Master's degree thesis

LOG950 Logistics

Evaluation of carbon footprint calculators: Do they tell the true story?: A Comparative Analysis

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Dedication

I dedicate this master's thesis to my late lovely grandmother ***Elizabeth Dione Nzue*** *who died during my study period in Molde, Norway.*

Preface

This master's thesis represents the compulsory final part of my Master of Science Degree in Petroleum Logistics at Molde University College – Specialized University in Logistics, Norway.

I will take this opportunity to thank my supervisor **Professor Hjelle Harald Martin** for his guidance and assistance throughout this thesis.

More so, I thank my family and friends for their enormous moral support that enabled me have the courage and right mindset to finalize this master's program despite the ongoing COVID19 global pandemic, and the political crises in my country, Cameroon, which started since October 2016 and has so far led to the killing of thousands of innocent civilians including closed relatives and enormous loss of properties. All these have affected me economically and psychologically.

Again, due to the outbreak of the corona virus, COVID19 my interview with the head of the aid scheme project at the Norwegian Coastal Administration (NCA) was cancelled due to the implementations put in place by the government to prevent the spread of COVID19. The interview rescheduling took a very long time as the interviewee was on a busy schedule and was working from home and, many of my emails sent to request for interviews to the various employees were cancelled, leading to a limited amount of data to be dealt with in this research.

Furthermore, most of the time, I had to send emails couple of times to get documentations and all the documentations they sent were in Norwegian language which required translation.

Molde, June 2020

Elone Elvistone Kanzoedie

Abstract

From an environmental point of view, the choice of an optimal transport chain by policymakers, cargo owners and operators is a key challenge. Due to these challenges, various calculation tools have been developed to help policymakers, cargo owner and operators assess the environmental performance of alternative transport chains. Some of these calculation tools have been made public whereas some are privately owned especially by prominent transport and logistics companies who use the tool as extra service to their customers.

When these calculation tools are used in the same set of transport alternatives, they provide different outputs. These research tried to study the documentations that accompany these calculation tools to know exactly what could be the reason for this difference in output and to equally know the extent at which these calculation tools can provide different outputs, then analyze the level at which these calculation tools are well documented or if there appear any "black boxes" about these tools. The hundreds of pages of documentation that accompanied these calculation tools is analyzed to identify if the empirical evidence upon which they were developed could explain the different output provided by the different calculation tools or if the output is affected by other factors.

More so, the calculation tools are used on the same set of transport chain alternatives, with similar inputs and the differences in environmental performance data output is analyzed. The three calculation tools used in my analysis are tools that are frequently used in European settings and one is precisely used for the Norwegian Coastal Administration (NCA) aid scheme of shifting modal freight from road to sea, and provides only output for external costs. A comparative analysis is then conducted with respect to the application areas, for instance, cargo type, the level of transparency of the documentation, if the tools cover all transport modes and functional units applied.

Key words: *Calculation tools, emissions, external costs, transport mode, comparative analysis.*

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List of Abbreviations

CBDR – Common but Differentiated Responsibility

CEN - European Committee for Standardization

CO2 – Carbon dioxide

ECA – Emission Control Area

EcoTransIT - Ecological Transport Information Tool

EEA – European Environment Agency

EFTA - European Free Trade Association

ETS - Emissions Trading System

EU – European Union

EUROSTAT - The Statistical Office of the European Union

GHG – Greenhouse Gases

HC – Hydrocarbon

HDV - Heavy Duty Vehicles

HSFO – High Sulphur Fuel Oil

ICAO – International Civil Aviation Organization

IMO – International Maritime Organisation

LDV - Light Duty Vehicles

LSFO – Low Sulphur Fuel Oil

MARPOL – International Convention for the Prevention of Pollution from Ships

MEPC – Marine Environment Protection Committee

MRV - Monitoring, Reporting and Verification

NM – Nautical Mile

NOx – Nitrogen oxides

NCA - The Norwegian Coastal Administration

NEZ - Norwegian Economic Zone

NTM - Network for Transport Measures

OECD – Organization for Economic Co-Operation and Development

PM – Particular matter

RQ - Research Questions

SOx – Sulphur oxides

SSS – Short Sea Shipping

SECAs - Sulphur Emission Control Areas

TEN's – Trans-European Networks

UNCTAD – United Nations Conference on Trade and Development

UNFCCC – United Nations Framework Convention of Climate Change

1 Introduction

About 20% of all EU emissions is caused by freight and passenger transport. Transport emissions share keeps increasing and if no action is taken, the emissions could reach more than 30% of all EU emissions in few years. Approximately one third of the total transport GHG emissions is caused by freight transport. About 93-95% of GHG emissions from transport operations is accounted for by CO_2 emissions. Industries have already made significant efforts to improve the energy efficiency of freight transport. Due to a strong increase in global trade and the further integration of the enlarged EU, the gains in energy efficiency have however not been sufficient to outweigh the growth in emissions caused by larger transport freight volumes (Cefic and ECTA 2011).

The reduction of CO_2 emissions from transport is already receiving a lot of attention and can be expected to receive even more attention in the coming years. Consequently, in order to contribute to the required GHG emission reduction targets, over the next few years, industries will need to develop more decarbonisation strategies for their logistics operations. The chemical industry for instance, which represents less than 10% of the total freight emissions has in collaboration with its logistics service providers have adopted a pro-active approach in reducing the environmental impact of its logistics activities (Cefic and ECTA 2011).

In order to ensure consistency, efforts have been made internationally to standardize the measurement and reporting of these emissions but until date, there is no single internationally agreed calculation method. In 2012, CEN developed a European standard for measuring emissions from transport services. Over the past 20 years, so many studies have been undertaken to develop emission factors for the different modes of transport. In those studies, they vary in their coverage of the different freight transport modes, the extent to which they differentiate by vehicle type, energy source and in the assumptions, they make about vehicle loading.

In order to allow transport companies to identify further opportunities for improving the performance of their freight transport operations, an understanding of their current transport carbon footprint is needed. By developing a common calculation methodology that respects the norms of the CEN standard, individual companies will be able to carry out a self-assessment of their emissions in a uniform way that is comparable across the industry.

1.1 Motivation

Due to the increasing concern about global climate change and carbon emissions as a casual factor, organizations and companies are behind carbon footprint projects to be able to estimate their own contribution to global climate change. More so, many logistics actors provide carbon footprint calculators to assess the carbon footprint of specific transports and in some cases, these calculators are provided as a voluntary service for customers, in other cases, documenting environmental friendly solutions is a requirement, either from the customers or from government bodies.

Furthermore, my country Cameroon has many huge ongoing industrial activities such as petroleum, forestry and mining exploration, construction of hydroelectric dams, stadium and roads. Thus, it will be interesting for me to grab the necessary theoretical and practical knowledge on emission calculation tools, and carbon footprint which is a casual factor for global climate change.

I am hopeful that, at the end of this research, I will gain the necessary skill to nourish my professional objectives, of becoming as expert in Green-logistics. More so, to use the skill developed in this research to make my own humble contribution in helping my country, the continent of Africa and while not the world at large to be a better place to live.

1.2 Research Objective

The main aim of this research is to evaluate carbon footprint calculators by investigating if these carbon footprint calculators tell the true story, that is, to investigate how transparent are these calculation tools, if the calculation tools are used as intended, if these calculation tools are well documented and developed based on scientific evidence. More so, to understand how to implement certain measures in combating global climate change, focusing on how carbon footprint evaluation can help in making decision of transferring freights from road to sea in order to reduce emissions. To achieve this aim, it is important to understand what is carbon footprint?, the regulatory regime of shipping versus road transport mode, emissions caused by transportation, emission trading, emission database, calculation of emissions, calculation of utility value, and to understand the background and applications of carbon footprint calculation tools (the NCA calculation tool, the Swedish Network for Transport Measures (NTM) calculation tool and the German EcoTransit calculation tool)

1.3 Research Questions

Based on the above-mentioned problems, this research seeks to address the following research questions, which are based on investigating if these carbon footprint calculators tell the true story.

RQ1 - Do different calculation tools follow the same principles and produce the same results?

RQ1.1 - How and why are the calculation tools different?

RQ1.2 – To what extent do the calcaulation tools produce the same results?

RQ2 – Is the NCA calculation tool well founded, and based on scientific evidence?

RQ2.1 – Is the NCA calculation tool well documented?

RQ2.2 – Is the NCA calculation tool transparent?

RQ2.3 - Is the NCA calculation tool suitable for its purpose of assessing application for a new incentive system for transferring cargo from road to sea transport?

1.4 Structure

This research encompasses of six main chapters; chapter One which involves the scope of the research and research objectives. Chapter Two includes the literature review of carbon footprint, the regulatory regime of shipping versus road transport mode, emissions caused by transportation, emission trading, emission database, calculation of emissions, calculation of utility value, and the background and applications of carbon footprint calculation tools. Chapter Three involves the methodology used in the research. Chapter Four is about the analysis and discussion of the research findings. Chapter Five involves the conclusion and the limitation of the research. Chapter Six and Seven are the references and appendix of the research respectively.

2. Literature Review

According to Creswell (2014), the purpose of a literature review is to help determine if a topic is worth studying and providing ways on how researchers can limit their scope to a specific research area. Literature review serves several purposes such as:

1) Presenting results from different studies that are closely related to the ongoing research.
2) Extending existing studies, identifying gaps in literature and relating the specific study to larger ongoing discussions.
3) Indicating the importance of the study while acting as a benchmark for its results.

In this research, my literature review is focused on specific topics such as carbon footprint, emission calculation tools, and transports mode.

2.1 Carbon Footprint

Carbon footprint is a term and concept being frequently and widely used in public debates on responsibility and actions taken in place to fight against the threat of global climate change. Carbon footprint had a huge increase in public appearance over the last years and today it is frequently and widely used across nations, the business world, and the media.

Despite its widely appearance, there was no specific definition of this term, measures and what unit is to be used. The term carbon footprint comes from the language of Ecological footprinting (Wackernagel 1996), where the simple meaning of carbon footprint stood for a certain amount of gaseous emissions that were relevant to climate change and associated with human production or consumption activities. But this definition was limited because there was no consensus on how to measure or quantify a carbon footprint since the spectrum of the definition ranged from direct Carbon Dioxide emissions to full life-cycle greenhouse gas emissions and the units of measurement were not clear.(Wiedmann and Minx 2008b)

More so, the concept of carbon footprint came up with several questions such as: Should it be restricted to carbon-based gases or can it include substances that do not have carbon in their molecule, e.g. Dinitrogen Oxide (N_2O), which is another powerful greenhouse gas. Some people even went far as asking whether the carbon footprint should be restricted to substances with a greenhouse warming potential at all or should the carbon footprint include just carbon dioxide (CO_2) emissions or other greenhouse gas emissions such as methane? After all, there are gaseous emissions such as carbon monoxide (CO) that are based on carbon and relevant to the environment and health, and CO can be converted into CO_2

through chemical processes in the atmosphere. Also, should the measure include all sources of emissions, including those that do not stem from fossil fuels, such as CO_2 emissions from soils? (Wiedmann and Minx 2008a)

After so many of these questions were brought up, discussed, and assess for many years, some answers were at hand but a clear definition of carbon footprint was still missing. This gave raise to so many definitions from different publishers. Finally, Thomas Wiedmann and Jan Minx publishers of the article "A Definition of Carbon Footprint" proposed the following definition of the term “Carbon Footprint” as:

> *"The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product."* (Wiedmann and Minx 2008b)

The activity mentioned in the definition includes activities of individuals, populations, governments, companies, organizations, processes, industry sectors etc. Whereas, products include goods and services. Whereby, all direct emissions (on-site, internal) and indirect emissions (off-site, external, embodied, upstream, downstream) need to be considered.

The definition equally provides some answers to the questions posed above. Only CO_2 is included in the analysis, knowing that there are other substances with greenhouse warming potential. However, many of those are either not based on carbon or are more difficult to quantify because of data availability. A comprehensive greenhouse gas indicator that include all these gases should be termed “Climate Footprint” because in the case of “Carbon Footprint” the most practical and clear solution is considered, and it includes only CO_2.

The definition holds back showing carbon footprint as an area-based indicator. That is, to show that the total amount of CO_2 is physically measured in mass units such as kilogram, ton, etc. and thus no conversion to an area unit such as hectare takes place. If any conversion into a land area must take place, then it would have to be based on a variety of different assumptions and these increases the uncertainties and errors associated with a particular footprint estimate. Following this rationale, a land-based measure does not seem appropriate and the more accurate representation in tons of carbon dioxide is preferred. (Wiedmann and Minx 2008b)

The clarity of the definition provided by Wiedmann and Minx shows that carbon footprint can be used by companies or individuals to calculate how much carbon emission they have produce during a project or time period. Usually there are two main reason while for wanting to determine a carbon footprint; to report the footprint accurately to a third party or to be able to manage the footprint and reduce emissions over time. To know or for an organization to know its carbon footprint can be an effective tool for ongoing energy and environmental management.

Nowadays, organizations and companies due to some reasons such as marketing purposes, to determine what quantity of emissions they need to offset for them to become "carbon neutral", or to fulfil requests from customers or investors, increasingly want to calculate their carbon footprint to disclose to the public. To come out with an accurate calculation, this requires a more robust approach, taking into consideration the full range of emissions for which the organization is responsible. (GOODIER 2011)

2.2 The Regulatory Regime of Shipping versus Road Transport Mode

The shipping industry is harder to regulate due to its global nature than the trucking business. The implementation of regulations must be on a supranational scale to be efficient. To some extent, this is also true for road transport, but with a much higher degree of national control on the road networks than for international waters. Through a series of emission standards that gradually reduces emissions of CO, NO, HC and particles (Figure 1), the environmental performance of trucks have improved significantly over the past decades in Europe. As from 2013, the Euro VI limits applied further cuts in NOX, HC and PM emissions. More so, Sulphur emission levels have also significantly reduced through stricter regulations of the Sulphur content in diesel oil. The reductions in fuel use and CO_2 emissions have not been as substantial. (Hjelle and Fridell 2012)

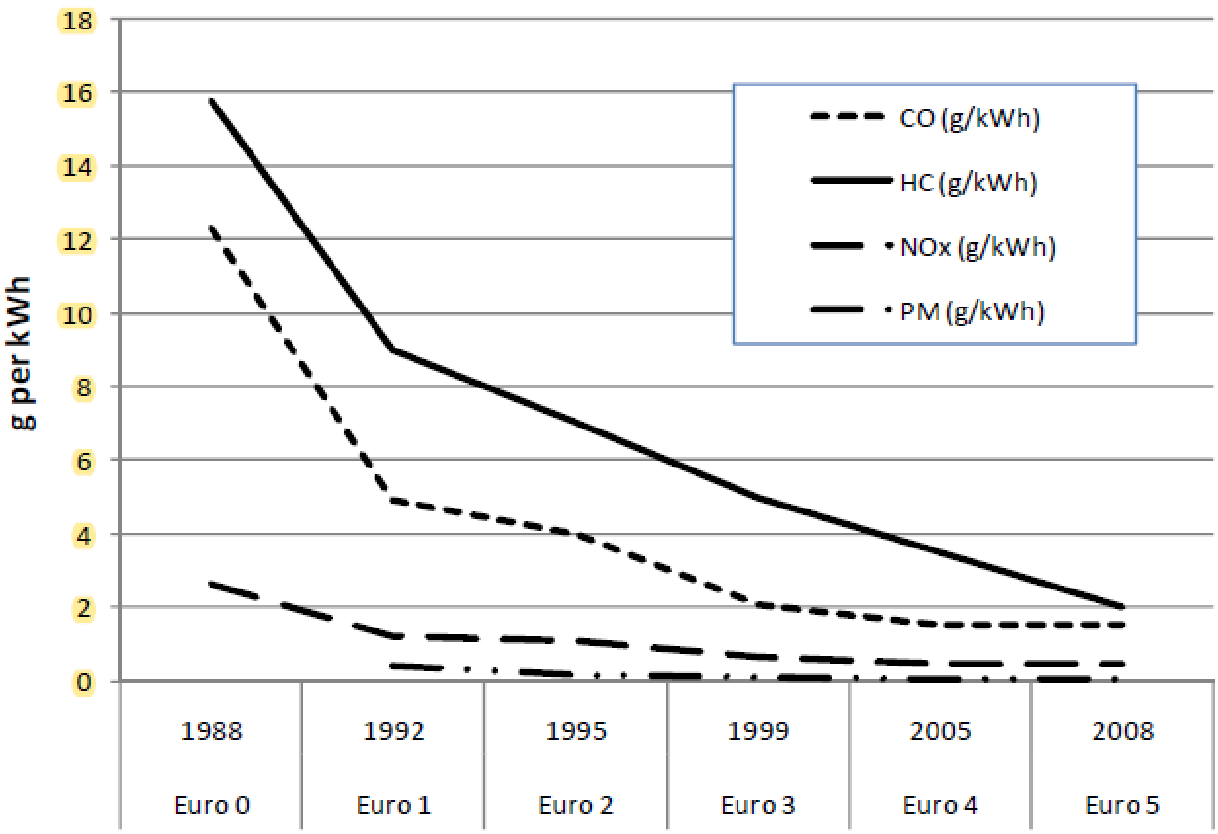


Figure 1. *Truck engine emission standards in Europe*

Source: (Hjelle and Fridell 2012) based on information from *EC DG Energy & Transport*

From 2012, the emission limits in the EU became similar to that of a Euro V truck. Electric engine has no direct emissions. However, emissions that arises from electricity production should be taken into consideration when doing a fair comparison with other modes of transport. The emissions vary significantly for CO_2, this means that, with the actual source of the electricity - from relatively large for coal-power to negligible for hydropower. (Hjelle and Fridell 2012)

Likewise, in the trucking business, international shipping has not been subjected to similar regulations over the same period of time, but through the Annex VI of the IMO Marpol convention in 2007, emissions to air was introduced to the global regulatory regime. The Tokyo protocol exempted emissions of CO_2 from international shipping because of the complexity of allocating emission to an individual partner states. Now, the Marpol Annex VI regulations are stricter, more especially in the Environmental Control Areas (ECAs). These areas can be for either or both SO_2 (SECAs), NO_x (NO_x-ECAs). Before 2012, the Baltic Sea, the North Sea and the English Channel were SECAs and in 2012, the North American coasts were both SECAs and NO_x-ECAs. In 2011, the Sulphur content in the fuel is was limited to 3.5% worldwide and to 1.0% in SECAs. From 2020, the restrictions of Sulphur will be further tightened to 0.5% worldwide and from 2015, it was 0.1% in SECAs. NO_x regulation is tightened gradually through another regulatory instrument - the NO_x-code, applied to marine engines. Nowadays, engines delivered have to comply with Tier 1 regulations. From 2012, Tier 2 regulations that gave a cut of about 20% was applied. From 2016, the Tier 3 regulations was applied representing a NO_x emission cut of about 80% in the NO_xECAs, compared to Tier 1. About 3.4g/kWh was the allowed emission for a slow-speed engine and no specific regulations for particle emissions are implemented for marine engines. (Hjelle and Fridell 2012)

Over the past decades, vessels have become more fuel efficient, but in the late 1970s and the 1980s, the most significant advances were made, which was triggered by a significant increase in bunker prices. Some national regulations have been put in place such as the environmentally differentiated fairway due system in Sweden and a NO_x tax in Norway. The European Commission considered implementing emissions from the shipping industry into its cap and trade system of CO_2 emissions. (Hjelle and Fridell 2012)

Due to the demanding process of reaching the necessary consensus among nations, international regulatory regime of maritime transport is moving quite slowly. More so, the penetration lead-time of technological advances is much longer for ships than for trucks all because of this sluggishness of new regulations (Hjelle and Fridell 2012). According to Hjelle (2010), the average age of a typical short sea vessel trading in European waters is probably around 15 years, while a typical long distance truck in Western Europe has an average age of 4 years. This means that the Euro V standard, and in a few years Euro VI, will shortly be representative of the fleet of long distance trucks.

2.3 Emission Caused by Transportation

Transportation is one of the biggest sources of pollution amongst other sources. The transportation of freight is carried out by different kind of transportation modes, and each of this mode has its own specialties and characteristics that have to be served and faced to find a way to reduce emissions caused by transportation. UN bodies such as the UNFCCC, IMO and ICAO develop standards and regulations for sea and air transport emissions on a supra-national level and oblige their member to be committed to them (OECD 2007). The European Union is adopting these standards and regulations for emissions and making them binding for its member states and the deviation of how each member state is converting these regimentations to national law is high.

The emission caused by the various transport mode is outline below;

2.3.1 Sea Transport Emissions

Sea transport has many related environmental issues. The early political focus such as the IMO MARPOL convention was related to emissions to sea but over the past decades, there have been an increasing focus on air emissions, which entered the regulatory regime of shipping through the new Annex VI to the MARPOL convention in 2007. Environmental hazards are related to air emissions and are traditionally divided into emissions that have local, regional or global impacts. Global warming is of a global scale and receives the main attention on the political agenda, mainly related to direct emissions of greenhouse gases from vessels, vehicles and to emissions related to the manufacturing of these means of transport (M. H. Hjelle, The comparative environmental performance of a modern short sea pallet liner operation with multiple port calls. ECONSHIP 2011 2011).

The major areas of concern on a regional (international) scale are emissions of Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) which may lead to acid rain and cause damage to crops and buildings. In the case of seaborne transport, there are also a number of regional issues related to emissions to sea, such as oil spills, disposal of other waste products and the discharging of ballast water, which may disturb the regional marine environment. Whereas at local level the most severe effects are related to poor air quality stemming from emissions to air. The main focus here is on emissions of NO_x, hydrocarbons (HC), non-methane volatile organic compounds (NMVOC), SO_2 and particles (Whall, et al. 2002). Apart from air emissions, noise effects can also be a major concern at local environmental level as well as factors such as severance, vibration, impairment of landscape, visual intrusion and effects stemming from local soil and water pollution. (Bickel and Droste-Franke 2006)

Naturally, majority of seaborne transport take place quite far away from residential areas, which implies that the local level impacts may be of less importance for shipping than for road transport. However, the local impacts from sea transport may be very significant in some areas where ports or inland waterways are located in the middle of cities, or where the fairways are close to the coast. Ports sometimes have rather long river or canal approaches that may lead to a high local impact of air emissions, and possibly noise (Bickel, et al. 2006). Eyring et al(2010) estimated that nearly 70% of all air emissions from shipping occur less than 400 km from land, meaning that these emissions will affect the local air quality of residential areas. There are cases where vessels actually spend quite a lot of the roundtrip time in ports and coastal areas that may be close to residential areas.

To quantify the impact of maritime emissions is complicated for local, regional and global effects. A lot of research about carbon emissions from various sectors including the transport sector has generally been triggered by the increasing awareness of global warming. The Kyoto protocol and subsequent policy initiatives have this far exempted the emissions from international aviation and international shipping because they have been difficult to allocate to the underwriting nations. However, due to the rapid increase in the demand for international shipping and aviation, the importance of including these sectors in climate policies has grown. Recent studies have contributed to determining the environmental footprint of shipping. Eyring, Köhler, et al.(2005) partially based on estimates of total fuel consumption to estimated total annual shipping emissions in 2001. Furthermore, Endresen, et al.(2007) conducted a historical reconstruction of fuel consumption from shipping with a more detailed modelling approach, putting in consideration changes in the average haul and speed, change in the demand for shipping services and including smaller fishing vessels. More so, Corbett, et al.(2007) provided new knowledge about the environmental footprint of the world-shipping sector in their review and calculations submitted to the International Maritime Organization (IMO). A debate about the overall net effect of emissions to air from shipping on global warming has been among the central issues of a research done by Eyring, Isaksen, et al.(2010). In the research, a thorough review of the current knowledge about the impacts of emissions to air from shipping is given. It involves many counteracting effects, recently implying that because the direct and indirect effects of Sulphate particles seem to be more than offset the positive radiative forcing stemming from emissions of CO_2, O_3 and black carbon, the net radiative forcing is negative (Dalsøren, et al. 2010). However, Sulphur oxides and NOx emissions contribute to critical problems related to local air pollution. Such emissions reduction that will follow from a stricter regulation may contribute to an increased net radiative forcing from future shipping emissions. (Borken-Kleefeld, Berntsen and Fuglestvedt 2010)

After reviewing existing evidence, Corbett, et al.(2007) concluded that SO_x and NO_x pollution from oceangoing ships represent some 5-7% of global SO_x-emissions and 15-30% of global NO_x-emissions. Fuel consumption (and consequently CO_2 emissions) represents 2-4% of global use of fossil fuels. Cofala, et al.(2007) and Metz, et al. (2007) stipulates that Carbon emissions from international shipping will probably continue to grow at a higher rate than emissions from land-based sources, effectively making shipping responsible for a growing share of global carbon emissions.

Estimating direct and indirect CO_2 emissions is a far less complicated issue than calculating the effects of maritime activities on global warming. The net effect on global temperatures is negative or positive based on the chosen time-horizon. It seems that the net temperature impact from maritime cargo-carrying vessels may be negative in the short term (5 years) and intermediate term (20 years). Whereas, in the longer term (50 years) perspective, the long term effects from CO_2 emissions seem to outweigh the counteracting effects related to SO_2 emissions and the resulting high concentration of Sulphate aerosols, and the formation of ozone stemming from NO_x emissions (Borken-Kleefeld, Berntsen and Fuglestvedt 2010)

2.3.2 Road Transport Emissions

The EU has come up several legislative initiatives to reduce emission by transportation. These legislations are mostly based on the “polluter pays” approach, whereby, the cost for polluting (marginal costs and social costs) is covered by the operator/shipper. The legislation is a successful application on road transportation due to the implementation of taxes on fuel and toll systems on roads. The taxes on fuel and tolls vary between the countries (Mayer, et al. 2012).

CO_2 is the main emission caused by road transport, and between 97% and 98% of the GHG emissions caused is by road transport. Road transport vehicles uses mainly gasoline and diesel fuel. Whereas, NO_x and PM emission are considered as the most critical for air quality. More so, road transport is the second largest emission source. In 2007, road transport was responsible for 17.4% of all CO_2 emission and it is the only source of emissions with a steady growth (Rexeis and & Hausberger 2009, Dwyer, et al. 2010, Pulles and & Yang 2011)

Country	Hours spent in road congestion annually (2017)	Share of renewable energy sources in transport (2016)	CO_2 emissions from new registered vehicles (g/km) (2016)		Share of electrified railway lines over total lines in use (2016)	Road fatalities per million inhabitants (2017)	Environmental taxes on transport (fuel and other taxes) (2016)		Plug-in electric vehicle share in new registrations of passenger cars (2017)	Charging points per 100 000 inhabitants in (peri-)urban areas (2018)
			Passenger cars	Light-duty vehicles			as % of GDP	as % of total taxation		
Belgium	39.1	5.9%	115.9	169.2	86.0%	54	1.9%	4.2%	2.7%	30.0
Bulgaria	35.0	7.3%	125.8	141.1	71.2%	96	2.6%	9.0%	0.4%	7.2
Czechia	23.6	6.4%	121.2	183.2	34.0%	55	1.9%	5.4%	0.2%	25.4
Denmark	22.3	6.8%	106.0	151.7	24.5%	30	2.5%	5.3%	0.6%	200.1
Germany	29.9	6.9%	126.9	178.7	52.8%	39	1.5%	3.8%	1.6%	71.0
Estonia	18.8	0.4%	133.9	161.9	14.4%	36	2.3%	6.7%	0.2%	66.3
Ireland	34.4	5.0%	112.0	163.5	2.7%	33	1.5%	6.3%	0.7%	77.6
Greece	35.5	1.7%	106.3	155.2	23.2%	69	2.7%	6.8%	0.2%	0.9
Spain	26.3	5.3%	114.4	148.0	63.7%	39	1.4%	4.1%	0.6%	17.4
France	30.1	8.9%	109.8	158.9	56.8%	51	1.5%	3.2%	1.8%	69.6
Croatia	23.5	1.3%	111.5	150.1	37.2%	80	3.1%	8.3%	0.1%	59.9
Italy	37.7	7.2%	113.3	145.0	71.5%	56	2.1%	5.0%	0.2%	10.8
Cyprus	31.8	2.7%	123.5	144.1		62	2.7%	8.2%	0.8%	4.2
Latvia	22.6	2.8%	128.9	156.6	13.5%	70	2.3%	7.5%	0.6%	7.3
Lithuania	21.5	3.6%	126.2	168.8	6.4%	67	1.8%	6.1%	0.3%	12.7
Luxembourg	36.4	5.9%	126.1	167.8	95.3%	42	1.7%	4.4%	1.9%	72.6
Hungary	26.4	7.4%	125.9	168.0	39.9%	64	2.1%	5.4%	1.0%	33.1
Malta	76.3	5.4%	111.8	146.9		41	2.3%	7.0%	0.4%	21.1
Netherlands	32.1	4.6%	105.9	155.5	75.7%	31	2.1%	5.3%	2.2%	275.4
Austria	27.3	10.6%	120.4	171.6	71.9%	47	2.0%	4.8%	2.1%	137.7
Poland	25.1	3.9%	125.8	171.3	64.0%	75	2.3%	6.9%	0.2%	6.0
Portugal	29.0	7.5%	104.7	140.1	64.9%	58	2.4%	7.0%	1.9%	32.9
Romania	31.8	6.2%	122.0	170.1	37.4%	99	1.9%	7.5%	0.4%	4.5
Slovenia	26.9	1.6%	119.0	168.2	41.4%	50	3.0%	8.2%	0.7%	57.9
Slovakia	23.7	7.5%	124.8	185.6	43.8%	51	1.6%	5.1%	0.4%	70.3
Finland	17.8	8.4%	120.0	167.0	55.2%	42	2.2%	5.0%	2.6%	58.9
Sweden	21.5	30.3%	123.1	155.2	75.2%	25	1.4%	3.3%	5.3%	104.3
United Kingdom	45.2	4.9%	120.1	172.9	33.7%	28	1.9%	5.6%	1.9%	33.9

Figure 2. *Environmental and Social Dimension*

Source: (EUROPEAN 2019)

In figure 2, the top five scores in green, bottom five scores in red, where relevant to provide ranking. If not otherwise specified, data are derived from European Commission sources.

The emission caused by road transport also includes private vehicles and their share of the emission is quite high compared to other transport modes e.g. passenger ships with only 3 % of the emissions (OECD 2007). Road transportation emission is distinguish between different vehicle types such as private cars, light duty-vehicles (LDVs) and heavy-duty vehicles (HDVs). LDVs are trucks with weight capacity of less than 3,5 tons, whereas the HDVs are trucks with weight capacity of over 3,5 tons. According to Takeshita (2011), the most important legislation by the EU in the last decades to reduce the emission within the EU by road transport was the change in fuel type, from leaded fuel to un-leaded fuel. The EU emission norms for road transport are limiting the maximum allowed emission of CO_2, HC, NO_x and PM measured in g/km for passenger cars, LDVs and HDVs, and differentiating between gasoline and diesel fuel. In 1994, the Euro 1 allowed for instance a LDVs Class III with a diesel engine to have maximum emission of 6.90g/km of CO_2 emission. Euro 5b allowed only a maximum emission of 0.74g/km for the same vehicle type. The continuous decrease in allowed emission from Euro 1 to Euro 6 is similar for NO_x, PM and HC for HDVs and passenger cars (DieselNet 2012). The demand for road transport by LDVs and

HVDs are expected to increase until 2050 and will together in the future contribute to global emissions (Takeshita 2011)

Another fact is that, road transport continue increasing especially in urban areas and this makes the emission by road transport a health issue for the inhabitants in these areas. PM emissions constitute a serious health risk especially for the respiratory system (Kousoulidou, et al. 2008). When it comes to the evaluation of road transport emissions, vehicle mass, road conditions and the payload of a transportation by road vehicles have to be considered because it the major influence of the enormous emissions by road transport.

2.3.3 Rail Transport Emissions

Emissions caused by rail transport is ambiguous because the kind of energy rail vehicle uses vary depending on the type of engine and train. Whereas in sea, road and aviation transport mostly different kinds of petroleum-based fuel are used. Trains uses diesel oil as well as electricity and sometimes coal. Therefore, the kind of energy chosen to be used has a huge impact on the emissions exhaled. More so, it is challenging to conclude if rail transport can be considered as a “green” mode of transport or the opposite. Furthermore, if a train uses electricity, it is important to know the source of the electricity to be able to make a statement about the real emission caused, that is, if the source is nuclear, coal or renewable energy. A study at the University of California, Barkley, USA in the newspaper “New Scientist” published by Catherine Brahic, asked if a commuter train across Boston caused less air pollution than a jumbo jet for the same distance. It was surprising that the answer was no, the commuter train does not cause less air pollution than the jumbo jet because Catherine Brahic considered the dimension of lifetime and the exploitation of tracks and roads in her research whereas air transport requires little infrastructure (Brahic 2009)

2.3.4 Aviation Transport Emissions

Aviation transport emissions accounts for approximately 3% of the worldwide CO_2 emissions. The aviation transport rather plays a more important role for the transportation of passengers than freights compared to sea, rail and road transportation. Aviation transport is typically used for high value or perishable goods due to the high unit costs in aviation transport. Until 2010, the aviation industry was excluded from taxation and other carbon policies (Rothengatter 2010). Furthermore, ICAO took very little actions to implement own emission restrictions leading to the fact that the EU took aviation into the ETS from January 2012 (Preston, Lee and Hooper 2012). This was the first step towards controlling and reducing the emissions of GHG and other air pollutants by air transport.

The aviation industry has been a growing industry since before 1989 with a 4,4% growth per year. The CO_2 emission by planes were mostly excluded in environmental agreements such as in the Kyoto protocol (Preston, Lee and Hooper 2012).

2.4 Emissions Trading

Emissions trading is a scheme implemented to solve the problem of emissions caused by freight transportation. EU implemented the first border crossing CO_2 emission trading scheme (ETS) in 2005 and its now approaching the end of the third trading phase. The EU ETS has gone through many reforms. In 2018, the revision of the system's framework was completed, and it will be implemented with the start of the fourth trading phase in January 2021. The EU ETS became linked to the Swiss ETS In January 2020, this is the first linking of this kind for both parties allocation rules, reporting, auctioning, the innovation fund, monitoring, accreditation and verification, and in the past year the Union Registry was adopted. More so, the market stability reserve (MSR) became operational on the 1st January 2019 as an instrument to address the supply/demand imbalance of allowances in the EU ETS and improve its resilience against future shocks (ICAP 2020).

The implementation of the ETS was an important step to achieve the requirements of the Kyoto protocol to transportation emissions, emissions by production plants and other emissions causers. The main objective of the ETS is to make emissions tradable and that the causers of emissions need to hold an emission certificates (pollution rights), which is equivalent to the amount of their produced emissions (Slate 2011). The ETS has four phases which are as follows:

- **Phase 1 (2005-2007)**: This phase involves combustion installations with >20MW thermal rated input (excluding hazardous or municipal waste installations) and power stations and, industry which includes coke ovens, oil refineries, production of glass, cement, lime, ceramics, bricks, paper, board and pulp, as well as iron and steel plants.
- **Phase 2 (2008-2012)**: In 2012, aviation was introduced with commercial aviation having >10,000t CO_2/year whereas non-commercial aviation having >1,000t CO_2/year since 2013. The emissions of Nitrous oxide from the production of nitric

acid were also included by some countries. The EU ETS expanded and included Norway, Liechtenstein and Iceland.

- **Phase 3 (2013-2020)**: This includes carbon capture and storage installations, production of nonferrous and ferrous metals, petrochemicals, aluminum, gypsum, ammonia, as well as adipic, glyoxylic and nitric acid.
- **Phase 4 (2021-2030)**: No changes to the scope have been agreed on for Phase 4 based on the current legislation (ICAP 2020).

According to the International Carbon Action Partnership (2020), the EU ETS is a cornerstone of the EU's policy to combat climate change and a key tool for cost-effectively reducing GHG emissions from the regulated sectors. The system covers about 45% of the EU's emissions, from the manufacturing industry, power sector and aviation limited to flights within the EEA. Emissions from carbon emissions from road and sea transport is not yet included in ETS. However, emissions related to electrified road vehicles is part of the ETS because emission from power plants is part of the ETS. According to Stoefs (2020), the EU is considering putting a price on carbon emissions from ships in the absence of movement in the international talks. Bringing shipping emissions into the EU ETS would be a big step in the right direction. However, finding the solutions to reduce GHG emissions from shipping emissions is the responsibility of the IMO, a UN body which is notorious for dragging its feet when it comes to tackling climate change when shipping accounts for 3% of global GHG emissions, and this could grow by between 50-250% by 2050 if any action is not taken (Stoefs 2020). The EU ETS is the largest and oldest ETS operating worldwide. Today, the "pollution rights" is introduced in the transportation industry setting a maximum limit level of emission for the entire industry and that this emission has to be allocated by the actors in the transportation industry. For the transportation industry, this would be based on fuel rights, which means the right to use fuel base on the importance of the relationship between fuel consumption and emission in transportation. The tradable fuel rights is thus based on quotas of CO_2 calculated from the carbon content in the fuel consumed by any fright vehicle user (mainly diesel oil for trucks) (Raux 2010).

2.5 Emissions Database

Generally, emissions databases represent a storage of collection of data of emissions from households, private companies and countries. The aim of the emissions database is to provide the possibility of control and monitor of the development of emissions. Emissions database came up as a result of the discussions on environmental policies in the last decades. Today, there are projects and databases by supranational institutions in the EU (inter alia ARTEMIS Project, EUROSTAT), projects by organizations like Green Freight Transport (GFT) or by private institutions. EX-TREMIS is the most recent project to collect data for air, sea and rail transport with regards to emissions. The emissions data is based on a fleet module that defines the engine specifications, ship loading capacities and ship categories, and uses data from Sea Web Lloyd's database, international literature and EUROSTAT (Schrooten, et al. 2009). The HBEFA published by the German Federal Environmental Agency in Berlin is the standard work for road transport emission, which came up as a result of a German-Swiss-Austrian cooperation. The databank allows a simulation of aggregated emissions factor from different transportation modes (Hausberger, et al. 2003). The project is a further development of the EUs COPERT project and it is partly related to the ARTEMIS project. In the 1990s, the COPERT III project was implemented for the predictions of fuel consumption and air pollutant emissions. This module produced emission factors (g/km) for each vehicle category and technology class (EU Norms) (Giannouli, et al. 2006).

In the EU, the database that collects emission data from transportation is the ARTEMIS project. TRENDS (Transport and Environment Database System) is a further developed emission database in the EU and the main objective of TRENDS is the calculation of environmental pressure indicators caused by transport (Giannouli, et al. 2006). TRENDS database is available for free use and it is MS Access based, and includes air emissions data from air, sea, rail and road transport. Furthermore, TRENDS has a particular outline for each transport mode considering the specificity of the different transport modes. The methodology of TRENDS is based on existing calculation methods such as FOREMOVE and CASPER (Giannouli, et al. 2006). Several projects are running on national level beside ARTEMIS and TRENDS such as the NABEL in Switzerland (Swiss national air pollution-monitoring network) (Hueglin, Buchmann and Weber 2006).

2.6 Calculation of Emissions

There are different approaches on which the calculation of emissions can be based on; for all kind of transport modes the most common is the so-called top-down approach, which is the calculation of emission based on the consumption of fuel. With regards to the chemical composition of fuel, the burning process and the emission caused can be calculated in laboratories. The emission factors (EFs) describes the emitted mass (g) for a driven distance (km or mile), and are widely used (Colberg, et al. 2005, Colberg, Tona, et al. 2005, Hueglin, Buchmann et al. 2006). The calculation of road traffic emissions is done 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 and Catone, et al. 2005). Calculation of emissions result derived in laboratories have the uncertainty of if they would be similar to calculation of emissions calculated in real life. The factors that influence emission are speed, payload, load weight, water current and wind for track and road conditions for trucks and trains, ships and planes respectively. All these circumstances create an almost unlimited number of possible settings (Colberg, Tona, et al. 2005, Hueglin, Buchmann el al. 2006).

Another approach on which the calculation of emissions can be based on 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 a real life setting. With the data not always, being up to date is the main problem in this approach. In the 90's, the "Handbook of Emission Factors for Road Traffic" (HBEFA) was established and have models to calculate emissions by road traffic. HBEFA is like a database that gives the user a simple simulation of aggregated emission factors for different traffic situations (Hausberger, et al. 2003).

Another alternative approach, on which the calculation of emissions can be based on, is to measure the emission of a transport vehicle with an on board sensors and also measures in traffic. This calculation of emissions approach is a bottom-top approach (Zhang and Frey 2006). Tunnels are often used to evaluate the emissions caused by road transport in real life settings. The tunnels are equipped with sensors gauging the emissions. The tunnels are chosen because they prevent mistakes in measurement by metrological influences (Colberg, Tona, et al. 2005, Hueglin, Buchmann et al. 2006, Colberg, Stahel, et al. 2005, Zechmeister, et al. 2006). In road transport, mountainous areas, altitude and the gradient of the road network has to be taken into consideration during calculation of emissions (Sturm, et al.

1996). The advantage of the tunnel evaluation is that the traffic emissions of a collection of vehicles can be surveyed and the results can be compared with the results achieved for a single vehicle on the dynamometer (Colberg, Tona and Stahel, et al. 2005). Generally, it is difficult to consider usual variations and differences in transport as inter alia due to difference in weight loading factors, loading and unloading methods, travel distance for different transport modes pre-trips and post-trips in intermodal transport and difference in energy consumption in non-driving conditions. More so, these factors influences the decision of what kind of transport mode is most environmentally friendly and always depends on a particular transportation (Kolb and Wacker 1995).

2.7 Calculation of Utility Value

Transport activities impose (external) costs on society in the form of noise, accidents, queues, greenhouse gas emission, local pollution, and wear and tear to the infrastructure. According to NCA (2017), sea transportation means reduced greenhouse gas emissions, fewer accidents and reduced maintenance costs per ton kilometers compared to road transportation. The saving in external costs in Norway as a result of moving freight from road to sea is equal to the utility value of a project, or the socio economic saving. To be able to calculate the utility value, detailed information as possible of the expected transferred quantity of freight, originating point and delivery destination must be provided (NCA 2017)

2.8 The Background and Applications of Carbon Footprint Calculation Tool for Calculating Environmental Impacts of Freight Transport Chains

With the recent increased concern for climate change and regulation implementations, many organizations both locally and internationally, have requirements for greenhouse gas emissions. Many calculators have been developed and put in the internet by environmental NGOs, private enterprises and government bodies to assist some actors to assess the environmental performance of alternative transport chains. Most of these calculators are related to passenger transport alternatives, and offer to calculate either carbon footprint or a more comprehensive set of emissions related to single journeys or the entire transport usage over a period of time. Fewer calculators provide services for freight transport. This could be because of the complication of things to do. The dimensions are normally many in the case of freight, as the cargo unit is not as easily defined as in the passenger case. Some companies have their private calculator for freight transport and often promoted as an extra service to customers to calculate the carbon footprint of their shipment, whereas other calculators have been developed for public use. These calculators are simple to use in most cases because they offer few input alternatives. Furthermore, the documentation they based on building the model is also often hard to come by. More so, they quite often as well limit themselves to providing carbon dioxide emissions and/or fuel use as output. However, there are exceptions to the rule. In relation to this research, the Norwegian Coastal Administration (NCA) calculation tool, the German Ecological Transport Information Tool (EcoTransIT) calculation tool and the Swedish Network for Transport Measures (NTM) calculation tool are chosen for a comparative analysis and the models are frequently used in European settings. The three models are explained below.

2.8.1 The NCA Calculation Tool

The Norwegian Coastal Administration (NCA) model was introduced by the NCA for an aid scheme to stimulate a permanent modal shift from road to waterborne transport by giving aid to new coastal and short sea services for freight between ports in the EEA, and for special cases to the upgrade of existing services.

Sometimes, high start-up costs and low freight volumes can prevent the early phase of the establishment of new maritime transport services. During the start-up phase, grants from this scheme will help to ensure that the establishment of socially profitable maritime transport services is not hindered by weak business economic profitability during. More so, the purpose of the scheme is to strengthen the competitiveness of maritime transport and contribute to the goal of transferring more freight from Norwegian roads to waterborne. By doing so, without weakening existing maritime transport market as well as the railway, the competitive conditions in the transport market should be corrected in favor of maritime transport (NCA 2017).

In 2015, the aid scheme for short sea shipping was endorsed in The National Port Strategy and was based on findings from The National Transport Plan's analysis of goods, where the relevant segments for transfer in Norway have been mapped out. In the context of modal shift, it is emphasized that the greatest potential for modal shift applies especially to road transport exceeding 300km. The combined potential for transfer of freight is estimated to be between 5 and 7 million tons per year from roads to sea and rail. Furthermore, on the 21th, November 2016, EFTA's Surveillance Authority approved the Norwegian aid scheme for short sea shipping. The aid scheme for the modal shift from road to the waterborne transport is funded over Chapter 1360, Post 72 of the Norwegian National Budget and the annual funds depend on the decisions of the Norwegian Stortinget annual budget (NCA 2017).

Transport activities impose costs (external costs) on the society in the form of noise, local pollution, GHG emissions, accidents, queues, and wear and tear to the infrastructure. Compare to road transport, sea transport have reduced maintenance costs per ton kilometers, reduced GHG emissions and fewer accidents. As a result of moving freight from road to sea, the utility value of a project or the socio-economic saving, is equal to the saving in external costs in Norway.

Those applying for the scheme must use the NCA's mapping tool to pre calculate the utility value. The NCA developed the mapping tool and calculates the external costs for a given distance of road in Norway, whereas, within the Norwegian Economic Zone (NEZ) the same costs for a given distance by sea is limited. The mapping tool uses the Google's mapping tool for calculation of distance by road and the NCA's own data for ports and calculation of routes at sea. The calculation from the mapping tool is a guide and it is expected that the tool will be further developed. If required, the NCA will assist in calculating the benefit value and will conduct the final calculation (NCA 2017).

- **Distance calculations at sea:** The calculations of distance at sea are based on the NCA's sea-lane dataset and the sea-lane dataset is used for the calculation of distances between ports. The number is subsequently multiplied by the VISTA Analysis' calculation of marginal external costs per ton kilometer for sea transport (Magnussen et al, 2015).
- **Distance calculations by road:** The calculation of distance on road are completely done with the use of Google based mapping solution. Therefore, there will be less deviation in distances. In road transport network, there is a separation between transports through areas of different degrees of population density, which produce different external costs. In densely populated areas, the external costs are higher and the rates were obtained from the Institute of Transport Economics' report on marginal external costs for transport by road (Thune-Larsen, et al. 2014).

The figure below provides a summary of the marginal cost per ton kilometers;

	Sea alternative	Road alternative		
		< 15 000 residents	15 – 100 000 residents	≥ 100 000 residents
Emissions to air	0.005	0.050	0.050	0.050
Local emissions	0.003	0.015	0.083	0.376
Noise	0.000	0.000	0.010	0.012
Congestion	0.000	0.000	0.000	0.080
Accidents (life and health)	0.0004	0.056	0.282	0.282
Acute emission to sea	0.002	0.000	0.000	0.000
Infrastructure	0.000	0.071	0.071	0.071
Winter related operations	0.000	0.05	0.05	0.05
Total	**0.010**	**0.197**	**0.502**	**0.877**

Source: Vista Analysis, 2015/TØI, 2014 and 2016

Figure 3. A summary of the marginal cost per ton kilometers

Based on an estimate of the total number of tons of freight the project is expected to move from road to sea during the whole of the aid period (3 periods), for the given freight routes, the utility value can be calculated. As shown in figure 3 above, different rates are set for the external costs per ton kilometer for road transport and sea transport, within and outside populated areas. The factor for marginal external costs for road transport is multiplied by the total number of ton kilometer for the road transport service. The sum of the marginal external costs for sea transport multiplied by the number of ton kilometers for the alternative of sea transport is then subtracted. In the external costs for transport by sea alternative, the transport by road to and from the port must be included and it is possible to include representative hubs at many of the points of origin and destinations, for instance port to port. For transport by road alternative, the mapping tool will display a map showing the relevant route. How the route can be altered by dragging the blue line towards the actual sector of road is shown in the figures below;

Figure 4.1 Road sector alternative 1

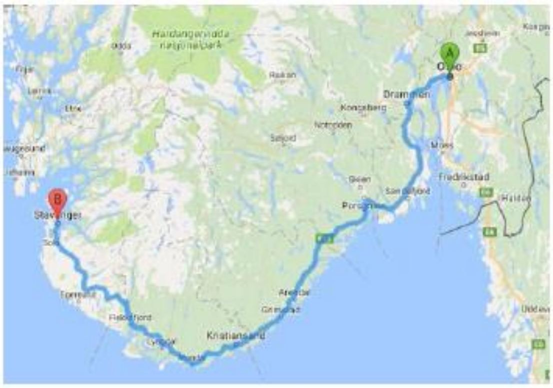
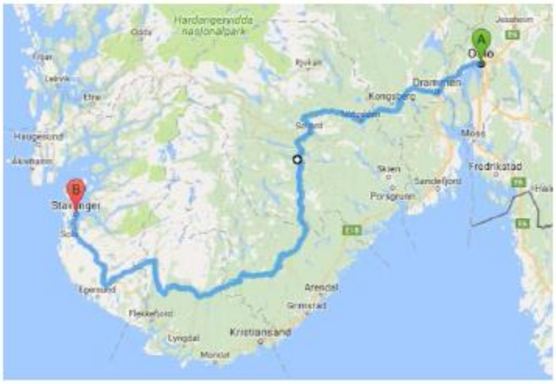


Figure 4.2 Road sector alternative 2



- **Transport between two limited geographical areas:** However, some transports have one point of origin, for example a central storage facility in Eastern Norway and several points of destination, for instance in Western Norway. To calculate the utility value for such cases, will take as a starting point the central storage facility and a representative place in Western Norway as ending point, for instance at a port.

  If the transport contains many points of origin in a limited geographical area and one point of destination, for instance from another country and to a production company in Norway, the calculation of the utility value must take its starting point in one representative place, for instance at Svinesund and end at the production company in Norway.

  Freight transportation can also have many points of origin and many points of destination, to defined geographical areas where the points of origin and destination can be limited. For instance many points of origin in Eastern Norway to many destination points in Western Norway. The calculation of utility value need to be based on the transport starting at a defined point of origin, like the port of Oslo, and ending at a defined representative destination in Western Norway, like the port of Bergen.
- **Line traffic:** Here, the calculation of utility value must be based on a defined representative transport sector for the freight. The line vessel can visit many ports, for instance A – B – C on its crossings between a point of origin and a destination point. The number of tons of freight to be carried in each segment in both directions must be estimated, that is, number of tons A-B, B-C and A-C. It must be completed

in this manner because the utility value of the transfer of freight (per ton kilometer) is different for each segment (NCA 2017).

2.8.2 The EcoTransIT Calculation Tool

More than eight scientists, each with their own expert knowledge, published Ecological Transport Information Tool (EcoTransIT) in 2003 with the regional scope limited to Europe. In 2010, EcoTransIT World, which is the latest version of EcoTransIT was published to permit the calculation of environmental impacts of worldwide transports. Due to the introduction of EcoTransIT World, the basis for calculating air and sea transport emissions as well as the logistics routing routines have been improved. A railway consortium originally initiated EcoTransIT World but today, it includes one logistic provider (DB Schenker Germany), six railway undertakings, and the International Union of Railways (UIC). The railway consortium aims to include players from all modes in the future, thus offering EcoTransIT World as a nice practice standard of carbon foot-printing and green accounting to the whole sector in compliance with international standards (EcoTransIT World 2019).

IVE mbH team/RmCon Hannover made the integrated route planner for all transport modes as well as the EcoTransIT internet version. IFEU Heidelberg and the Öko-Institut developed the data and basic methodology for the emission calculator. EcoTransIT World aims to meet the needs of various actors, especially political decision-makers and forwarding companies, carriers and logistics companies. Air pollutants, energy consumption and greenhouse gas emissions (NO_x, SO_2, NMHC and particulate matter) are the environmental parameters covered. EcoTransIT offers two levels of detail regarding inputs: The standard input mode, which permits a rough estimate to be made, based on simple input data and the extended input mode, which permits the user to enter relevant parameters like load factor, length, engine types, factor of empty trips, vehicle size, and route characteristics (Knörr, et al. 2011).

The data sources for EcoTransIT is as follows;

- **For road:** The major source for vehicle emission factors and final energy consumption is the "Handbook emission factors for road transport" (HBEFA) (INFRAS 2010) for trucks with EU emission limits and the MOVES model for EPA standard.

According to Matzer, et al. (2019), HBEFA includes emission factors for every important road vehicle type for a variety of traffic situations from stop and go up to highway driving with no speed limits. The emission factors from HBEFA are based on real world driving cycles emission measurements on chassis dynamometers on the road to parametrise the vehicle emission model, Passenger car and Heavy-duty Emission Model (PHEM). The emission factors are then computed for all combinations of vehicle segments and traffic situation by simulation. The PHEM model provides the emission factors under hot running conditions for HBEFA. Cold start emissions from evaporation and extra emissions are described in different reports. However, to maintain a high representativeness of the emission factors, regular updates of the underlying test data base and of the emission model are performed (Matzer, et al. 2019).

The Handbook of Emission Factors is also used to model the influence of the load factor, which means that fuel consumption of vehicles is also depended on load factors. This influence can be even stronger depending on the gradient and driving characteristics.

Emissions and energy consumption can also depend on the driving pattern. There are two typical driving patterns that are considered by EcoTransIT World: One for traffic on other (mainly extra urban) roads and one for highway traffic.

The can only estimate the gradient shares for the different countries on international transport road. For "hilly countries" such as Germany, no adjustments will be made, whereas emissions and energy consumption are assumed 5% higher for “mountainous countries” such as Switzerland and Austria, and 5% lower for “flat countries” such as Sweden and Denmark.

CO_2-emissions depend directly in the fuel properties. An emission factor of 74,000 kg/TJ for diesel fuel was used in EcoTransIT World. More so, the emission factors for SO_2 are derived from the actual Sulphur content in the fuel. The Sulphur content in diesel fuel is assumed according the valid legislation. In 2010, the value was 10 ppm in Europe (= 0.47 kg/TJ) (Knörr, et al. 2011).

For sea: A bottom-up approach is used to derive the emission factors for ships used in the EcoTransIT World model. For marine vessels, the bottom-up approach is based on technical data and on the activity, and offers a reliable methodology for estimating emissions from individual ships as well as groups of ships, emissions and ship types in specific geographies. The IMO used the bottom-up approach to estimate the global maritime emissions (IMO 2009). “The international team of scientists behind the (IMO) study concluded that the activity-based estimate is a more correct representation of the total emissions from the world fleet (…) than what is obtained from fuel statistics." (Buhaug, et al. 2008).

In EcoTransIT World, underlying emission factors are developed for different vessel types: RoRo vessels, liquid bulk carriers, general cargo vessels, dry bulk carriers and container carriers whereas ferry services are treated as extensions of the road network.

A technical data of 4616 sample vessels are used to model the emission factors. The technical data was collected from Lloyds Register of Shipping. By comparing the findings with the aggregate results for CO_2 emissions in the updated GHG study by IMO, the validity of the sample was tested (Buhaug, et al. 2008, IMO 2009). Emission factors are developed for each individual vessel (EFv). The principle derivation of emission factors uses main and auxiliary engine data, activity data and capacity data. Emission factors for container vessels is derived in g/TEU-km (TEU = twenty foot equivalent unit = standard container of 20" length), while for all others vessels the factors are based on g/ton-km. The EFv are based on nominal carrying capacity with the subsequent inclusion of vessel utilization and empty trips as shown in formula below which was derived by IFEU (2010);

EFv = engine data x vessel capacity data x vessel activity data x vessel utilization factor

The final emission factors for the different vessel types, size classes and trade lanes are then weighted averages of the vessels' individual emission factors. In the extended input mode, specific vessel types and size classes can be selected. Vessel types and size classes have been grouped to derive trade lane specific emission factors in the default mode of EcoTransIT World. When selecting the type of cargo and the port pairs in the model, the appropriate vessel emission factor is automatically selected (EcoTransIT World 2019).

For Sulphur Emission Control Areas (SECAs) such as the North Sea and Baltic Sea, separate emission factors have been developed. Sulphur oxides and particulate matter emissions are automatically reduced for vessel route with ports in those sea areas. Emissions of vessels travelling beyond the SECA will show a combination of non-SECA and SECA emissions, with the assumption that the vessels switched to a higher-S bunker fuels outside the SECA area. Different Sulphur levels in fuel apply for each region. The global average Sulphur level is generally assumed to be 2.37% in heavy fuel oil. Lower Sulphur levels were assumed for auxiliary engines, because of the partial use of marine gas oil and marine diesel oil for those engines. More so, different Sulphur levels were assumed for the in-port and SECA area (H. M. Hjelle 2012).

The EcoTransIT-model is different from the above NTM-model. EcoTransIT-model provides routing choices based on a big database of aviation, rail, sea, road and inland waterway networks (GIS-based), combined with algorithms for the shortest or fastest path based on a system of different link resistances (Knörr, et al. 2011).

2.8.3 The NTM Calculation Tool

NTM (Network for Transport and Environment) is a Swedish non-profit organization, which started in spring 1993. In order to promote and develop the environmental work in the transport sector, NTM established a common base for calculating the environmental performance of all modes of transport. The NTM calculation tool is primarily developed for customers and providers of transport services, to enable them evaluate the environmental impact of their own transports (NTM 2012).

As described below, the input to the model can be provided with different levels of accuracy;

- **Level 1:** The accuracy level here includes average vehicles/vessels consuming average fuel and engine/motor specifications. Based on average load factors, there is an allocation of environmental burden on a specific cargo.
- **Level 2:** In this accuracy level, there is a specified average performance for vehicles/vessels with average load factors consuming average fuel and with average engine/motor specifications linked to a general goods flow. The general technical improvements are included during estimation carried out by the informed user in order to evaluate logistics changes.
- **Level 3:** This accuracy level includes specified vehicles/vessels and fuel use and engine/motor specifications linking a shipment to a specified vehicle/vessel in each transport leg in a transport chain. The technical improvements are included during estimation carried out by the very informed user in order to evaluate logistics changes. Regarding performance differences, the analysis can also be supportive to the supplier evaluation. In integrated logistics systems nowadays, only few operators are able to deliver this accuracy (H. M. Hjelle 2012).

According to NTM, their idea is to use and develop data in accordance to best and most credible publicly available sources of data presently available and they follow the ISO 14 048 standard for LCA data documentation (NTM 2008a).

The data sources for NTM is as follows

For road: NTM has previously relied on emission values reported from the emission evaluation tool Handbook of Emission Factors, HBEFA 2.1 (2004). The new

ARTEMIS Road Model, hereafter named ARTEMIS which was developed within the EU FP5 project ARTEMIS have most of the HBEFA data, together with new measurements and a developed methodology. According to André, et al. (2008) ARTEMIS was designed for three main applications:

- Inventories for classical emission at national or regional scale, monthly or annually.
- Scenario calculation (time series over years) for assessing the impacts of alternative measures.
- Inputs for the quality of air models for assessing temporal and local impacts on the environment.

The model was later designed to permit the calculation at a street level and at an aggregated level. Over the 1980-2030 period, the daily calculation can be declined on a hourly basis or aggregated anually (André, et al. 2008). These data are considered to be more representative for real-world traffic emissions and NTM now uses ARTEMIS as a base for emission and fuel consumption data (Bäckström and Jerksjö 2010).

For sea: NTM chose to use the emissions report presented by (Whall, et al. 2002). These reports cover a large number of published data as well as IVLs own measurements carried out on board vessels in operation (NTM 2008a).

A sea transport alternatives analyst will generally face one of the following situations;

- Cargo capacity utilization, engine emission profile and fuel consumption is known for the vessel(s) carrying the investigated cargo. A high quality result will be yield using such data.
- The type of vessel, cargo capacity utilization and fuel consumption is known for the vessel(s) carrying the investigated cargo. The emission profile can be calculated by using the average emission profiles of different type of vessels emission profile can be calculated. This will yield a less precise result as the values gained in option 1.
- If vessel type is the only available information, then data from a collection of common ship types (fuel consumption, emission profile and capacity utilization) can be used. However, the use of this data will yield a result that is less representative of the real live setting (Bäckström and Jerksjö 2010 and (NTM 2008a).

3. Methodology

The background for which the analysis for this research has been included has been to establish to investigate the transparency, if the calculation tools are used as intended, if these calculation tools are well documented and developed based on scientific evidence. All the investigate is to know if carbon footprint calculators tell the true story. This investigation requires me to evaluate some carbon footprint calculators and do some comparative analysis to be able to answer to the research questions that this thesis was set to accomplish. By doing so, I will evaluate three carbon footprint calculators, namely, the NCA, EcoTransIT and the NTM calculation tools. These calculation tools are accompanied with hundreds of pages of documentations that explains the background of the model use to develop the calculation tools.

Base on the review of these calculation tools, the NCA calculation toll provides CO_2 emissions output and output for external cost, which is composed of environmental costs, time costs, accident costs and noise costs whereas the NTM and EcoTransIT calculation tool provides outputs for emissions and energy consumption. Regarding the output results provided, a comparative analyse will be made to conclude my research.

3.1 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 2013). This thesis adopted a qualitative comparative analysis approach of research.

Qualitative Comparative Analysis (QCA) is a method of research that offers a new, systematic way of studying configurations of cases. QCA is used in comparative research and when using case study research methods. The QCA analysts interprets the data qualitatively but also looks at causality between the variables. Therefore, the two-stage approach to study causality has a qualitative first stage and a systematic second stage using the QCA. QCA is truly a mixed-methods approach to research and it is best suited to small to medium case study projects with between 3 and 250 cases (Wendy 2008).

3.1.1 Source of data

Information gathered for this thesis is based on two main data sources – primary and secondary source. Primary data are data that are collected for the specific research problem at hand, using procedures that fit the research problem best, (Hox and Boeije 2005). Secondary sources of data are those that were collected by different researchers and are proven. The secondary data can be collected directly either form published or unpublished sources (Maxwell 2012). The secondary data for this thesis includes articles, company records, and electronic resources.

3.1.2 Data Collection

In many research projects, primary data collection is an important piece. Using proper techniques during a research ensures that qualitative data are collected in a scientific and progressive format, and improving data collection techniques will improve the validity, reliability, and accuracy of the research. Most importantly, using the following methods helped me achieve the goal of carrying this research.(Bradley 2009)

3.1.3 Interview

Interviews are usually one-on-one discussions between an interviewer and an individual, purposely to collect information on a particular set of topics, conducted in person or electronically (phone or e-mail) (Bradley 2009).

In this research, I interviewed the NCA who offers one of the calculation tool I reviewed in my literature review to enable me to know the following;

- The extend at which their calculation tool is being offered in the market
- The transparency of their calculation tool
- The background of the model use to develop their calculation tool and its application and
- If the is any evaluations on how the model works and if customers appreciate the information provided by the calculation tools (Do customers really care about the transparency and reliability of the results?).

3.1.4 Extraction

Extraction is a method of collecting data from documents, records, or other archival sources. This method of collecting data is generally done by using an abstraction process to gather the required information from the source (Bradley 2009).

Implementing this method of collecting data enabled me to get opinions from different publishers and organizations regarding my research questions and it helped me to come out with a better analysis.

3.1.5 Data Analysis

In a qualitative research, data collection and analysis occur simultaneously (Baxter & Jack, 2008). The type of analysis used in a research depend on the type of study. Yin (2003) briefly describes five techniques for data analysis: explanation building, pattern matching, times-series analysis, linking data to propositions, cross-case synthesis and logic models (Baxter & Jack, 2008). So many qualitative research are as a results of richly detailed and subjective data, which come from the interviews and observations represented in the study conducted.

3.2 Validity and Reliability

To have a logical test of the variability and reliability of the research strategies that has been planned, it is required to come up with criteria for the evaluation of a case study methodology (Schell, 1992). The two most important aspect of all research are validity and reliability. There is high credibility and trustworthiness given which makes the research acceptable when particular attention of these two elements are given in a research (Brink, 1993).

A research method's ability to yield the same results over repeated testing methods when used consistently is referred as reliability (Brink, 1993). Selltiz et al (1976: 182) also stipulates that, it is concerned with the consistency. Therefore, reliability is the extent to which repeatedly measuring the same property produces the same results (Office of Quality Improvement, 2010). The stability and ability to repeat what the respondents have accounted as well as the researchers' ability to collect and record the given information accurately (Brink, 1993).

Yin (2003) also outlined the various categories by which validity and reliability can be achieved. The use of several sources as data collection establishes chain of evidence which makes this thesis constructively valid. More so, pattern-matching was used in the data analysis where similar information were found in the different units, this also gives the internal validity. Reliability is equally acknowledged where case study procedure were observed.

4. Analysis and Findings

This chapter talks about the results provided by the different calculation tools reviewed in chapter 2 and these results will be analyzed base on different cases. To limit the scope of the analysis of this research, my illustrations will be limited to the comparison of road and sea shipping solutions.

4.1 Setting up cases for Analysis and findings

Two concrete cases will be illustrated, designed to highlight certain similarities for calculations in the NTM and EcoTransIT calculation tool whereas a different highlight will be illustrated in the NCA calculation tool. This is because, as reviewed in chapter 2, the NCA calculation toll provides CO_2 emissions output and output for external cost, which is composed of environmental costs, time costs, accident costs and noise costs which is quite different from the output provided by the NTM and EcoTransIT calculation tool. In the end of my illustrations, I will do a comparative analysis of the environmental cost and physical units of emissions provided by the NCA calculation tool and the outputs provided by the NTM and EcoTransIT calculation tool.

All the cases have to be representative of a Norwegian freight transport chains with an estimated freight weight of 10.5tons.

Case 1: Road (Molde to Oslo)

This case is comprise of the road transport from Molde to Oslo and a general cargo weight of 1TEU which according to Knörr, et al. (2011) documentation model it is equivalent to 10.5 tons. A screenshot example is used below to illustrate the truck and ship input and outcome on the EcoTransIT calculation tool.

Figure 5. *EcoTransIT input data*

General Information

Creation Date: 21.04.2020
Origin: [City district] [no] Molde
Destination: [City district] [no] Oslo
Cargo weight: 1 teu (t/TEU: 10.5)

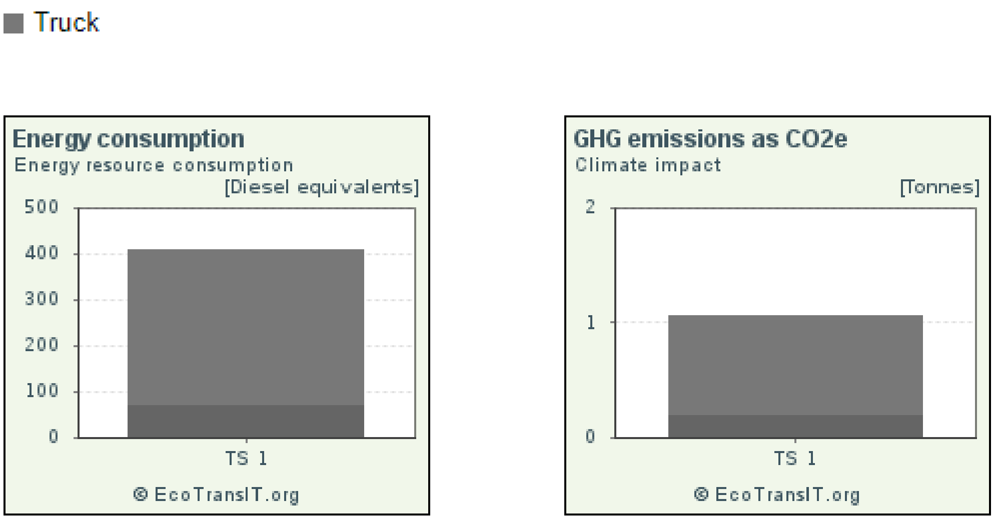
Detailed description of the calculated transport services

Transport service TS 1 - 497.71 km

Origin: [City district] [no] Molde
Truck (7.5-12 t,diesel,EURO 5,LF: 65.0%,ETF: 20%) - 497.71 km
Destination: [City district] [no] Oslo

LF is Load Factor, TEU or teu is Twenty-feet Equivalent Unit while ETF is Exchange Traded Fund.

Figure 6. *EcoTransIT data output provided*



Energy consumption (WTW)
Energy resource consumption [Diesel equivalents]

	TS 1
Truck	405
Sum:	**405**

© EcoTransIT.org

GHG emissions as CO2e (WTW)
Climate impact [Tonnes]

	TS 1
Truck	1.06
Sum:	**1.06**

© EcoTransIT.org

Energy consumption (TTW)
Energy resource consumption [Diesel equivalents]

	TS 1
Truck	331
Sum:	**331**

© EcoTransIT.org

GHG emissions as CO2e (TTW)
Climate impact [Tonnes]

	TS 1
Truck	0.85
Sum:	**0.85**

© EcoTransIT.org

Case 2: Sea (Molde to Oslo)

This case is comprise of a waterborne transport from Molde to Oslo and a general cargo weight of 1TEU.

Figure 7. *EcoTransIT data input*

General Information

Creation Date:	21.04.2020
Origin:	[City district] [no] Molde
Destination:	[City district] [no] Oslo
Cargo weight:	1 teu (t/TEU: 10.5)

Detailed description of the calculated transport services

Transport service TS 1 - 1,087.23 km

Origin: [City district] [no] Molde

Truck (26-40 t,diesel,EURO 5,LF: 95.77%,ETF: 20%) - 1.22 km

Via: [no] Molde (UN/LOCODE: NOMOL)

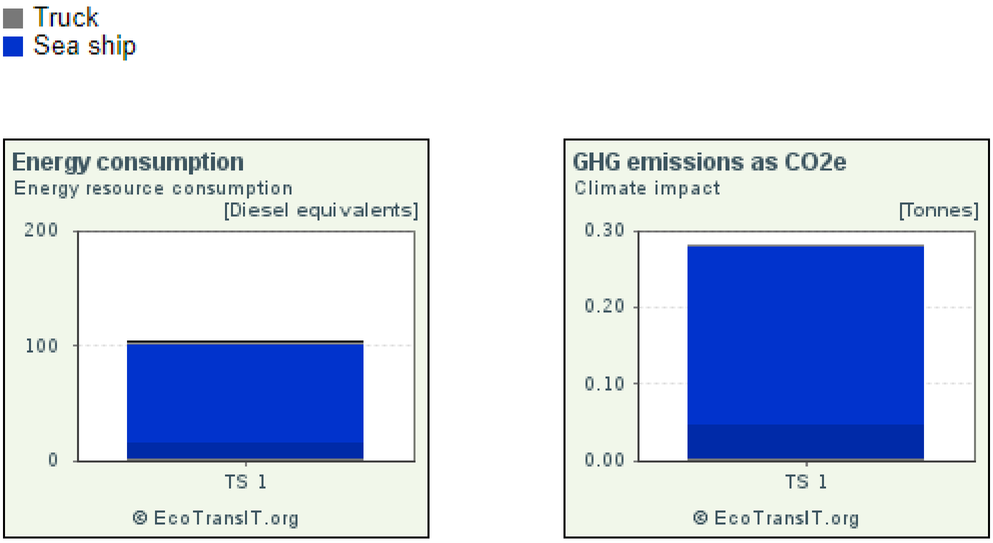
Sea ship (CC Intra-continental EU (0,5-2k TEU),LF: 65.0%,SR: 0%,Scac: null#) - 1,080.59 km

Via: [no] Oslo (UN/LOCODE: NOOSL)

Truck (26-40 t,diesel,EURO 5,LF: 95.77%,ETF: 20%) - 5.42 km

Destination: [City district] [no] Oslo

Figure 8. *EcoTransIT data output provided*



Energy consumption (WTW)
Energy resource consumption
[Diesel equivalents]

	TS 1
Truck	1.74
Sea ship	100.07
Sum:	**101.81**
Reporting:	
Intermodal transfer	1.96

© EcoTransIT.org

GHG emissions as CO2e (WTW)
Climate impact
[Tonnes]

	TS 1
Truck	0.0045
Sea ship	0.2754
Sum:	**0.2799**
Reporting:	
Intermodal transfer	0.0001

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Energy consumption (TTW)
Energy resource consumption
[Diesel equivalents]

	TS 1
Truck	1.42
Sea ship	85.21
Sum:	**86.63**
Reporting:	
Intermodal transfer	0.88

© EcoTransIT.org

GHG emissions as CO2e (TTW)
Climate impact
[Tonnes]

	TS 1
Truck	0.0037
Sea ship	0.2312
Sum:	**0.2349**
Reporting:	
Intermodal transfer	0

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The NCA case

This case provides CO_2 emissions and external costs result for both road and waterborne alternative at the same time as shown below;

Figure 9. *NCA transport alternatives*

Figure 10. *NCA input and output data*

External benefit of modal shift:

Difference between road and sea option: 952.2 kr

Emission difference between road and sea option: 0.5 tonn CO2

Tonn: 10

From: Molde, Norway

To: Oslo, Norway

Your calculation ID: **fbc89470-83e4-11ea-b822-77a498aebd9a**

Land and sea part, overview:

	Summary land	Summary sea
Total cost (kr)	1074.3	122.1
CO2 emission in Norway (tonn)	0.6	0.1
Dist in Norway (km)	481.7	1032.7
Dist on road in Norway (km)	480.9	2.4
Dist on sea / ferry in Norway (km)	0.8	1030.3
Cost on road in Norway (kr)	1074.2	19.1
Cost on sea / ferry in Norway (kr)	0.1	103.0
Dist rural areas <15 000 inh. (km)	456.5	null
Dist urban areas (15-100 000 inh.) (km)	10.4	0.5
Dist urban areas > 100 000 inh. (km)	14.0	1.9
Dist ferry (km)	0.8	null
Cost rural areas <15 000 inh. (kr)	899.3	null
Cost urban areas (15-100 000 inh.) (kr)	52.2	2.8
Cost urban areas > 100 000 inh. (kr)	122.7	16.3
Cost ferry (kr)	0.1	null

Tool	Mode	Freight weight
EcoTransIT	Road/Sea	10.5tons
NTM	Road/Sea	10.5tons
NCA	Road/Sea	10.5tons

Table 1: Data input for road or sea from Molde to Oslo

Due to the fact that, I am also trying to investigate if it possible for the three different calculation tools used in this thesis to produce the same result, I tried to use same input data in all the above calculation tools to see if they will produce the same result but it was not possible. However, despite the fact that I used the “Extended” version of EcoTransIT calculation tool and NTMcal “Advance” that give the possibility to input more specific data than in others versions or than what would be typical for many users, it was still difficult to input similar data in all the different calculation tools. For instance, it is possible to input a specific diesel type in NTM calculation tool but such input is not possible in EcoTransIT and NCA calculation tool. Again, the NTM calculation tool give more detailed result on GHG emissions than EcoTransIT and the NCA calculation tool.

More so, the three different calculation tools used in this thesis generates different distances for both alternative transport from Molde to Oslo. Furthermore, these calculation tools have web-interfaces which is not accessible to users, for example in the NCA calculation tool, the only input data required is the cargo weight, transportation starting point and final destination to produce results without the user knowing or verifying the underlying assumptions or default values applied . All these really makes it difficult to explain while the calculation tools produce different results as shown in the different output data provided by the different calculation tools in Table 2, calculating the environmental footprint of such transport chains includes hundreds of factors (cargo characteristics, vessel/vehicle characteristics, road choice, actual load factor) and varies from shipment to shipment.

The emissions outcome that different calculation tools measured are CO_2, SO_x, NO_x, HC and PM.

Tool/Outcome		CO_2	SO_x	NO_x	HC	PM	Distance
EcoTransIT	Road	2,100	0.66	9.63	-	0.34	1,087
	Sea	1,500	1.84	0.52	-	0.07	498
NTM	Road	1,153	0.21	1.50	0.44	0.02	552
	Sea	165.79	0.89	1.12	0.07	0.08	368
NCA	Road	0.6	-	-	-	-	482
	Sea	0.1	-	-	-	-	1,033

Table 2: *Data output for road and sea emissions from Molde to Oslo in Kilograms and distance in Kilometers.*

4.2 Discussion

From the reviews I did on documentation related to carbon footprint calculators and the interview I did, these are the summary of what was assessed after reviewing those documents and carrying out the interview. This summary also give the answers to the research questions that this thesis was set to accomplish. Which are;

- Are these calculators well-documented and founded base on scientific evidence?
- Regarding the results provided by the calculators, how are the calculators comparable?
- Does the NCA calculation tool suitable for its purpose of assessing application for a new incentive system for transferring cargo from road to inland waters?

To investigate if carbon footprint calculators tell the true story required me to evaluate some carbon footprint calculators and do some comparative analysis to be able to answer to the research questions that this thesis was set to accomplish. By doing so, I evaluated three carbon footprint calculators, namely, the NCA, EcoTransIT and the NTM calculation tools. These calculation tools are accompanied with hundreds of pages of documentations that explains the background of the model use to develop the calculation tools.

4.2.1 Scientific Evidence

The three calculation tools used in this thesis were all developed with scientific proven applications and the calculation tools are well documented.

For NCA calculation tool

- The calculations of distance at sea are based on the NCA's sea-lane dataset and the sea-lane dataset is used for the calculation of distances between ports. The number is subsequently multiplied by the VISTA Analysis' calculation of marginal external costs per ton kilometer for sea transport (Magnussen et al, 2015).
- The calculation of distance on road are completely done with the use of Google based mapping solution.

For EcoTransIT calculation tool

- The major source for vehicle emission factors and final energy consumption is the "Handbook emission factors for road transport" (HBEFA) (INFRAS 2010) for trucks with EU emission limits and the MOVES model for EPA standard.

- A bottom-up approach is used to derive the emission factors for ships used in the EcoTransIT World calculation tool. Likewise, the IMO uses the bottom-up approach to estimate the global maritime emissions (IMO 2009) and the international team of scientists behind the (IMO) study concluded that the activity-based estimate is a more correct representation of the total emissions from the world fleet (…) than what is obtained from fuel statistics." (Buhaug, et al. 2008).
- The technical data of 4616 sample vessels are used to model the emission factors. Technical data was collected from Lloyds Register of Shipping.
- Emission factors for container vessels is derived in g/TEU-km (TEU = twenty foot equivalent unit = standard container of 20" length), while for all others vessels the factors are based on g/ton-km. The EFv are based on nominal carrying capacity with the subsequent inclusion of vessel utilization and empty trips as shown in formula below;

  EFv = engine data x vessel capacity data x vessel activity data x vessel utilization factor

For NTM calculation tool

- According to NTM, their idea is to use and develop data in accordance to best and most credible publicly available sources of data presently available and they follow the ISO 14 048 standard for LCA data documentation.
- NTM has previously relied on emission values reported from the emission evaluation tool Handbook of Emission Factors, HBEFA 2.1 (2004). The new ARTEMIS Road Model, hereafter named ARTEMIS which was developed within the EU FP5 project ARTEMIS have most of the HBEFA data, together with new measurements and a developed methodology. These data are considered to be more representative for real-world traffic emissions and NTM now uses ARTEMIS as a base for emission and fuel consumption data (Bäckström and Jerksjö 2010).

4.2.2 Comparative Analysis

Regarding the results provided by the calculation tools, NCA calculation tool only provides output for CO_2 emissions and external cost, which is a composition of environmental costs, time costs, accident costs, noise cost whereas EcoTransIT and NTM calculation tool provides outputs of energy consumption and GHG emissions.

It is possible to enter even more specific data such as data for specific vessels into the NTM calculation tool that will make results from this tool would probably have been more comparable because such input is not possible in EcoTransIT.

The results produced by these calculation tools reveal a lack of uniformity among calculation tools and these variations may be as result of distinct methodologies utilized or different conversion factors employed to calculate estimates of emissions, energy consumption and external costs. Despite the fact that EcoTransIT and NTM calculation tool employ similar approaches to their estimations, their results still vary, even when using similar inputs, as shown in my analysis. These variations may be as a result of differences in calculating methodologies, conversion factors, behavioral estimates or other sources. More so, the lack of transparency makes it difficult to determine the specific reasons for these variations and to assess the accuracy and relevance of the calculations.

4.2.3 The NCA Calculation tool

The NCA calculation tool was developed for assessing application for a new incentive system for transferring cargo from road to inland waters. The new incentive system/aid scheme was administered and managed by the NCA.

The purpose of the aid was to stimulate a permanent a modal shift from road to waterborne transport by giving aid to new coastal and short sea services for freight between ports in the EEA, and for special cases to upgraded existing services, not to subsidize the transport of freight already transported by sea. Modal shift is understood to be the transfer of road transport to sea, measure in tons kilometer (*quantity of freight x transport distance*) (NCA 2017). The goal achievement of the aid scheme is assessed base on the volume of freight transferred from Norwegian road to sea, measured in ton kilometers.

The duration of the aid scheme was three years, started on the, 16th February 2016 and ended on the, 16th February 2020. The deadline was the last date on which confirmation of support could have been given. The example of the allocation of the aid shown below are based on the following prerequisites:

- Awarded aid of 12 million NOK were based on an anticipated transfer of freight of 10,000 tons during the first period, 20,000 tons in the second period and 40.000 tons in the third period.

- Measured aid for the three periods considers a descending payment profile (50% of the total amount of grant aid after the first period, 1/3 after the second period and 1/6 after the third period). The maximum amount of aid that can be paid for the three periods will then be 6 million NOK, 4 million NOK and 2 million NOK for the third period.
- The payment factor for the three periods is equal to the period's aid amount divided over anticipated transferred quantity of freight during the period:

- PF1 = (6 million NOK /10,000 tons) = 600 NOK per ton
- PF2 = (4 million NOK /20,000 tons) = 200 NOK per ton
- PF3 = (2 million NOK /40,000 tons) = 50 NOK per ton

The NCA calculation tool only provides an output of external cost, which is a negative effect applied by a third party due to financial activities (NCA 2017) because transports activities imposes external costs to the society in the form GHG emissions, noise, accident, congestion, local pollution and wear and tear to infrastructures. External costs differ between transport modes. Generally, the external costs per unit (ton-kilometer) of maritime transport are lower than the external costs per unit (ton-kilometer) of road transport. Therefore, a modal shift from road to sea will generally lead to lower external costs from transport, which will benefit the society environment. This external benefit to the society and environment as applied here is the difference in marginal external costs of freight transport by sea and road transport in the Norwegian area due to a modal shift in transport of freight from road to sea. This forms the basis of the aid and it is calculated as the difference between the total external costs for the alternative of road transport and the alternative of sea transport (NCA 2017).

A reduction in socio-economic costs or a socio-economic gain is arrived at as the difference between the marginal external costs of the different modes of transport, as calculated for road haulage by Thune-Larsen, et al. (2014) and for sea and rail transport by Magnussen et al (2015).

Base on the fact that, the following institutions financed, approved and endorsed this aid scheme, the calculation tool used for the aid scheme probably underwent some thorough evaluation.

- The aid scheme was financed by the National Budget section 1360, item 72 and the aid scheme is designed in line with the EFTA Surveillance Authority (ESA) guidelines for state support for shipping (maritime guidelines) paragraph 10, regarding support for short sea shipping.

- The aid scheme was approved by the ESA on the 21st November 2016 (208/16/COL) and the Norwegian Ministry of Transport and Communications designed guidelines for the aid scheme based on this decision.
- In 2015, the aid scheme was endorsed in the National Port Strategy and has been based on findings from The National Transport Plan's analysis of goods.
- The NCA was also responsible for planning and conducting evaluations on this aid scheme. The evaluation was conducted to acquire information about whether the aid is effective in terms of the established objectives, benefit to society, use of resources and organization.

The aid recipients must be willing to supply information in conjunction with the evaluations but as for now, the NCA is still working on the final report and evaluation of the aid scheme as the aid just end in February and the COVID19 pandemic eventually breakout.

5. Conclusion

Environmental footprint calculators are important tools used to estimate carbon footprint emissions and to provide information that can lead to policy and behavioral changes. Despite the fact that most carbon footprint calculators are relatively new, their methods are proliferating and their numbers are growing. These carbon footprint calculators can increase public awareness about GHG emissions, energy consumption, external costs, and ways to reduce them. They can equally affect the type and magnitude of emissions reduction efforts and offset purchases. However, due to the fact that carbon footprint calculators lack transparency, policymakers and individuals will be less able to understand and validate the results. Carbon footprint calculators, given their prevalence and potential influence can provide even greater public benefit by providing greater consistency and clarity.

The comparative analysis presented in this thesis, in relation to road and sea shows that the calculation tools convert to a higher degree, emissions from trucks than emissions from ships. This could be as a result of the fact that trucks are far more standardized than ships. Furthermore, there is also much more available evidence related to truck emissions than for ship emissions. More so, realistic evidence on load factors may also be easier to obtain for truck than for ships. Some calculators base emissions from ships on deadweight tonnage, is only relevant for bulk vessels. According to Hjelle (2011), real load factors for RoRo and container vessels must encompass the "double load factor" which is an inherent characteristic of these modes. He adds that, instead of using calculation tools that are not fully transparent and well adapted to reality, such a comparative analysis should be based on detailed information regarding real world cases, with specific ships and trucks, specific routes and specific cargoes.

5.1 Limitation and Future Research

The evaluation of carbon footprint calculators is a very large topic but in this thesis, it was limited to investigate if carbon footprint calculators tell the true story. There is a vast amount of information related to carbon footprint calculators, and the challenge was to limit the information to my research objective.

Initially, when I started my research, I was thinking of using a case study approach in the thesis but when I started data collection, I decided to limit the thesis to comparative analysis approach because that was the best way for me to come out with answers to my research questions.

Research on carbon footprint calculators has emerge through various studies with both exploratory and empirical studies, and has led to many frameworks and divergent views. These different views can be put together in order to create a standard framework for the evaluation of carbon footprint calculators.

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7. Appendix

Sample of interview questions:

1) To what extend is the NCA calculation tool being offered in the market?

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2) How transparent is the calculation tool?

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3) Are they documentations, which explain the background of the model use to develop the NCA calculation tool and its application?

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4) Is there any evaluations on how the NCA calculation tool works?

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5) Do customers/aid applicants appreciate the information provided by the NCA calculation tools (Do customers/aid applicants really care about the transparency and reliability of the results?)?
