MASTER

An assessment methodology for the logistics emissions of companies

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An assessment methodology for the logistics emissions of companies

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Abstract

This master thesis describes the creation of a method to assess, allocate and compare carbon dioxide emissions resulting from air, rail, road and sea transport companies according to the New European Norm EN 16258. Computing emissions can be made either by using Fuel based methodology or an Activity based one. The default values are taken from NTM methodology, and then the allocation methodology is created in accordance with the European Norm based on the Unit and the Distance. An overview of the reduction possibilities from actual studies is presented and concluded with an intermodal decision making model. Finally, a case study is made for the Lean and green Second star program pilot with the cooperation of Connekt. This second star program is a step further into sustainability that consists of reducing companies' emissions. This Study Case is developed with the creation of an Excel tool that computes the emissions and provides the relevant KPI's (CO2 per Unit and CO2 per Unit km) for each Company. Lastly, a comparison among these KPI's is performed for the Lean&Green Second Star second star program.

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A special word to you as a reader, you are maybe one of the people previously mentioned, or a person doing his review or thesis. In the latter case, make sure you enjoy the process of the thesis and take every possibility to learn. Not only from a theoretical perspective, but also with the aim to become wiser, as I would like to think I have become in these last couple of months.

Management Summary

In response to the growing pressure on companies to be more sustainable from external parties, there has been an increasing focus on carbon emission assessment and reduction. However, to meet the long term goal of the European Union (from 60 to 80 % reduction in 2050 compared to 1990's level), the transport sector, which represents 30% of the overall CO2 emissions from Fossil fuel combustion (according to the International Transport Forum in 2010), needs to reduce its emission as well. The new European norm aims to standardize the carbon emission calculation and allocation for transport companies. However this European norm allows some flexibility. This study aims to create a methodology according to this new norm and to fill the knowledge gap by creating a common standard for assessing, allocating and comparing emissions from transport companies.

Research design

The following central question and sub-questions are defined for this project:

How can the CO2 emissions of different companies be computed, compared and reduced?

1. What are the relevant parameters in order to compute CO2 emissions depending on the level of information companies give?
2. How can CO2equivalent emissions resulting from transport be determined?
3. What alternative for the allocation of CO2 emissions can we introduce?
4. What methodology can we use to cluster companies into groups in order to provide a relevant and fair comparison?
5. How to provide feedback to companies to reduce their carbon emissions?

This study takes into account the logistic emissions from European countries only (due to the factor used applicable in Europe). Furthermore, this project is made according to the European norms and our scope is limited by it. Thus, the calculation of CO2 equivalent is made including CO2, CH4, N2O, and other minor gases.

CO2 Calculation methodology

Computing CO2 emissions needs a method to approximate the fuel consumption when it is not available. In order to choose the best one for our case we compare 3 different methods: Artemis, GHG Protocol and NTM. As our aim is to create a fair methodology for companies, a trade-off has to be made between high flexibility in the number of inputs, a high level of detail and the fit with our scope. From this, we choose the NTM method which provides default factors that can be used if not enough accuracy is reached. It makes the NTM method the best suited for our project. Thus we provide a calculation method based on the level of information companies have.

First the Fuel based methodology is used if information about the fuel consumption is available. If not, an estimation with the NTM method has to be made and the Activity based methodology is applied.The minimum level of detail needed in order to perform this is dependent on the method used. Hence, for the Fuel based methodology the type of fuel and the fuel consumption are required, and for the Activity based methodology further information is needed to estimate the fuel consumption, where the type of vehicle, the country, the distance, the weight of cargo shipment and the type of fuel are required.

Some assumptions had to be made in order to adequately fit with the NTM methodology chosen, and further parameters had to be taken into account while computing logistic emissions for the Handling or the Positioning.

CO2 allocation methodology

The Second research question aims to allocate CO2 equivalent emissions for a given cargo, among the owner of the goods in the transport mode. This is made according to the European norm, by using both the unit, which can be either the Weight or the Cubic Meter, and the Distance. However, the European norm is very vague and only stipulates to take origin and destination into account for a trip. Our allocation also considers the trip travelled on several days, a parameter that is not clearly specified in the new norm.

In this case we won't only take the locations of origin and destination of the trips into account, but we will separate them into several trips: from the origin to the end of a day's stop (usually a warehouse), and from the warehouse to the destination.

Clustering company methodology

A clustering of companies was created by using the product characteristics: density; and the transport characteristics: temperature control and Stow-ability, in order to create fair and comparable clusters. This aims to compare companies not by their activity, but depending on the goods they ship. A company can be part of several clusters, where each is defined by their performance by comparing their fuel consumption, and so be qualified or not into "green companies".

Reduction opportunity

The last question aims to provide relevant feedback to companies in order to offer several reductions possibilities. Thus 4 carbon emission reductions possibilities are investigated in the area of load factor increase, Alternative fuel, the use of intermodal transport and are delivered to the company for achieving a greener transportation. A particular focus has been made in the field of Intermodal transport by the creation of a Decision Model in order to choose the adapted transport mode and see the CO2 reduction possibilities. Thus depending on the distance and the payload we compute the cost per transport mode and minimize it.

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Introduction

The field known as Green supply chain management has received more and more interest during the last years. The commitment of companies for sustainability issues rises due to external pressure. The present report aims to develop a model with which companies can measure their logistic performance in terms of their emissions, according to the European norm, and compare it against competitors. Academic literature discusses several concepts of green supply chain management as shown in the following section.

Background

In this part research is enumerated which has provided the necessary knowledge in order to perform this Master Thesis project.

First, The Kyoto Protocol in 1997 has determined expectations towards the 83 countries and the European Union that have signed the protocol. It has provided a baseline where countries need to reduce emissions.

In Europe, in 2006, around 23% of all carbon dioxide (CO2) emissions were due to the transport sector, which makes it the second biggest contributor after the energy sector (European Commission, 2011).The Carbon Regulated Supply Chain (CRSG) in 2007 has given more insights about Carbon emission regulation and a study in 2009 by van den Akker, te Loo, Ozsalih, & Schers provides relevant information about the different calculation methods for transportation. The different calculation methodologies were analyzed in order to extract the level of accuracy for each calculation tool that was available at that point of time. ARTEMIS, EcoTranSIT, GHG Protocol, NTM and STREAM are the methodologies that were discussed.

The method chosen in the CRSC studies was the NTM methodology due to the high level of detail and its flexibility. Hence, the emission can be computed with various levels of detail, which offer the possibility to add parameters or take the default values if some values are missing.

During the CRSC project, the TERRA (Transport Emission Reporting and Reduction Analysis) tool was developed. It is based on the NTM (2008) methodology. The following parameters were added during the CRSC project: cleaning, temperature control (mainly cooling and freezing) and vertical handling.

Moreover, further information has been given about the KPIs which influence the CO_2 calculation (Note: In the scope of the present Thesis CO_2 emissions refers to CO_2 equivalent emissions). Thus, sourcing locations, locations of the factory and warehouses, and locations of clients (= the way a shipper has organized its supply chain) greatly impact the outcome of the KPI. Of course, other (reduction) factors such as load optimization, fuel efficiency, clean fuels will also have an impact on the outcome of the KPI.

Finally, the new European norm EN16258 "Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)" form the basis on which the assumptions were made.

The company

Connekt is an independent private-public partnership, in which private companies and public authorities work together to achieve a more sustainable mobility in the Netherlands for both people and goods transport. Connekt is in charge of the Lean and Green program.

The Lean and Green Program has been set up in 2007 by the Dutch Ministry for Infrastructure and Mobility, which wanted to give incentives to the Dutch logistic sector to be more sustainable in transport and logistics. This new approach called Lean and Green has successfully been set up in the past five years to make freight transport both more effective and sustainable. This approach is based on creating a vibrant logistics community of shippers, distributors, retailers, transport companies, other logistics service providers and local and national public authorities, together taking actions to decrease the amount of CO_2 emissions on their supply chains.

At this moment, more than 300 organizations are officially participating as a partner in the Lean and Green Community, of which the majority are private companies. The partners are called Frontrunners (Koplopers in Dutch) who stand out and are therefore role models for other similar organizations.

Furthermore the Lean and Green program has also been exported to other European countries, as the frontrunners active across different European countries are interested to also participate in Lean and Green programs in other countries. Currently the Lean and Green program is also running in Germany, Belgium, and Italy, and other countries are currently being investigated.

The Lean and Green Award companies demonstrate that they are actively making an effort to turn their logistic process into a more sustainable one by committing to a CO_2 reduction of at least 20% over a 5 years period. That in itself is something to be proud of. They are willing to commit themselves to this objective, because decreasing the CO_2 emissions in a part of their supply chain can- in practice- often be combined with making the logistic processes more effective and profitable. The Lean and Green Award is granted on the basis of a written plan, in which concrete CO_2 objectives for a 5 year period have been defined together with the KPI's (Key Performance Indicators). The Lean and Green plan is certified by TNO. In the external certification the baseline calculation, the feasibility of the proposed measures and the embedding of the proposed actions in the organization are taken into account.

When the 20% reduction is externally certified by an auditor/accountant the participant receives the Lean and Green Star. This demonstrates that the participant has actually realized the commitment made in the Award phase.

Research area

As said previously the field of Green supply chain management has received a great interest during the last years. Lenoble (2013) summarizes several practices done within the field of Green supply chain management by using the SCOR model. The influences on the environment have become important criteria which must be taken into account by companies due to different forces. These forces are the pressure from public, laws and environmental standards; enterprises are required to focus on environmental management (WU Chun一you, ZHU Qing一hua, GENG Yong 2001) and the pressure from the partners among the supply chain. Furthermore Customer awareness, economic and competitive pressure push companies to focus on environmental issues (Sarkis, Zhu, & Lai, 2010).

The first large international agreement to reduce greenhouse gases was the Kyoto Protocol where 83 countries and the European Union have signed the protocol (UNFCCC , 2009). These countries have agreed to reduce their overall emissions by at least 5 percent (compared to their levels in 1990) within the commitment period 2008 to 2012 (UNFCCC, 1998). The main aim of this protocol is:

"to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (European Union 2006).

According to the International Transport Forum (2010), the CO2 emissions in the transport-sector represent 30% (OECD) of the overall CO2 emissions from Fossil fuel combustion. The sector accounts for approximately 15% of the overall greenhouse gas emissions. Furthermore, there was a growth of Global CO2 emission by 45% from 1990 to 2007.

This increase of CO2 emissions from transport is a huge challenge for companies. That's why calculation methods are used in order to provide relevant information on companies' performances.

With more and more LSP (Logistic Service Providers) the problem of allocation between companies becomes more relevant. Also, calculation tools with allocation methodology had to be developing according to some regulation methodology in order to know which companies in which country contribute to the emissions.

This project takes place in the context where companies want to have deep insight about transport linked with their own transport emissions.

Research design

This part explains the design of the project in detail. In the first section the problem is defined and leads to the general research question. The next section divides the global research question into sub questions in order to find solutions for the stated problem. Finally, the last part explains the scope of the project and includes its boundaries.

Problem definition

This section defines a question which is answered throughout the research project according to Connekt.In order to be able to meet the long-term climate goals set by the European Union (60 – 80 percent reduction in 2050 compared to 1990 levels) the transport sector needs to reduce its emissions as well. In order to be more sustainable, the Dutch government had established the Lean and Green program.

Lean and Green is a major program that has been initiated from Connekt in the Netherlands making road freight transport both more effective and sustainable by reducing the emissions of CO2. It concerns businesses and government bodies that take measures for minimizing not only their costs but also their impact on the environment. More than 300 organizations are participating in this program aiming at a 20% reduction of CO2 within 5 years. This reduction concerns the sector of transportation offering a decline in the emissions generally in their supply chain.

Furthermore, companies become more and more aware of carbon emissions and participate in the Lean and Green program for mainly 4 reasons:

- Using **Cost effective** carbon reduction methods and learning from others
- Using the Lean and green label as a **competitive advantage** or customer requirement
- Communication/ branding of Lean and Green
- Being Environmental friendly

The companies having their first star want to make a next step towards sustainability, and star's winners have voiced the wish for:

- More **comparison** with peers (stand out against peers)
- More focus on **cooperation** in the supply chain
- Learn from others, stimulate and challenge each other to realise **further improvements and innovation** in the chain
- A **uniform calculation methodology** to specify and monitor challenging targets.

The present thesis addresses those wishes and concerns of the participating companies by developing a model that allows them to compute their emissions according to the European norm and to compare their logistic performances with those of their competitors. The following question can be derived from this context:

How can the CO2 equivalent emissions of different companies be computed, compared and reduced?

Research questions

From the central question 5 sub-questions can be extracted. For each research question the relevance and the scientific importance are mentioned.

1) What are the relevant parameters in order to compute CO2 emissions depending on the level of information companies give?
2) How can CO2equivalent emission resulting from transport be determined?

The first two research question set a standard for computing emission depending on the availability of information a company can provide. Furthermore, there is the minimum requirement a company must provide for calculating their CO2 equivalent. Hence, a detailed explanation of the created methodology is explained as answer to the second research question in order to determine the CO2 equivalent emission.

3) What alternative for the allocation of CO2 emission can we introduce?

As the routing transportation produces CO2-emissions for each lane, it is a complex task to say which customer is responsible for which part of the carbon emissions. The aim of this question is to design a methodology according to the new European norm for the allocation problem which can be used by LSPs to allocate their CO2-emissions among their shippers.

4) What methodology can we use to cluster companies into groups in order to provide relevant and fair comparison?

One wish of the one star companies is to be compared with their peers. However, it would be inappropriate to compare companies that are too different. Hence, a methodology is created in order to compare the companies sharing the same characteristics. Additionally, a description of the clustering parameters is established and an evaluation of these clusters depending on the fuel consumption is made.

5) How to provide feedback to companies for reducing their carbon emission?

A short feedback is given to companies for the reduction possibilities. Hence reduction options, together with the applicability are evaluated. The calculation tool created is used to quantify the possibilities of reduction.

Project Scope

This section describes the scope of the project. First, the main aim of this Master thesis is the creation of a standard methodology. This methodology is established in accordance with the New European Norm EN 16258. After establishing this standard for computing, allocating and comparing the emissions, the methodology will be used in a practical and professional environment, In Connekt for the Lean and Green Program.

In order to follow the New European norm EN 16258, the gases which have to be taken into account do not anymore only include CO2 but also the CO2 equivalent. Thus, the calculation must include the following six gases: Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulphur hexafluoride (SF6).

From those who use only CO2, according to the European Norm, a factor of 1.23 from the CO2 has to be applied to have the CO2 equivalent. These factors can be found in appendix 1.

Furthermore, any other gases shall be excluded. The European norm provides GHG Emissions Factors (See Appendix 1 A and B) in order to compute directly the CO2 equivalent depending on the number of liters which are used. These tables will be the basis for the calculation.

The data that companies will provide for the study case is restrained to periods of one year as the Second Star program has to be recompleted every year by companies.

As expressed in the European norm, this study focuses on European countries. That is why only the origin and destination in Europe have to be taken into account.

The case study: Lean and green second star project is limited to the quantitative part which takes into consideration all transport activities, and our study is limited to logistics emissions, all other emissions have to be excluded. As our study will impact mainly logistic companies (LSP and shippers), a limitation in the logistic emissions is acceptable.

Methodology

In this part we will describe our methodology in order to compute CO2 equivalent's emission, cluster companies into groups and provide relevant feedback to companies in order to reduce emissions depending on parameters. Our methodology will use either real data or approximations by using the default values. For each way of computing CO2 equivalent emissions we state the data dependency.

Calculation methodology

The first part of the methodology is to establish a calculation methodology in order to compute the emission. Hence, the choice of the calculation methodology is made within the first section. Then the computation is explained followed by a description of the assumptions which are used. This calculation methodology is made for computing the emission in the most accurate way by using real values for each parameter. Computations become less accurate the less information is provided and hence, estimations and assumptions are made. That is why our methodology will be able to compute emissions subject to the company's data availability and depending in the data, how to accurately compute the emissions. This chapter aims to provide the minimum parameters needed for calculating emissions and the several ways to compute the emissions.

Choice of the methodology

There are different methodologies existing and available, those are designed to compute the Carbon Dioxide Emissions. However these methodologies differ in their scope, their assumptions, based on real data in different countries and therefore, leads to different results. Thus, it is important for us to take a methodology allowing a good flexibility in order to determine emissions depending on the level of information that a company can provide. We will just introduce briefly the main methodologies used in Europe and America (GHG protocol, Artemis and NTM methodology).

The Greenhouse Gas (GHG) Protocol

The GHG protocol has been launched in 1998 on the initiative of businesses, non-governmental organizations, and other institutes (according to GHG protocol 2005) and aims to be the widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions according to their website. The protocol distinguishes between the three scopes to achieve a higher level of transparency and accuracy regarding the calculations.

- Scope 1: Direct emissions: this scope includes emissions from sources that are owned or controlled by the reporting entity.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- Scope 3: Other indirect GHG emissions such as the extraction and production of purchased materials and fuels.

Furthermore, two methodologies are explained in order to compute emissions: Fuel based methodology allowing computing the emission depending on the liters of fuel used and the conversion factor for fuel type. The second methodology is the distance based methodology where emissions can be calculated depending on the distance that is driven by the vehicle.

Artemis methodology

Artemis means Assessment and Reliability of Transport Emission Modelling and Inventory Systems and is a project initiated by the European Commission in the year 2000 (Artemis, 2007). For the European Commission two things are of high importance: firstly, setting a standard for computing emissions and secondly, enabling a common calculation method which is able to compare the emissions of the different countries. Therefore, the Artemis project was started up.

Artemis is based on European data. The level of accuracy as well as the level of detail a company must provide are high. Hence, there is less flexibility than in the GHG protocol but the accuracy of the result is higher.

NTM Methodology

The Network for Transport and Environment is a non-profit organization started in 1993 for creating a “common base of values on how to calculate the environmental performance for various modes of transport” (NTM Air, 2008; NTM Rail, 2008; NTM Road 2008; NTM Sea 2008).This methodology uses EcoTransit data source and is updated by the Swedish LSPs and Shippers who are contributing to the project in order to increase the accuracy of the results. The scope of NTM is Europe.

We can notice that NTM methodology includes high flexibility: High level of detail for the several factors can be taken into account and offer the possibility to take the default value in case the company cannot provide the necessary data. The level of detail can be varied depending on the information a company provides. Furthermore, NTM is collaborating with the European Committee for Standardization (the CEN) for calculating emissions from transport's activity.

The following table gives an overview of the methodology presented above.

Table 1 : Overview of the Available Methodology

Methodology	GHG Protocol	Artemis	NTM
Scope	Global	Europe	Europe
Level of detail	Medium	Very High	High
Flexibility (use of estimate default value in case of missing values)	High	High	Very High

Each methodology has some advantage and disadvantage. However, NTM has a high level of detail and emissions per lane can be calculated. Plus, the European scope fits our study. Furthermore, NTM provides default factors that can be used in case of not (accurate) enough information is available. Hence, NTM methodology suits this master thesis project as the basis of our calculation tool. In the next section the calculation of CO2 equivalent is described.

CO2 Equivalent calculation

This part describes the methodology used to compute the CO2 equivalent emissions resulting from transport activities. All the calculations are done in accordance with the New European norm EN 16258 in order to fit the future standards. This new European norm establishes a common methodology for the calculation and declaration of energy consumption for passengers and freight transport services. Therefore, the new conversion factors and some assumptions are taken from the European norm.

In addition, we use the NTM methodology (NTM Air 2008; NTM Rail 2008; NTM Road 2008; NTM Sea 2008) and some assumptions of the NTM methodology are made in order to compute the emission depending on the level of information a company provides.

First, we describe the fuel based calculation method and then the activity based one in order to provide different calculation possibilities. Then the assumptions concerning the different parameters are described and finally a summary is made providing the minimum requirements in order to compute the CO2 equivalent emissions resulting from transportation.

Fuel based method

The first way to compute the emissions is to use the fuel consumption. Depending on the number of litters used for a period or for a lane, corresponding emissions are associated. This section outlines the calculation of CO2 equivalent emissions from mobile sources. The fuel based approach doesn't make a difference between the modes of transportation that are used.

The best case will be to have available data about the fuel consumption (Fuel Based Method 1) ; it is the most accurate way of calculating the emissions (Guidance on measuring and reporting Greenhouse Gas (GHG) emissions from freight transport operations;2013). Having the number of liters which is used also gives the total emission, including the temperature control and the empty return. From the type of fuel an emission factor is given and by multiplying it with the number of liter which was used by a truck, a vessel, a plane or a train, we obtain the CO2equivalent emissions. These emissions will be computed in Kg CO2eq or ton CO2eq.

$$\text{CO2eq Emission} = \text{Number of liter of Fuel X (l)} * \text{ Emission Factor of fuel X (Kg. CO2eq/l)}$$

An example of emission factor is given in Appendix 1.A from EN 16258. In this Table we have to take into account the density of each fuel and the emission factor "well to wheel". If some biofuel are used, we use the table in Appendix 1.B.

These emissions can be compute lane by lane or for a given period. The most accurate way is lane by lane, providing exact information for each truck and also the variability can be computed. The other way is to compute by using fuel consumption for a given period which provides limited information (Fuel based Method 2). However, companies may not have this level of accuracy and may have different information.

A less accurate way would be to have the type of the used vehicle in order to compute emissions (Fuel based method 3). In this case we will use the following formula:

$$CO2\ emission = Distance\ (Km) * Fuel\ efficiency\ by\ vehicle\ (Kg\ CO2\ per\ Km)$$

This formula is much less specific than the previous ones and assumes that for a given vehicle, only the distance makes a change. Therefore, no comparison and feedback can be obtained. Hence, we recommend using this case only if no information about the weight or the fuel consumption is available. Furthermore, choosing this method will not lead to any comparison.

To summarize the following parameter are needed in order to use the Fuel based methodology:

- Type of fuel used
- Number of litter for a given period or per lane

If the last method is used the minimum parameters are:

- Distance driven
- Type of vehicle used

If the company does not possess the previous parameters, we use the NTM methodology in order to have an accurate estimation of the fuel consumption for a given mode of transport. This method is called activity based

Activity based

The calculation method is mainly based on the NTM methodology and assumptions are made to correspond with the European norm. In the following part we describe the calculation per mode and then the assumptions used for the calculations are summarized.

Road Transport

The most used way in Europe in order to ship globally is road transport. The reasons for this are mainly its flexibility, the ability to make it easier than the others modes to collect and distribute goods and also secure the load. However, some regulations about the maximum size of the vehicle and the loading capacity of trucks exist.

In order to compute the emissions coming from road, we use the fuel consumption taken from the database of NTM (Hereby, NTM distinguishes between 10 different vehicles from the pick-up truck to the 60 tones.) Furthermore, flat countries (i.e. the Netherlands, Denmark, Sweden, etc.) are not compensated, while alpine countries (i.e. Switzerland and Austria) are charged with a 10% increase in fuel consumption. All other European countries are compensated by a 5% increase.

By knowing the load factor and the country we estimate the fuel consumption of the specific vehicle and compute the associated CO2eq emissions with the following formula:

$$CO2\ emission = FC_{LF} * D * EF_{CO2} * c_z$$

$$FC_{LF} = FC_{empty} + (FC_{full} - FC_{empty}) * LF$$

Where:

- FC_{empty} Fuel consumption of the empty vehicle (liters per kilometer)
- FC_{full} Fuel consumption of the fully loaded vehicle (liters per kilometer)
- LF Specified load factor
- FC_{LF} Fuel consumption at the specified load factor (liters per kilometer)
- D Distance (kilometers)
- EFCO2 Emission factor for fuel (kilogram carbon dioxide per liter fuel)

Hence in order to compute the emissions by this way, we need the following parameters:

- Weight of the cargo for computing the load factor
- The distance travelled
- The type of fuel
- Type of vehicle used
- Country
- Cz Terrain factor as explained above

Rail Transport

Transporting goods by railway has lots of benefits for companies: the weight and volume capacities are much higher than trucks and the fact that emissions are much lower than truck especially for electrical trains. The disadvantage is the lack of flexibility because they cannot reach customers easily.

Trains can be divided into two types: the electrical one and the diesel one. For each of them the co2 emission can be approximated thanks to the following formulas:

Electrical train:

$$CO2\ emission = \sum_z W_c * D_z * \frac{EF_{z,CO2}}{10^6} * \frac{675 * c_z}{LF * (1 - TL)\sqrt{W_{gr}}}$$

Diesel train:

$$CO2\ emission = W_c * D * \frac{EF_{CO2}}{10^6} * \frac{153.07 * c_z}{LF * \sqrt{W_{gr}}}$$

Where:

- Wc Weight of the customer's cargo (tones)
- D Transport distance (kilometer)
- EFCO2 Emission factor for diesel(kilogram carbon dioxide per kilogram diesel)
- EFzCO2 Emission factor for electricity generation in country z (kilogram carbon dioxide per Kilowatt hour)

- Cz Terrain factor as explained above
- Wgr Gross weight of the total train (tones)
- LF Load factor
- z Country
- TL Transport loose

In order to compute the emissions the following parameters are needed:

- Weight of the shipment
- Gross weight of the train
- The country the rail travel on
- The distance
- Electricity generation emission factor in the specified country

Sea Transport

According to the NTM methodology, Water transport is defined as transport over sea or inland waterways with diesel-oil powered vessels. The energy efficiency of this mode and the capacity in weight are the advantages of this mode. However, the long lead time associated with this mode and the difficulties to reach customers are the disadvantages. For water transport with the NTM methodology, the fuel consumption is given for a fixed load factor and a fixed average speed. The emission can be computed by the following formula:

$$CO2\,emission = FC * D * EF_{CO2}$$

Where

- FC Fuel consumption for a given fuel (tones per km) and vessel
- D Distance (km)
- FCO2 Emission Factor for fuel (Kg CO2 per tones)

Hence the parameters needed are:

- The distance
- The type of vessel
- The fuel used by the vessel

Air Transport

The air transport is fast and leads to a good weight capacity. However, the environmental impact is much higher compared to the other modes. For air transport the emissions are divided into two emissions:

The first is the constant emission factor depending on the airplane used and corresponds to the high fuel usage during take-off and landing. The second part is the variable emissions depending on the number of kilometre that are travelled.

$$CO2\ emission = CEF(Kg\ CO2) + D(Km) * VEF(KgCO2\ per\ Km)$$

Where

- CEF: Constant emission factor
- VEF: Variable emission factor
- D: Distance

In order to perform this calculation, the availability of the data from NTM methodology is required as it provides constant as well as variable emission factors for several load factors. In order to compute it for all load factors, we will use the following interpolation method:

$$CEF_{x\%} = CEF_{y\%} + \frac{(CEF_{z\%} - CEF_{y\%}) * (x\% - y\%)}{(z\% - y\%)}$$

In this formula x is the load factor where the emission factor needs to be calculated. y is the load factor which is smaller than x for which the constant emission factor is known. z is the load factor which needs to be larger than x for which the constant emission factor is known.

The parameters needed in order to make an approximation are:

- Distance travelled
- Weight of the cargo
- Type of airplane used
- Type of fuel

As the emissions are given for CO2 and not for CO2 equivalent, we then have to convert the CO2 in Kg into the number of liters (or in Kg) for the fuel consumption depending on the fuel used by the airplane. Then it is multiplied by the associated factor depending on the fuel and the CO2 equivalent is estimated for the trip.

Hence, for each transport mode, parameters are needed in order to compute emissions. However, not all of this data is compulsory in order to compute emissions. We have seen that different methods are available in order to compute the emission, either fuel based or activity based. The following table provides an overview of these 4 methods.

Table 2 : Overview of CO2 computation method

Method	Accuracy	Flexibility	Information needed
Fuel based method 1	High	low	Fuel consumption per lane
Fuel based method 2	Medium	low	Fuel consumption for a given period
Fuel based method 3	Low	medium	Distance; Vehicle used
Activity based method	Medium	high	Vehicle characteristic; Distance; Weight shipped

Thus, some assumptions can be drawn to make approximations on some parameters if this information is not given by companies.

Assumption used

The following part enumerates the assumptions that are used in accordance with the European norm and the NTM methodology which uses the default values.

The assumptions used for the Positioning, Terrain factor, Load factor and Driving and Speed behavior can be found both in literature (Akker 2009; Schers, 2009; Loo, 2009) and in the NTM methodology (NTM Rail, 2008; NTM Sea,2008; NTM Road,2010;NTM Air, 2011).

Handling

Sometimes in order to load and unload products or when intermodal transport is used, handling is necessary in order to shift from one transport mode to another.

This handling generates CO2 emissions as it is done mainly by Crane or Reach Stackers. In our project we will consider only handling which corresponds to intermodal transport. According to (IFEU, 2001) the CO2 emissions per handling are:

Table 3 : Co2 emission per handling depending on the handling equipment

Handling equipment	Average CO_2 emission (Kg/handling)
Reach stacker	7 Kg
Crane	2 Kg

An important assumption has to be made in order to use these values: for moving containers from water to another mode, we will use the crane emission and for rail to road, road to plane and plane to rail and vice versa, Reach Stacker will be used.

In order to compute the emissions for handling pallets, no relevant data concerning the CO2 emissions could be found so that we will assume that the handling emissions for Reach stackers equals the ones which occur while emptying or loading pallets on the truck.

When intermodal transport is used it convenes to add the emissions corresponding to handling in order to take all the logistic activity into account.

Temperature control

Some companies, especially food companies, need to control the temperature during the whole transport of the product. These controls generate more CO2 emissions for the transport mode than without any control. In our project we will take the freezing and the cooling into account.

The heating will not be taken into consideration due to the fact that no relevant information has been found which can be applied to our project. Furthermore, the heating system is not often used unless in chemical companies. If there is information available about the fuel consumption, it includes the heating and we can make assumptions about the heating system.
Cooling is used generally in food or medical companies in order to keep a product within a given temperature above 0°C. According to Inge van den Akker and al. in 2009, field studies have shown an average increase in fuel consumption of 25% when cooled transport is used and hence, we will take this value for our calculation.
Freezing is also used a lot for food and chemical companies in order to keep the product below 0° C. According to McKinnon and Campbell (1998) an increase of 26% is generally observed when a transportation mode uses a freezing system. However, according to Inge van den Akker and al. in 2009 logistic service providers show a value of 20%. Therefore, we assume an increase of 23% whenever Freezing systems are used.

These assumptions are made according to NTM methodology and EN 16258. Each parameter which is added makes this study more relevant by taking real values instead of the estimated ones. The next part summarizes the calculation method and provides the minimum parameters required.

Summary of calculation method

The Fuel based methodology is used if the company can provide information about **the number of liters and the type of fuel that is used. From this information (lane by lane or per period) the CO2 equivalent is computed.**

The activity based methodology to approximate fuel consumption consists of a mode of transport depending on some parameters. First **the type of fuel is needed for each mode**. The detail of parameters that are needed per mode is described below:

- For Road transport, **the Load factor, the country where the vehicle drives, the vehicle category and the distance** are needed.
- For Rail, **the Gross weight** is required (or vehicle category in order to approximate the Gross weight).**The country** where the train travels within is important for having **the Terrain factors** (Can be approximated by 1 if no information is available). Additionally, **the distance and the weight are needed.**
- For Sea transport more detailed information about **the type of vessel and the distance travelled is requested**.
- For Air transportation, **the type of fuel is needed plus the distance, load factor and the vehicle category.**

For each mode the Load factor can be approximated by the NTM data, but will lead to less accurate results. Furthermore, the Distance can be approximated if we know the origin and destination.

Allocation methodology

The following part describes the methodology used for allocating the emission among shippers in case of non-dedicated shipment. Hence, for the LSPs, we investigate for each shipment which customer is responsible for the CO_2 equivalent emission.

First the allocation's requirements of the new European norm are described. Then the allocation method is explained based on the available information that the company provides and finally the resulting methodology is compared to another model.

En 16258 requirement

In order to create the methodology according to the New European norm we first describe the requirements in this norm:

"The amount of freight must be characterized by the transported cargo, including any packaging, container and means of handling or transportation, except those that are not part of the expedition."

"The distance travelled should be the real distance travelled, except for collection and distribution round trips. If distance is used in aviation, it shall be the Great Circle Distance (GCD) plus 95 kilometers. Therefore, the allocation parameter should be the product of the mass by the real distance travelled. Corresponding allocation unit is unit kilometer (unit.km)."

Concerning the distance travelled for distribution and collection trip, one of the two following options should be taken:

- use of the Great Circle Distance (GCD);
- use of the Shortest Feasible Distance (SFD).

Then the formula to compute the Great Circle Distance (knowing the longitude and latitude of the origin and destination) is:

$$D = r \cdot acos\big(sin(lat1) \cdot sin(lat2) + cos(lat2) \cdot cos(lon1 - lon2)\big).$$ (Te loo,2009)

Allocation methodology used for the calculation

General allocation rule

As previously mentioned, our allocation methodology will be created by closely following the cited European norm. The allocation for each mode of transport will be made based on the utilization. This utilization will be depending on the information available about the weight, the number of pallets or the volume (Inge van den Akker MSc; Roel te Loo MSc ;Robbie Schers MSc;2009).

According to the European norm, the weight or volume should be used. However, if using the number of pallets suits the company better, then they can use other units. Especially it can be done if it's not possible to convert the units into weight or if there's huge variability in the Volume or Weight for one pallet. Furthermore, allocation based purely on the weight appears to be insufficient in cases where other characteristics limit the amount of goods that can be transported. Hence, when no information is provided about volume or number of pallets, the allocation will be made based on the weight. Otherwise we will compare the utilization using the following formulas, and compare the different factors.

$$Weight\ capacity\ utilization = \frac{Weight\ of\ the\ cargo\ of\ the\ shipper}{Total\ weight\ capacity\ of\ the\ transport\ mode}$$

$$Volume\ capacity\ utilization = \frac{Volume\ of\ the\ cargo\ of\ the\ shipper}{Total\ Volume\ capacity\ of\ the\ transport\ mode}$$

$$Pallet\ capacity\ utilization = \frac{Number\ of\ pallets\ of\ the\ cargo\ of\ the\ shipper}{Total\ pallet\ capacity\ of\ the\ transport\ mode}$$

We won't use the real distance, instead we will take the shortest feasible distance (SFD) or the Great Circle Distance (GCD) as suggested by the European norm EN 16258.

If the weight is the selected factor or if we don't have information about the volume or the pallet capacity, then the amount allocated to the shipper will be computed as:

$$CO2\ Allocated\ to\ shipper\ i\ = TE * \frac{Wi*Di}{\sum_i Wi*Di}$$

If the volume is the selected factor, then the amount allocated to the shipper will be computed as the total emission for one lane times the following number:

$$CO2\ Allocated\ to\ shipper\ i\ for\ lane\ j = TE * TE * \frac{Vi * Di}{\sum_i Vi * Di}$$

If the number of pallets is the selected factor; the amount allocated to the shipper will be computed as the total emission for one lane times the following number:

$$CO2\ Allocated\ to\ shipper\ i = TE * \frac{NPi * Di}{\sum_i NPi * Di}$$

With

- $Di = Shortest\ feasible\ distance\ for\ shipper\ i$
- $TE = Total\ emissions\ for\ a\ trip$
- $Wi = Weight\ of\ the\ cargo\ of\ the\ shipper\ i$
- $Vi = Volume\ of\ the\ cargo\ of\ the\ shipper\ i$
- $NP_i = Number\ of\ pallets\ in\ the\ cargo\ for\ shipper\ i$

As we can see in the model, the distance and the weight have the same impact on the result. However, there is different way to compute the distance according to the European norm: the Great circle distance or the shortest feasible distance. These two different calculations bring to different results. That is why, for the same company, only one should be used, preferably the shortest feasible distance. A comparison of these two measures can be found in the Appendix 2. This comparison was made for cities in the Netherlands by comparing the GCD and the SFD. As we do not have a complete shortest feasible distance calculator, we have used MS MapPoint by entering lane by lane the 94 different locations.

For having a relevant and rigorous comparison among companies afterwards, we recommend to companies to use the great circle distance. Due to the variation of the results no exact factor between Great Circle Distance and Shortest Feasible Distance can be totally accurate. However we see significant changes by using factors. So we apply a factor of 1.39 regardless the initial GCD and see relevant improvement in standard deviation. By using adjustment depending on the initial GSC by applying 1.44 if the distance is lower than 100Km and 1.33 if the distance is bigger than 100Km, even more improvement are made concerning the standard deviation. The following table summarizes the previous results and shows also the importance of making adjustment.

Table 4 :Average and Standard deviation of the difference between GCD and SFD depending on adjustment made

	No adjustment made			Correction regardless of the distance			Correction depending on the distance		
GCD initially	<100 Km	>100 Km	all	<100 Km	>100 Km	all	<100 Km	>100 Km	all
Average	144%	133%	139%	103%	96%	100%	100%	100%	100%
Std dev	31%	14%	25%	22%	10%	18%	21%	11%	17%

In conclusion, the Distance and the Units are needed in order to perform the allocation part. In addition to these two parameters, according to the first part, we can either use the real fuel consumption or approximate it using NTM methodology in order to have all parameters for the allocation of the CO2equivalent emission.

Empty trips

When the emissions are dedicated to the customer's request then the emissions from empty return trips are allocated to the customer. However, if the logistics service provider has the possibility to take another shipment on the return trip, the emissions are allocated to the logistics service provider, no matter whether the logistics service provider takes another shipment or not.

As it is very difficult to know if the LSP had another choice, we assume that 100 % of the CO2 equivalent is divided among the customers.

Two or more days trip:

One challenge that arose during the project was the case including 2 or more days trips. This is the case when the LSP loads some goods in the truck during the trip and comes back in the Warehouse to deliver these good during the next days. The European norm is very vague and only stipulates to take origin and destination into account for a trip. In that case we won't just take the location of the origin and the destination into account, but separate it into two trips: from the Origin to the Warehouse, and from the Warehouse to the destination. In order to illustrate this case, a detailed example is explained Appendix 3

Comparison with another case

In order to bring relevance to this methodology, which follows the European norm rules and assumptions, we will compare the allocation method previously explained with others described in the master thesis of B.P.J. Leenders in 2012. This study investigates the allocation of CO2.

The first comparison is that the several allocations of Lenders are for trucks. Hence only Road transportation is covered. Our allocation methodology covers the four modes of transport as the selected unit can be volume, weight or pallets. The method we used is also expressed in the thesis of Leenders as "the current allocation method" but is only made for the pallets and thus it doesn't cover the others units.

The methodology developed By Bart Leenders provides a more accurate and powerful tool for decision making by choosing the best allocation depending on criteria that the company can select. Furthermore, by using this level of detail, the customer service is taken into account in the Tau allocation. This allocation, selected by Leenders, takes into consideration the order quantity between every route; the distance between the origin and destination of the shipment; and, the start and end location of the trip.

However the weight and distance of every stop is needed. Furthermore for the Tau allocation, less CO2-emission per pallet will be allocated to larger orders compared to similar smaller orders. The distance impact is less, which means that increasing the number of pallets will have more impact to the allocation than increasing the distance driven. This method can be criticized due to the fact that in our methodology large orders don't have to be favored and a common and fair standard is used: the unit times the distance.

Company clustering methodology

The following section explains the methodology we use in order to create a comparison for companies' CO2 equivalent performances. As companies want to know where their possibility of improvement is, we use a methodology based on the product characteristics and transport conditions to allow a fair comparison. The first part will enumerate the different parameters we include in the clustering methodology and then a summary of the clustering method is provided including the ideal parameters a company should aim for being defined as a "Green company".

Parameters of the Methodology

The creation of this methodology begins by defining the parameters having the highest impact on the comparison of company according to logistics concerns. Furthermore we have to keep in mind the final purpose of this methodology: Creating a clustering for a fair comparison of CO2 performances. The Product characteristic and the transport condition are the principals parameters involve in this clustering.

Product characteristic

The first parameter we will use is the product characteristic which are shipped. We can understand this due to the importance of the load factor in the calculations. Products packed with very high density on pallets make the fuel consumption increase, and thus the performance of the shipper will be worse than one shipping very light density product.

In order to find the suitable value range, as no literature was found on how to cluster companies depending on logistics parameters, we studied how logistics companies charge shippers for delivering products. A famous classification is called "Freight classes" which get a common standardized freight pricing for shipment. The principal condition for charging companies is the Density of the freight. The density is the space the item occupies in relation to its weight. These cut of values were chosen according to the Freight Classification. But due to the Freight classification 18 density clusters, we have reduced this number down to 3 Clusters for more clarity. These following clusters are made according to range values as defined below:

Low density products: having a density lower than 100Kg per cubic meter. This first cluster includes companies shipping wood material, health care products and clothes for example.

Intermediate density products: having a density between 100 and 400 Kg per cubic meter.This cluster includes companies that ship mostly food items; computers and household appliances.

High density products: having a density higher than 400Kg per cubic meter. This last cluster includes companies shipping bulk shipments; metals and bottle beverages.

This first cluster focuses in the product shipped, describing the volumetric weight of it. As the constraint is the capacity of the vehicle for most cases, products with low density will have a very low load factor by using the unit of the weight, instead the high density will have a higher load factor for most of cases in terms of weight. The others clusters will depend on the transport conditions as follows:

Transport characteristics

The second parameter to take into consideration is the transport condition. In order to make a fair comparison we have to transport shipments having the same constraint. Regardless the transportation mode, the comparison's criteria is the temperature control. As we saw previously in the calculation part, a huge difference, up to 25% of fuel consumption, is seen for trucks using or not cooling system. For the other modes of transportation, the fuel consumption increases greatly if cooling, freezing or heating system are used. Hence the second cluster is the Temperature control which is divided into 4 sub categories:

Transport mode using Cooling equipment for mainly food, drinks and pharmaceutical companies

Transport mode using Freezing equipment for mainly food companies

Transport mode using Heating equipment for construction firms and bulk transportation

Transport mode with no temperature control.

Another aspect which is primordial in the transport condition is the Stow ability. According to the Freight Classification "Stowability refers to how goods being shipped fit into the dimensions of the container that is used to ship the product across the various transportation modes." This parameter will include the type of shipment according to the item which can or not be loaded together. This is enlarged by the fact that LSP can use dedicated or shared transportation. Also dedicated transportation is used by LSP when the goods don't fit for groupage transportation. Moreover

Hazardous goods shipped are included in dedicated transportation in our methodology because for them the use of a single shipment is generally used.

Shared shipment: Shared shipment, also known as groupage, is the practice of combining shipments together in a single shipping container for shipping purposes. It aims to increase the Load factor and reduce the Cost and number of shipments to do for LsP. Furthermore, groupage practice is a way to improve sustainability by definition.

Dedicated shipment: Instead of the shared transport, the dedicated transport is a practice of using a single vehicle for shipping goods of a single shipment/ order. We take into account the Hazardeous Shipment as Dedicated transport.

The difference between these two parameters is mainly for the comparison of companies which is fairer, if the fleet used is dedicated or shared. It also makes a differentiation between the LsP and Shippers. This cluster allows companies to be in one or more clusters depending on their parameters. Then in order to give relevance to this comparison, we will evaluate what a "Green company" should have as fuel consumption. We chose the fuel consumption per Km as a primordial factor. This will be compute according to the clustering parameters.

An extension to this clustering methodology is to take the geographical parameter into account. As we previously saw in the calculation part for the Road and the Rail, the fuel consumption increase depends on the type of country the vehicle drives on. Hence, according to NTM methodology for the Road transportation, the fuel consumption increases by 5% for mountainous countries, decreases by 5% for flat countries, and doesn't change for hilly country. This new cluster can be added in our methodology in order to bring more relevance and accuracy for clustering companies also depending on the country their activity is based on.

This additional parameter allows more accuracy depending on the country's activity. Further research can be done in order to implement the region by region characteristics. For example for France, this country has this kind of field characteristics: mountainous near the Alps, hilly for the center of France near Poitier, and flat for the west south near Toulouse.

The NTM methodology explains that on average France is a hilly country, however for a company operating exclusively on the East part near the Alps, approximating as Hilly country is inaccurate. Therefore the geography region per country and even more accurate, per region is more appropriate and accurate.

In the following part we will only consider the three first clusters in order to define "Green companies".

Performance for defining a Green company

According to the different cluster a company could be in, we will evaluate the fuel consumption by using assumptions depending on each cluster and NTM calculation and default values. In order to give relevant definition of Green companies, we will define fuel consumption only for Road. However we will use the following condition for determining these companies:

- **If a company has the choice to use a greener mode of transportation, they have to choose it in order to be classified as a Green company.**
- **Companies using mainly (more than 10% of the fleet) Euro 1-2 and 3 and 80-ties won't be classified as Green companies due to their high fuel consumption per kilometer compare to Euro 4 and 5.**
- **If a company has the choice to use shared transportation instead of dedicated transportation, (unless their load factor is higher than 80%) they have to do it in order to be classified as a Green company.**

The calculation that we will use in order to create the methodology to express the cut off value for defining a Green company is based on the fuel consumption of the company.

The first cluster will be expressed by the load factor for companies depending on the density of the product as a variable. Then by applying NTM methodology (described in the part: Calculation methodology), we will express what fuel consumption a company should have to be classified as a Green company. In order to compute this Fuel consumption we use the following formulas:

$$FC_{LF;TC} = \beta_{TC} * (FC_{empty} + (FC_{full} - FC_{empty}) * LF_D)$$

$$\text{With } LF_D = \frac{Density\ product\left(\frac{Kg}{m^3}\right) * Vehicule\ volumetric\ capacity\ NTM\ (m^3)}{1000 * Vehicule\ capacity\ (t)}$$

This load factor takes in account the NTM average volumetric load factor. It uses the fact that the volumetric capacity is used at the NTM value as percentage but the Load factor in weight will be different.

In order to have relevant results, we define which categories of trucks that are owned by companies can be defined as green and which allow companies to be consider as "Green companies".

The use of small, medium lorry trucks which have a capacity of respectively 7.5t, 14t doesn't make sense for logistic companies and shippers due to their low capacity of load. Hence we will consider mainly large lorry trucks, tractor city trailer; tractor + semi-trailer, tractor mega trailer and finally lorry +semi semi-trailer. As the tractor +semi-trailer and truck+trailer as defined by NTM have exactly the same fuel consumption and capacity, we consider that they have the same performances and hence only the tractor +semi-trailer is studied.

The second parameter, the use of temperature control equipment, adds a factor (β in the previous formula) in front of the fuel consumption according to NTM methodology (as explain in the calculation methodology part).

The appendix 5 presents for each vehicle studied, the fuel consumption for "Green companies". A range is presented by using the NTM average capacity load in terms of volume occupied in the truck as load factor. This is our lower bound, and the upper bond is by using 100% capacity load (Full Truck Volumetric load) which is considered as the best for being qualified as a "Green company". Hence we have a range of values where companies can be defined as a "Green company" in terms of CO2 emissions. These graphs were made by using exclusively Euro 4 Diesel trucks for esthetical reasons to not surcharge the graphs. The difference between euro 4 and euro 5 is at maximum 1.8% higher in terms of fuel consumption.

The following table summarizes the different densities per truck in the Lower and upper bounds without any temperature control equipment, hence for cooling system 25% increase of fuel consumption has to be planned and 23 % increase for freezing as stipulated by NTM methodology.

Table 5 :

Density		Large lorry/truck		Tractor_semi_trailer		Tractor_MEGA_trailer		Lorry_Truck_Semi_trailer	
Cluster	Kg per cubic meter	Fuel consumption min	Fuel consumption max	Fuel consumption min	Fuel consumption max	Fuel consumption min	Fuel consumption max	Fuel consumption min	Fuel consumption max
Low	25	0,199	0,201	0,197	0,200	0,242	0,248	0,282	0,287
	50	0,200	0,204	0,199	0,205	0,248	0,258	0,290	0,302
	100	0,202	0,209	0,202	0,215	0,258	0,279	0,308	0,331
Medium	150	0,205	0,215	0,206	0,225	0,269	0,300	0,325	0,359
	300	0,211	0,231	0,216	0,255	0,300	0,363	0,377	0,446
	400	0,216	0,242	0,223	0,275	0,321	0,405	0,411	0,504
high	450	0,218	0,248	0,227	0,283	0,332	0,426	0,429	0,520
	500	0,220	0,253	0,230	0,283	0,342	0,428	0,446	0,520
	550	0,222	0,259	0,234	0,283	0,353	0,428	0,463	0,520

Every company that shows for a given product density a fuel consumption lower or equal to the recommended one by our methodology should be qualified as Green company.

In summary the clustering of companies was created by using the Product characteristic: density and the transport characteristics: Temperature control and Stow-ability, in order to create fair and comparable clusters. A company can be part of several clusters and for each define the performance by comparing their fuel consumption and be qualified or not into Green companies. Through this clustering, companies can be compare to their peers and according to their fuel consumption, see the possibilities of improvement in order to be seen as Green companies. In addition, this allocation provides a comparison which is based on the product and not the sector the company is part of. The following part will summarize the reduction possibilities.

CO2 reduction possibility for companies

The companies which will use our methodology will want to know how to achieve a better sustainability level. Hence some CO2 reduction will be expressed in the following section. These CO2 reduction possibilities are expressed by the change of parameters which can save a relevant amount of CO2. Furthermore, the last part presents an intermodal model in order to give the decision maker alternatives for using other modes or vehicles to ship the goods in function of the lead time and the target emission of the company.

The following methodology expresses the possible reduction practice that a company should apply depending on some parameters. The load factor increase, the Alternative fuel, reducing empty kilometer ad the use of intermodal transport is the reduction possibilities studied in this report.

Increase in load factor and consolidation orders

As previously seen, the Load factor plays an important role in the calculation of the CO2 emissions. According tp Inge Van den Akker and al. in 2009 in the CRSC report, a large improvement can be done on the CO2 emissions by changing the load factor from 20 to 30%, where a decrease of emissions could be achieved for up to 30%, and for an increase from 80 to 90 % of the Load factor (a more realistic assumption) a decrease in emissions for up to 7%.These calculations have been made for Road transport. However for all transport modes, CO2 reduction can be achieved by increasing the load factor by seeing the way to compute the emissions of several transport modes and the importance of the load factor in these computations, especially for road, air and train where the load factor has a direct impact for NTM methodology. Furthermore, the performance of the LSP, by the CO2 per unit Km, an increase of the load factor will increase the unit Km and hence make the performance better for a given shipment.

The rightsizing of shipment could also improve performance. The load factor and the rightsizing of the truck depending on the cargo the vehicle ships is one of the most common reductions. Hence depending on the load factor of the company vehicle, they can change it in order for the cargo to fit better with the vehicle used. The dimension of the trucks and the NTM description of the trucks with capacity load are used.

Hence for a Tractor Mega trailer that has a capacity of 50 tons, having a load factor of 50-60% brings extra emissions which can be avoided by using a lorry trailer which has a capacity of 40 tons and thus improves the load factor from 50-60% to 62.5-75%. This load factor increase by changing to a shorter truck can decrease up to 22 % of the CO_2 emissions according to NTM methodology (with a total trip of 500 kilometers, and Diesel-Euro 4 used in both cases and no temperature control used).

In order to increase the load factor consolidation of orders there is one option which had been studied in the literature. According to Koc (2010) and Cansiz Selcan (2010), consolidation of shipments and orders can bring reductions of CO_2 emissions. Hence using tractor semi-trailer and combining several orders for the same location instead of 2 or 3 small lorry trailers is a way for LSP to reduce their CO_2 emissions and increase their performance.

Alternative fuel

In order to reduce CO_2 emissions the impact of the fuel used is crucial (see appendix 4 A-Transport fuels: density, energy factor and GHG emission factor) in order to see the importance of CO_2 emitted per liter of diesel, gasoline or biofuel.

For Road transport a change from Diesel euro 3 to Euro 5 can bring a decrease of on average 5.9% of fuel consumption according to NTM values. Otherwise for a bigger impact, the change from diesel to biofuel could decrease up to 68 %.

According to the CRSC report in 2009 and the master thesis of Inge Van den Akker in 2009; the most popular and realistic fuel that companies nowadays use:

- Bio fuel vehicles;
- Hydrogen vehicles;
- Electric vehicles;
- Vehicles on solar power;
- Hybrid vehicles (this actually is not a vehicle using a different fuel type, but a vehicle that is designed with a battery which makes it more efficient)

These vehicles can greatly reduce the carbon emission for companies. However the vehicles are not developed in order to be used at large scale due to their constraint compared to diesel engines. Furthermore the use in large scales of bio diesel or bio fuel could bring some unexpected consequences and could be a disaster due to deforestation (Energy Portal website, 2009). Hence, as recommend in the two reports quoted previously. More research has to be done for the large scale use of these vehicles.

For LSP serving local customers, the use of Electrical trucks is a good way to reduce the carbon emissions. As the main constraint is the low autonomy of these vehicles, using it to serve local customers means that the turn the truck makes won't have to be longer than 150 Km.

Improvements that can be obtained by using electrical trucks instead of diesel ones for locals' customer could bring up to 60% emissions savings. Furthermore, this change doesn't imply any Supply Cain redesign involving location modifications of the warehouses, which is costly. That is why we advise companies to use alternative fuels and electrical vehicles.

Reduce empty kilometer

A good way to reduce CO2 emission is by reducing the empty kilometer. The positioning distance which is the distance traveled by the mean of transport in order to reach the cargo location. It is assume for Road transport that this distance is about 20 percent of the total distance according to CRSC in 2009. Hence this 20% are the empty kilometer that the transport mode drives.

Method in order to reduce this distance have been studied in the literature and the CRSC advice to choose the logistics service providers that are located close to the origin location of the cargo. One can reduce empty returns by synchronizing shipments. Also pallet banking is a way to reduce empty kilometers travelled.

Hande Koc advises in 2009 to move production next to customers in order to reduce empty distance. This practice could bring according to Hande Cok master thesis up to 60% reduction of total logistic emissions. Nevertheless it may seem unrealistic to consider such changes in the supply chain structure, only considering the environmental benefits they yield and ignoring the effect on costs.

Modality shift and Intermodal transportation

In order to reduce CO2 emissions, an opportunity is to change transport mode from the actual one to a greener one. This switch from a carbon intensive mode to a lower one is one of the most well accepted methods for CO2 savings; We can see in appendix 4 (Average emission factor for transport modes) that the savings can be important from road to sea for example. And by doing this, intermodal transportation has to be used as Sea transportation needs pre and post transport by road.

For the switch Road rail, when the terminal is close to the shipping location, is not a problem. However, in case of remote locations the road distance can become quite high which can even result in higher emissions in some cases. This means that switching modalities can be a good method to reduce emissions but a careful analysis is needed for each specific case. This opportunity was studied intensively in the literature. Te loo in 2009, Van den Akker in 2009 and Schers in 2009 showed that reduction can be possible by using intermodal transportation, but these reductions highly depend on the distribution of modalities already used. The result of the three study cases shows this variation from 7 to 40 % reduction of CO2 emissions. This variance is explained by the differences in supply chain design among these companies.

For the companies of these studies, using a better transport mode in terms of carbon emissions is not an easy thing to do. First the lead time pressure from the customers doesn't allow them to use vessels instead of road or instead of Air transportation. If we take into account the cost reduction while applying the modal shift , the result decreases till 7% up to 15% reduction. Even with these numbers we see that the reduction can still be significant with no increase in cost

The following part exposes a decision model for choosing or not to use intermodal transportation. In the literature, articles focus on decision models depending on the haulage distance, or the payload. And most of them focus on particular study cases without taking into account general parameters like taking at the same time the several costs. Hence the goal of this model is to optimize the routing problem depending on the set of vehicles available, the lead time available and the emission target the company wants to reach.In this study the decision model is cost and emission driven. Depending on the distance and the payload we compute the cost per transport mode and minimize it. Hence 4 routes are proposed with their cost, emission and lead time. From this opportunity of changing the transport mode we compute the decrease of emissions implied. The case is as following:

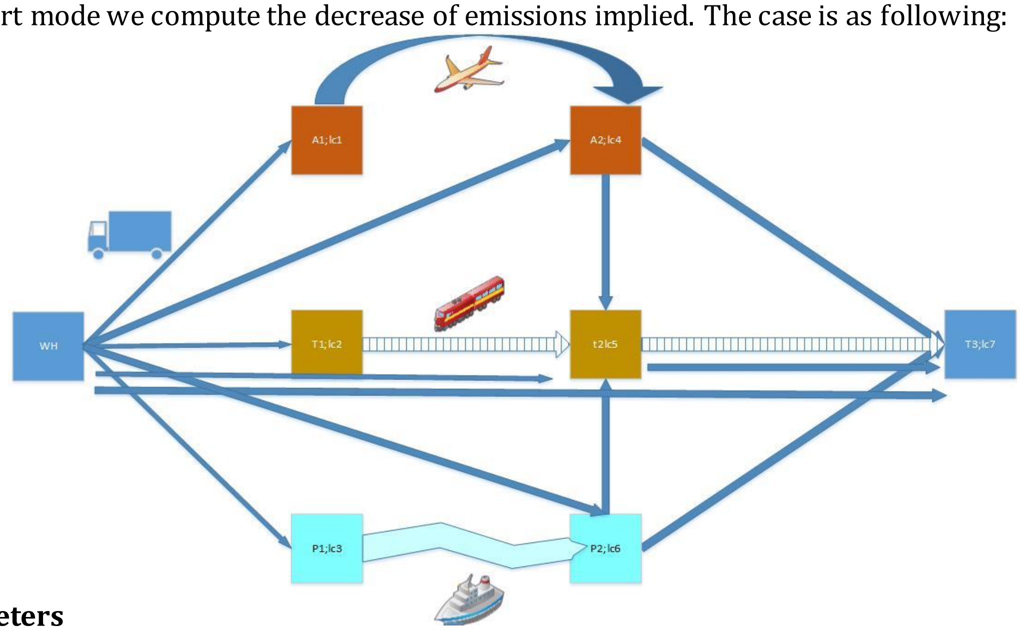


Figure 1 : Overview of the example investigated

Parameters

Sets:

Let I∈{T1;…;T6;R1;…;R18;S1;…;S18;A1;…;A30} the transport mode used according to appendix 6.

Let $I=\{I_T \cup I_R \cup I_S \cup I_A\}$ With $I_T=\{T1;\ldots;T6\}$ $I_R=\{R1;\ldots;R18\}$ $I_S=\{S1;\ldots;S18\}$ and $I_A=\{A1;\ldots;A30\}$

Let G=(V,A) be a directed graph with V the set of different locations (Hub , Terminal, Airport and Logistic Center, the warehouse and the destination). Hence $V=\{WH \cup A \cup LC \cup P \cup T \cup De\}$

With Air=$\{a_1;\ldots;a_{n2}\}$the different available Airports

LC=$\{lc1;\ldots;lc_{n3}\}$ the different available Logistic centers

P=$\{p_1;\ldots p_{n1}\}$ the different available Ports

T=$\{t1;\ldots;t_{n4}\}$ the different available terminals

Wh the warehouse and De the destination

$\{WH; Air; LC; P; T; De\ not\ necessarily\ disjoint\}$

A is an arc between two locations. A=$\{((i;j): i, j \in V; i \neq j\}$

LT_{ijk}:{ i∈I; (j,k)∈A} lead time using the transport mode i between location j and k .

LT_{max}: Maximum Lead time allowed for shipping the goods from the Warehouse to the Customer.

D_{ijk} : { i∈I; (j,k)∈A} Distance between location j and k by the transport mode i.

W: Weight of goods which have to be shipped from the Warehouse to the customer

Y_{ijk}: { i∈I; (j,k)∈A} Maximum payload authorized between locations j and k by the transport mode i.

Z_{ijk}: { i∈I; (j,k)∈A} the number of Vehicles of the transport mode i between locations j and k .

With $Z_{i;j;k} = \frac{W}{Y_{i;j}}$

Costs:

Administrational Cost (AC): This Fix cost includes the following parameters:

- cost of material transfer activities;
- cost of information and telecommunications integration;
- cost of logistics system management;

This cost can be seen as the cost of having the right to use one arc and so it will depend on the arc used and the vehicle used.

Handling Cost (HC): this cost includes the Loading/ unloading activities and is constituted as follows:

By assuming that the loading and the unloading depend on the transport mode used and also the leg used:

$$HC_{i;j;k} = LC_{i;j;k} + UC_{i;j;k}$$

With LC loading cost and UC unloading cost of the transport mode i between locations j and k.

Inventory Cost ($IC_{i;j}$): This cost includes the activity of storage before loading and after unloading by using the mode I i at location j

The Transport cost ($TrC_{i;j;k}$) which includes the activity of transport, the usage and maintenance of the vehicle, and depends on the mode used and the lane between location j and k.

Emission:

The emissions E_{ij} for the mode used I and the lane between location j and k are computed using the methodology presented above.

If the leg j cannot be made by a transport mode I; set D_{ijk} and LT_{ijk} at infinity (+999999) in order to make it unfeasible due to constraints.

Variable:

Let's set one additional variable;

$$Xijk = \begin{cases} 1 \text{ if arc (i,j)}\in\text{J is used with } i\neq j \\ 0 \quad \text{Otherwise} \end{cases}$$

Model:

In this section a general model will be presented in order to obtain the transport mode depending on the choice of the decision maker and an alternative to this one is offered.

General model

First we define for each mode the best trip:

$$Min \sum_{i\in I} \sum_{(j,k)\in A} x_{i,j,k}[D_{i,j,k}TrC_{i,j,k} + HC_{j,k} + AC_{i,j,k} + IC_{j,k}]$$

S.t

$$\sum_{j\in V\backslash\{De\}} x_{i,j,k} = 1 \; with \; k = \{De\} \forall i \in I$$

$$\sum_{k\in V} x_{i,j,k} = 1 \; with \; j = \{O\} \forall i \in I$$

$$\sum_{k\in V} x_{i,j,k} - \sum_{k\in V} x_{i,k,j} = 0 \;\; \forall (j,k) \in A \; \forall j \in V \; \forall i \in I$$

$$\sum_{i\in I} \sum_{(j,k)\in A} x_{i,j,k} * E_{i,j,k} \leq E_{max}$$

$$\sum_{i\in I} \sum_{(j,k)\in A} x_{i,j,k} * LT_{i,j,k} \leq LT_{max}$$

$\forall i \in I, j, k \in V$; $E_{i,j,k}$; $LT_{i,j,k} \geq 0$

Mode constraint: $\sum_{i\in mode\ chosen} \sum_{(j,k)\in A} x_{i,j,k} \geq 1$

With Mode chosen = I_T for Truck ; I_R for Rail ; I_S for Sea and I_A for Air Transportation.

This first model gives an initial overview in order to choose the best mode depending on the target the company wants to reach, and can appreciate the savings allowed by an increase of lead time.

In order to fit better to get closer to reality, we adjust the previous model by including the carbon cost into the minimization objective. We see that the Carbon cost acts like a Lagrange multiplier. For this model , for the clarity of the model we includes in TCijk (the Total Cost) all costs previously mentioned. Hence TCijk=$[D_{i,j,k}TrC_{i,j,k} + HC_{j,k} + AC_{i,j,k} + IC_{j,k}]$

Alternative: Lagrangian modelization

$$Min \sum_{i\in I} \sum_{(j,k)\in A} x_{i,j,k} * TC_{i,j,k} + Ca \sum_{i\in I} \sum_{(j,k)\in A} x_{i,j,k} * E_{i,j,k}$$

S.t

$$\sum_{j\in V\backslash\{De\}} x_{i,j,k} = 1 \; with \; k = \{De\} \forall i \in I$$

$$\sum_{k\in V} x_{i,j,k} = 1 \; with \; j = \{O\} \forall i \in I$$

$$\sum_{k\in V} x_{i,j,k} - \sum_{k\in V} x_{i,k,j} = 0 \;\; \forall (j,k) \in A \; \forall j \in V \; \forall i \in I$$

$$\sum_{i\in I} \sum_{(j,k)\in A} x_{i,j,k} * LT_{i,j,k} \leq LT_{max}$$

$\forall i \in I, j, k \in V$; $E_{i,j,k}$; $LT_{i,j,k} \geq 0$

Mode constraint : $\sum_{i\in mode\ chosen} x_{i,j,k} \geq 1 \; \forall \; j, k \in V$

With Mode chosen = I_T for Truck ; I_R for Rail ; I_S for Sea and I_A for Air Transportation.

For each mode chosen, the cheapest way is computed depending on the emissions' and Lead time's target. Then the decision maker can choose by viewing the different saving possibilities or change the current contract to allow more lead time for a significant CO2 and Cost reduction. Furthermore advantages about this model include the adaptability it provides. As any kind of VRP problem can be included in this model as the basis of an oriented graph is present. Hence VRP with time windows, vehicle capacity or warehouse capacity and multi-customer turns, can be taken into account in this model by the adjustment of the constraints and adding parameters.

Furthermore the development of road transportation sector is a growing concern for sustainability due to its negative impact as explained Quak in 2007:

"These include impacts on the environment (e.g., atmospheric emissions, use of non-renewable fuels, waste and loss of ecosystems), on society (e.g. public health, accidents, noise and reduction of quality of life) and on the economy (e.g. waste of resources and congestion resulting in decreasing journey reliability and city accessibility)"

Because of this, more insight and attention has been paid in order to create a model for intermodal choice. In order to add relevance and practicality to the present report, an example of the use of this model is presented in appendices 7. This example takes data from a real life case of one Shipper. An excel tool has been created for this goal and the following assumption are taken into consideration:

- NTM data has been taken as Default value.
- The distance driven doesn't depend on the vehicle within the same mode
- Administrational and holding costs are assumed the same within the same mode due to low reliability of the results found with too high variability among the sources.
- The Cost takes into account all operational costs and hence, no cost for building infrastructure is considered, as creating a port or terminals is already taken into account.
- Other sources come from :
    - Lead time: Intermodal transport From a Dutch Perspective. [1]
    - Transport costs: Analysis of the contribution of transport policies and the competitiveness of the EU economy and the comparison with the United States, 2006;
    - The distance is taken from a real life scenario for a trip (the distance between two cities) and Google maps is used to search the distance between this city and the

[1] http://www.bureauvoorlichtingbinnenvaart.nl/assets/files/def-boekje%20intermodal.pdf

terminals and port. Note that only Rail, Road and Sea transport distances were taken from the real cases, the Air transport was not available due to the short distance (250Km by Road).

- For each mode of transport, the administrational cost is assumed arbitrary due to the confidentiality of this parameter, the difficulty to estimate it and the cost which belongs to the shipper among all of which will use the terminal, port, airplane or logistic center.
- The Co2 is allocated depending only on weight and by assuming 100% load factor on the vehicle. This allocation is realistic because we assume only one warehouse, one destination and hence the same distance is made for the whole shipment, hence only allocation on the weight can be made.

All parameters have been set and the model is run on Excel 2010. As the solver of excel was pretty limited (200 variable maximum and an impossibility to find relevant and possible solution, we add in Open solver which is an optimizer for the current excel solver and that is better suited for larger problems. The Appendix 7 presents the methodology and the set of parameters we use in for the calculation. The Results are as followed:

Table 6 : Cost; emissions and lead time per transport mode

Summary	Air	Sea	Electric Rail	Diesel Rail	Road
Cost	4180	1280	1562	1562	1508
Difference cost	277%	85%	104%	104%	100%
Emission (Kg CO2 eq)	7700	250,45	122	137	279,45
Difference emission	2755%	90%	44%	49%	100%
Lead time (days)	0,3	1,22	0,48	0,48	0,55
Difference Lead time	55%	222%	87%	87%	100%

We can see that the cheapest mode is Sea transportation with a cost of around 1280. The sea transportation offers a relatively low carbon emission (-10% instead of road), however the lead time is really high: 1.22 days for the trip instead of 0.55 by road.

The rail transportation has a low increase in cost of 4%, but leads to a better lead time than road (13% lower), and also lower emissions (-56 for electrical train and -51 for diesel).

The air transportation is irrelevant in a case with low distance traveled due to the very high constant emissions.

From this model, we see that if no construction cost is present, the saving of emissions and lead time can be simultaneously achieved.

Through these 3 carbons emissions reductions possibilities, the feedback to companies can be delivered. Hence by investigating in the area of load factor increase, Alternative fuel and the use of intermodal transport, companies can achieve greener transportation.

Case study

Further relevance to our study is added with the company Connekt in the Netherlands, by applying our methodology in a Study case for the Lean and Green second star project. This pilot project unites 13 companies. However, due to difficulties with the data collection and confidentiality issues , only the result of 8 of them appears in the present report. They are divided into Logistic Service Providers (LSP) and Shippers.

The following part explains how the project was carried out and describes the assumptions made and methodology adjustments in order to remain in the scope of the project. Then the data gathering section will show how the data was gathered and used for the project and points out the adjustments we had to face in order to obtain relevant data. The last part summarizes the results of the study case. The aim of our practical application of the methodology previously cited is to compute the emissions, compare the companies KPI's and provide requirements for the Lean and Green second star. The second star awarding will take place in May.

Methodology application and assumptions used

As previously said in the research design, the aim of the company is to create a standard calculation tool for comparing emissions, and to compute the two KPI's CO_2 per unit and CO_2 per Unit-Km in order to have the performance of the company.

The first step is to apply our methodology according to Connekt's constraints and scope of calculation. Connekt specified that only logistics emissions have to be part of the study, which is in the scope of our methodology. The following paragraph enumerates the several assumptions which were used for the Lean and Green Project.

First, the project implies only shippers and LSP. Connekt stipulates to not use any positioning. The reason for that is that the LSP and Shippers in the groups mainly have products in their own location and begin the turn already charged in order to reduce the empty trips. Hence, the total fuel consumption must be divided among the several shippers and we do not apply the 20% positioning for the activity based methodology.

Concerning the road transportation, we will use only motorway values, as the LSP and Shipper use more than 95% of their distance on motorway and the information of motorway/rural road/urban road is most of the time not available.

The handling is also not taken into consideration in our study case due to the fact that, if possible, we compute per lane (best accuracy) and otherwise per given period (lowest data accuracy the). Hence, companies cannot know how much handling was made in one year. Considering this we decided not to take this parameter into account.

From these assumptions the data was collected from the companies which took part in the project. The following part describes how the data was gathered during the first month of this Master thesis project.

Data gathering

The evaluation of the different reduction options first required us to gather data from the companies. This chapter describes which data was already available in the different company visited and assumptions will be presented.

During the first meeting with companies in September we asked for some data including:

- The fuel consumption
- The unit which can be either the Volume, the Weight or the number of pallets
- The distance travelled for LSP

We were surprised by the different kind of input we received. As the KPI's must be computed by using these 3 Inputs, companies provided us their data which was either structured lane by lane or by a given period. For both cases, we received the actual data or an estimate of the actual data. The following table depicts the different kind of data we received. Due to confidentiality of the data, the companies are named by letters from A to H.

Table 7 :Overview of data received from pilot's companies for computing the KPI

			Companies							
			A	B	C	D	E	F	G	H
Fuel consumption	Lane by lane	Actual	X			X			X	
		Estimated		X	X			X		
	For a given period	Actual					X			X
		Estimated								
Unit	Lane by lane	Actual	X	X		Missing		X	X	
		Estimated			X					
	For a given period	Actual								X
		Estimated					X			
Distance	Lane by lane	Actual	X	X	X			X	X	
		Estimated				X				
	For a given period	Actual					X			X
		Estimated								

As we can see all different configurations of the data are present. The level of accuracy for these data is crucial for determining the KPI. Moreover, a fair comparison of companies can only be done if companies provide data with sufficient accuracy. That is why we create an accuracy model in order to determine whether or not the level is sufficient to claim the Lean and Green Second Star.

Determine the level of Accuracy

Depending on the parameters that are taken into consideration, the formula for calculating the emissions slightly changes. There is a difference between the information provided by the LSP and the Shippers. The LSP's, due to their activity, will have more information about the fuel. The shippers will mainly have different orders with distance, origin and destination and some other information; except for those shippers which use their own truck and thus will mainly have the same fuel consumption as the LSP's.

One of the requirements we set for companies to obtain the second star is to have enough accuracy. For computing the KPI the accuracy of three parameters needs to be evaluated: the fuel consumption, the unit and the distance. For each parameter all levels of accuracy were considered and a grading system was developed jointly with Connekt. This grading system is made for pointing out the companies' accuracy level, and they must have enough accuracy (decided up to 5 point with Connekt) to obtain the second star. . The grading system is as follow:

- Three points for high accuracy, one for medium accuracy and no point for low/lowest accuracy
- Companies must have 5 points or more for claiming the second star
- A minimum of medium accuracy is needed for the allocation criteria

We set the last criteria because of the following reason: Even if a company provides the best accuracy for the KPI's calculation parameters, the fact that they make their own allocation can cofound the result. Hence, if the Allocation unit does not fit the calculation unit (e.g. using the volume for the calculation and the weight for the allocation) or the allocation is based only on the unit or the distance, the company cannot claim the second star because the accuracy of the input is too low.

Only the companies which fulfill the above criteria can claim the Lean and Green second star. Thus; for Connekt it is crucial to have control over the accuracy of the data provided by the companies. Therefore, we decided to include information about the accuracy in the Excel file we present in the following paragraph. The Appendix 8 presents the accuracy file.

The following figure describes the several accuracy score for the companies:

Table 8 :Overview of the accuracy level of pilot's companies

Company	A	B	C	D	E	F	G	H
CO2/ Fuel consumption	High Accuracy	Medium Accuracy	Medium Accuracy	High Accuracy	High Accuracy	High Accuracy	High Accuracy	High Accuracy
Unit	High Accuracy	High Accuracy	Medium Accuracy	Missing	Medium Accuracy	Medium Accuracy	High Accuracy	Medium Accuracy
Distance	High Accuracy	High Accuracy	Medium Accuracy	High Accuracy	Medium Accuracy	Low Accuracy	High Accuracy	Medium Accuracy
Subscore	9	7	3	/	5	4	9	5
Allocation	Lowest accuracy	N.A	N.A	N.A	N.A	N.A	N.A	N.A

From the 8 companies for which the results are shown above, only 4 can currently claim the Lean and Green second star.

Once the relevant data was gathered from companies, a calculation tool using the methodology previously explained with the Connekt's assumption computed the KPI. This calculation tool is an Excel file which uses the requirement mentioned in the calculation methodology part as input and automatically provides the KPI. Hence, this tool computes CO2 emissions using the previous methodology mentioned (only Fuel consumption 3 is not used due to its inaccuracy).Then the allocation is made automatically among shippers sharing goods in the same truck. And the computation of the two KPIs is performed to give the company an opportunity to see their position as explained in the following paragraph. A differentiation per shipper can be made by entering the name of a shipper in the tab "Per Shipper".

This file was developed during the first month of the Master thesis project, and takes into account all several ways to compute the KPI previously describe in the methodology part. However, as the file uses NTM methodology values, if a company wants to use the Excel file presented above, a license has to be obtained from NTM.The next part describes the results of the companies KPI's during the project and describes the companies' requirements for acquiring the Second Star in May.

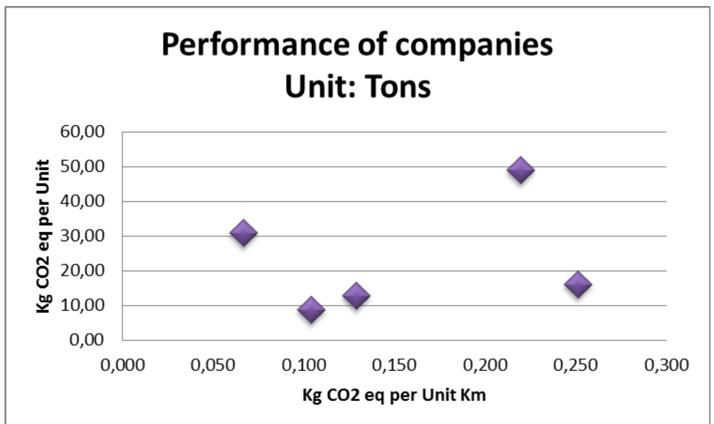
Results

Overview of the KPI

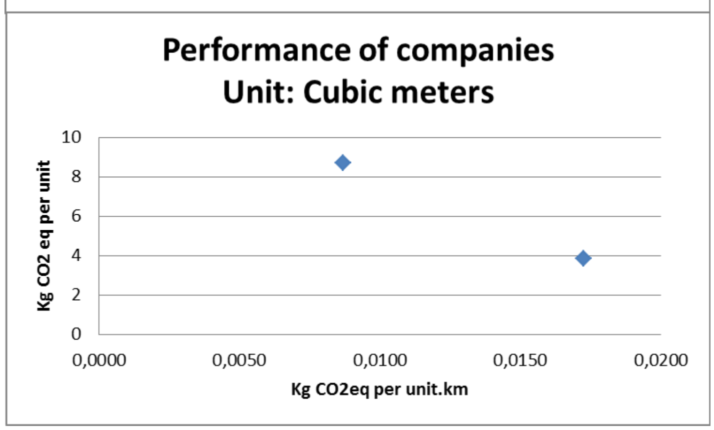
When data of sufficent accuracy is entered into the excel file, it provides the KPI's of companies which can then be plotted (see the following graphs). The next table and graphs show the result of companies' data in December.

Table 9 :KPI plotted for several participating companies

Unit used: Tonnes			
Companies	Total CO2	CO2 eq per Unit	CO2 eq per Unit .Km
A	281429	15,97	0,2512
B	30920	12,84	0,1291
C	3645493	8,76	0,1043
E	3066608	30,84	0,0671
G	106527	48,95	0,2197



Unit used Cubic Meter			
Companies	Total CO2	CO2 eq per Unit	CO2 eq per Unit .Km
G	106527	3,85	0,0173
H	15183416	8,71	0,0087



We can see some outliers like Company A and G in the first graph. The Company A score shows that using bad allocation (an allocation unit which doesn't fit with the calculation unit) can lead to some irrelevant results. By plotting the same graph using the unit cubic meter other comparison can be made (a tradeoff had to be made for choosing the unit; thus, if companies use very light product, the cubic meter can be chosen instead of the weight).

Second Star requirements for quantitative criteria

As said previously, the Lean and Green Second Star Awarding for the year 2014 will take place on May. It has been decided that companies have until end of March in order to give relevant data to Connekt. A feedback document was sent to the company during January in order to inform them about their current level of accuracy and their actual KPI. In addition, recommendations were given depending on the Fuel consumption of companies and the kind of data they should provide until March if they want to acquire the second star.

Based on the result we collected from the company during the first 4 month, it was not possible to make any valid comparisons among companies (only 4 companies among 13 were able to reach the accuracy cap). During this time, Connekt and I understood the importance of the level accuracy and that, if a company has more accurate data via advance monitoring for most of cases, it already shows a step into sustainability. The requirements for the Lean and Green Second star awarding are the following:
Companies have to show results and how to compute 50% of their total emissions, and for that they have to meet the accuracy criterion:

- Companies must have 5 points or more for claiming the second star
- A minimum of medium accuracy is needed for the allocation criteria

However, these requirements will evolve, as the Second star is a yearly Label and more requirements will be set for next year featuring an extension from 50 to 75% of companies' activity and a higher sub score needed from 5 to 7 with regard to accuracy. Furthermore, KPI's graph will be made and cut off values will be set to define the next second star winner.

Conclusion

In this study we have created a methodology in order to compute, allocate and compare companies' logistic emissions. From the results obtained, intermodal opportunities tool was created capable of increasing companies' performances. Additionally, companies can have better insight into their logistic emissions due to a standardized methodology adapted to the scope of the New European Norm EN16258. From this computation and monitoring of CO2 emissions, companies can benchmark their emissions, consider possibilities of improvement and rank their position with respect to their peers.

Methodology to assess, allocate and compare carbon emissions made by transport companies

This study compared 3 different methods: Artemis, the GHG Protocol, and NTM; and concluded that NTM is the best suited for our case due to the flexibility and the default values proposed by this method. If the company can provide the data about the number of liters and the type of fuel that is used then the fuel based method should be applied for exact results. If some of this data is not available then the best suited methodology for an approximation is the Activity based method to estimate the fuel consumption

Then the allocation of these emissions needs to be computed among the several shippers of a LSP. The method we suggest, according with the New European Norm EN 16258, says to use both the distance and the unit. This way allows fair trading and incites companies to increase their load factor for a given distance in order to be greener. Our allocation also takes into account the trip travelled on several days, a parameter that is not clearly specified in the new norm.

The clustering of companies was created by using the main characteristics. First the product characteristic: the density, and then the transport characteristics: Temperature control and Stow-ability, in order to create fair and comparable clusters. This clustering allows companies to compare their performance according to their shipment and the products shipped. A company can be part of several clusters, for each cluster the performance is defined by analyzing the fuel consumption, and in turn is used to determine which the Green companies are. Table 3 summarizes the fuel consumption for the definition of "the Green companies".

Finally, the feedback to companies is provided in function of several parameters. A load factor decrease and an order consolidation can bring up to 30 % CO_2 reduction (from 50 to 90 % load factor change). Alternative fuels also contribute to the sustainability by decreasing CO_2, by using green fuels like biodiesel instead of diesel or better: the use of an electrical transport mode. The use of intermodal transport is also a way for companies to achieve a greener transportation. For this goal a mathematical problem was created, which provides a good overview for the decision maker to pick the most efficient transportation mode subject to lead time and emissions constraint.

Recommendations and limitations

This part summarizes the several recommendations and limitations occurred while applying this methodology, then recommendations are given for the company Connekt.

First of all, the NTM license is crucial in order to use the Excel tool for comparing CO_2 emissions. Hence we recommend strongly buying this license before any use of the Excel tool.

Furthermore this project only took carbon dioxide equivalent emissions into account. A possible evaluation of logistic companies can be performed by adding the warehousing. It would be interesting to get insight of these effects in future research.

During this project transport emissions are calculated with the use of the NTM methodology. This implies that the results are subject to parameters and assumptions made by this methodology (NTM Road, NTM Air, NTM Sea, NTM Rail).

The operational costs for implementing the reduction possibilities are not taken into account. It would be interesting to see this cost in order to give better feedback to the companies for supply chain design. Moreover, the intermodal switch would be better suited if investment in the creation of shared terminals was a possibility given to the LSP.

The intermodal transport is a good opportunity to reduce CO_2 emissions and increase the performance of a company. As we have seen in this thesis, we recommend to companies to make pilots as this can lead to a reduction of CO_2, which in some cases doesn't increase the cost incurred. Therefore, companies should spend time to evaluate their possibility of using intermodal transport.

In this study the supply chain (re)design is left out of scope. But savings are expected for this option. It is recommended to include this area in further research in order to find the trade-offs between carbon emissions, transport costs and inventory holding costs. Moreover, these findings could be added into the tool for companies to be able to evaluate the possibility of intermodal logistic switch by for greener transportation.

We recommend to Connekt that for having an efficient second star program, to stimulate extra effort in order to be a second star winner, by convincing companies to be more conscious about their sustainability. This can be achieved by increasing the second star requirements from the past year.

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Appendices

Appendix 1.A -Transport fuels: density, energy factor and GHG emission factor

Table A.1 — Transport fuels: density, energy factor and GHG emission factor

	Density (d)	Energy factor				GHG emission factor					
		Tank-to-wheels (e_t)		Well-to-wheels (e_w)		Tank-to-wheels (g_t)			Well-to-wheels (g_w)		
Fuel type description	kg/l	MJ/kg	MJ/l	MJ/kg	MJ/l	gCO_2e/MJ	$kgCO_2e$/kg	$kgCO_2e$/l	gCO_2e/MJ	$kgCO_2e$/kg	$kgCO_2e$/l
Gasoline	0,745	43,2	32,2	50,5	37,7	75,2	3,25	2,42	89,4	3,86	2,88
Ethanol	0,794	26,8	21,3	65,7	52,1	0	0	0	58,1	1,56	1,24
Gasoline/Ethanol blend 95/5	0,747	42,4	31,7	51,4	38,4	72,6	3,08	2,30	88,4	3,74	2,80
Diesel	0,832	43,1	35,9	51,3	42,7	74,5	3,21	2,67	90,4	3,90	3,24
Bio-diesel	0,890	36,8	32,8	76,9	68,5	0	0	0	58,8	2,16	1,92
Diesel/bio-diesel blend 95/5	0,835	42,8	35,7	52,7	44,0	71,0	3,04	2,54	88,8	3,80	3,17
Liquefied Petroleum Gas (LPG)	0,550	46,0	25,3	51,5	28,3	67,3	3,10	1,70	75,3	3,46	1,90
Compressed Natural Gas (CNG)		45,1		50,5		59,4	2,68		68,1	3,07	
Aviation Gasoline (AvGas)	0,800	44,3	35,4	51,8	41,5	70,6	3,13	2,50	84,8	3,76	3,01
Jet Gasoline (Jet B)	0,800	44,3	35,4	51,8	41,5	70,6	3,13	2,50	84,8	3,76	3,01
Jet Kerosene (Jet A1 and Jet A)	0,800	44,1	35,3	52,5	42,0	72,1	3,18	2,54	88,0	3,88	3,10
Heavy Fuel Oil (HFO)	0,970	40,5	39,3	44,1	42,7	77,7	3,15	3,05	84,3	3,41	3,31
Marine Diesel Oil (MDO)	0,900	43,0	38,7	51,2	46,1	75,3	3,24	2,92	91,2	3,92	3,53
Marine Gas Oil (MGO)	0,890	43,0	38,3	51,2	45,5	75,3	3,24	2,88	91,2	3,92	3,49

Appendix 1.B -Gasoline/Ethanol blend factors, %biofuel

Gasoline/Ethanol blend	Density (d)	Energy factor				GHG emission factor					
% of ethanol in volume		Tank-to-wheels (e_t)		Well-to-wheels (e_w)		Tank-to-wheels (g_t)			Well-to-wheels (g_w)		
	kg/l	MJ/kg	MJ/l	MJ/kg	MJ/l	gCO_2e/MJ	$kgCO_2e$/kg	$kgCO_2e$/l	gCO_2e/MJ	$kgCO_2e$/kg	$kgCO_2e$/l
1 %	0,74549	43,0	32,1	50,8	37,8	74,7	3,21	2,40	89,23	3,84	2,86
2 %	0,74598	42,9	32,0	50,9	38,0	74,2	3,18	2,37	89,03	3,82	2,85
3 %	0,74647	42,7	31,9	51,1	38,1	73,6	3,14	2,35	88,81	3,79	2,83
4 %	0,74696	42,5	31,8	51,2	38,3	73,1	3,11	2,32	88,60	3,77	2,81
5 %	0,74745	42,4	31,7	51,4	38,4	72,6	3,08	2,30	88,39	3,74	2,80
6 %	0,74794	42,2	31,5	51,6	38,6	72,1	3,04	2,27	88,18	3,72	2,78
7 %	0,74843	42,0	31,4	51,7	38,7	71,6	3,01	2,25	87,96	3,69	2,77
8 %	0,74892	41,8	31,3	51,9	38,9	71,1	2,97	2,23	87,74	3,67	2,75
9 %	0,74941	41,7	31,2	52,0	39,0	70,5	2,94	2,20	87,52	3,65	2,73
10 %	0,74990	41,5	31,1	52,2	39,1	70,0	2,90	2,18	87,30	3,62	2,72
15 %	0,75235	40,6	30,6	53,0	39,9	67,3	2,73	2,06	86,18	3,50	2,63
20 %	0,75480	39,8	30,0	53,8	40,6	64,5	2,56	1,94	85,01	3,38	2,55
30 %	0,75970	38,1	28,9	55,3	42,0	58,6	2,23	1,69	82,54	3,14	2,39

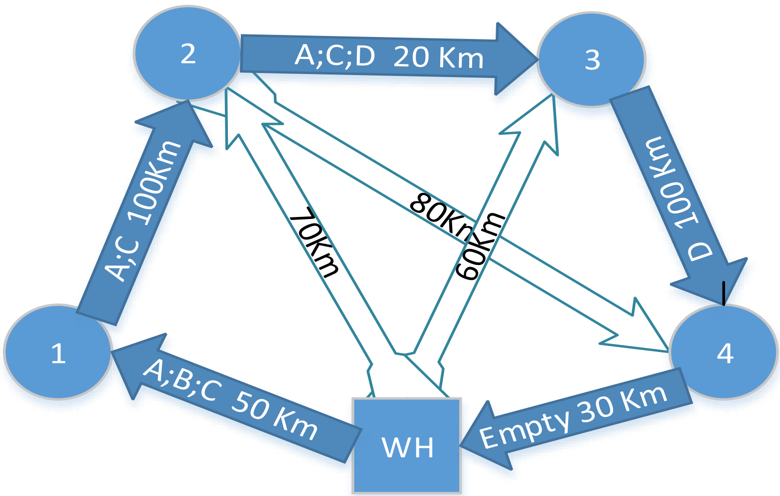
Appendix 2: Comparison Shortest feasible Distance / Great Circle Distance

From	to	Great Circle Distance (Km)	Shortest Feasible Distance (Km)	Diff	From	to	Great Circle Distance (Km)	Shortest Feasible Distance (Km)	Diff
GELEEN	GIETEN	284,6	307,0	108%	NOORDWIJK	OOSTERBLOKKER	82,7	86,8	105%
SLUIS	SNEEK	268,9	355,0	132%	NIEUW-BERGEN	NIEUWEGEIN	81,6	119,0	146%
GIETEN	GOES	257,0	325,5	127%	BERGSCHENHOEK	BEST	81,2	118,0	145%
MAASTRICHT	MAKKUM FR	246,0	321,0	131%	GOES	GOIRLE	81,2	108,5	134%
GOIRLE	GRONINGEN	214,4	274,5	128%	PUTTEN	RAAMSDONKSVEI	80,0	96,2	120%
HELLENDOORN	HELLEVOETSLUIS	190,3	212,0	111%	OOSTERBLOKKER	OOSTERWOLDE	79,7	149,0	187%
HOENSBROEK	HOOFDDORP	176,1	218,0	124%	SIRJANSLAND	SLUIS	78,3	93,9	120%
ENSCHEDE	ETTEN LEUR	168,3	217,0	129%	AMSTERDAM	APELDOORN	75,2	89,7	119%
EINDHOVEN	EMMEN	162,0	223,0	138%	WERVERSHOOF	WOERDEN	75,0	111,0	148%
VELSEN-NOORD	VENLO	161,5	204,0	126%	BREDA	BURGH-HAAMSTE	73,0	100,0	137%
HENGELO	HOENSBROEK	160,0	249,0	156%	HARDERWIJK	HEERENVEEN	71,4	94,8	133%
GRONINGEN	HAARLEM	159,6	202,0	127%	PURMEREND	PUTTEN	70,1	79,7	114%
ROERMOND	ROELOFARENDSV	152,9	198,0	129%	TWELLO	UTRECHT	69,0	82,9	120%
DIRKSLAND	DOETINCHEM	152,9	192,5	126%	HAARLEM	HARDERWIJK	68,1	93,8	138%
OSS	OUDESCHILD	149,1	196,0	131%	SCHIEDAM	S-HERTOGENBOS(	66,8	89,4	134%
VENLO	VOORSCHOTEN	145,6	208,0	143%	MAKKUM FR	MEPPEL	66,7	83,2	125%
UTRECHT	VALKENBURG	145,2	187,0	129%	ZEIST	ZEVENBERGEN	65,5	87,0	133%
DEN BOSCH	DEN HELDER	144,8	165,5	114%	VOORSCHOTEN	WAALWIJK	64,2	98,3	153%
HEERENVEEN	HEIJEN	143,1	189,0	132%	REUSEL	ROERMOND	63,7	72,1	113%
KAMPEN	KAPELLE	143,0	233,0	163%	NIEUWEGEIN	NIJMEGEN	57,1	77,7	136%
DEN HELDER	DIRKSLAND	141,9	188,5	133%	CAPELLE AAN DEN	DEN BOSCH	56,2	79,0	140%
SPIJKENISSE	TERBORG	141,5	166,0	117%	BUSSUM	CAPELLE AAN DEN	55,5	80,0	144%
TILBURG	TUITJENHORN	133,1	168,0	126%	ETTEN LEUR	GELDERMALSEN	54,1	75,7	140%
VALKENBURG	VEENENDAAL	130,5	190,0	146%	MAARHEEZE	MAASTRICHT	51,3	70,3	137%
HOOFDDORP	HOOGEVEEN	130,5	174,5	134%	ALPHEN AAN DEN	AMERSFOORT	49,2	62,3	127%
LEIDERDORP	LOCHEM	128,8	163,0	127%	HOORN NH	KAMPEN	47,1	83,2	177%
ZWIJNDRECHT	ZWOLLE	126,6	154,0	122%	WAALWIJK	WADDINXVEEN	47,0	85,0	181%
DOETINCHEM	DRACHTEN	126,4	181,0	143%	ZEVENBERGEN	ZOETERMEER	46,8	66,0	141%
MEPPEL	NIEUW-BERGEN	121,5	162,0	133%	ALMERE	ALPHEN AAN DEN	46,4	69,7	150%
DRACHTEN	EDE	120,0	165,5	138%	VEENENDAAL	VEGHEL	45,7	79,9	175%
BURGH-HAAMSTE	BUSSUM	117,5	196,0	167%	ALKMAAR	ALMERE	43,1	77,0	179%
OUDESCHILD	PIJNACKER	116,8	141,0	121%	RAAMSDONKSVEI	REUSEL	42,2	61,3	145%
ZOETERMEER	ZUTPHEN	116,6	138,0	118%	AMERSFOORT	AMSTERDAM	41,1	52,9	129%
HELMOND	HENGELO	116,2	177,0	152%	BOXTEL	BREDA	37,0	47,9	129%
NIJMEGEN	NOORDWIJK	114,0	153,0	134%	EMMEN	ENSCHEDE	36,2	98,1	271%
VEGHEL	VELSEN-NOORD	113,4	126,0	111%	PIJNACKER	PURMEREND	34,9	84,8	243%
LOCHEM	MAARHEEZE	109,5	169,0	154%	ROELOFARENDSV	ROTTERDAM	32,5	46,3	142%
HELLEVOETSLUIS	HELMOND	109,2	149,5	137%	APELDOORN	ARNHEM	25,6	32,2	126%
OOSTERWOLDE	OOSTZAAN	107,1	172,0	161%	WOERDEN	ZEIST	25,3	34,7	137%
TUITJENHORN	TWELLO	107,0	168,0	157%	BARENDRECHT	BERGSCHENHOEK	15,2	20,2	133%
ZWAAG	ZWIJNDRECHT	100,0	135,0	135%	BEST	BOXTEL	12,0	12,0	100%
HOOGEVEEN	HOORN NH	96,9	174,5	180%	ROTTERDAM	SCHIEDAM	5,7	9,0	157%
ZUTPHEN	ZWAAG	95,9	149,0	155%	OOSTZAAN	OSS	87,2	116,0	133%
TERBORG	TILBURG	95,8	140,0	146%	HEIJEN	HELLENDOORN	85,6	130,0	152%
ARNHEM	BARENDRECHT	93,8	111,0	118%	WADDINXVEEN	WERVERSHOOF	84,7	99,8	118%
EDE	EINDHOVEN	90,7	91,7	101%	KAPELLE	LEIDERDORP	83,8	144,0	172%
S-HERTOGENBOS(	SIRJANSLAND	87,7	112,0	128%					

Appendix 3: Allocation example

A.One day trip allocation

Lets assume the following case:



Parameters:

Company A: 5 Tones

Company B: 20 tones

Company C : 10 tones

Company D : 15 Tones

Our project describes each trip by a succession of lanes and in order to compute the allocation of this example we will use the formula previously introduced. Hence we take the shortest feasible distance each time: so the total emissions are allocated as described below:

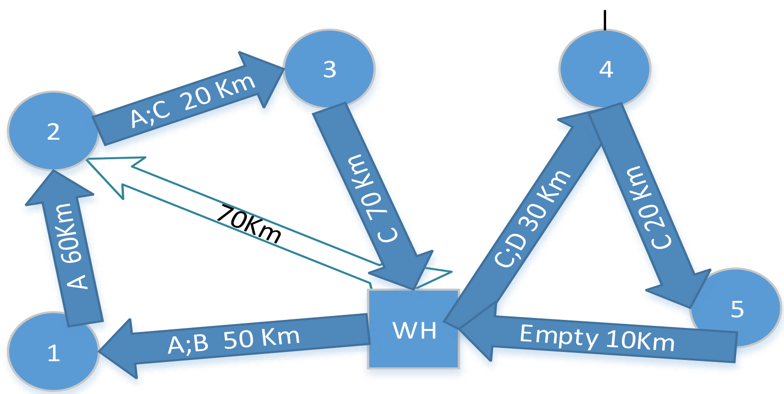
Shipper	Weight	Distance	Weight*Distance	Allocation %
A	5	60	300	10%
B	20	50	1000	32%
C	10	60	600	19%
D	15	80	1200	39%
Total			3100	

Here we must make sure that the shipper D is from the location 2 to 4, hence the shortest distance to take into consideration doesn't include the warehouse, but only the shortest feasible distance between 2 and 4. Then if we know by the calculation that the LSP has used 60 Liters of diesel, we have to compute the total emissions and allocate them using the data provided in the table, and allocate it among the shippers.

B.2 **Or More day trip**

Let's assume the following case:

There is a two day trip. First the truck is loaded in the Warehouse with cargo from companies A and B. The truck drops the Cargo of company B at location 1, then drive until location 2 to load shipment from location C. At location 3 the truck unloads the shipment from company A then returns to the warehouse. The next day, the truck loads at the warehouse the shipment from company D which is delivered at location 4, and then the remaining cargo from company C is dropped at location 5



Parameters

Company A: 10 Tones

Company B: 15 Tones

Company C: 20 Tones

Company D: 25 Tones

According to our methodology we won't take into account the distance between the origins 2 and the destination 5 for the shipment of company C, instead we divide it into two trips. One from 2 to the Wh and the second from the WH to 5 as following:

Shipper	Weight	Distance	Weight *Distance	Allocation %
A	10	70	700	25%
B	15	50	750	26%
C	20	70	1400	49%
Total			2850	**Day 1**

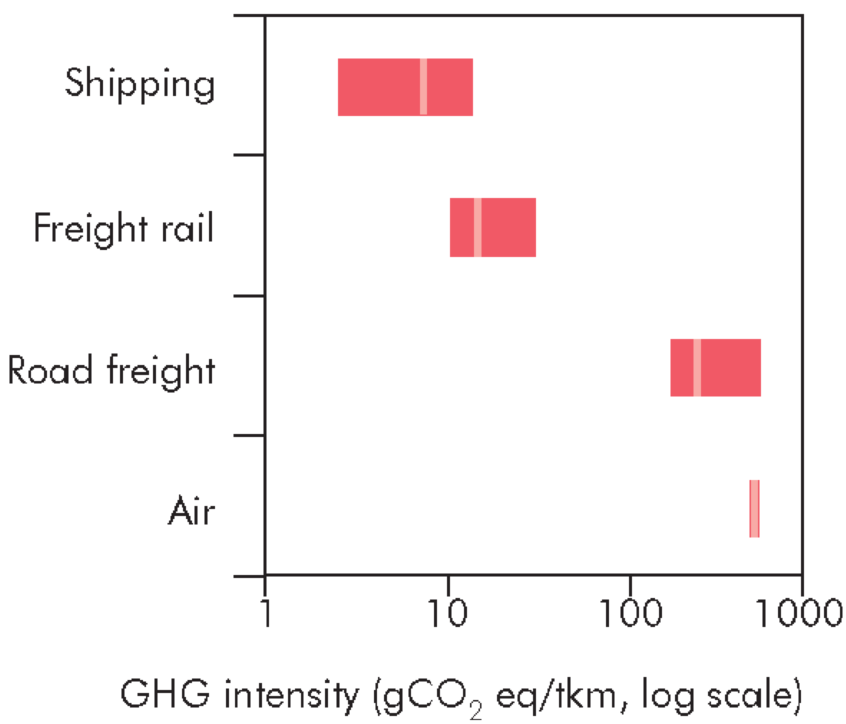
Shipper	Weight	Distance	Weight *Distance	Allocation %
C	20	10	200	21%
D	25	30	750	79%
Total			950	**Day 2**

The two tables present the percentage of emissions of CO2 equivalent that each company has for each trip.

Appendix 4 Average emission factor for transport modes (source: Cefic,ECTA and Responsible Care,2011)

Transport mode	gCO_2/tonne-km
Road transport	62
Rail transport.	22
Barge transport	31
Short sea	16
Intermodal road/rail	26
Intermodal road/barge	34
Intermodal road/short sea	21
Pipelines	5
Deep-sea container	8
Deep-sea tanker	5
Airfreight	602

GHG Efficiency of different modes source: IE Mobility Model ; bughaug (2008)



Appendix 5 Fuel consumption requirement for "Good companies"

These computations have been made with no temperature control equipment, using NTM methodology (NTM Road 2008) For Full capacity truck loads in volume and NTM average capacity truck load in volume.

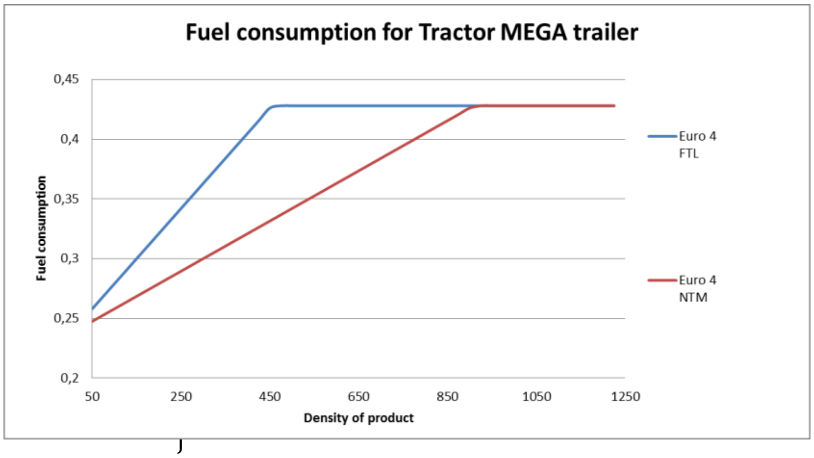


Figure 2 : Fuel consumption for Tractor Mega Trailer

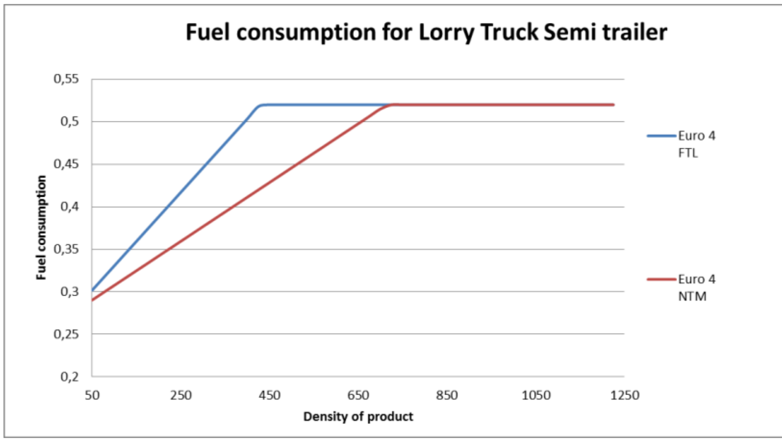


Figure 3 : Fuel consumption for Lorry Truck semi Trailer

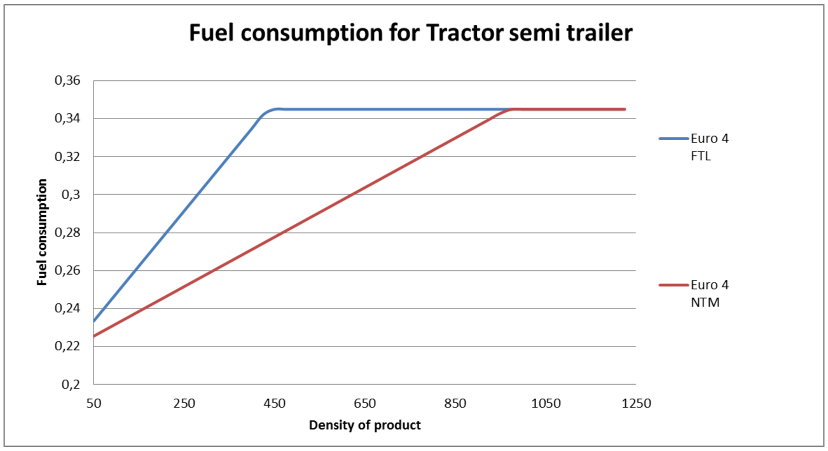


Figure 4 :Fuel consumption for Tractor Semi Trailer

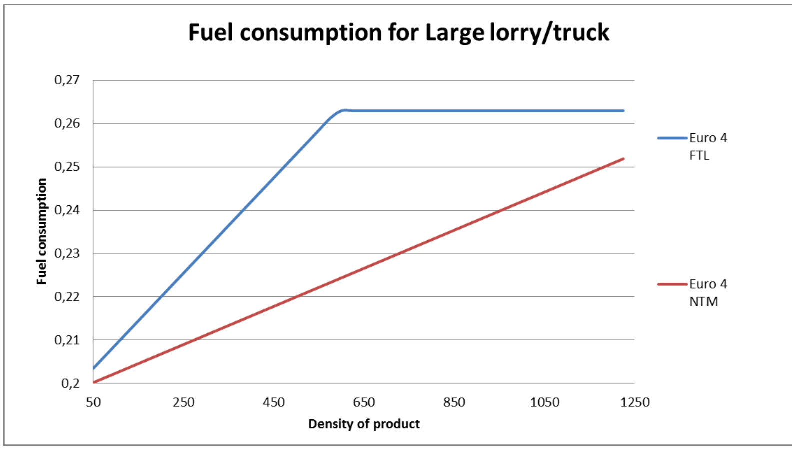


Figure 5: Fuel consumption for Large Lorry/ Truck

Appendix 6 Set of vehicle used per mode

Rail	Diesel Short Bulk	R1
	Diesel Short Average	R2
	Diesel Short Volume	R3
	Diesel Medium Bulk	R4
	Diesel Medium Average	R5
	Diesel Medium Volume	R6
	Diesel Large Bulk	R7
	Diesel Large Average	R8
	Diesel Large Volume	R9
	Electrical Short Bulk	R10
	Electrical Short Average	R11
	Electrical Short Volume	R12
	Electrical Medium Bulk	R13
	Electrical Medium Average	R14
	Electrical Medium Volume	R15
	Electrical Large Bulk	R16
	Electrical Large Average	R17
	Electrical Large Volume	R18
Road	Small lorry/truck	T1
	Medium lorry/truck	T2
	Large lorry/truck	T3
	Tractor +city-trailer	T4
	Lorry/truck +trailer	T5
	Tractor + semi-trailer	T6
	Tractor + MEGA-trailer	T7
	Lorry/truck + semi-trailer	T8
Sea	Container Inland WW	S1
	Container Feeder small	S2
	Container Feeder (A type)	S3
	Container Panamax	S4
	Container Post panamax	S5
	Tanker Inland WW	S6
	Tanker Coastal	S7
	Tanker Product	S8
	Tanker VLCC	S9
	BulkDry Inland WW	S10
	BulkDry Coastal	S11
	BulkDry Handy size	S12
	Bulk DryOcean	S13
	General CargoInland WW	S14
	General CargoCoastal	S15
	General CargoHandy size	S16
	General CargoOcean	S17
	General Cargo Refrigirated	S18
Air	Saab 340BCT7-9B	A1
	ATR 42-300 FreighterPW 120	A2
	AN-26 FreighterAI-24VT	A3
	F-27-500DART 552-7 (RDa,7)	A4
	BAe-146-200FALF 502R-5	A5
	L-188 Electra FreighterT56-A-14	A6
	B737-300SFCFM56-3-B1	A7
	A320 FreighterCFM56-5-A1	A8
	AN-12T56-A-1461000T56-A-14	A9
	TU-204-100CPS-90A	A10
	B727-200FJT8D-9 series	A11
	B757-200SFRB211-535E4	A12
	A310-300 FreighterCF6-80C2A3	A13
	B757-200FRB211-535E4	A14
	B757-200PFPW2037	A15
	A300-B4 FreighterCF6-50C2	A16
	B767-200ERFCF6-80C2B7F	A17
	IL-76MDD-30KP-2	A18
	A300-600FCF6-80C2A3	A19
	DC-8-63FJT3D-7 series	A20
	DC-8-73FCFM56-2-C5	A21
	B767-300 FreighterPW4060	A22
	B767-300FCF6-80C2B7F	A23
	DC-10-30FCF6-50C2	A24
	MD-11 FreighterPW4460	A25
	MD-11FCF6-80C2D1F	A26
	B777-200FGE90-110B1	A27
	B747-200FJT9D-7R4D, -7R4D1	A28
	B747-400FCF6-80C2B5F	A29
	B747-800FTrent 970-84	A30

Appendix 7 Study case intermodal transport

This appendix is an example of the intermodal model presented in the report. It uses the real values of one of the companies that took part in the project for the distances and the places used.

The distances are displayed in the following tables.

First the distance between the warehouse and the several Logistic centers:

Table 10: Distance from the warehouse to the logistics center

Distance	LC1	LC2	LC3	LC4	LC5	LC6	LC7
Warehouse	20	40	25	210	200	200	250

We assume that no distance is made between the logistic center and the corresponding port, terminal or airport. The distances between the terminals, ports and airports are:

Table 11 : Distance between airports, ports and terminals

Distance	Airport 2
Airport 1	90

Distance	Port 2
Port 1	100

Distance	Terminal 2	Terminal 3
Terminal 1	120	150
Terminal 2	/	30

Finally the distances to reach the destination by road are:

Table 12 : Distance between logistics center

Distance	LC5	LC7
LC4	20	60
LC5	/	50
LC6	45	70

These values are taken by using Google maps, and the distance by road from the warehouse to the customer is taken from One lane of company A.

We choose the vehicles to compare (two vehicles per mode available in the excel file created) and the fixed parameters as follow:

Table 13 : Companies parameters

Weight of shipment (t)	40	Country	Belgium
Emission max	508	Ltmax	3

Table 14 : Vehicle informations per mode

Air						
Vehicle	Payload	mber of vehicle nee	Load factor	Cst emission	Emission per km	Transport cost er Km
MD-11 FreighterPW4460	80	1	0,50	5835,70	19,53	30
A300-600FCF6-80C2A3	48,036	1	0,83	8804,30	23,15	30
Rail						
Vehicle	Payload	mber of vehicle nee	Load factor	Emission per km		Transport cost er Km
Diesel Medium Volume	400	1	0,10	0,19		4,8
Diesel Short Volume	200	1	0,20	0,53		4,8
Sea						
Vehicle	Payload	mber of vehicle nee	Load factor	Emission per Km		Transport cost er Km
Container Inland WW	1046	1	0,04	0,46		0,36
BulkDry Coastal	2852	1	0,01	0,57		0,32
Road						
Vehicle	Payload	mber of vehicle nee	Load factor	Emission per Km		Transport cost er Km
Lorry/truck + semi-trailer	60	1	0,67	1,42		5,6
Tractor + semi-trailer	40	1	1,00	1,12		5,6

The several costs are described as the following

Table 15 : Fix cost per mode

Cost	Air	Road	Rail	Sea
Loading	**4**	**4**	**5**	**10**
Unloading	**4**	**4**	**5**	**10**
Administrative	**700**	**100**	**450**	**480**
Inventory	**0**	**0**	**0**	**0**
Total	**708**	**108**	**460**	**500**

We can note that these costs are arbitrary due to the lack of information we could obtain on the Internet. However we make sure that Roadfix cost <Sea fix cost ~Rail fix cost < Air fix costs

From these values we run the model and the solutions are displayed in the following table:

Table 16 : Cost; emissions and lead time per transport mode

Summary	Air	Sea	Electric Rail	Diesel Rail	Road
Cost	4180	1280	1562	1562	1508
Difference cost	277%	85%	104%	104%	100%
Emission	7700	250,45	122	137	279,45
Difference emission	2755%	90%	44%	49%	100%
Lead time	0,3	1,22	0,48	0,48	0,55
Difference Lead time	55%	222%	87%	87%	100%

Appendix 8: Accuracy file

	A. High accuracy	B. Medium accuracy	C. Low accuracy	D. Lowest accuracy
Points	**3**	**1**	**0**	**0**
1. CO_2 emission / Fuel consumption	Actual fuel consumption	Estimated fuel consumption	Conversion factor per (unit)km	
If 1.B		Based on driven distance	Based on direct distance*	
If 1.C			Based on driven distance	Based on direct distance*
2. Units	Actual units per trip (in ton or m3)	Estimated units per trip or Actual units per period	Estimated units per period	
If 2.B		Direct estimate in weight/volume	Converted from other unit indicator	
If 2.C			Direct estimate in weight/volume	Converted from other unit indicator
3. Distance used for KPI calculation ($C0_2$ per unit.km),	Direct distance*	Shortest Feasible distance for Both		Driven distance for shared transport
Sub score (minimum =5)				
4. Allocation	Based on EN.16258 approach (unit and direct distance*)	Based on unit and driven distance Or	Based on only unit or distance	allocation units doesn't fit with calculation
If 4.A	Based on trip by trip performance per shipper	Based on average performance per shipper		

Figure 6 : Accuracy grading system

* Great circle distance or Shortest feasible Distance