methodology* of research into *epistemological* considerations and *ontological* considerations (Bryman and Bell 2011). *Epistomology* is questioning what kind of knowledge is gathered, *Ontology* is covering the question of the entity of knowledge.

Besides, for a successful research the theory underlying the research is important and that the right theory and the appropriate approach are chosen by the author. The first question is if to select an *inductive theory* or a *deductive theory*. The *inductive theory* represents the classical approach for a *quantitative research* and means that the researcher first builds a hypothesis based on the theory of the topic, collecting relevant data and test the data with regards to the hypothesis. With help of the findings, the hypothesis will then be rejected or confirmed and finally leads to revision of the theory, a top-down approach. The *inductive theory* on the other hand is going the opposite way from bottom to the top. Starting with an observation through some tentative hypothesis to developing a theory (Research Methods

Knowledge Base 2006). The *inductive theory* might be the appropriate approach for a qualitative research.

It should be mentioned that the differentiations between this two theories is a general differentiation among them. That means that in the real research world the differentiation is not a clear-cut rather than these theories representing tendencies for an implemented research. The same is effectual for distinguishing between a *quantitative* research approach and a *qualitative* research approach. While a *quantitative* research mainly contains numerical analyses and the *qualitative* research focuses on a scripture analysis, both can and mostly will contain elements from the opposite approach. In other words, running a qualitative research it does not necessarily exclude a *quantitative* analysis.

The research for this Master thesis will be based on the theory of an *inductive* approach for a *qualitative* research. This means that an observation will be analysed with the goal to see a pattern in it and to put it in a bigger context. In this thesis different calculation tools, offered to the transportation industry to calculate emissions are analysed. The starting observation is that more and more of these calculation tools are appearing and that the calculation of a so called "carbon footprint" is becoming common and interesting for companies as well as for private persons. Now, with the bottom-top approach of the *inductive* research approach the first step is to find a possible pattern, relationships, connections and background of the different tools to develop a theory about the use of calculation tools and their outcome for further analysis. As mentioned before, this Master thesis will also contain numbers and some elements of *quantitative* analysis as the use of the software MS Excel to analyse the different outcome of a comparable event of different tools to be able to sketch a possible pattern. The analysis is based on a *case study*, in particular a *competitive case study*. The methodology of case study and the competitive case study is explained in chapter 2.4 and 2.5.

After deciding about what kind of *research methodology* should be used, the *research design* has to be considered. The *research design* is like a sailing list on the voyage from the known to the unknown and will be covered in chapter 2.1. The *research quality* will be shed light on chapter 2.2 and is important with regards to the comparability of the gathered results. Chapter 2.3 contains the developed *research questions* with the goal of answering them by accomplishing the analysis. In the end of chapter 2 (2.6, 2.7) the *method* of the data collection and the data classification will be discussed.

2.1 Research design

"A research design is the logic that links the data to be collected (and the conclusion to be drawn) to the initial questions of a study. Every empirical study has an implicit, if not explicit, research design" (Yin 1995 p.18).

In other words the *research design* provides the further research with a direction, structure and a particular setting. In literature one can find several kinds of research designs for different research approaches. Some of them are experimental design; cross-sectional or social survey design, longitudinal design; *case study design* and *comparative design*; where each of them applies a particular problem. Some designs fit more for a *qualitative* research and others more for *quantitative* research. The *case study design* is thereby the most often used and most popular research design in social science, cf. (Bryman and Bell 2011). In any case, the selected research design should be able to provide the best and most accurate results.

"A good [research] *design*, one in which the components work harmoniously together, promotes efficient and successful functioning; a flawed *(research) design* leads to poor operation or failure" (Maxwell 2005 p.2).

To find the right research design the main differentiation has been made on the fact if the research is a *qualitative* or a *quantitative* research. As described in the first part of chapter 2, the analysis in this Master thesis contains a *qualitative* research based on an *inductive* approach. To achieve this goal the research will be designed as a *comparative case study*. The idea is to make different calculation tools with different transport modes in a particular voyage with a fixed amount of goods introducing comparability in a case study. For that reason two cases will be used, one is a case from "real life", the case of a Norwegian company, and a second constructed case. The "real life" case contains an inter-modal transportation as well as perfect sea transportation, the constructed case combines inter-modal transportation, perfect road transportation and a perfect sea voyage. Therefore one of the three dimensions (calculation tool, transportation mode, voyage/weight), the dimension voyage/weight, will be fixed in the cases. The other two dimensions, calculation tool and transportation mode will be variable.

To make the generated outcome for each case and the two variable dimensions a cross-sectional design will be used. The cross-sectional design is chosen to display the outcome of the different tools and transportation modes for the two cases in a standardized table (Table 1).

Tool / Mode	Inter-modal	Sea	Road
$Tool_1$			
$Tool_2$			
$Tool_3$			
$Tool_4$			
$Tool_5$			
$Tool_6$			
$Tool_x$			

Table 1: Cross-sectional table

The purpose in the analysis of the different outcome of the cases is to find a possible pattern as well as to map the different tools with regard to their data background and their relation to each other, if existing, with help of the research design of a comparative case study.

2.2 *Research quality*

To ensure the quality of the research during the several stages of research four aspects for the quality of the research design has to be considered. These four aspects are the construct validity, internal validity, external validity and the reliability of the design (Yin 1995). In addition the replicability – the possibility of replication – is a criteria of quality for the design of a research, cf. (Bryman and Bell 2011).

(Yin 1995 p. 33) is citing Kidder & Judd, 1986 pp. 26-29 to summarize the four quality attributes as follows:

- *Construct validity*: establishing correct operational measures for the concepts being studied.

- *Internal validity* (for explanatory or causal studies only, and not for descriptive or explanatory studies): establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships.

- *External validity*: establishing the domain to which a study's findings can be generalized.

- *Reliability*: demonstrating that the operations of a study – such as the data collection procedures can be repeated, with the same results.

(Bryman and Bell 2011 p. 41) is adding the quality measurement of replicability, what is closely related to reliability, to this list.

- *Replicability*: In order for replication to take place, a study must be capable of replication – it must be replicable. This is a very obvious point: if a researcher does not spell out his or her procedures in great detail, replication is impossible.

Construct validity and reliability occurs and has to be controlled during the research phase of data collection, internal validity for the duration of data analysis and external validity during the phase of designing the research, cf. (Yin 1995).

It means for this Master thesis that the constructtion of the case study has to be made in a way that the analysis can be repeated with the same results. Furthermore, that the findings can be applied in a general way, and overall that the case is constructed and adressed in a sensfull way to the transportation industry.

2.3 Research questions

A central part of the research are the research questions, in other words what has to be analysed. They have to be clearly formulated to avoid poor results and a risk of missing the direction of research. The research questions for this Master thesis are developed by the author out of the research area: emissions / green transport and the specially selected aspect of this research area: calculating tools for emissions. The author developed the following selected research questions based on the theory and methodology:

Q1: In what way are the existing calculation tools comparable with regards to the results provided by them? (Are the different analysis tools providing significantly comparable results, for a well-defined transportation of a fixed amount of goods and for a well-defined trip).

Q2: What is the background of the existing calculation tools and do they have a solid basis regarding research and a scientific relevance?

Q3: Are these instruments rather marketing gadgets to create a greener image than analysis tools?

The goal is to answer the formulated research question with the described methodology, methods and research design.

2.4 Case study design

The design of a case study contains two dimensions, first if only one (single-case design) ore several cases (multiple-case design) will be analysed and second if the design should be holistic or embedded, cf. (Yin 1995).

For this Master thesis the approach of a multiple-case study has been chosen, to increase the comparability of the outcome the analysis is provided with a real life setting (the case of a Norwegian company) and a constructed case. Where the setting is constructed to avoid poor comparable results due to for example significant different distances for different transportation modes, but has to be similar to achieve the requirements of a multiple-case study (Yin 1995).

Holistic in general means that the study examines only the global nature of a program while the embedded approach also covers units and subunits of a program, cf (Yin 1995).

In the situation of a multiple-case study, like in this Master thesis each individual case has rather a holistic or an embedded approach. For the cases of this Master thesis an embedded approach is chosen due to the fact that each tool (program) will provide calculations for several kind of emissions in each analysed case.

2.5 Comparative case study

A comparative case study is generally spoken "(…) simply, the design entails the study using more or less identical methods of two or more contrasting cases."(Bryman and Bell 2011 p. 63)
In this Master thesis the "real life" case of a Norwegian company and a constructed case with a different setting, hereby is the focus of the comparison on the outcome of each calculation tool for the different transportation modes (inter-modal, sea, road) in two different settings.

The methods and methodology used for the analysis in both cases is identical.

2.6 Data classification

In scientific literature there are two main types of data mentioned, the *primary* and the *secondary* data. While the author collects the *primary data* through interviews or survey, the *secondary* data is representing already existing data. In both cases this data can be either of qualitative or quantitative nature.

Qualitative data contains mainly numbers and are mainly analysed in some mathematical way of analyse. *Quantitative* data is mainly written information that contains several kinds of data beside the *qualitative* data.

2.7 Data collection and classification for the further analysis

As before mentioned there are different types of data that can be used for a scientific paper. The *method* (cf. chapter 2) of gathering all necessary data and information will be described in the following.

The author will use mainly *secondary qualitative* data from scientific literature, essays, and newspapers, the Internet etc. as for the theoretical background, about the different analysis tools, the use and outcome of them as well as the topic of environment and transportation in general. The *quantitative* data that is going to be used will be generated mainly by the outcome of the different calculation tools and a further going analysis of the similarities and differences and the reason for eventual differences.

3. Literature review

In chapter three the theoretical framework for this Master thesis will be provided and the critical points of the topic will be reviewed. As addressed in the introduction part environmental issues and emissions are the overriding topic in this Master thesis and in particular calculation tools for emissions caused by freight transportation. The dilemma of a common global environment policy and restrictions by national and supra-national bodies will be illustrated. In addition the way to calculate emissions and collect data for the different transportation modes and their characteristics with regard to emissions will be discussed. Thereby the focus will be on the particular problems and specifications for emission of sea, road, air and rail transportation. Furthermore the carbon footprint and recent studies of calculation tools for emission caused by transportation are considered as relevant for this Master thesis and will be outlined.

3.1 Political and general framework of transportation emissions

Environmental policy is nowadays a supra-national issue and is therefore often difficult to compare between countries because of the different implementation of laws and restrictions on national level. It started with the "Report of the World Commission on Environment and Development: Our Common Future" published in 1987 by the World Commission on Environment and Development (WCED), an institution of the United Nations (UN), better known as the Brudtland[4] Comission named after the chairman of the report (United Nations 1987). After this report follwed in 1992 the by the UN established United Nations Framework Convention on Climate Change (UNFCCC) "(…) which purpose was to establish a scheme for trading emissions in order to avoid dangerous manifestations in the climate system" (Slate 2011 p. 61).

The Kyoto protocol followed the UNFCCC in 1997. Nowadays 191 countries ratified the Kyoto protocol, the main problem for the implementation is the fact that the USA did not ratified the treaty until today. However, the aim of the Kyoto protocol is generally spoken to stop the global warming by reducing GHG on a global level, and one of the main causes of GHG is transportation of goods and people. In 2007, transport of goods and people was

[4] Gro Harlem Brudtland, former Norwegian Prime Minister.

responsible for 23,5 % of all emissions and the only cause which emissions values have continuously been increasing since 1990 in the EU (European Comission 2010 p. 4). In 2003 the share between the different transportation modes was as follows: 18 % of the emissions were caused by road transport, 3 % by air and 2 % by maritime transport (OECD 2007 p. 6). To distinguish clearly between pure freight transport and public transportation can be challenging if one thinks about ferries and airplanes, where freight and persons are transported together.

In 1997 the EU adopted the guidelines of the Kyoto protocol with the goal of a reduction of GHG with 8 % until 2012 compared to 1990 (Slate 2011). The global treaties as the UNFCCC Kyoto protocol and a common EU environmental policies being binding for all member states are milestones for the reduction of GHG, but they seem not to be as effective as necessary. Especially with the background that the "(…) EU claims to be a front runner in climate policies and considers itself a leader in international clime negotiations" (Kulessa 2007 p. 64). What are the reasons that until today the emission of GHG could not be significantly reduced until today?

3.1.1 Emissions and economic growth

It seems that the implementation of such common rules is difficult and time consuming. One of the main reasons for that is the dependency between economic growth and energy consumption and that emission is following energy consumption.

Without doubt a strong dependency between the level of emission in a country and economic growth exists. *Emission is following energy; energy causes costs for the transportation industry and shows again that the transportation industry has at least indirect interest to minimize emission, with the result of cost saving and therefore having an interest to control their emission, by controlling energy consumption, for particular transportations with help of emission calculation tools*.

In general the framework to address emissions caused by transportation looks as follows:

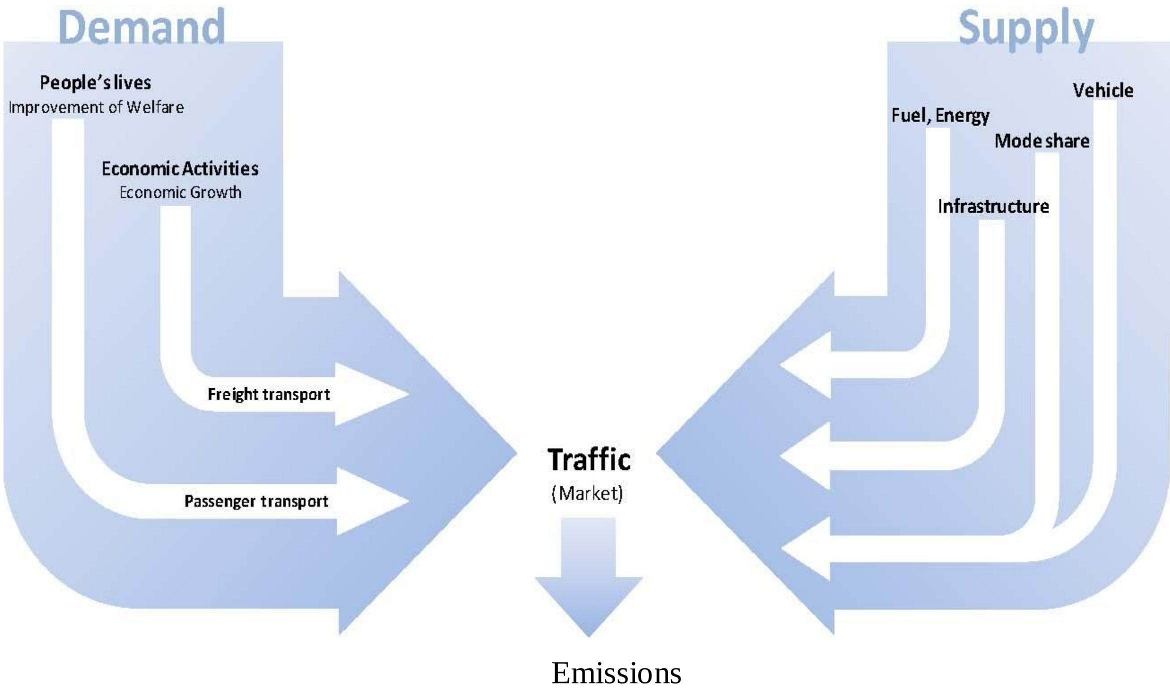


Figure 1: Framework addressing emissions by transport

Source:(OECD - International Transport Forum 2009 p. 11), graph simplified by the author.

Figure 1 shows the framework of emission caused by transportation where traffic is in the centre to satisfy the market for transportation and finally ends in emission by transportation.

Countries with a low level of industrialisation and a low productivity are causing less emission and vice versa due to the fact that production and transportation of goods need energy, and that this energy should be as cheap as possible. Therefore, oil is mainly used to produce the needed energy. In 2006, 95 % of the energy for transportation were generated by carbon-intensive fuels, cf. (OECD 2011). The described coherence between the need for cheap energy to generate prosperity and growth resulting in higher emission outline the dilemma to define and to converse a common global environment policy. “US, China, Japan, India, Germany, the UK, France, Russia, Canada and Australia as well as South Korea, Mexico and Brazil – who are representing basically the G20 countries - causing 80 % of all greenhouse gases in 2006 (Lane 2009 p. 408)”. That means that emissions are not just originated in the EU, but neither by too many developing countries. Anyhow, this means that their emission policy, especially for the transportation industry, is tremendously important to decrease emission of transportation.

It is not only on a global level that regulations to embark emissions are generating a conflict between transport policy and climate policy. In the EU the harmonization of inter-European transport and the mobility and accessibility has to be ensured (Walz, Schade et al. 2007). The situation of opposite interests stresses the need for a common environmental and transportation policy.

3.1.2 Counteractions for emissions

To achieve the goal of decreasing emission caused by transportation a mixture of counteractions are chosen. These actions resulting in restrictions for the different modes however if adopted (as from the IMO for shipping, ICAO for aviation) or developed by the EU and their responsible bodies as e.g. the European Environmental Agency (EEA). Every mode has it specialities when it comes to the possibilities for reduction of emission. On the one hand are these technical specialities and on the other hand specifications due to the mode in general, as e.g. the average life cycle of a transport vehicle. While vessels have an average life cycle of about 25-30 years, the life cycle time span for airplanes is much more difficult to state because it depends on flight hours. However the life cycle at least for trucks is relatively shorter compared to the other modes of transportation. In addition, the purchasing process for vessels and airplanes is significantly longer than for trucks and trains because of investment costs and construction time. Due to that many old vessels and airplanes are still in service without the newest technical features for emission reduction. This results in a longer implementation time for these modes compared to road transportation. Therefore and because of the fact that road transport is responsible for the major part of transportation emissions the focus of emission politics is on road transportation in the EU. Road transport has profited most from the harmonization of transportation in the EU over the last decades (Raux 2010). In addition road transportation is often needed for the inter-modal transportation of goods, both for the hinterland transportation of sea- and airports as well as for door-door services in combination with all other modes.

For this reason several actions have been taken place, not only for road transport but also for rail, sea and air transport. These are technical restrictions, restrictions by law, fiscal and political actions. Technical restrictions are often combined with restrictions by law and

aiming on the technical development of e.g. filters and catalysers for the end-of-pipe emission as well as innovations such as gas turbines for vessels and electric cars. These developments are often caused by legal restrictions for the transportation industry as the Euro norm for vehicles in the EU. Fiscal regulations as for instance the taxation of gasoline and diesel, emission tax and road pricing are further cornerstone in the EU policy.
Fiscal actions are end-user paid regulations (Jarzembowski 2007) which are aiming by the consequent indirect rise of prices for road transportation to cause a shift to more environmentally friendly modes of transportation. This shift from environmental unfriendly modes to apparently environmentally friendly modes of transportation is the political dimension of the attempt to reduce emissions. The developing of infrastructure for environmental friendly modes such as shipping and rail transportation is the main tool to push the shift in transportation mode. “The revitalisation of rail transport is urgent. Both from an environmental point of view and efficiency reasons a railway network across Europe is essential” and further one “The [EU] council believes it is important to encourage the use of maritime transport and inland navigation in community transport by promoting short sea shipping, (…)” (Westermark 2001 p. 177).
These are projects of the so called TEN and are launched to encourage inland waterways and railways as well as SSS as modes of transportation to bring the “goods from the road” to the rail respectively to transportation by on inland waterways and SSS.(Walz, Schade et al. 2007; Jarzembowski 2007)

3.2 Emissions trading

Another innovative idea to solve the problem of emissions caused by freight transportation is to implement an emission-trading scheme for transportation vehicles and to include the trading scheme into the EU Emission Trading Scheme, ETS. In 2005 the EU implemented the first border crossing CO_2 emission trading scheme. The implementation of the ETS was an important step to achieve the requirements of the Kyoto protocol but is until today not applied to transportation emission, only for emissions by production plants and other causers than transportation. The idea of the ETS is to make emissions tradable and that the causers of emissions need to hold emission certificates, “pollution rights”, equivalent to the amount of their produced emission (Egenhofer 2007; Slate 2011).

Today scientists start discussing to implement such “pollution rights” also in the transportation industry, with the same basis which is to set a maximum level of emission for the entire industry and that these emission has to be allocated by the actors in the transportation industry. For the transportation industry this would be on the basis of fuel rights, which means the right to use fuel because of the before discussed important relationship between fuel consumption and emission in transportation. “The tradable fuel rights would be thus based on quotas of CO_2 calculated from the carbon contained in the fuel (mainly diesel oil for trucks) consumed by any fright vehicle user, i.e. a for hire carrier or a shipper performing its own transport” (Raux 2010 p. 143).
This approach contains threats as of examples that a shipper might make use of old vehicles in the beginning to raise the need for emission obligation to be in the position to make use of “grandfather rights” (first phase, the phase of implementation) in the future as well as opportunities to reduce emission by transportation in the long run. In the second phase (2008-2020) 10 % of the “pollution rights” will be auctioned.

The emission by transportation is different depending on the mode of transport and thus the possible restrictions vary based on what kind of emissions is produced. The emissions specification of the different transportation modes is reviewed in the following paragraph.

3.3 Emissions caused by transportation

As reviewed in chapter 3.1 the approaches and problems institutions are faced with, to restrict and to decrease the emission of GHG are multiple. This is on the one hand because of the dimension of a global solution and on the other hand because of the various numbers of causers of emission involved. As carved out in the previous section transportation is one of the biggest sources of pollution amongst others. Freight transportation is carried out by different kind of transportation modes, and each mode has its own specialities and characteristics that have to be served and faced to find a way to reduce emissions of transportation. As an example the before mentioned Kyoto protocol can be named, excluding actions for sea and air transportation and where instead the responsibility is given by the UNFCCC to the IMO and ICAO (as bodies of the UN) to develop standards and restrictions for sea and air transport emissions on a supra-national level and to make their members committing to them (OECD 2007). The EU is mainly adopting these regulations and standards for emissions and making them binding for the member states. However, the deviation of how each member state is converting these regimentations to national law is high. All these factors are exalting the complexity of the situation in the transportation sector. The current situation for sea, road, air and rail transportation is outlined in chapter 3.3.1 - 3.3.4 to explain the details and specialties of each transportation mode in particular with regards to emissions.

3.3.1 Sea transport emissions

As described in chapter 3.1 shipping is responsible for approximately 2 % of the global emission of GHG (2007). Mid-range scenarios show that until 2050 the emission by shipping will rise by the factor 2 to 3, compared to 2007, due to the growth in shipping. At the same time the potential to reduce emission by technical and operational measures is taxed between 25 % and 75 % (IMO 2011).

“Per kilometre, shipping is one of the lowest emitting freight transport options around; at 10-15 grams per tonne-kilometre, it is lower than rail (19-41 g/tkm), trucking (51-91 g/tkm) and aviation (673-867 g/tkm). But the carbon footprint of the sector as a whole is as large as some major countries” (OECD 2008 p. 58). That the overall emission by shipping is so extremely high has its causes in a doubling of maritime trade between 1985 and 2007 and the long life circles of vessels (OECD 2008).

“The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes” (IMO 2011). The MARPOL convention was a reaction to a number of accidental pollutions in international shipping and was adopted by the IMO in 1973. The MARPOL convention has seven annex, and was developed and adjusted continuously over the last decades to the challenges of growing trade overseas and blast in numbers of vessels in service. The newest annex is annex number seven which regulates the air pollution for seagoing vessels. It restricts the concentration of air polluting matters as CO_x, SO_x, NO_x, HC and PM in fuel used by vessels, which are representing the most important emissions by shipping to the atmosphere (Matthias, Bewesdorff et al. 2010). For a general understanding of emissions caused by sea transport different aspects have to be mentioned. First of all, it depends on where the vessel is operating, e.g. in the port, on open seas or in special areas such as channels, or other specially controlled areas. Each area has own restrictions regarding what kind of engine and fuel is allowed to run. While a vessel is at berth or approaching a port, they are using in most ports the auxiliary engine (depending on vessel size between three and seven) to produce electricity on board (if not provided with on-shore electricity, which is provided only by few ports) to keep the vessel manoeuvrable and to run e.g. cranes, winches, cargo refrigerating, manoeuvring or hatches (Jayaram, Abhilash et al. 2011). The auxiliary engine is run with Marine Diesel Oil, which is more expensive but consists lower rates of air pollutant causing chemicals such as CO_2, SO_x, NO_x than the Heavy Fuel Oil most vessels using to run their main engine on open waters, for the reason that ports are often located in populated areas and effecting the air quality in these areas significantly (Matthias, Bewesdorff et al. 2010). Beside that fact, the IMO determined maximum levels of SO_x, NO_x and PM in special regions, the so-called ECA regions (Formally, Sulphur Emission Control Areas, SECA). ECA stands for Emission Control Area. In these areas vessels are only allowed to use LSFO, Low Sulphur Fuel Oil, while as mentioned before on open waters outside these areas the vessels are burning HSFO, High Sulfur Fuel Oil.

Annex VI: Prevention of air pollution by ships (Emission Control Areas)			
Baltic Sea (SOx)	26 Sept 1997	19 May 2005	19 May 2006
North Sea (SOx)	22 Jul 2005	22 Nov 2006	22 Nov 2007
North American (SOx, and NOx and PM)	26 Mar 2010	1 Aug 2011	1 Aug 2012
United States Caribbean Sea ECA (SOx, NOx and PM)	26 Jul 2011	1 Jan 2013	1 Jan 2014

Figure 2: Emission Control Areas

Source: (IMO 2011).

The columns in Figure 2 display the dates when the different ECA where adopted (column 1), the date of entry into force (column 2) and when it will be effect form (column 3), which means when it is binding for all vessels entering the ECAs. As the table displays the first ECA "Baltic Sea" was in effect form in 2006, followed from the ECA "North Sea" and then by the ECA "North America" and finally the ECA "United States and Caribbean Sea" this year. When a vessel is entering one of these ECAs they have to change at the "Point of change over" from HSFO to LFSO; this point is different from vessel to vessel and is determined by the technical particulars of the vessel. Today the SO_x share in Maritime Fuel is limited to 3,5 % outside the ECAs and 1 % inside. From the 1st January 2015 the limit in ECAs will be cut down to 0,1 % inside the ECAs. This has a big impact on the shipping industry from an economic point of view. One tonne of LSFO costs abt. 1000 EUR in April 2012; this is around 40 % more than the price for HSFO (Behling 2012 p. 7).

In times of continuously rising fuel prices and slow steaming it leads to a sharp rise in prices for shipments by sea. The map below Figure 3 shows the ECAs around the world according to Annex VI of the MARPOL convention, as one can see the convention therefore affects the most important European and American ports.

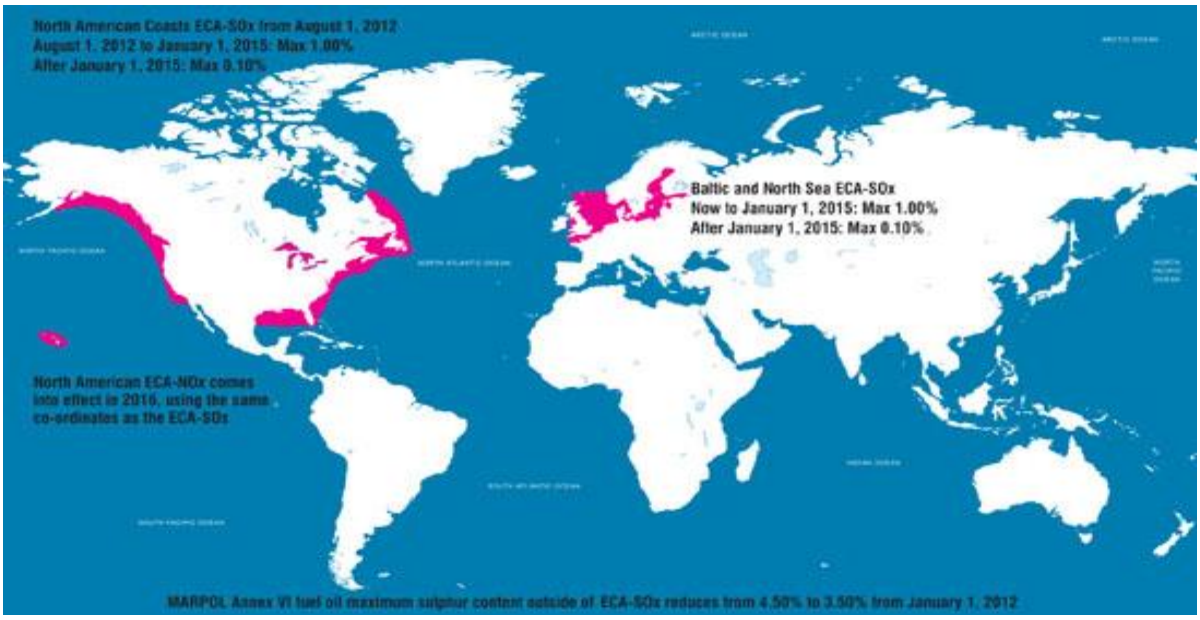


Figure 3: Map of Emission Control Areas

Source: (BC Shipping News 2012)

Not only the economic point is challenging owner and charterer, but also technical challenges have to be solved to upgrade the engines and make them capable to meet the new requirements (Wingrove and Eason 2010).

That the SECA/ECAs are necessary is shown by the research of Derwent, Stevenson et al. (2005), who are demonstrating that the sulphur emission derived by shipping in the North Sea and Baltic Sea contribute significantly to the total sulphur emission in these areas

(Derwent, Stevenson et al. 2005). Nevertheless, also technical innovations and new ship designs contribute to reduce emission by the maritime industry. Energy efficient hull designs, gas turbines and new propulsion systems should help to decrease the fuel consumption and thus the emission. Another innovation is to use big kites or sails for ocean liners to sail on long distance hauls without using the main engine, but the plans for that have more or less been put on ice recently (OECD 2008).

3.3.2 Road transport emissions

As discussed in the previous section, the EU has forwarded several legislative initiatives to reduce emission by transportation. Most of them are based on the "polluter pays" approach where the costs for pollution (marginal costs and social costs) is covered by the operator / shipper (Mayer, Poulikakos et al. 2012). In road transportation it is accomplished mainly due taxes on fuel and toll systems for using roads, the different kinds of taxes and tolls vary between the countries.

The main emission caused by road transport is CO_2; between 97% and 98% of the GHG emissions caused is by road transport. Road transport vehicles are using mainly gasoline and second most diesel oil, but for all that NO_X and PM are considered as the most critical for air quality (Rexeis and Hausberger 2008; Dwyer, Ayala et al. 2010; Pulles and Yang 2011). Furthermore, is road transport is the second largest emission source overall. In 2007 it was responsible for 17,4 % of all CO_2 emission with an increase of 25,2 % compared to 1990 and is thus the only source of emissions with a steady growth.

All other emission sources have shown a decrease worldwide (Pulles and Yang 2011). In the EU 27 the modal split shows the following development over the last decade measured in total inland tonne-km, see Figure 4 in the beginning of the next page.

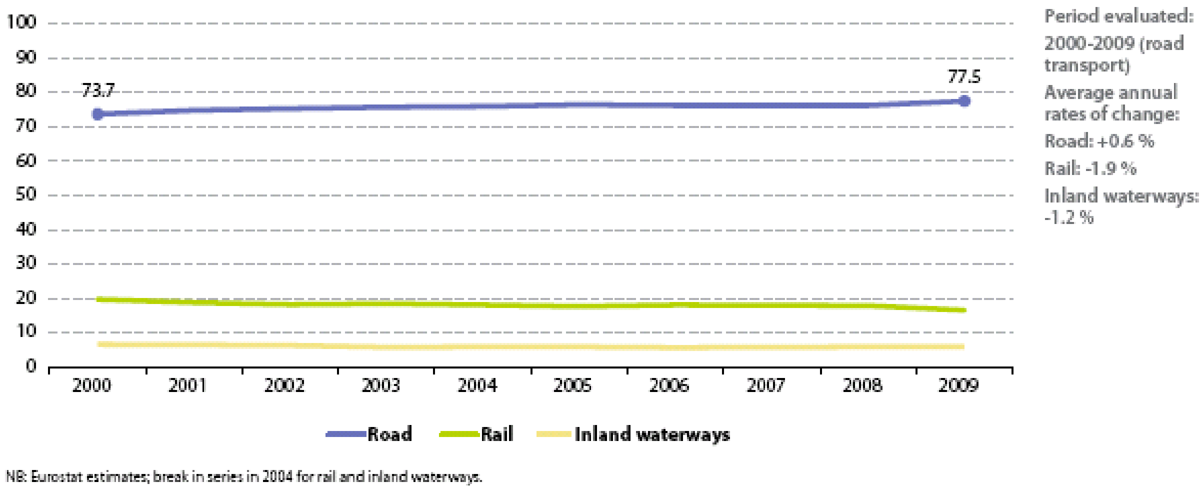


Figure 4: Emissions development for the modal split in the EU 27 2000-2009

Source: (Eurostat 2011).

Figure 4 shows a more moderate development in the EU countries but the tendency is the same with continuous growth of road transport. Especially in the EU the harmonization of the markets where a product is designed in one country, produced in another and finally sold throughout whole Europe road transport still remains as the cheapest and easiest mode of transportation (Mayer, Poulikakos et al. 2012).

The emission caused by road transport which is also including private vehicles and their share of the emission is quite high compared to e.g. in shipping where only 3 % (OECD 2008) of the emission by shipping is caused by transportation of people. Therefore the analyses for road emission distinguish between different vehicle types, private cars, light duty-vehicles (LDVs) and heavy-duty vehicles (HDVs). LDVs are trucks with a maximum all over weight of less than 3,5 tons, while the HDVs are all kind of trucks over 3,5 tons. The most important legislation in the last decades to reduce the emission by road was the change from leaded fuel to un-leaded fuel and the implementation of the Euro norms for vehicles inside the EU. The EU emission norms for road transport are limiting the maximum allowed emission of CO_2, HC, NOx and PM measured in g/km for passenger cars, LDVs and HDVs and differenciates between gasoline and diesel oil. It started in 1994 with Euro 1, which allowed for instance a LDVs Class III with a diesel engine and a weight of over 1,760 tons but below 3,5 tons to have maximum emission of 6.90 g/km of CO emission. Today Euro 5b is required and allows only 0.74 g/km for the same vehicle type; the next higher Euro 6 norm comes into force in September 2015. This continuous decrease in allowed emission from Euro 1 to Euro 6 is similar for HC, NOx and PM for

passenger cars and HDVs (DieselNet 2012). It is expected that the demand for road transport by HVDs will increase by approximately 125 %[5] until 2050 and will together with LDVs also in the future contribute to global emissions (Takeshita 2011).
A different fact is that road transport is especially often augmented in urban areas and thus makes the emission by road transport a health issue for the inhabitants in these areas. PM emissions constitute an important health risk especially for the respiratory system and causes serious diseases (Kousoulidou, Ntziachristos et al. 2008).

As for all modes, models to display the emission of a transportation mode are a central point in scientific research regarding emission. For the emission from road two application fields are important; the application of specifics of this mode as e.g. speed limits or traffic calming and the prognosis of the expected emission level (Rexeis and Hausberger 2008). In addition the vehicle mass, road conditions and the payload of a transportation by road vehicles have influence of the exhausted emissions and have to be considered when it comes to the evaluation of road transport emissions.

3.3.3 Rail transport emissions

The emission caused by rail transport is an ambivalent issue since rail vehicles are using several kinds of energy depending on the type of engine and train. While in maritime, aviation and road transport mostly different types of oil-based fuel are used, trains are using diesel oil as well as electricity and sometimes even coal. The kind of energy chosen has a huge impact on the emissions exhaled. Therefore, it is challenging to assign if rail transport can really be considered as a “green” mode of transport or rather the opposite. Furthermore one if the train is using electricity it is important to know how the electricity is produced to be able to make a statement about the real emission caused, i.e. if produced by nuclear plant, coal plant or renewable energy source as water or wind energy. Catherine Brahic published a study of the University of California, Barkley, USA in the newspaper “New Scientist”, where the question was asked if a commuter train across Boston caused less air pollution than a jumbo jet for the same distance. The surprising answer was that the train does not cause less air pollution than the jumbo jet. The scientists included the

[5] Calculation by the author based on Figure 2. p. 2 in Takeshita, Takayuki: Global Scenarios of Air Pollutant from Road Transport through to 2050.

dimension of lifetime and the exploitation of tracks and roads, leading to the unexpected answer due to the fact that air transport requires little infrastructure (Brahic 2009).

3.3.4 Aviation transport emissions

The aviation industry is a growing industry; between 1989 and 2009 it was growing with 4,4 % per year. The CO_2 transportation by plane were mostly excluded in environmental agreements as the Koyoto protocol (Preston, Lee et al. 2012). “The aviation industry is in the focus of this discussion [reducing of emissions] and first attempts are being made in the European Union to integrated aviation in an emission trading system” (Rothengatter 2009 p. 5).

Aviation accounts for approximately. 3 % of the worldwide CO_2 emissions, whereby aviation plays a more important role for the passenger transportation than for freight compared to maritime, road and rail transportation. Typically air transport is used for high value or perishable goods due to the high unit costs for air transport. Concerning environmental policy, the aviation industry was excluded until 2010 from taxation and other carbon policies (Rothengatter 2009). Additionally, too little actions have been taken by ICAO to implement own emission restrictions leading to the fact that the EU have taken aviation into the ETS from January 2012 (Preston, Lee et al. 2012). This is the first step towards controlling and reducing the emissions of GHG and other air pollutants by air transport.

3.4 Carbon footprint

All processes causing emissions whether to produce goods or services provided to the customer, the globalization and the worldwide link between nations for trade makes it challenging to allocate GHG emissions precisely to the causer (Hertwich and Peters 2008). The complexity of the carbon footprint lay in the different dimensions and factors that are influencing the carbon footprint of a product, service, and supply chain or in a broader perspective of a nation or even to find a global carbon footprint.

However, producers as well as customers are getting more and more aware of the carbon footprint, which can be shown by the 2011 realised survey among 9,000 people in eight different countries. It was conducted between April and Mai 2011 by the ImagePower Green Brands survey and described by Lisa Swallow and Jerry Furniss in 2011. The key findings of this survey are that the majority of consumers across all countries say that it is important for them to purchase from environmentally friendly companies and that green certifications hold by the companies or the brand influences the buying behaviour positively (to see more findings cf. (Swallow and Furniss 2011). Other authors describe the concept of the carbon footprint as follows: “The concept of a carbon footprint captures the interest of businesses, consumers, and policy makers alike. Investors watch the carbon footprint of their portfolios as an indicator of investment risks. Purchasing managers are curious about the carbon footprint of their supply chains, and consumers are increasingly offered carbon-labelled products” (Hertwich and Peters 2008 p. 6414). Both articles describe the change in the mind as well as in business but also in private house holds towards more sustainability. Although what does a “carbon footprint” really mean?

One of the main driver of the carbon footprint concept is the before discussed Kyoto protocol for reduction of GHG emissions on a global level. The concept of a carbon footprint can be broken down from a global to a national level towards production and transportation. Overall the aim is, to assign the originator of CO_2 emissions to the amount caused. The concept of a global carbon footprint in literature is also described as the “ecological footprint”; the concept is comparing available bio productivity and how much of it is appropriated by humanity and it is measured in hectares (Kitzes, Peller et al. 2007). On a national level, the carbon footprint of a country is the sum of all CO_2 emissions caused by consuming or investing a specific number of goods or services by their inhabitants (Aichele and Felbermayr 2012). On a business level the carbon footprint describes the amount of CO_2 emissions caused by the production of a good or service. This creates the challenging situation that it is often difficult to indentify all originators in a production or supply chain. The complex inter-dependence between economic performance, logistical parameters and freight transport is described by Piecyk and MacKinnon in a well-arranged way (Piecyk and McKinnon 2010).

To give a short example: given the carbon footprint for transportation the question becomes up to what point it is necessary to go back to find the actual overall emission caused. Transport needs a transportation vehicle, this vehicle has to be produced, the plant where the vehicle is produced has to be built as well as the machine assembling the vehicle and the track or the road the vehicle is moving must be constructed and so on. All of these steps and processes are causing CO_2 emission and have to be taken into consideration. Consequently, to find the carbon footprint of a product or service might be more difficult than it seems (Hertwich and Peters 2008; Buildings 2011). To address and to model the carbon footprint of transportation and supply chains an environmental thinking has to be included as a factor to the classical focus of supply chain management as inter alia the maximisation of value creation, cost reduction, reduction of lead times and costs (Sundarakani, de Souza et al. 2010). This thinking needs to integrate the entire production process from the design through the material sourcing, the manufacturing, packing and the delivery to the customer (Sundarakani, de Souza et al. 2010). In addition, concepts as Just-in-time delivery and the minimizing of inventory by using transportation vehicles as warehouses have increased the emissions of transportation and make a rethinking of these concepts necessary. To include environmental aspects into a company's demand forecast and to measure and to control the carbon footprint across the supply chain is indeed challenging. To calculate the carbon footprint mostly a life cycle assessment or an input-output analysis is used (Hertwich and Peters 2008; Sundarakani, de Souza et al. 2010; Piecyk and McKinnon 2010). Another alternative is to use free available calculation tools calculating the emission caused by transportation of goods as analysed further on in this Master thesis.

3.5 Calculation of emissions

The calculation of emissions can be based on different approaches; most common for all kind of modes is the calculation of emission based on the consumption of fuel, the so-called top-down approach. Based on the chemical compounding of the fuel, the burning process and the emission caused can be calculated in laboratories. Therefore, emission factors (EFs) are used, these EFs describe the emitted mass (g) for a driven distance (km or mile), and are widely used (Colberg, Stahel et al. 2005; Colberg, Tona et al. 2005; Hueglin, Buchmann et al. 2006). "Road traffic emissions are calculated by emission models that are based on dynamometer measurements for a number of single vehicles tested under appropriate driving conditions and on model calculations of mileages for these conditions (Colberg, Tona et al. 2005 p. 2499)". A procedure used for all kind of road vehicles. Calculation results derived in laboratories have the uncertainty of if they would lead to the same results when calculated in real life. The dependency of emission on speed, road and track conditions for truck and trains or the currency and wind for ships and planes as well as the loaded quantities and the payload influence the caused emission. All these circumstances create an almost unlimited number of possible settings (Colberg, Stahel et al. 2005; Hueglin, Buchmann et al. 2006).

A second approach is to build models calculating emissions based on data collected from different sources and to aggregate and allocate them to the different transportation alternatives to be able to take the mentioned real life circumstances into consideration. The problem hereby is that the data is not always up to date. The "Handbook of Emission Factors for Road Traffic" (HBEFA) was established in the 1990`s and is one of these models to calculate emissions by road traffic. It is "(…) a databank which allows the user a simple simulation of aggregated emission factors for different traffic situations" (Hausberger, Rodler et al. 2003 p. 5237). The problem is that the data the HBEFA database is using for HDVs is based on measurements from engines constructed between 1984 and 1990, while the data for LDVs have constantly been updated. This leads to an underestimation of the real emission level of HDVs. In addition these databases are collecting data from governments and private sources about emission caused in a country, one of the institutions in the EU collecting this data is EUROSTAT.

To be more up to date, several actions have been taken inside the EU, such as the ARTEMIS project in 1999 as a new framework for the emission calculation (Hausberger, Rodler et al. 2003; Colberg, Tona et al. 2005).

To collect more precise data, a third approach is to measure the emission of a transport vehicle with on board sensors and measurement in traffic (Zhang and Frey 2006) ; this is a bottom-up approach to calculate emissions. To evaluate the emissions caused in real life settings of road transport in traffic often tunnels are used. The tunnels are equipped with sensors gauging the emissions. The tunnels are chosen because they prevent mistakes in measurement by metrological influences (Colberg, Stahel et al. 2005; Colberg, Tona et al. 2005; Hueglin, Buchmann et al. 2006; Zechmeister, Dullinger et al. 2006). In road transport in mountain areas also the altitude and road gradient of the road network has to be taken into consideration (Sturm, Pucher et al. 1996). The advantages of tunnel studies are that the traffic emissions of a collective of vehicles can be surveyed and that the results can be compared with the results achieved for a single vehicle on the dynamometer (Colberg, Stahel et al. 2005). Overall, it is difficult to consider differences and usual variations in transport as inter alia: dissimilar weight loading factors, pre-trips and pos-trips in intermodal transport, different travel distances for different transport modes, loading and unloading actions, energy consumption in non-driving conditions. These factors influence the decision of what kind of mode is most environmentally friendly and depends always on the particular transportation (Kolb and Wacker 1995).

Moreover, equivalent databases for the calculation of emission for other transportation modes are being developed. One is the EUs EX-TREMIS (EXploring non road TRansport EMISsion in Europe) project, "(…) a new reference system for emission factors, energy consumption and total emissions for maritime sources as well as for rail and air transport" (Schrooten, Vlieger De et al. 2009 p. 318). As discussed before, it is also the most common currently used way to estimate the emission for maritime transportation caused by maritime source based on bunker fuel sales. The bottom-up approach is calculating the emission on particular vessel's characteristics, engine performance and real vessel traffic provided by governments and private sources (e.g. vessel's owner). The EX-TERMIS project is following the bottom-up approach and is using data from EUROSTAT and national data sources (Schrooten, Vlieger De et al. 2009). The model was necessary to provide the maritime industry with more accurate emission data. It is a new approach with respect to a more detailed emission calculation in coastal areas where the pollution is especially significant related to the shipping industry and the data derived from fuel bunker sales.

3.6 Data bases for emissions

Generally spoken, databases for emission are representing a collection of emission data from countries, private companies and house holdings and function as storage and aim to provide it to control and monitor the development of emissions. It is a result of the discussed environmental policies in the last decades. These are projects and data bases by supranational institutions as the EU (inter alia ARTEMIS Project, EUROSTAT), projects by organisations like Green Freight Transport (GFT) or by private institutions. An overview of the currently existent databases in the EU and how they are related to each other as well as to different calculation tools is provided in chapter 4. However, in the previous sections some of the existing databases were already addressed. For sea, rail and air transport EX-TREMIS is the most recent project to collect data with regards to emissions. It is based on a fleet module that defines the ship categories, loading capacities, and the engine specifications and uses data from EUROSTAT, Sea Web Lloyd's database and international literature (Schrooten, Vlieger De et al. 2009). For road transport the HBEFA published by the German Federal Environmental Agency, Berlin is the standard work for road transport emission as a result of a German-Austrian-Swiss cooperation (Hausberger, Rodler et al. 2003). It is a databank which allows a simulation of aggregated emissions factor from different modes of transportation (Hausberger, Rodler et al. 2003). It is a further development of the EUs COPERT project and is partly related to the ARTEMIS project. The COPERT III project was implemented in the 1990s for predictions of air pollutant emissions and fuel consumption. This module produced emission factors (g/km) for each vehicle category and technology class (EU Norms) (Giannouli, Samaras et al. 2006).

The ARTEMIS project is a database that collects emission data from transportation within the EU. A further emission database in the EU developed recently is TRENDS (TRansport and ENvironment Database System). "The main objective of TRENDS was the calculation of environmental pressure indicators caused by transport" (Giannouli, Samaras et al. 2006 p. 247). The TRENDS database is MS Access based and is free available for further use and calculations. TRENDS is covering air emissions from road, rail, shipping and air transport. Additionally, it has a particular outline for each mode considering the specifics of the different modes. The methodology of TRENDS is based on existing calculation methods such as FOREMOVE and CASPER (Giannouli, Samaras et al. 2006). Beside these projects several projects on national level are running e.g. in the UK or the NABEL in Switzerland (Swiss national air pollution-monitoring network) (Hueglin, Buchmann et al. 2006; McKinnon and Piecyk 2009).

3.7 Recent studies

In the same extend as the need for a change in mind for global warming and GHG emissions arose, the amount of research papers and literature about emissions increased.

As figured out in the previous sections, transporting emissions are an important factor in this coherence. In the following, five recent studies about calculation of emissions, and calculation tools used for it will be reviewed to give an overview about the current state of research. Three of these studies are conducted as projects involving academic institutions, governments and private companies (Green Freight Transport, EcoTransIT, Guidance on measuring and reporting Greenhouse Gas (GHG) emissions from freight transport operations). One is based on pure private researches from PE International and another one as reference research from outside the EU; the final report on FREAT to the US Department of Transportation prepared by several US Universities.

The Green Freight Transport project was running between 2008 and March 2011. The project was under the auspices of the Norwegian Research Council program "SMARTRANS – Intelligent Freight Transport". "The purpose of the project is to make freight transport cleaner by developing systems for environmental accounting in transport companies, and to develop a decision support system for the handling of environmental challenges of freight transport"(Norvik, Levin et al. 2011 p. 14). Involved in the project where transportation companies as Tollpost Globe, Cargo Net and transport related institutions as Norges Lastebileier –Forbund, Statens vegvesen and Jernbarnverket. SINTEF Teknologi and samfunn, avdeling Transportforskning of NTNUI Trondheim, did the scientific research and worked on the project. As a part of the study, SINTEF tested some of the existing calculation tools for emissions in transport (EcoTransIT, NTM-Calc, ITD Emission Calculator og OMIT, Schenker, Tollpost Globe and Vestlandsforskning) in real life settings within Norway (Norvik, Levin et al. 2011 p. 35). The second objective of the project was it to develop an own emission calculator based on a bottom-up approach with data from the EU ARTEMIS project as a key methodology. These emission functions are gathered in a database named SEMBA (SINTEF Emission Module Based on ARTEMIS).

EcoTransIT is one of the most commonly used net-based emission calculators for transportation at the moment. It is conducted by the IFEU Heidelberg, Germany, Öko-Institute e.V., rmcon Rail Management Consultants and the IVE mbh. The project is commissioned by DB Schenker Germany and UIC (International Union of Railways). The first online application offered by EcoTransIT was launched in 2003 and was restricted to Europe; in 2010 the recent version was introduced, now usable all around the world. The reason for that is the need of data that is used to provide a precise outcome. The main aim of the project is to provide a calculation tool for emissions to the transportation industry, enhancing the forwarders to reduce environmental impacts of their shipments, the ability for the companies to satisfy the customer request for a carbon footprint of their shipments and finally a tool for political decision makers, consumers and non-governmental organisations to compare the different impact of all transportation modes (rail, road, air, sea). “The environmental parameters covered are energy consumption, green house gas emission and air pollutants, such as nitrogen oxides (NOx), sulfur oxides (SOx), non-methane hydro carbons (NMHC) and particular matter” (Knörr, Seum et al. 2011 p. 4).

“Guidance of measuring and reporting Greenhouse Gas (GHG) emissions from freight transport operations” is a work conducted by researchers of the University of Westminster, Harriot-Watt University in Edinburg and the Cranfield School of Management in cooperation with several companies and institutions as The Chartered Institute of Logistics and Transport (UK), Department for Environment Food and Rural Affairs (UK), Department for Transport (UK), Freight by Water, Food Storage and Distribution Federation, Freight Transport Association, IGD, RHA and the Rail Freight Group. The focus of the report is more to provide the transportation industry with a guideline how to calculate emissions in general, rather than focussing on calculation tools or databases for emissions. This means that the paper does not want to provide a whole “carbon footprint” for a shipment, but shows how to calculate emission from a top-down approach based on EFs of different types of fuel burned by transportation vehicles (Leonardi, McKinnon et al. 2012).

PE International is a software company, specialised on software solutions for sustainability related issues in companies, based in the USA with dependences around the world, inter alia in Germany. Based on the question of the most environmental friendly mode of transport, the German dependence analysed the emissions of transportation of rail, truck, inland navigation and air transport in Europe. They are concluding and assessing as other researchers that it is not longer possible to make general statements about the environmental friendliness of different modes, rather that each shipment has to be taken in consideration to make an educated statement how environmental friendly a transportation mode is. The overall aim was it to make an ecological comparison of road, rail and inland waterway and their emissions in a long distance freight transport. The scope of the study was Germany and the main GHG emissions. As an approach the conductors chose a holistic approach i.e. that not only the direct emissions by e.g. burning fuel are considerate but also electricity and other needed energy resources using a life cycle approach (Spielmann, Faltenbacher et al. 2010).

The FREAT tool, developed in the USA by the University of Deleware, Rochester Institute of Technology and the University of California Barkley for The United States Department of Transportation, is out of the scope of this Master thesis but noteworthy with regards to the fact that some parts of the calculation tool is related to the NTM Calculator from Sweden and also mentioning the ARTEMIS project. Based on a older model emission calculation tool, the GREET tool, they developed a MS Excel based interface to provide non-linear optimisations of travel time, travel cost, VOC, CO, NOx, PM, SOx and CO_2 emissions (Corbett, Winebrake et al. 2008).

4. Analysis

Chapter four is covering the analysis of the selected calculation tools for emissions by transportation done for this Master thesis. First of all, an synopsis of the main existing calculation tools will be provide, in order to clarify how elements they consists of and how they work in particular to finally be able to determinate similarities and differences between them. Based on this collection, the calculation tools to be analysed are chosen with respect to the criteria's defined in chapter 1.3. How these kinds of tools are used and what kind of outcome they provide will be explained thereafter. The chosen methodology to analyse the calculation tools in this Master thesis is the comparative case study design. The two different cases will be outlined and especially how the constructed case is designed to fulfil the requirements for the analysis. The results and findings of the case analysis are finally concluded and recommendations for further analysis are given. The mentioned case analysis is the core of the analysis part and will be compare how the existing calculation tools measure the environmental performance of different transport alternatives, their reliability and accuracy as well as the theoretical background behind these tools. The first step in the analysis process will be the comparative analysis with regards to the provided outcome for a comparable transportation chain: if it is done based on the same approach and how the outcome may differ from one to the other tool. The outcomes from the different calculation tools applied to the two different cases are providing some commonalities and differences. The following Figure 5 shows the main process of the analysis.

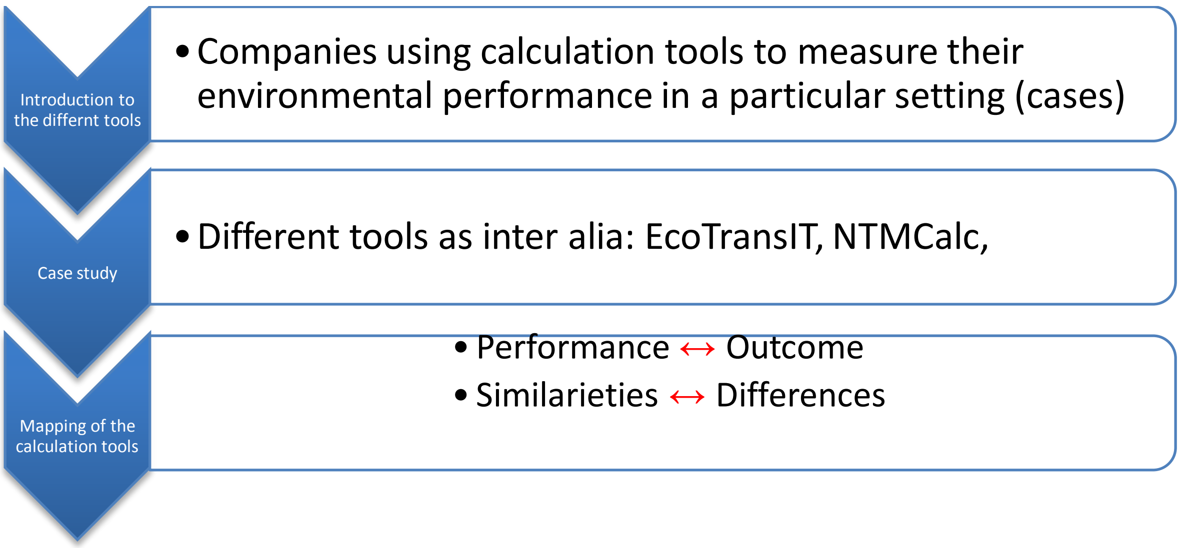


Figure 5: Analysing process

The analysis of this Master thesis contains different analysis dimensions; on the one hand it makes use of two different cases and on the other hand of the generated numeric outcome from the different calculation tools as well as the data behind the calculation tools.

The main challenge of the analysis is to create comparable cases and to select the most comparable and most important calculation tools for the transportation industry.
To construct the cases, comparable specialities for road, sea and intermodal mode of transportation have to be taken into consideration; especially the lengths of the transportation haul but also the loaded quantity. With regard to the loaded quantity the existing imbalances in round trips between the forth and back transportation of goods is remarkable, especially for container shipments. For this Master thesis a container roundtrip with a 20` TEU standard container is chosen.

4.1 Container imbalances

Therefore the problem of imbalances and repositioning in container transportation and the different payload is shortly reviewed in the following to show the difficulty to design a significant setting. The problem of container imbalances has been discussed by the author before in the course paper "Containerisation: Globalisation at Sea", 2008 at Molde University College.
"Once a container is unloaded it has to be refilled again. However, it is uncommon that the location of unloading is the place where the container is loaded again. This often leads to the problem that there will be an empty container at a place where there is no further need for it and at the same time the transportation space of this unit is required at another place. These facts require repositioning to enable the reuse of the container as a transport unit (Böhm 2008 p. 9)".
Jean-Paul Rodrigue (2009) is mentioning three major repositioning strategies in his publication "The Geography of Transport Systems" to approach the problem of relocation of empty containers. These three stages are:

- Local (Empty interchange), is the regular mode of repositioning. The containers are used without long storage times, are emptied and forwarded to the place were they refilled.
- Regional (Intermodal repositioning), means relocation in a region, between different areas and using different modes of transportation.
- International (Overseas repositioning), is needed due to trading imbalances between East and West, with a higher number of empty containers in the East (Rodrigue 2009).

All three strategies have different needs for relocating the empty containers. While the local and regional repositioning of empty containers affect all modes of transportation, is the global repositioning of empty containers mainly a problem of the maritime shipping industry. The reason for that is the fact that container vessels are able to transport big amounts of low value goods efficently due to economics of scale.

4.2 Load factor problem

In addition to the imbalance problem the "double load factor problem" has to be considered when finding an appropriate load factor for the analysis. Hjelle and Fridell, describe this "double load factor" problem as follows: " The fact that containers and trailers transported are not always carrying cargo [compare previous section] – and may be only partly filled – effectively means that the relevant load factor of such vessels [RoRo and Container vessels] is a multiple of two load factors (Hjelle and Fridell 2012 p. 6)."

This means in other words that in intermodal transportation that is containing sea voyage, the actual load factor of the vessels is lower because of empty / not fully loaded containers and the fact that not all lane metres of the vessel are used by trucks but also by private cars. Thus, the calculation of such transportation with regards to the emissions contains some difficulties.

	1985	1990	1995	2000	2001	2002	2003	2004
Tonnage (millions)	23.7	34.5	47.6	51.6	51.7	51.1	51.3	56.4
Containers (millions)	2.13	2.84	3.64	4.32	4.45	4.49	4.51	4.90
TEU (millions)	3.05	3.97	5.36	6.71	6.98	7.22	7.30	7.99
TEU per container	1.43	1.40	1.47	1.55	1.57	1.61	1.62	1.63
% of containers empty	21	19	15	19	21	24	28	28

Table 2: UK container traffic, 1985 – 2004

(Woodburn 2007) above shows the development of the container handling in the UK. The last row displays the increasing numbers of empty containers transported in the UK from 19985 until 2004. While in 1985 only 21 % of the transported containers were empty, in 2004 already 28 % of all handled containers were without load. In argumentum e contrario this means this that in 2004 the container had an average load factor of 72 %. The difference between 2003 and 2004 was 1 % increase of empty containers handled. Assuming that this development continues in the same degree, this would for 2012 result in 36 % of empty containers handled. That this assumption is justified is based on the fact that the numbers of produced containers and as well as the number of container tonnage in service has continuously grown and events such as the financial crisis with a down peak in global trade even more arouse the overcapacities of containers provided. Based on this argumentation, *a calculated load factor of 65 % will be used for the further analysis of this Master thesis.*

In order to make the transportation comparable, a 20` TEU standard container is chosen, the load factor of the container is assumed with 65 %. A 20 ` TEU has a total weight of 24,000 kg, with a maximum payload of 21,750 kg. Using a 65 % load factor the payload for the 20` TEU used in this Master thesis is 14,137.5 kg. The overall weight of the container equals:

21,750 x 65 % + 2,250 (dead weight of the container) = 16,423.5 kg.

To summarise the cornerstones for the following analysis; the analysis will be performed with a comparative case study, containing two cases; the cases contains a road, a sea and a intermodal transportation. The constructed cases are taking into consideration that the haulage lengths of the different modes are not significantly different. In addition, a load factor of 65 % is assumed for both cases, which results in a transported total weight of 16, 423.5 kg in a 20` TEU container.

4.3 Overview over existing calculation tools

During the research for this Master thesis many different possible calculation tools were found, tested and evaluated. The operating companies were contacted to gather information about the background data and methodology used for the different tools.

As an assortment of the calculation tools found can be inter alia named:

- *EcoTransIT*

One of the most known and used among the transport industry provides with a wide range of emissions and energy outcome. Allows all kind of transportation mode, later this tool will be used to explain the use of such tools exemplarily. It is designed and developed from the IFH Institute in Heidelberg, Germany in cooperation with transportation companies as e.g. Schenker International (EcoTransIT 2012).

- *NTMCalc*

The NTMCalc is a non-profit institution founded in 1993 to develop a calculation tool to measure the emissions caused by transportation. The institution is supported by a broad range of Swedish transportation institutions and organisations and allows the calculation of emission from all modes of transportation (NTMCalc 2012).

- *NYK Group emission calculation tool*

It is a calculation tool for the shipping industry. The user has the possibility to choose between transportation with container vessel or with airplane. The tool is provided directly on the company the company website. It only allows calculations for defined routes (NYK Group 2012).

- *GTCC*

The Global Transport Carbon Calculator (GTCC) is a calculation tool from the company Kuehne & Nagel and was introduced in 2009 to satisfy the wish of their customer to display the carbon footprint of their shipments. The tool provides calculation of emission from each mode of transportation. The users has no direct access to the calculation tool and needs to be registered to get access (Kuehne + Nagel 2012).

- *Tollpost Globe*

Tollpost Globe is a Norwegian transport company and provides a "Miljøkalkulator" ("environment calculator") for their customers. The calculation tool is not free accessible and requires a valid contract for the registration and the use of the calculation tool (TollpostGlobe 2012).

- *Martrans.org*

The website of Martrans.org is hosted by the National Technical University of Athens, Laboratory for Maritime Transport in Greece. It is a really specific and technical calculation tool for the maritime industry. It is necessary to enter the fuel consumption for a specific voyage of a specific vessel type and provides a detailed report and the emission of CO_2, NOx, and SO_2. The routes cannot be entered by the user and are fixed with regards to the vessel type (Martrans 2012).

- *Shippingefficiency.org*

The aim of shipping efficiency is not a calculation tool for the end customer in the transportation industry rather is than offering the possibility to calculate the emission efficiency of vessels both for new buildings and for older vessels in service (Shipping Efficency 2012).

- *Epa.org*

Epa is the abbreviation for the US Environment Protection Agency and offers several calculation tools to measure the carbon footprint of private households, private and freight transportation based on fuel and energy consumption (EPA 2011).

- *Atmosfair.de*

Atmosfair is a website which provides an emission calculator for private persons and companies to calculate the emission caused by their travelling, mainly for air travel. It does not provide a special input option for the transport industry (Atmosfair 2012).

- *Co2-tec.com*

The Co2-tec project has the aim to provide the transportation industry with a calculation tool to measure the emission from the entire transportation chain. The tool was designed in 2009 and is still in the Beta testing phase. A passwort and username is needed to get access to the test version (C02 TEC 2012).

- *Cleanerandgreener.org*

Is a free accessible calculation tool for the based on energy consumption, this can be natural gas or electricity. It provides thereafter CO_2, CH_4, SO_2, NO_2 and HC for the USA. It provides calculations only for private cars (Cleaner + Greener 2012).

- *Carbonfootprint.com*

Carbonfootprint.com is one of the several existing carbon footprint calculators that are calculating the emissions from households and travel activities by train, car, bus and airplane (Carbon footprint 2012).

- *Freightemissioncalculator.com*

The U.S. Department of Energy offers a quite simple net-based solution to calculate the emission of transportation. The tool provides CO_2 emission quantities for the transportation by road, the input parameters aret travel distance and weight of the shippment (US Department of Energy 2012).

This overview is not depletive and just an extraction of existing tools; the extent to which they are useful for the transportation industry varies significantly. The main finding during the research is that most of the free available calculation tools in the Internet are not especially designed for the transportation industry, but rather for private cars and households. Among the calculation tools designed for the transportation industry many are covering only one mode of transport. Additionally, the focus is more often on energy consumption and CO_2 emission than on other transport related emissions.

Furthermore, the outcomes from the different tools are often totally different with regards what kind of emissions are calculated and provided by the different calculation tools. To find calculation tools designed for the need of the transportation industry which are providing comparable outcomes of emissions and energy consumption was one of the main challenges during the work on this Master thesis.

4.4 Selected calculation tools

The selection of the calculation tools which are analysed in this Master thesis was a *three step* process. The *first step* was the research and collection of possible calculation tools for the analysis. The criteria to collect the tools have been mentioned in chapter 1.3 whereby the free availability in the Internet and the outcome the each tools provides was in the focus of the research. The *second step* was to group and map the found calculation tools into three different groups. The three groups are: Transport & Logistics; Universities, Research Institutions and Consultancies and finally Public institutions. The first group Transport & Logistics presents the transportation industry and companies that are providing calculation tools for the environmental performance of transportation. The second group cover the Research institutions; in this group the calculation tools developed or provided by Universities, Research Institutions and Consultancies. The last group contains the calculation tools provided by governmental instituions as e.g. the EEA of the EU. In the last *third step*, the final selection, *three calculation tools* from the different groups have been selected one from each group.

The decision for or against a calculation tool was based mainly on small tests of the provided outcome (if the outcome is useful for the transportation industry by providing the transport relevant emissions) and on the input parameters if the calculation tool covers several transportation modes. In addition the analysis allows taking the outcome from calculation tools providing numbers for only one certain transportation mode, e.g. the NYK Group calculation tool is only providing the possibility to calculate emission of shipping, into consideration to increase the comparability of the analysis. In the case of the NYK Group emission calculator the problem is that the calculator only gives outcome from routes including ports the company is serving, which are mainly East-West connections and not intra-European routes, and can therefore not been used for further analysis. Same counts for the tool of Matrans.org, which is only providing calculation for emissions from vessels for some particular voyages.

The *first step* and the findings were already addressed in the previous section 4.1 and summarised it can be stated that the Internet research provides the user with a broad range of calculation tools for transportation, households and the carbon footprint of products and services. The research done was with focus on Internet research to fulfil the requirements of this Master thesis for calculation tools (cf. chapter 1.3).

In the *second step* the found calculation tools were mapped and grouped. The focus in this step was not to make a statement about the possible quality of the calculation tool for the further analysis, but rather to get a sorted overview and to collect available tools. The sorting was done under the promises to group the calculation tools with regards to their origin of development. Subsequently, the goal was to achieve a grouping with the most possible variation to make the analysis comparable.
Finally in the *third step*, the calculation tools that should be further analysed were chosen. Hereby was the focus on the provided outcome by each tool and if the outcome is applicable for only one or for several modes of transportation. In addition all selected calculation tools should not violate the set constraints mentioned in chapter 1.3. The table below displays the calculation tools selected for the further analysis of their outcome and background.

Groups	**Transport & Logistics**	**Universities, Research Institutions & Consultancies**	**Public institutions**
	EcoTransIT	NTM Calculator	US Department of Energy

Table 3: Selected calculation tools

Table 3 displays the grouping of the selected calculation tools for the further analysis. It has to be mentioned that some of the tools are cooperation between the transportation industry and Universities or Research Institutions. The classification has in these cases been based on who is designing the tool or which companies from the transportation industry standing behind the development of the calculation tool. The US Department have been chosen to have a non-European tool for comparison in the analysis.

During the process of researching calculation tools to be analysed one main difficulty appear, the comparability of different tools. The existing calculation tools have a high verity when it comes to the output provided by the tool and the purpose the tool is designed for. The calculation tools designed only for freight transportation are rarely among calculation tools provided in the Internet. The main part of the free accessible emission calculation tools is designed for the carbon footprint and energy consumption of private households.

In general the existing emission calculation tools can be categorised in four big groups. The *first* and biggest *group* is the group of the carbon calculator for private houses and leisure travelling. The *second group* contains the carbon footprint calculation tools of daily consumption by private persons. The *third group* contains the carbon footprint calculator of products. And finally the smallest *fourth group* is the group of calculation tools for the transportation industry. The reason for that seems that the pure calculation tools for the emission of transportation are mostly addressed to companies rather than to private persons. Furthermore, these kinds of tools are more complex due to the fact that for the transportation industry not only the emission of CO_2 is interesting, but also emissions such as NOx, SOx, HC and PM are relevant. However, the selection process includes in the *third step* those limitations for the calculation tools made in chapter 1.3 are not violated. This reduces the range of possible calculation tools considerably in addition to the already small amount of relevant emission calculation tools for the transportation industry.

The three selected tools are not or only in a low degree violating the made restrictions and limitations.

4.5 Exemplary use and outcome

The best known non-commercial and free in the Internet available analysis tool for the measurement of environmental performance of transportation modes is the web based analysis tool from EcotTransIT (2012). The use of the tool is free for everyone and the handling easy and is utilized in this chapter to explain the use and the provided outcome of such tools exemplarily.
The user is entering the necessary parameters weight (in metric tons), type of goods (heavy, average, light), defined handling (break, liquid, container, other), the origin and the end of the trip as well as the requested mode (inter-modal possible) of transportation. After that the user will be provided with the needed energy for the transport (measured in kilo joule) and the emission of CO_2, SO_x, NO_x, HC and PM.

For example for a transportation of 30 tons in container (is equivalent to one FCL loaded TEU) with heavy goods from Molde (City district) to Kiel (City district) using an intermodal transportation with truck and ship. Following energy is needed and emission produced (here only presented the primary energy consumption and the carbon dioxide emission, which represent the standard outcome of the tool. Further detailed graphs and numbers regarding other emissions and consumptions are available):

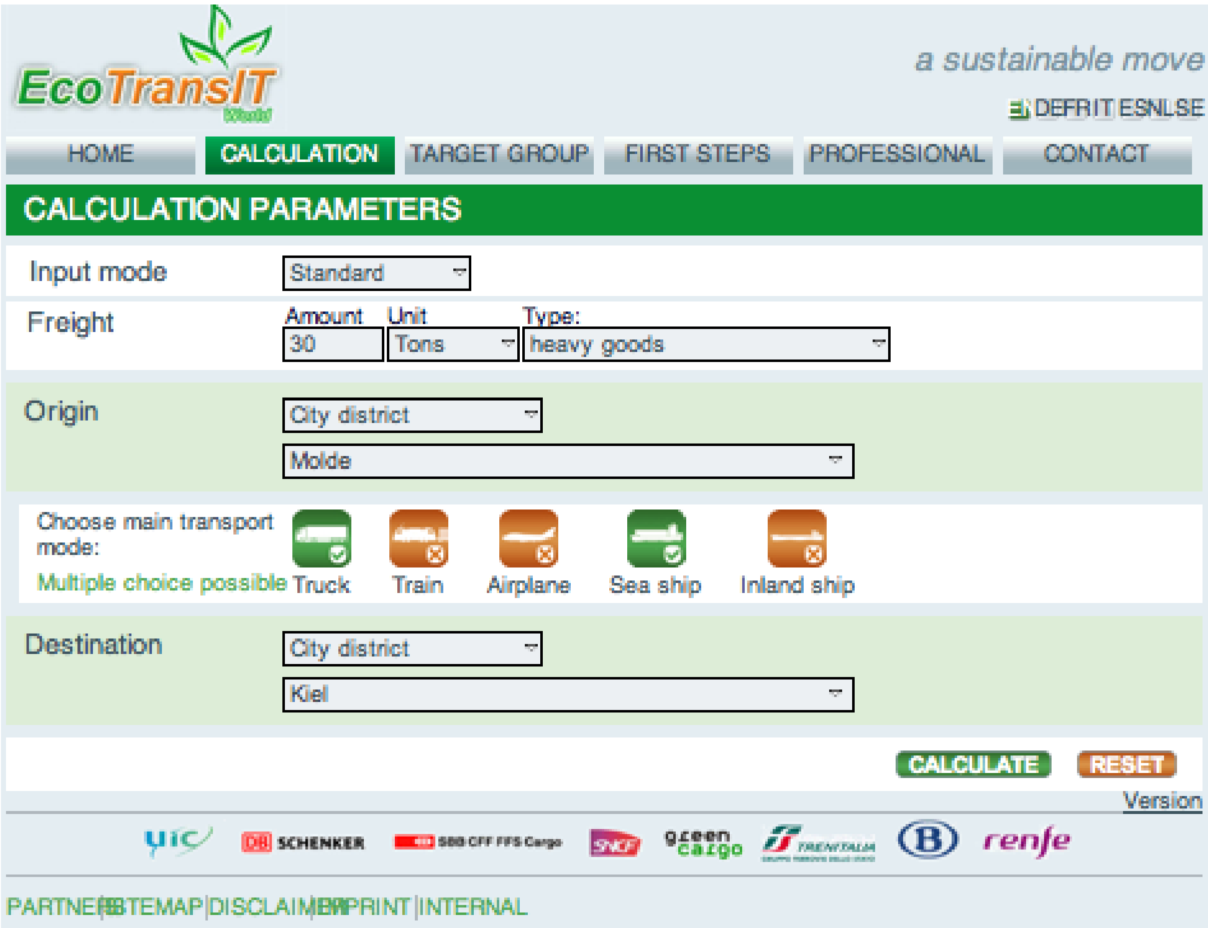
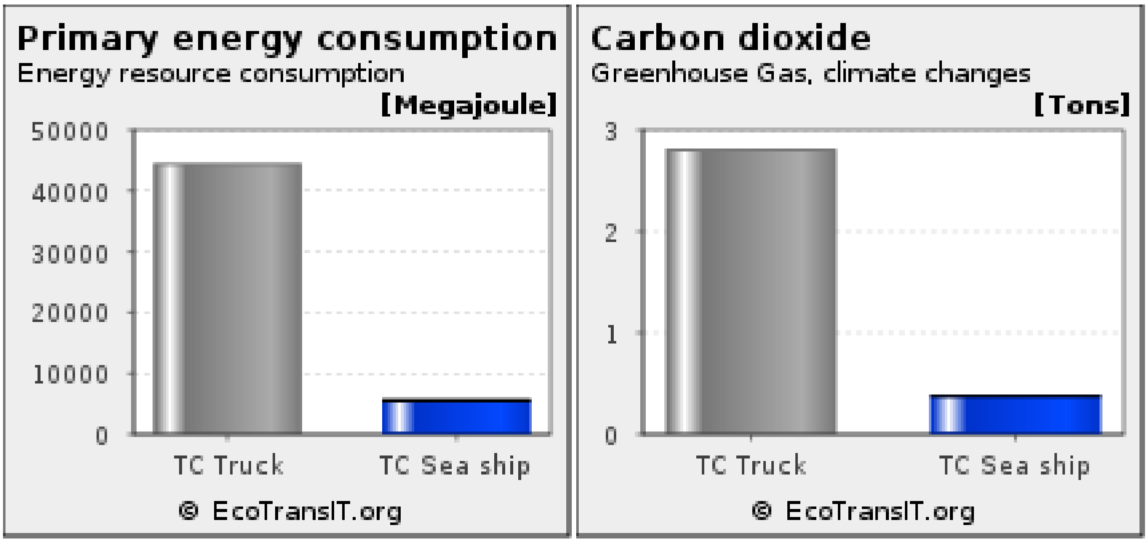


Figure 6: Calculation parameters in EcoTransIT



	TC Truck	**TC Sea ship**
Truck	44.361	174
Sea ship	0	5.326
Intermodal transfer	0	130
Sum	44.361	5.631

	TC Truck	**TC Sea ship**
Truck	2,803	0,011
Sea ship	0	0,365
Intermodal transfer	0	0,004
Sum	2,803	0,380

Figure 7: Outcome EcoTransIT

For the Transport chain (TC) Truck the calculation is based on 1.563,34 kilometres by truck, for the TC Sea ship on 1.277,29 kilometres intermodal transportation with truck and ship. The distances are a part of the outcome provided by the Ecotransit calculation tool, in addition the tool provides a map of the chosen route with Google maps.

4.6 Case studies

This Master thesis contains as mentioned before two different cases, whereby one case is from the transportation industry while the other case is a constructed case. The cases are introduced to the analysis in the following.

4.6.1 Norwegian industry case study

Description: the company will be held anonymous; the company is operating in the producing maritime industry in the middle of Norway. The final product after the refining process has to be sent and distributed to their customers. Usually the fluid good has been transported by road from Kristiansund to the terminals in Oslo to be forwarded to the different markets by truck or vessel. Between January 2011 and February 2012 North Sea Container Line (NCL) AS was operating a direct line to Rotterdam, which enabled the company to send their goods directly from Kristiansund with avoiding the road transportation to Oslo.

Both different modes of transportation, the inter-modal transportation via Oslo and the direct transportation by sea will be analysed with the different tools with regards to the defined emissions.

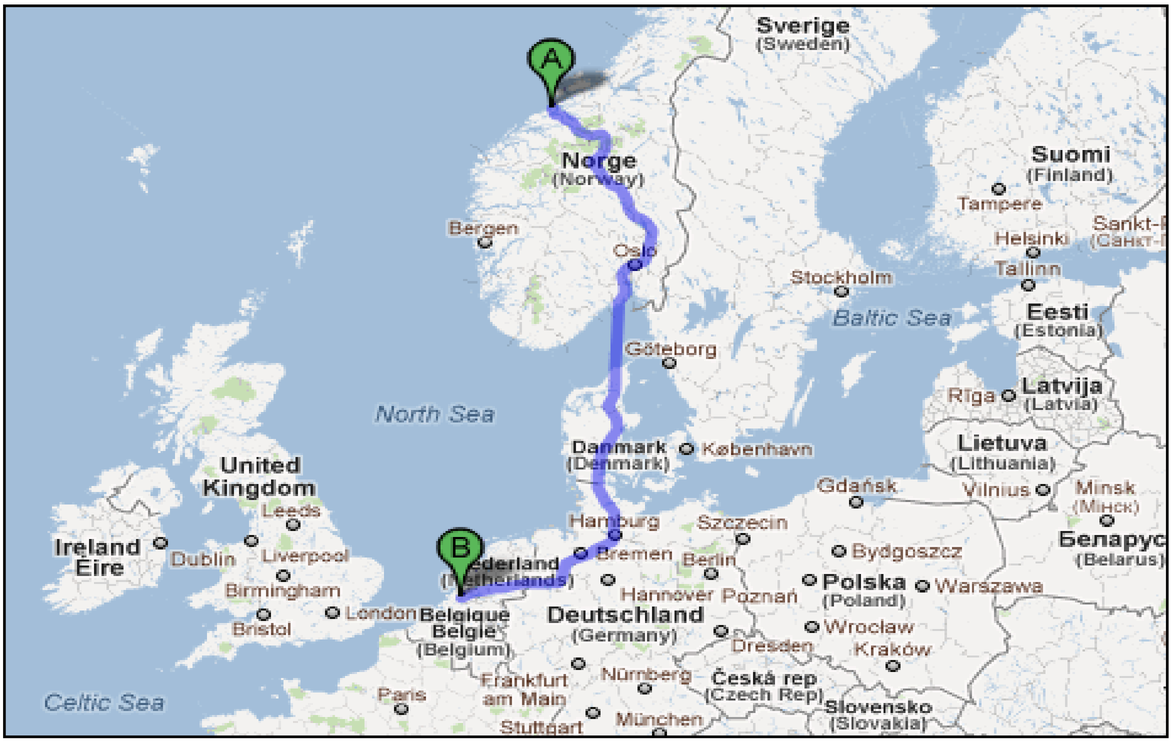


Figure 8: Map, Kristiansund – Rotterdam

The map shows the inter-modal transportation between Kristiansund and Rotterdam by road and sea transport; for the sea transport lag making use of the ferry service between Larvik / Norway and Hirtshals / Denmark.

The goal is to analyse the case of the different transportation modes the company used for their transportations with regards to emission measured by different calculating tools.

The parameters of the Norwegian transport industry case and the used tools will be given in the following table.

Tool	Mode	Distance
Ecotransit	Road / Sea	1.893 km / 1458 km[6,7]
NTMCalc	Road / Sea	1.893 km / 1458 km
US Dept. of Energy	Road / Sea	1.893 km / 1458 km

Table 4: Input parameters Norwegian industry case

[6] Calculated by http://sea-distances.com/; http://maps.google.no/maps?hl=no&tab=wl

[7] One nautical mile (nm) equals 1.952 kilometres (km).

The purpose of the Norwegian transport industry case is to use a real life setting beside the second constructed case to analyse the outcome of the different calculating tools.

The reasons to choose the company is the fact that the company had two different possibilities to send their goods and is now forced to go back to the original mode by road transportation. Between January 2011 and February 2012 North Sea Container Lines (NCL) implemented a liner service between Kristiansund in Norway and Rotterdam in the Netherlands. Rotterdam was already before the liner service existed chosen by the company as the distribution hub for the forwarding to the different markets in Europe and worldwide.

In the setting before January 2011 and after February 2012 the goods were sent by truck to Rotterdam including a ferry voyage from Norway either from Larvik to Hirtshals or from Oslo to Kiel or even using the Øresund bridge. This setting includes the interesting case of the direct comparison between road and sea transportation.

The second setting describes the situation between January 2011 and February 2012 when the company could use the liner service from Kristiansund to Rotterdam. In this setting the products were packed and handled only twice, once in Kristiansund by loading the liner and then while discharging in Rotterdam. This had direct decreasing impact on the costs for handling the goods. In what degree the different transportation modes had impact on the emission produced by the transportation of a Twenty-foot Equivalent Unit (TEU) loaded with 16.423,5 kg from Kristiansund to Rotterdam will be used to analyse the calculation tools mentioned in the above table and their outcome.

4.6.2 Constructed case study

Description: the aim of the constructed case is to design a setting that allows the best and most significant comparison between several emission calculation tools. For the reason that the main aim of the analysis is the comparison between different calculation tools and not the comparison between different transportation alternatives is the main focus not on creating a setting where the length of the legs of the different transportation modes are equal but more on a setting where road, ship and intermodal transportation are considered. However, the case will until some degree try to consider as well some equal length of transportation legs for the different transportation modes. Furthermore should the selected transportation route for the case be a route with a relevance to the transportation industry. In other words the chosen route should not only fulfil scientific requirements but should be also related with relevance to the transportation industry in Europe.

Under the mentioned requirements the case was constructed as transportation from Gothenburg in Sweden to Rotterdam in the Netherlands. As mentioned before is as transportation unit a 20` TEU container, both Gothenburg and Rotterdam are important container hubs in Europe. Rotterdam as the biggest seaport in Europe is a hub for entire Europe and Gothenburg is the equivalent for Scandinavia. The route distance between the different modes are the following. The pure ship voyage from Gothenburg to Rotterdam is 501 nm, which equals 977.952 km[8][9]. The pure transportation distance by truck is 1132 km (via Øresund bridge) and for the intermodal transportation by ship and truck using the ferry from Gothenburg to Kiel is 1098, 376 km, where the transportation by ferry response with 263 nm (513, 376 km) and 585 km transportation by truck from Kiel to Rotterdam.
As the numbers show are all legs almost equally long, whereby the pure ship transportation has a small distance advantage, followed by the intermodal transportation and truck transportation have the longest distance. In this way are all requirements for the case fulfilled.

The map on the next page shows the map for route from Gothenburg to Rotterdam.

[8] Calculated by http://sea-distances.com/; http://maps.google.no/maps?hl=no&tab=wl
[9] One nautical mile (nm) equals 1.952 kilometres (km).

Figure 9: Map, Gothenburg – Rotterdam

The described constructed case will be used with the three selected tools as follows.

Tool	Mode	Distance
Ecotransit	Road / Intermodal / Sea	1.132 km / 977,952 km / 1098,376 km[10][11]
NTMCalc	Road / Intermodal / Sea	1.132 km / 977,952 km / 1098,376 km
US Dept. of Energy	Road / Intermodal / Sea	1.132 km / 977,952 km / 1098,376 km

Table 5: Input parameters constructed case

4.7 *Case analysis*

In the following section the three selected calculation tools for the emission from freight transportation industry will be used in the two different described cases. The generated outcome from the three emission tools will be compared between the tools rather than between the different modes of transportation.

The process of the analysis is shown in the below Figure 10.

[10] Calculated by http://sea-distances.com/; http://maps.google.no/maps?hl=no&tab=wl
[11] One nautical mile (nm) equals 1.952 kilometres (km).

Process chart calculation tools analysis

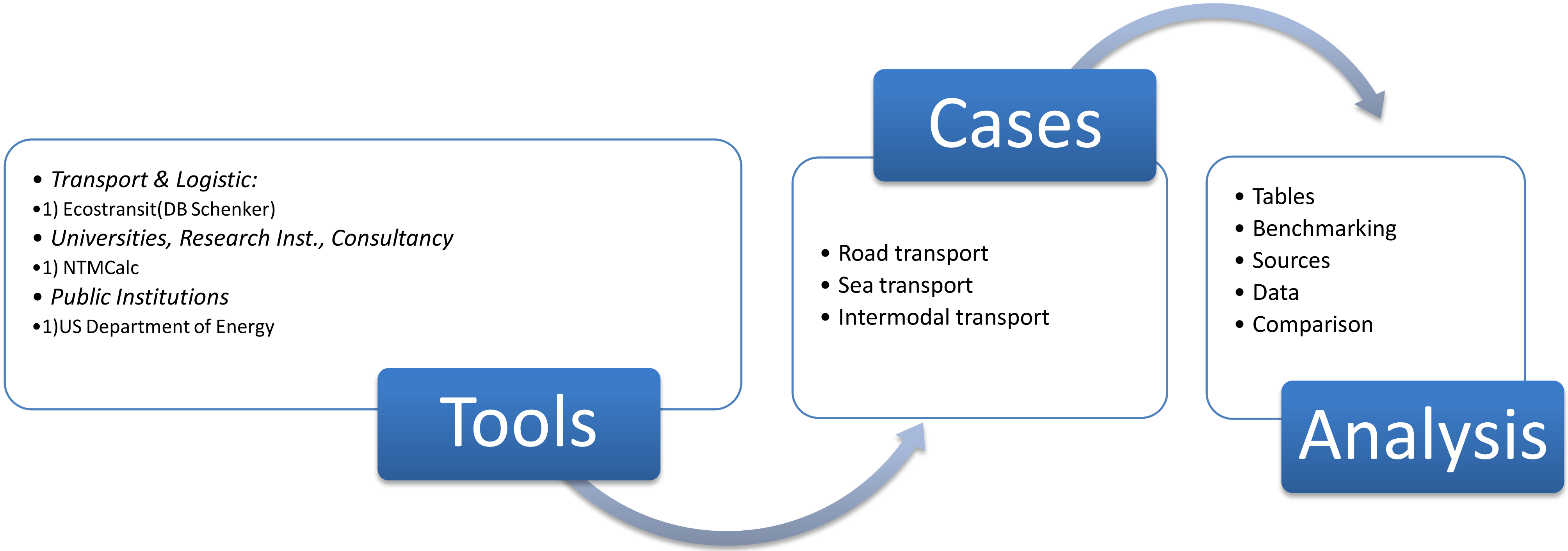


Figure 10: Case analysis process

The process chart gives an overview about the overall organisation of the analysis of the different calculation tools. In the first step the tools are grouped into the fields they have been developed. These are the groups *Transport & Logistic*; *Universities, Research Institutes, Consultancy*; *Public Institution*. The selected tools are in step two run through four different scenarios, called "cases". The outcome of the tools generated are analysed by applying them to the two different cases with help of MS Excel software. In addition the generated figures and tables are displaying the outcome. The data and the sources used by the tools is benchmarked and compared.

4.7.1 Analysis of Norwegian industry case study

In the following the case from the Norwegian transportation industry will be analysed. In particular it will contain the analysis of the three selected tools and the display of the generated outcome by using MS Excel software. The used weight of freight corresponds to a 65 % loaded 20`TEU container for both the truck and the sea transport of this transportation unit from Kristiansund in Norway to Rotterdam in the Netherlands. The outcomes measures of the different tools are CO_2, SOx, NOx, HC and PM.

Outcome	**CO2**	**SO x**	**NO x**	**HC**	**PM**
EcoTransIT	270,00	3,11	5,20	0,29	0,43
NTMCalc	368,79	0,00	6,99	0,24	0,48
Kristiansund - Rotterdam by vessel, emissions in kg					

Table 6: Kristiansund –Rotterdam by vessel, emissions in kg

Outcome	**CO2**	**SO x**	**NO x**	**HC**	**PM**
EcoTransIT	2000,00	3,00	7,00	1,00	0,20
NTMCalc	3855,00	0,00	30,16	1,24	0,62
USDept. of E.	3486,00	0,00	0,00	0,00	0,00
Kristiansund - Rotterdam by truck, emissions in kg					

Table 7: Kristiansund – Rotterdam by truck, emissions in kg

The tables Table 6 and Table 7 display the calculated outcome from EcoTransIT, NTMCalc and the US Department of Energy emission tool for the transport from Kristiansund to Rotterdam. The EPA tool only provides CO_2 emission while the other two also calculate the emission of SOx, NOx, HC and PM. Two figures are especially notably these are the red marked emissions of CO_2 calculated for the transportation by ship by the US Department of Energy tool and the NOx emission calculated by the NTMCalc emission calculator. Both figures are significantly higher than the comparable figures produced by the other tools. Besides that it can be seen that the EcoTransIT tool delivers throughout the smallest numbers as well for the transportation by ship and by truck. Also when these differences overall between the three tools are not that big, the trend to smaller numbers produced by the EcoTransIT tool is obvious.

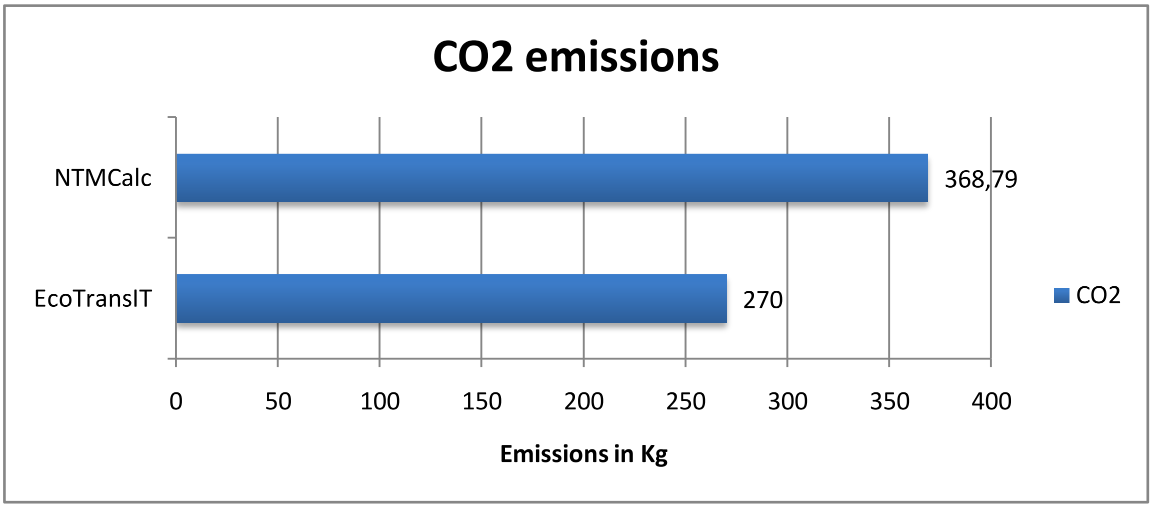


Figure 11: CO_2 emissions, Kristiansund – Rotterdam by vessel

Figure 11 above displays the relationship between the outcomes for CO_2 calculated by the NTMCalc and EcoTransIT calculation tools. It can be seen that the NTMCalc tool provides significantly higher CO_2 emissions than the other tool for the transportation by vessel.

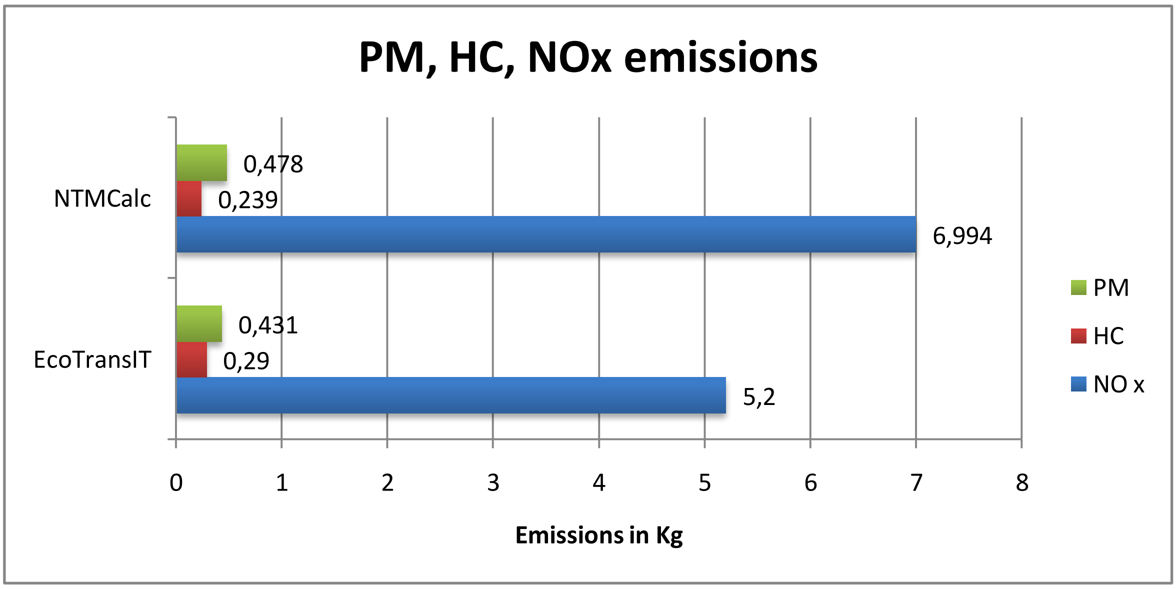


Figure 12: PM, HC, NOx emissions, Kristiansund – Rotterdam by vessel

Figure 12 the relationship between the calculated outcome for PM, HC and NOx for the NTMCalc and the EcoTranIT tool. It can be seen that the NTMCalc calculator gives higher numbers for both the emission of PM and NOx. Only for the HC the tool from EcoTransIT gives a higher number.

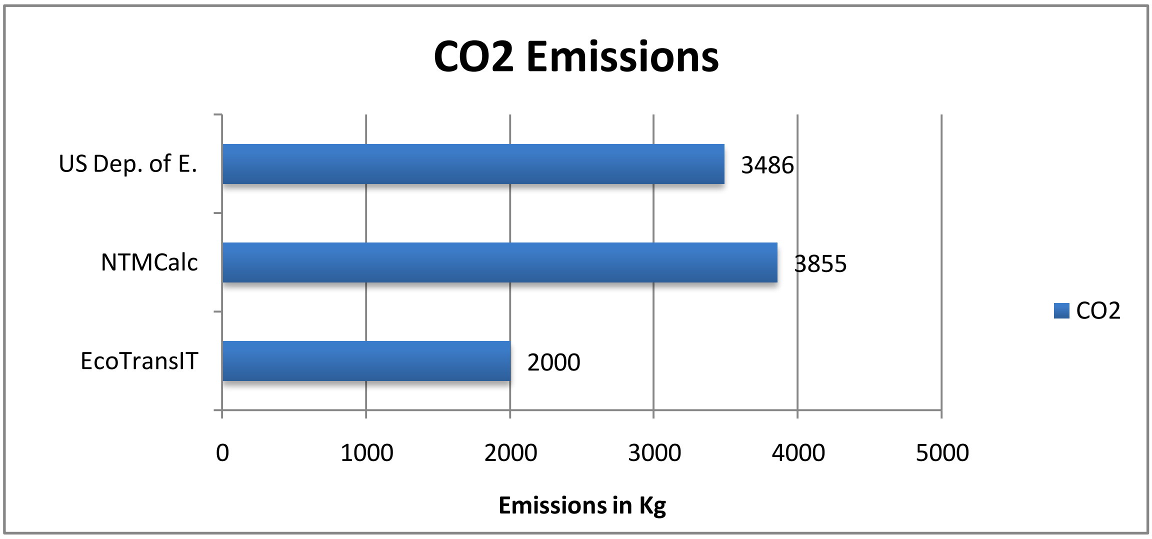


Figure 13: CO_2 emissions, Kristiansund – Rotterdam by truck

For the case of transportation by truck Figure 13 above confirms the overall trend for CO_2 emissions of lower numbers calculated by the EcoTransIT tool compared to the other two. Also when for the numbers for the truck transportation the fright emission calculator of the US Department of Energy and the NTMCalc calculator are rather closer with their outcome to each other.

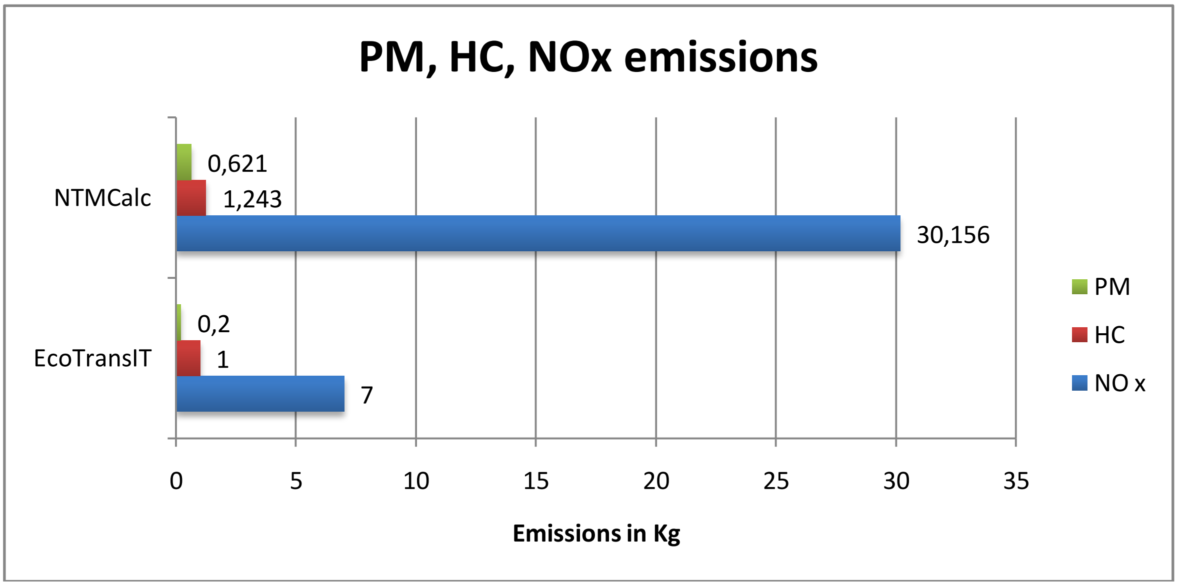


Figure 14: PM, HC, NOx emissions, Kristiansund – Rotterdam by truck

Figure 14 shows the different outcomes for PM, HC and NOx from the NTMCalc and the EcoTransIT tools. Once again the NTMCalc tool is providing higher numbers than the EcoTransIT tool. Especially for the emission of NOx, which is significantly higher, while the outcome for the PM and HC are closer.

Overall the case of the Norwegian transport industry shows the tendency that the EcoTransIT tool gives overall lower outcomes that the NTMCalc emission calculator. The results from the US Department of Energy caculator are in average below the result of the NTMCalc and above the results of the EcoTransIT tool for the emission of CO_2. For PM,HC and NOx emissions can be stated that the NTMCalc and EcoTransIT produces really close results for PM and HC emissions, while the NOx emission is significantly higher from the NTMCalc calculator compared to the EcoTransIT tool.

4.7.2 Analysis constructed case study

In the following the constructed case for this Master thesis will be analysed in the same manner as the previous Norwegian industry case.

Outcome	**CO2**	**SO x**	**NO x**	**HC**	**PM**
EcoTransIT	140,00	2,07	0,20	0,18	0,32
NTMCalc	247,34	0,00	4,66	0,16	0,29
Gothenburg - Rotterdam by vessel, emissions in kg					

Table 8: Gothenburg – Rotterdam by vessel, emissions in kg

Outcome	**CO2**	**SO x**	**NO x**	**HC**	**PM**
EcoTransIT	1280,00	2,00	4,20	0,60	0,10
NTMCalc	2305,26	0,00	18,03	0,74	0,37
USDept. of E.	2085,00	0,00	0,00	0,00	0,00
Gothenburg - Rotterdam by truck, emissions in kg					

Table 9: Gothenburg – Rotterdam by truck, emissions in kg

Outcome	**CO2**	**SO x**	**NO x**	**HC**	**PM**
EcoTransIT	220,00	2,16	3,60	0,21	0,30
NTMCalc	1509,18	0,00	21,21	0,55	0,53
USDept. of E.	2023,00	0,00	0,00	0,00	0,00
Gothenburg - Rotterdam, inter-modal transport, emissions in kg					

Table 10: Gothenburg – Rotterdam, inter-modal transport, emissions in kg

The red highlighted numbers in the tables Table 8, Table 9 and Table 10 show the main deviations between the outcomes of the three tools for the constructed case. The EcoTransIT tool shows a significantly lower number for CO_2 emissions for the inter-modal transportation. Furthermore, just as for the first case, the NOx emission calculated by the NTMCalc calculator is significantly higher than by the EcoTransIT tool. The high number of th eUS Department of Energy is a result of the fact that the tools is orginally designed for transportation by truck only.

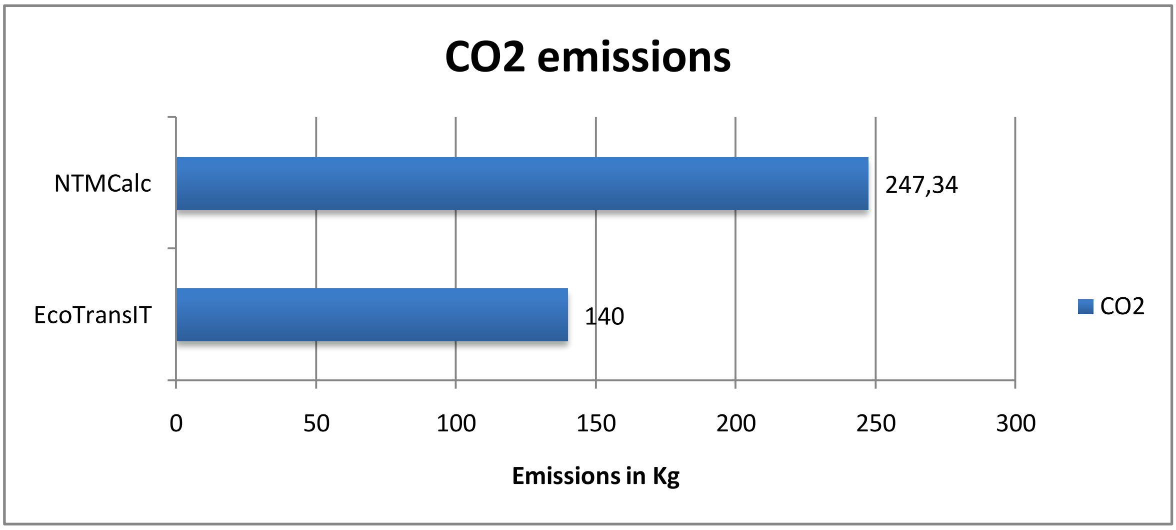


Figure 15: CO_2 emissions, Gotheburg – Rotterdam by vessel

Figure 15 above. As one can see is the NTMCalc calculation tool providing a signifinatly higher outcome of CO_2 emission than the EcoTransIT tool.

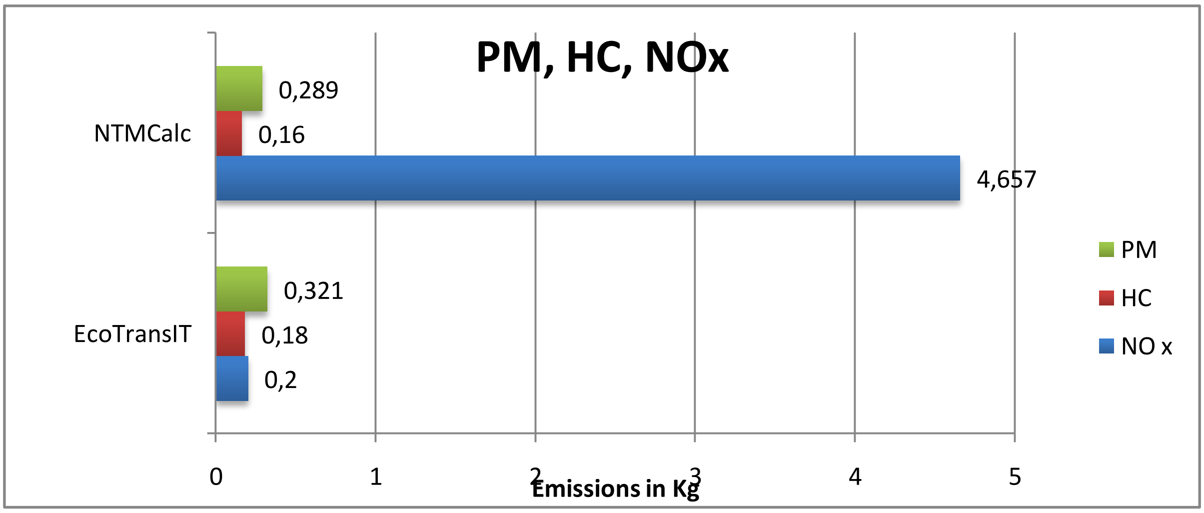


Figure 16: PM, HC, NOx emissions, Gotheburg – Rotterdam by vessel

Figure 16 displays the relationship between the outcome of PM, HC and NOx for the NTMCalc and the EcoTranIT calculation tool for the shipment by sea. It shows the relatively equal outcome for PM and HC emissions and a notably higher number for the emission of NOx by the NTMCalc calculator.

For the transportation by truck and the inter-modal transportation for the constructed case from Gothenburg to Rotterdam, the particular emissions are displayed in the following diagrams.

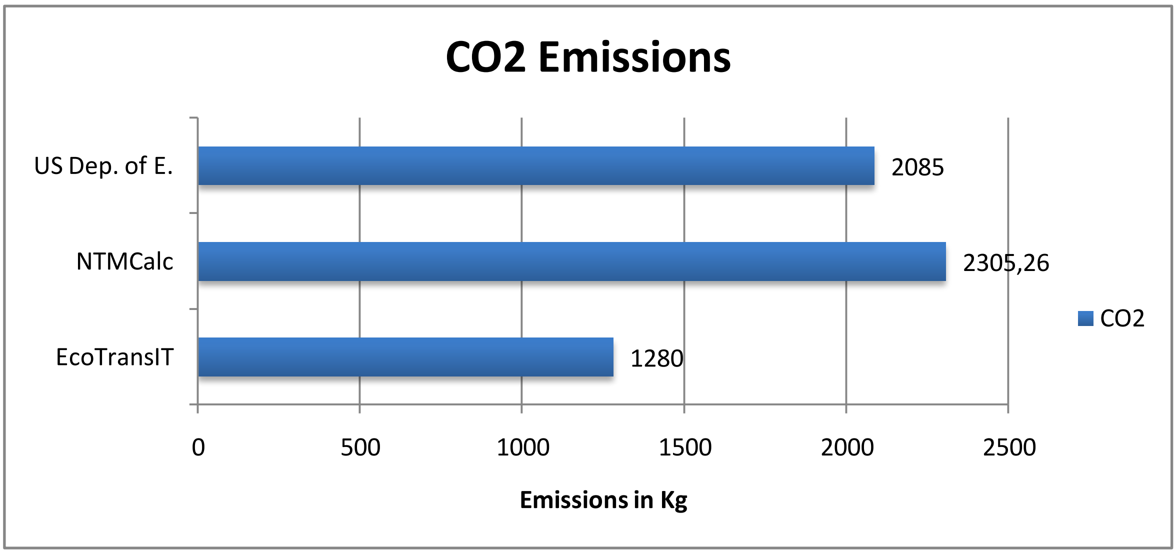


Figure 17: CO_2 emissions, Gothenburg – Rotterdam by truck

Figure 17 above shows the emissions of CO_2 from the transportation by truck calculated from the three tools. It can be seen that again EcoTransit provides the lowest number while the other two outcomes are close to each other, on a significantly higher level.

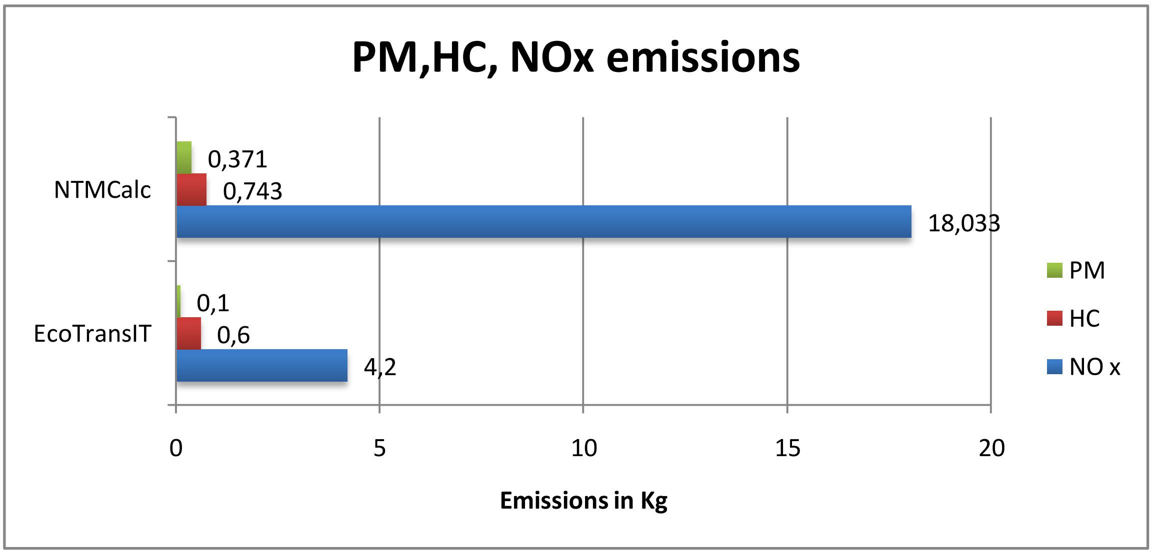


Figure 18: PM, HC, NOx emissions, Gothenburg – Rotterdam by truck

Figure 18 provides the emissions of PM, HC and NOx for the transportation by truck. Repeatedly the number of NOx emissions by the NTMCalc emission tool is higher compared to the EcoTransIT tool.

The figures for the inter-modal transportation are as follows.

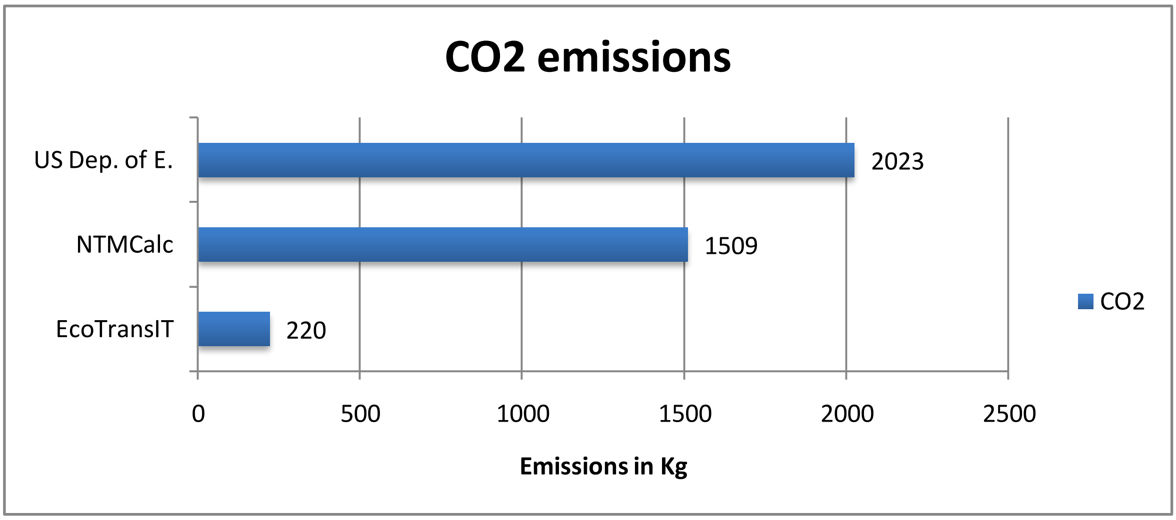


Figure 19: CO_2 emissions, Gothenburg – Rotterdam, inter-modal transport

Figure 19 displays the different CO_2 emissions calculated by the three tools. Again the figure shows the picture of EcoTransIT as the tool, which calculates the lowest number. It is again significantly lower while the other two tools are closer to each other in their outcome. Thereby is the US Department of Energy tool providing the highest number followed by the NTMCalc tool.

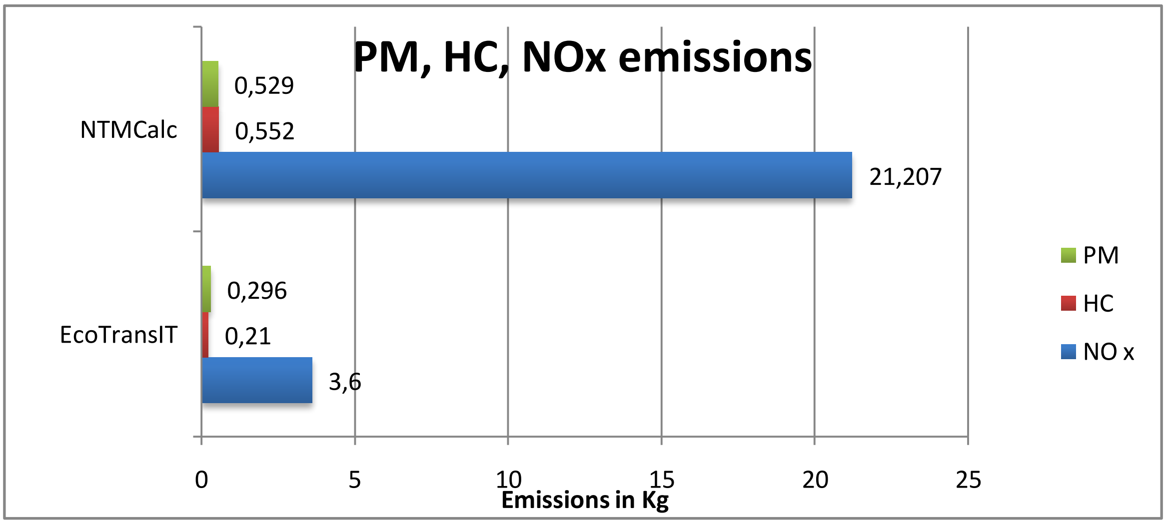


Figure 20: PM, HC, NOx emissions, Gothenburg – Rotterdam, inter-modal transport

The last Figure 20 displays the PM, HC and NOx emissions for the inter-modal transportation from Gothenburg to Rotterdam. It shows the same picture and confirms the outcome from the first case that the emissions provided from EcoTransIT are generally lower than the comparable outcomes from the NTMCalc calculator. Additionally, the NOx emissions calculated by the NTMCalc tool are considerably higher.

Overall it can be stated that the results for the constructed case are in line with the outcome generated by the three different tools in the first case from the Norwegian transport industry. The EcoTransIT calculation tool has consistently the lowest numbers among all emissions. Moreover, the outcomes for PM, HC are almost the same between EcoTransIT and NTMCalc while the results for CO_2 emissions are slightly different and for the NOx emissions significantly higher by the NTMCalc emission calculator. The possible reasons for that and the conclusions that can be drawn by the achieved analysis result will be discussed in the next section.

4.8 Findings and discussion

The analysis of the different tools by using two different cases gave two main results.

- *First* of all, that the results between the two European tools, NTMCalc and EcoTransIT, and the US American tool from the US Department of Energy differ in the way that the US tool gives an outcome for the emission of CO_2 constantly between the two European tools. This is a result of the use of different databases as the background for the calculations. Furthermore, the input options for the EcoTransIT tool and the NTMCalc emission tool are more detailed which allows a more detailed calculation. While the US Department of Energy tool only requires miles and lbs as input without a specific voyage, the EcoTransIT tool is considering a specific voyage from an origin of departure and arrival. In addition, the EcoTransIT tool is taking the load factor for the different modes of transportation into consideration. The load factor for the transportation of goods is taken into consideration by the tool with 60 % both for vessel and truck. Moreover, the EcoTransIT tool is using the EURO 5 norm for their calculations, this information is not provided in the outcome for the two other tools. The NTMCalc emission tool on the other hand is considering what kind of truck or ship is used for the transport of the good. For the analysis in this Master thesis a "heavy truck" and a 1.400 TEU container vessel was chosen. The reason for this choice is the fact that the "heavy truck" (HDV, cf. chapter 3.3.2) is the only possible kind of truck, which is enabled to handle the weight of 16.423,5 Kg, and that the 1.400 TEU container vessels is a common size in the Baltic Sea for feeder services between the port of Gothenburg (in general Nordic ports) and Rotterdam (Svendsen and Tiedemann 2012). This possibility of choosing different types of transportation vehicles will influence the outcome and considers specifics of the emission produced by this different kind of vehicles and improves in this way the accuracy of the calculated outcome.

- The *second* important finding is that the produced outcome of the analysis by a competitive case study is only significant to a limited extent, with regards to finding the reasons for the different outcome by the different tools. However, the case study is able to show a clear trend between the different tools, which is that the EcoTransIT emission tool gives continuously lower numbers for all different emissions while the NTMCalc emission calculator has a significant higher calculated emission for NOx.

The following Table 11 sums up the findings for NOx emissions by the NTMCalc and EcoTransit calculation tool. (K-R=Kristiansund-Rotterdam; G-R=Gothenburg-Rotterdam).

	K - R, vessel	**K-R, truck**	**G - R, vessel**	**G - R, truck**	**G - R,inter-m.**
EcoTransIT	5,20	7,00	0,20	4,20	3,60
NTMCalc	6,99	30,16	4,66	18,03	21,21
Difference %	**34,50**	**330,80**	**2228,50**	**329,36**	**489,08**

Table 11: Percentage differences in NOx emissions

As one can see, are the NOx emissions calculated by the NTMCalc tool significantly higher than the numbers provided by the EcoTransIT tool. While the difference for the voyage from Ktistiansund to Rotterdam by vessel is moderate higher with 34,50 %, is the value for the voyage from Gothenburg to Rotterdam is notable higher with 2228,50 % more than the calculated emissions from the NTMCalc tool compared to the EcoTransIT tool. The US Department of Energy tool was chosen as a additional tool from outside Europe. The next Table 12 shows the main commodities and differences between the two tools EcoTransIT and NTMCalc.

Tool	**Commonalities**	**Differences**
EcoTransIT	Possibility of different modes of transportations. Input parameters.	Provides also SOx emission output, continously lower outputs for all emissions.
NTMCalc	Output of CO_2, HC, PM and NOx.	Significantly higher output of NOx, provides no route map.

Table 12: Commonalities and differences of selected tools

During the process of the analysis it became clear that the main problem is the existing lack of comparable calculation tools. As discussed before, many tools are existent for the calculation of emission and energy consumption, but only a few of them are useful for the transportation industry. In addition, from the few tools only some of them are freely available or are not violating any other of the made restrictions for the analysis in this Master thesis. A few examples are the tools from the NYK Group and Martrans.org, which are restricting the possibility of a free input of the voyage or the distance to be transported. Other tools as the Tollpost Globe "Miljøkalkulator" and the GTCC emission tool from the transportation company Kuhene & Nagel are only available for their customers. In other words one can only calculate the emission of a specific transportation made by this company in the customers favour. Other emission tools as the Greenfreight Project are still under construction and several tools exist as download versions or software that has to be purchased by a private person or company.

To make a statement why the outcome is different from one to the other tool it is necessary to know what kind of data and methodology has been used. Detailed information about that only exists for the EcoTransIT tool at the moment; the new report for the NTMCalc will be published in the end of May 2012. Additionally, the gathering of information regarding the data used and the methodology behind the in house solutions of transportation companies is one of the biggest challenges to make a statement about with regards to the quality of the provided outcome. For this Master thesis the respond rate on requests made for information regarding the provided calculation tools to both companies and institutions - even for just obtaining a username and password to use the tools – was zero.

It seems that the interest to share this kind of information does not exist or the reason for this might be the fact that most of the companies are using one of the two free available tools EcoTransIT and NTMCalc because of their detailed outcome. This assumption is based on the fact that the use of these free available tools makes own investments into in house solutions obsolete and it is a convenient alternative to serve the customers request of a carbon footprint for their transportations.

However, the known relationship of the selected and analysed tools to the databases used for the calculations will be presented in the following
Figure 21 in chapter 4.9.

4.9 Mapping selected tools

Figure 21 on the next page shows the relationship between the analysed calculation tools and the data background of each of them. The data background for the EcoTransIT calculation tool is well documented in the literature. The EcoTransIT emission calculation tool is using a mixture of own data, data from the GEMIS, TERMOD and HBEFA data bases, additionally should be mentioned that the HBFA actually includes data from the ARTEMIS and COPERT projects. For the NTMCalc emission calculation tool it is expected that the data background and its methodology related information will be published by the end of May 2012. Due to the fact that the ARTEMIS is a European project under Swedish project management it can be assumed that the NTMCalc emission calculator is using the data collected in the ARTEMIS project. This could be one of the reasons for the significantly different outcome for the NOx emission calculated by EcoTransIT and NTMCalc. The US Department of Energy tool is based on miles and lbs and therefore it can be assumed that this tool uses data collected from the U.S. American transportation market. Due to the different outcomes between the U.S. American tool and the two European tools it can be stated that the data and methodology between them differs.

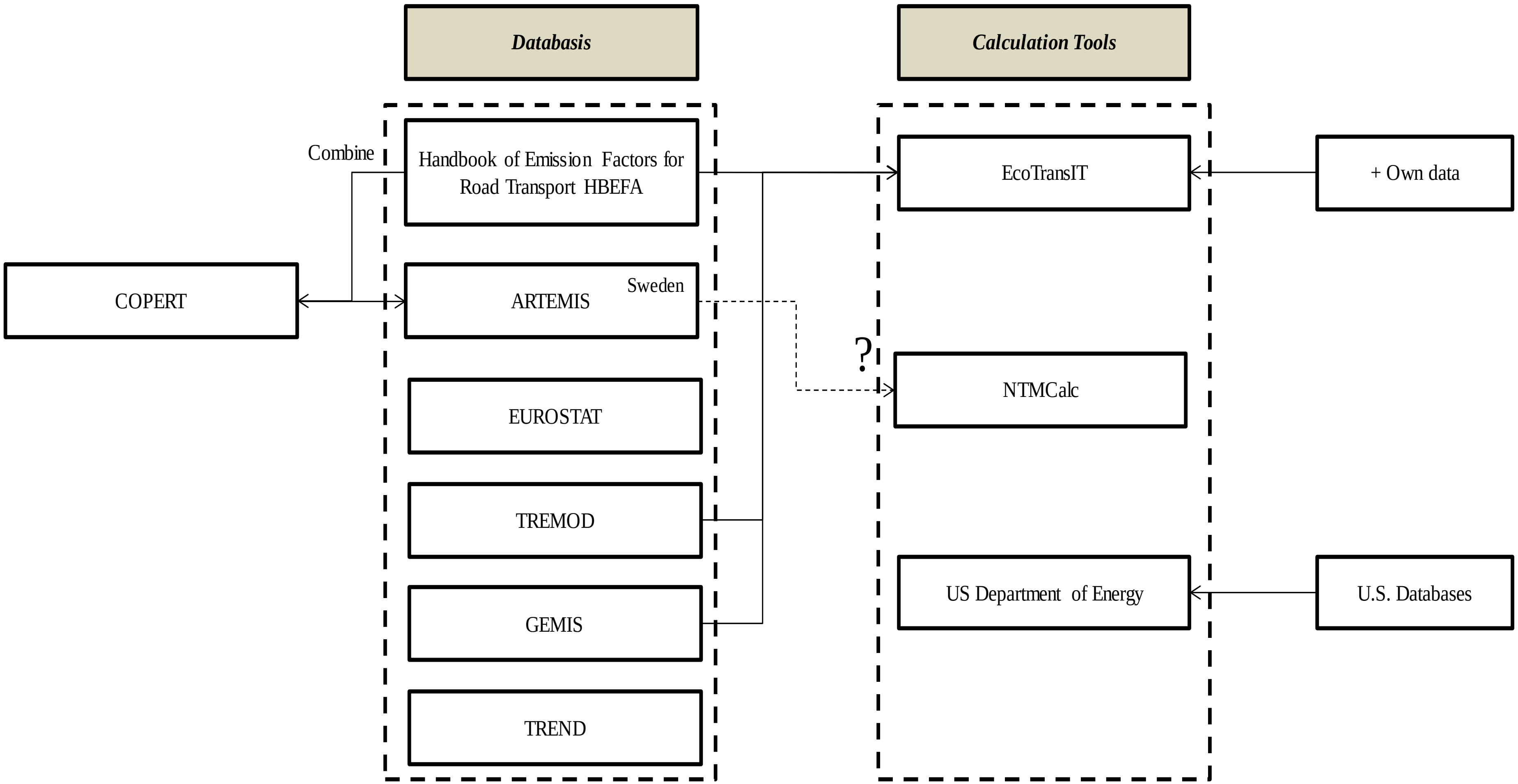


Figure 21: Mapping of the selected tool

4.10 Further analysis

For further analysis of environmental calculation tools for the transportation industry, two different approaches can be suggested. On the one hand the relaxation of the made restrictions, and including several non-transportation related calculation tools and on the other hand a wider long-term project including the transportation industry, as for example the Green freight transport project did.
The first approach including more non-related tools has the challenge of comparability between the outcome and the constraint that these tools might not be relevant for the transportation industry. It can be helpful in a way to get a wider picture of existing tools, but with regards to the research of this Master thesis this approach seems too wide.

The second and more promising approach includes the industry and designers of the emission calculation tools. This approach has a high need for resources both time and personal wise, as well as probably the need for financial support founded by governments or institution in the transportation industry. In this way it could be possible to gather the needed information regarding the used data background and methodology for the different tools. At the same time the interest among the transportation industry for cooperation will be higher if the companies see the possibility to gain an advantage of improvement of the used calculation tools, data and methodology by such a project with a strong background in e.g. optimizing the existing tools or even designing an own tool.

5. Conclusion

The need for a change to lower global emissions of all kinds, which represent a hazard toenvironment and human health and develop towards a more environmentally friendly transport has been described and the political actions taken to achieve this goal have been shed light on. That emissions caused by transportation, as the backbone of the global economy, are responsible in a high degree for the overall exhaled emissions worldwide is proven. The main described emissions caused by transportation are CO_2, NOx, SOx, HC and PM. To measure these emissions, different approaches and methods are used and the achieved data is stored in emission databases and is used to calculate emissions by transportation. One use for this data and methodologies are the calculation tools for emission provided to cunsumers, goods owners and producers. Three research questions were developed for this Master thesis in order to evaluate emission calculation tools for the transportation industry.

- Q 1: *"In what way are the existing calculation tools comparable with regards to the results provided by them?"*. This question cannot be answered distinct after the performed analysis. The analysis process showed that not many free available analysis tools, designed only for the transportation industry, exist. The choice of the three tools for the further analysis after the set requirements for quality and the made limitations already show that the other calculation tools available are far from being comparable. Therefore, only for the two most known and deeper analysed calculation tools, the NTMCalc and EcoTransIT tool, it can be stated that the provided results are relatively different. One of the main findings is that the result of the calculated NOx emission is considerably different. But with regards to the output parameters they provide same output as CO_2, NOx, SOx, HC and PM.

- Q 2: *"What is the background of the existing calculation tools and do they have a solid basis regarding research and a scientific relevance?"*. With regards to the research made it can be stated that the backround of the two most used free tools, NTMCalc and EcoTransIT is scientific relevant and that they are based on a solid methodology. To degree in-house solutions provided by companies fulfil these requirements cannot be answered due to a lack of information regarding the data and methodology used.

- Q 3: *“Are these instruments rather marketing gadgets to create a greener image than analysis tools?”*. Generally, there is a raising interest from both consumers and customers of products and services, to which also transportation counts, towards a greener and more sustainable world. To show the state and argumentations on this topic, the background and current discussions on both global warming and the focus on environmental issues have been pointed out. Therfore, it can be stated that these tools contain elements of both. On the one hand, the scientifically prooven tools providing a useful outcome, as e.g. the two analysed tools for the transportation industry helping companies to fulfil the wishes of their customer as well as themselves to monitor their emissions. This can be become even more relevant for transporting companies when transport emissions become part of the ETS of the EU. On the other hand, there are at the same time existing tools with the aim to create a greener image as e.g. the “Ecophant” project of the Deutsche Bahn in Germany, where the customer of transport services earning “Ecophants” when using the services of the Deutsche Bahn and saving CO_2 emissons due to that, which is not possible to be proven for the general public.

Overall, it can be concluded that the field of transportation emissions and tools to calculate the emissions is broad and complex and implies the need for further analyis with the before mentioned possible approaches in order to develop more suitable tools especially for the transport industry.

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