Carbon Regulated Supply Chains: Assessing and reducing carbon dioxide emissions in transport at Cargill Cocoa & Chocolate

by

Stefan Boere

BSc Industrial Engineering and Management Science — TU/e
Student identity number 0554197

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Supervisors:
Dr. T. Tan, TU/e, OPAC
Prof.dr.ir. J.C. Fransoo, TU/e, OPAC
K.M.R. Hoen MSc, TU/e, OPAC
Niels Juel Hansen, Cargill, European Transport Procurement
Abstract

In this Master thesis report the carbon dioxide emissions resulting from bulk liquid transport in Cargill Cocoa & Chocolate are assessed. Different opportunities to reduce the emission of carbon dioxide in transport are reviewed. Payload increase, transport modality shift and inventory management are found as the options with highest potential to decrease carbon emissions in Cargill Cocoa & Chocolate transport and are analyzed in detail. The effect of each reduction option on carbon dioxide emissions, transport cost and lead time is assessed. Furthermore, insight is given on transport lane selection for different emission reduction options. This results in recommendations to Cargill on how to implement the carbon reduction opportunities and monitor the progress of carbon emission reduction in their transport.
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Management Summary

In response to a growing pressure on companies to pay more attention to the impact of their products and services on the climate, there has been an increasing stream of research with a focus on carbon dioxide emission assessment and reduction. So far, most attention has been paid to GHG emissions from manufacturing of goods. However, 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. A minor stream of research has focused on carbon dioxide emission assessment of transport activities. However, detailed insight is lacking on how to reduce carbon dioxide emissions and what its implications are. This study aims to fill this knowledge gap and to give practical insights in carbon emission reduction in Full Truck Load bulk transport.

Research design

Five research questions are defined:
1) How can carbon dioxide emissions resulting from transport be reduced?
2) How can transport lanes be selected for carbon dioxide emission reduction?
3) What are the effects of carbon dioxide emission reducing activities on carbon dioxide emissions, costs and lead time of the transport?
4) How can carbon dioxide emission reducing activities be implemented and what is the effect of implementation on internal administration?
5) How can the progress of reducing carbon dioxide emissions in the transport be monitored?

The research questions are applied to the following scope:

Carbon dioxide emissions due to outbound ETP transport within Europe of Full Truck Load direct delivery bulk liquid goods of the business unit Cargill Cocoa & Chocolate.

The starting point for this study is the Carbon Regulated Supply Chain project (CRSC, 2009). In the CRSC project a method has been developed to assess carbon dioxide emissions in transport, mainly based upon NTM (2008) methodology. This method is used for carbon emission calculations in this study. The accompanying emission calculation tool resulting from the CRSC project is called TERRA (Transport Emission Reporting and Reduction Analysis). The transport data is based on the award plans (the overview of contracts between Cargill and the logistics service providers), data collected in the first Cargill project by Te Loo (2009) and additional data collected in this project.

Carbon emission reduction opportunities assessment

The total yearly carbon dioxide emissions for Cargill Cocoa & Chocolate (CC) are 7,326 tonnes for approximately 123 million tonnekm (equivalent to one tonne of cargo transported over one kilometer). Carbon dioxide emission reduction options existing in literature are reviewed. Payload increase, modal shift and inventory management have the largest expected impact and best practicability for the transport under scope. The current average payload is 17.2 tonnes, while in general a maximum gross weight of a truck of 40 tonnes is allowed, typically resulting in a maximum payload of about 25 tonnes. The current modal split is such that about 95% of the lanes is road transport, representing about 90% of the total tonnekm of the BU Cocoa & Chocolate.

Payload increase

Payload is defined as the absolute weight loaded in a vehicle. Payload increase affects the load factor in terms of weight. Higher load factors result in higher emissions per trip, but a decrease in number of trips. In general this will result in a reduction of total emissions, since the emission per tonne kilometer decreases. Formulas are designed for the calculation of the maximum payload allowed per routing, based on legal maximum gross weight requirements and weight of transport equipment. The
potential emission savings for payload increase per lane are calculated by subtracting the emissions using maximum payload from the emissions using the current payload.

Applying this method to the large volume lanes of bulk liquid CC (> 650 tonnes per year) results in a maximum emission saving of 20% (1040 tonnes) and transport cost savings of 27% on these lanes. This corresponds with an emission reduction of more than 14% compared to emissions of the total dataset of bulk liquid CC lanes. Each trip saved, automatically results in savings in transport costs as well. Furthermore, it is expected that an increased payload has only a minor effect on the lead time. Moreover, it is demonstrated that the weight of the equipment used has a significant effect on the potential of payload increase.

**Modal shift**

A method is designed to calculate the upper bound of carbon emission savings when shifting from road to intermodal rail or intermodal short-sea transport. This method attempts to choose the most carbon-efficient modality and routing on a transport lane. The method can be used to select lanes with high potential for a modal shift from. Applying the method to Cargill shows that about 20% of the lanes result in 80% of the expected emission savings. This implies that companies can focus their effort on a relatively small number of lanes, while still including the largest fraction of potential emissions savings. On a small selection of lanes a maximum carbon emission saving of 1598 tonnes (48%) is possible, which is a reduction of 22% of the current total emission level of bulk liquid CC transport. However, this emission reduction requires a cost increase of 19%, due to higher transport cost. On the other hand, a maximum cost savings of 9.5% can be obtained in combination with an emission reduction of 27.9%. Furthermore, practically all emission savings (40.8% of 47.8% in total) can be done without an increase of total costs. Moreover, it is found that it is not always true that intermodal transport requires a longer lead time.

Current intermodal emission levels are in the majority of the cases significantly larger than the lower bound calculated with our method. It is concluded that large savings can be achieved by optimizing the routings and modality choice of intermodal transport.

A ‘savings index’ has been created, which expresses the expected %-savings of carbon emission on a lane when shifting from road to intermodal transport. The savings index can be used to select the lanes with highest expected % carbon savings. The savings index can be used for a quick scan with high success scores expected, i.e. matching results of our method, only using a few parameters: distance, road distances to the terminals, allowed payload increase, average electricity factor of countries crossed (for intermodal rail), whether there is a sea in between origin and destination (for intermodal short-sea) and the number of Twenty-foot equivalent units (for intermodal short-sea). Because the savings index only requires a few input parameters, it allows us to apply it in an easy and quick way on large datasets. Both the savings index and the method can be applied to FTL bulk transport in Europe.

**Inventory management**

A case study of several lanes to Northern Italy is executed to investigate the potential of floating stock (in containers) and Vendor Managed Inventory (VMI). Both options result in large emission savings, respectively (48% and 67%). For both, the transport costs are lower than in the current situation, however, compared to VMI, floating stock has a relatively high transport cost due to additional handling, an additional road leg and rush order transport costs. For VMI the increase in inventory holding cost is relatively small compared to the decrease in transportation costs. The inventory holding costs at the floating stock point are significantly larger than at the customer due to container hire cost.

In general it is found that carbon emission reductions often can be applied cost effectively. For both payload increase and modal shift it is concluded that carbon cost are relatively small compared to transport cost.
Recommendations for further research

The study leads to the following recommendations for further research:

• It is recommended to conduct further research to the effect of carbon dioxide emission reduction in transport on the emission of other greenhouse gases

• Further research should focus on the design of the intermodal infrastructure to make intermodal transport more attractive. Furthermore, the effect of the frequency of connections between intermodal terminals on the choice of the routing is an interesting area for further research.

• It is recommended to include supply chain (re)design in further research to carbon dioxide emission reduction in transport. This will provide better insight in the trade-off between carbon emission, transport cost and inventory holding cost.

Implementation & monitoring

Since the carbon emissions in transport can be measured with TERRA, a clear quantifiable goal can be set on carbon dioxide emission reduction from transport. Two types of goals have been identified:

• Reduce CO$_2$ emissions from ETP transport with X percent by year Y compared to base line year Z.

• Reduce CO$_2$ emissions from ETP transport with X percent per metric tonne of delivered product by year Y compared to base line year Z.

Concrete recommendations to Cargill to reduce carbon emissions from transport are made. It is recommended to:

• Stimulate customers to order maximum instead of partial payloads by: 1) visualizing the effect of the order behavior of customers on carbon emissions and show what can be saved when ordering maximum payload instead; 2) setting contract requirements with respect to minimum order quantity; 3) applying order quantity-based pricing.

• Punish logistics service providers (LSPs) which use too heavy equipment and stimulate LSPs to use light-weight vehicles, such that payload can be further increased.

• Apply the savings index to classify the lanes for a modal shift. Next, apply the modal shift identification method to get insight in the maximum emission savings.

• Set requirements (or give LSPs an incentive) to quote ‘intermodal’ in the tender on the lanes, which have been identified as ‘high’ potential. Extend the optimizer for awarding decisions with carbon emission as an extra decision parameter.

• Stimulate customers to place orders in advance such that cleaner transport modes can be used: visualize carbon savings of extended order lead time, restrict the minimum order lead time in the contract (require ‘X days advance notice’) or apply order lead time-based pricing.

• Optimize the routing and modality used in current intermodal lanes with LSPs.

• Investigate inventory management options (Vendor Managed Inventory and floating stock) in more detail for high potential intermodal lanes.

Five Key Performance Indicators have been defined to monitor the progress of carbon emission reduction in transport:

• **KPI 1**: Absolute amount of carbon dioxide emitted as measured in tonne

• **KPI 2**: Efficiency of carbon dioxide emissions as measured in grams per tonnekm

• **KPI 3**: Average payload as measured in tonnes per shipment

• **KPI 4**: % intermodal transport as measured in percentage of lanes

• **KPI 5**: % intermodal transport as measured in percentage of tonnekm
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1 Research context

In this Master thesis project the assessment and reduction of carbon dioxide emissions resulting from transport are studied. The study is a continuation of the Carbon Regulated Supply Chain (CRSC) project, which is described in Section 1.2. One of the organizations involved in the CRSC project is Cargill. A short company description of Cargill is given in Section 1.3. Next, the main insights from the first project at Cargill (Te Loo, 2009) are summed up. Finally, the current problems in the area of carbon dioxide assessment and reduction are described.

1.1 Background

During the past two decades, there has been a growing pressure on companies to pay more attention to the impact of their products and services on the environment and natural resources. The increasing scarcity of resources and the escalating deterioration of the environment have led to increased pressure from several stakeholder groups, which have driven companies towards including environmental issues. The drivers for this “greenification” are (Hui et al., 2001; Kleindorfer et al., 2005; Srivastava, 2007; Zhu & Sarkis, 2006):

- **Regulations:** increasingly the European Union (EU) and national governments have created legal requirements focusing on the environmental part of business, e.g. on decreasing the emission of Greenhouse Gases (GHG).
- **Customer awareness:** customers become more aware of environmental problems and feel a larger responsibility in contributing to sustainability leading to more demand for products produced in a sustainable manner.
- **Market trend:** companies tend to show ‘copy’-behavior resulting in a snowball effect with respect to moving towards green strategies if their competitors do so.
- **Public pressure:** The increased public awareness of environmental problems and lobbying of various pressure groups have made some businesses more vulnerable, in some cases reflecting negatively on their economic performance.
- **Potential economic benefits / competitiveness:** companies have started moving towards sustainability more voluntarily since it has become clear that benefits can be made in this way as well.

Nowadays, one area which receives the most attention is climate change. The historical and estimated average global temperature is visualized in Figure 1-1. Climate change has been identified as one of the greatest challenges facing nations, governments, business and citizens over future decades (Pachauri & Reisinger, 2007). The emission of greenhouse gases is seen as an important causal factor for the climate change (IPCC Working Group 1, 2007).

The first large international agreement to reduce greenhouse gases was the Kyoto protocol, initially adopted by many countries in 1997. The Kyoto protocol sets targets of decreasing the greenhouse gases by on average 5% in 2008 – 2012 compared to 1990 values for 37 industrialized countries and the European community (UNFCCC, 1998). The Climate Conference in Copenhagen (COP15), which took place during the execution of this project, was supposed to translate the Kyoto protocol into legally binding targets, however only agreement was reached upon legally non-binding commitments (UNFCCC, 2009). Especially the EU has been taking serious steps to address its greenhouse gas emissions by launching numerous climate related programs since Kyoto. Of the wide range of new policies and measures the EU Emissions Trading Scheme (ETS) has become the cornerstone of EU’s climate efforts. The aim of the ETS is to help EU member states achieve their commitments to limit or reduce greenhouse gas emissions in a cost-effective way. It is the first international trading system for carbon emissions in the world. The ETS is a ‘cap and trade’ system, where the overall level of emissions allowed is capped, but, within that limit, allows participants in the system to buy and sell allowances as they require. These allowances are the common trading ‘currency’ of the system. One allowance gives the holder the right to emit one tonne of carbon. The ETS tends to expand globally,
incorporating more sectors and a more complete scope of environmental issues, according to the European Supply Chain Forum (2008).

The World Business Council for Sustainable Development (2004) has classified emissions in three scopes (Figure 1-2). Unlike emissions from scope 3, emissions from scope 1 and 2 (resulting from production and direct energy use) have received a lot of attention both in research and practice. Scope 3 emissions occur as a result of the activities of the company, the company’s demand for goods or services, but are from sources not owned or controlled by the company. One very important area in scope 3 is the transport sector. 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. Without any emission reduction from transport, the transport sector will account for the entire amount of the GHG emissions target of the EU by the year 2050 (RWS, 2008), leaving nothing for other sectors like industry or households. It is clearly unavoidable, therefore, that the transport sector itself also has to make a major contribution to reducing carbon emissions.

Regulations like the ETS and other external pressures influence the way companies do business. From a managerial point of view “companies may face a new challenge to consider a new decision variable, namely cost of emissions, while deciding on critical supply chain management decisions” (European Supply Chain Forum, 2008). However, companies do not only reduce emissions out of regulatory reasons, they can also benefit from it, since in many cases green and less costly go hand in hand, e.g. often cheaper modes of transport also result in less carbon emission; re-manufacturing in general decreases manufacturing costs in addition to a reduction of the carbon emissions. Moreover, reducing emissions can be used for marketing purposes like creating a green image of the company and branding of products.
1.2 Carbon Regulated Supply Chain project

The starting point for this Master thesis project is the Carbon Regulated Supply Chains project (CRSC, 2009) initiated by the European Supply Chain Forum (eSCF) at the end of 2007. The objectives of the project were (CRSC, 2009):

- To understand the impact of the various regulation alternatives on the design and operation of supply chains
- To assist decision makers in industry by preparing strategies for coping with the upcoming regulations
- To impact policy makers and the public opinion on the effectiveness and problems of new regulations.

The project consisted of two phases. In the first phase, until the beginning of 2009, literature research was done on methods for calculating emissions resulting from transport. The second phase, as from the beginning of 2009, built upon four simultaneous Master’s theses investigating the carbon dioxide emissions due to transportation at four different eSCF member companies. In these Master’s theses a method to assess carbon dioxide emissions in transport has been developed, mainly based upon NTM (2008) methodology. The aim was to serve as a building block towards designing supply chains where carbon emission is considered along with typical supply chain performance indicators, like costs and service levels. The four participating companies were:

- Bausch & Lomb: an eye-health company
- Cargill: a producer and marketer of food, industrial, agricultural and financial products and services
- Dow Chemical: a chemical company
- Unilever: a food manufacturing company

In this project the CRSC methodology is used for carbon emission calculations. This implies that the results are subject to parameter- and assumption influences and limitations of this methodology on carbon emission assessment and allocation. However it should be kept in mind that different viewpoints exist. E.g. CRSC (2009) assumes that emissions from empty returns (when the means of transport are returning without another shipment) are allocated to the customer only if transport is dedicated to the customer, otherwise these emissions are allocated to the logistics service provider. Contradictory, WEF (2010) states that emissions from each leg of a regular route should be pooled and shared between legs, on the basis of relative economic value, if there is on average a significant difference between the values of the legs (i.e. more than 50%). It is obvious that the choice of assumptions has its effect on the emission calculations.
The accompanying emission calculation tool resulting from the CRSC project is called TERRA (Transport Emission Reporting and Reduction Analysis). In Appendix 1 a summary is given of the CRSC methodology. During this project several bugs have been found in TERRA. The main problem concerns the unreliability of distance tables, which use postal code information (country code and first two digits of postal code) to automatically calculate the distance between two locations. An overview of the issues and how is dealt with them is briefly described in Appendix 2. None of the issues has effect on the calculations in this project, unless this is explicitly mentioned in the report.

1.3 Cargill

Cargill is an international producer and marketer of food, agricultural, financial and industrial products and services. Founded in the United States in 1865, nowadays one of world’s largest privately held companies employs 159,000 people in 68 countries. In the fiscal year 2009 Cargill had $116.6 billion in sales and other revenues, and net earnings of $3.33 billion (Cargill, 2009a). Cargill’s mission, vision and strategy statements and the geographic spread of investments and employees worldwide is visualized in Appendix 3.

Cargill is subdivided into 74 Business Units (BUs) around seven major platforms:

- Cargill Agricultural Supply Chain
- Cargill Animal Nutrition & Salt
- Cargill Animal Protein
- Cargill BioFuels, BioIndustrial & Emerging Business
- Cargill Energy, Transportation & Industrial
- Cargill Financial Services
- Cargill Food Ingredients & Systems

Cargill is organized in a network where different BUs share several services, one of which is European Transport Procurement, where this project has been executed. Section 1.3.2 describes Cargill’s commitment towards carbon dioxide emission reduction.

1.3.1 European Transport Procurement

European Transport Procurement (ETP), located in Haubourdin in the North of France, is shared by four BUs; Cargill Cocoa & Chocolate (CC), Cargill Refined Oils Europe (CROE), Starch & Sweeteners Europe (SSE) and Cargill Texturizing Solutions (CTS). The relation between ETP and the BUs and ETP’s organization diagram are shown in Appendix 3. This project focuses on the transport concerning the business unit Cargill Cocoa & Chocolate (Section 1.3.3). Reasons for and implications of this choice are described in Section 2.2.

ETP takes care of the European outbound transport (direct delivery to the customer) for the four business units mentioned. It attempts to optimize transport cost within agreed service levels to European Food Ingredients BUs and in compliance with Cargill’s corporate requirements. The main tasks of the ETP involve negotiating and managing contracts with logistics service providers (LSPs) and maintaining and sharing the central transport database.

The total amount spent on European outbound transport is about € 400 million. Around 10 million tonnes of finished goods is transported within Europe and managed by the ETP, divide into three types: 5 million for bulk liquid, 2.5 million for bulk powder and 2.5 millions for packed goods. The large transport volumes in combination with a wide-spread network of factories and customers makes Cargill an interesting company in the area of carbon assessment and reduction. In the beginning of 2009 ETP has launched the Green Transport Project in effort to reduce carbon dioxide emissions resulting from transport.

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1.3.2 Green Transport Project

So far reducing carbon dioxide emissions in Cargill has mainly focused on direct emissions of scope 1 and 2 of Kyoto. However on a corporate level Cargill has made the first steps to address scope 3 emissions, as stated in Cargill (2008). Appendix 4 provides some statements (collected during the project) that demonstrate Cargill’s corporate commitment towards sustainability and corporate responsibility.

Practically all transport managed by the ETP is contracted out to LSPs, so is part of scope 3. In line with the corporate view in the effort to reduce the carbon emissions of scope 3, the ETP has launched the Green Transport Project (GTP) in the beginning of 2009. The goal of the Green Transport Project is to reduce carbon emissions resulting from transport, mainly by shifting from road transport to more ‘environmental friendly’ transport modes. Cargill has set as a 2010 goal to reduce greenhouse gas emission by 8 percent per metric tonne of production, against fiscal year 2006 baseline (Cargill, 2009d). As verified with Cargill’s Corporate Environmental Manager, for carbon emissions in transport there is not yet a clear goal set by Cargill, because on a corporate level there is not yet clear insight in the current level of transport emissions. Similarly, the ETP has not yet put an official objective on emission reduction in its transport.

1.3.3 Business Unit Cargill Cocoa & Chocolate

This project is applied to the transport of the Business Unit Cargill Cocoa & Chocolate (CC). The BU’s product range consists of cocoa liquor, cocoa powder, cocoa butter and chocolate. All CC production facilities are located in North-West Europe, more specifically they are spread over five countries: The Netherlands, Germany, Belgium, France and United Kingdom. These production locations deliver to a wide range of customers in Europe (and Russia). The production process and the European production locations are visualized in Appendix 5.

1.4 First Cargill project (Te Loo, 2009)

In the first project at Cargill three research questions have been defined (Te Loo, 2009):

- How can carbon dioxide emissions resulting from transport be determined?
- How can carbon dioxide emissions resulting from transport be reduced?
- How will possible upcoming regulations of the European Union impact transport costs and reduction possibilities?

The transport taken into account in this study was all outbound ETP transport within Europe. The CRSC calculation methodology has been applied to assess the carbon emissions of ETP’s transport. This has resulted in the first insights in reduction options of carbon emissions in the transport of Cargill. Furthermore, four possible regulation scenarios have been evaluated, taking into account the current European Union Emission Trading Scheme (ETS) and possible extensions.

1.5 Problem description

The CRSC (2009) project has resulted in a methodology to assess carbon emissions resulting from transport. Furthermore, the CRSC case studies have given the first insights in carbon reduction options in transport. This topic emerged recently and therefore the literature is not as extensive as in many other fields of operations management and logistics. However, several authors address the area of emission reduction in transport.

Chapman (2007) reviews approaches to reduce emissions from road freight, including: technological change, alternative fuels, ecological driving, use of lighter equipment, modal shift and efficient vehicle loading. According to Chapman (2007), there is a tendency to focus on long-term technological solutions, however short-term behavioural change is crucial if the benefits of new technology are to be fully realized. McKinnon (2000) goes into more detail on efficient vehicle loading and surveys opportunities to improve the utilization of road vehicles and investigates the potential economic and environmental benefits. Intermodal transport is a topic within emission
reduction in transport that has received slightly more attention than most other reduction options. Rondinelli & Berry (2000) explore the forces driving the growth of intermodal transportation services and infrastructure and examine alternative means of controlling and preventing environmental hazards. A comprehensive overview of the use of operations research in intermodal freight research is provided by Macharis & Bontekoning (2004). Léonardi & Baumgarter (2004) conducted a survey in Germany to quantify the potential for carbon reduction and the effect of specific activities, such as introducing computer assisted scheduling systems to trucking firms.

Although several papers have discussed carbon reduction options in transport, no paper exists with a complete overview of all options. Furthermore, there is only a limited amount of literature available on accompanying effects of emission reduction, e.g. effects on cost and lead time of the transport. Another part were research is lacking is in the field of lane selection for carbon reduction options. Untill now it is unclear which carbon reduction options can be best applied to which transport lanes. Finally, implementation issues of carbon reducing activities have been hardly addressed in research. This study aims to fill this knowledge gap and to provide practical insights in these topics. In Chapter 2 research questions are identified based upon the problems described in this section.
2 Research design

Based upon the problems discussed in Section 1.5, research questions have been identified for this study (Section 2.1). The second section of this chapter describes and explains the scope of this study.

2.1 Research questions & project approach

Five research questions have been identified. For each research question the scientific importance and practical relevance is pointed out. Furthermore, the approach to answer the research questions is briefly discussed.

1) How can carbon dioxide emissions resulting from transport be reduced?

There is a wide variety of carbon reduction options, as shortly described in section 1.5. However it is not clear what the impact of each reduction option is. Furthermore, there is limited insight in the applicability of reduction options to a specified scope. The first step is to make a complete overview of reduction options by reviewing literature and recent studies in this area. Next, the potential of the options is judged based on applicability to the scope and expected impact. This leads to a selection of carbon reduction options for the remainder of the study.

2) How can transport lanes be selected for carbon dioxide emission reduction?

Knowing which carbon reduction options to incorporate, does not automatically tell on which transport lanes to apply these options. For research it is desirable to find general lane selection methods, which can be applied industry-wide. For companies that want to reduce their carbon dioxide emissions it is crucial to know on which lanes to focus their effort in order to obtain the largest emission savings possible.

Per selected reduction option it is assessed which parameters are important and what the limitations are. Methodologies are designed which can be used to identify lanes with high potential on the reduction options. Both insights are given in the real emissions savings and relative potential compared to other lanes.

3) What are the effects of carbon dioxide emission reducing activities on carbon dioxide emissions, costs and lead time of the transport?

Although more and more companies focus on emission reductions, carbon emission is not an isolated decision variable when organizing the transport. It is interesting to investigate in the first place, whether emission reducing activities have positive or negative effects on transport cost and lead time. Insights in the direction and magnitude of effects on transport cost and lead time are required to make grounded decisions on emission saving activities. Especially emission reduction options, which at the same time have positive effects on cost and lead time, are extra attractive for industry. On the other hand, if the side effects are negative, insight in the magnitude of these effects is useful for decision making as well.

After applying the methodologies on Cargill several scenarios are analyzed and compared to the current situation. This leads to a quantification of the carbon emission reductions, transport costs and lead time and insight in the relation between these parameters.

4) How can carbon dioxide emission reducing activities be implemented and what is the effect of implementation on internal administration?

Besides cost and lead time, emission reducing activities have effect on other aspects the organization, e.g. the planning system, handling of transport order and collaboration with the customer. If it is known which carbon reduction option to apply, it is important to know how these options can be applied in a systematic and effective way, taking into account other organizational aspects as well.
Based on the findings and current transport organization structure, a strategy is developed in order to best navigate the company to the goal of emission reduction.

5) How can the progress of reducing carbon dioxide emissions in the transport be monitored?

Companies that commit to carbon reduction should be able to measure the progress of their activities. Insights are needed in what and how to measure. As part of the implementation plan effective Key Performance Indicators (KPIs) are provided and recommendations how to use these KPIs for continuous measurement and improvement of the carbon performance are given.

2.2 Scope

The research questions are applied on the following scope:

Carbon dioxide emissions due to outbound ETP transport within Europe of Full Truck Load direct delivery bulk liquid goods of the business unit Cargill Cocoa & Chocolate.

In the remainder of this chapter the choice and implications of this scope are discussed.

Carbon dioxide emissions

Although the emissions of different GHGs has increased significantly over the past centuries, only carbon dioxide is taken into account in this study. It is commonly accepted that not all greenhouse gases have the same contribution to global warming. The absolute impact on climate change is determined by the Global Warming Potential (GWP) in combination with the amount emitted. The GWP is an equivalence scale to determine the relative impact of the GHGs on global warming compared to CO₂. A GWP of two means that emitting one kilogram of that gas has a double impact compared to emitting one kilogram of CO₂. This is illustrated for different GHGs in Table 2-1.

<table>
<thead>
<tr>
<th>Greenhouse gas</th>
<th>GWP (100 yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ (baseline)</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>21</td>
</tr>
<tr>
<td>N₂O</td>
<td>310</td>
</tr>
<tr>
<td>HFCs</td>
<td>12 – 11,700</td>
</tr>
<tr>
<td>PFCs</td>
<td>6,500 – 9,200</td>
</tr>
<tr>
<td>SF₆</td>
<td>23,900</td>
</tr>
</tbody>
</table>

Table 2-1: GWP (100 yrs) of different GHGs within Kyoto (extracted from EPA, 2009)

Although the other GHGs have a relatively larger impact on global warming than CO₂, not all gases are emitted during transport, e.g. HFCs, PFCs and SF₆. CH₄ and N₂O are emitted in relatively small quantities compared to CO₂. This is illustrated in the second column of Table 2-2. Combining the GWP with the emission quantity, results in the ratio of effect of the greenhouse gas compared to CO₂ (column 3 in Table 2-2). As one can see the contribution of CH₄ and N₂O in transport is relatively small. Furthermore, CH₄ and N₂O emissions in transport are already better regulated than CO₂. This leads to the decision to only include CO₂ in this study.

<table>
<thead>
<tr>
<th>GHG emission</th>
<th>Emission factor (kg/GigaJoule)</th>
<th>Kg CO₂e / GigaJoule</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>70.101</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>0.0028</td>
<td>0.060</td>
</tr>
<tr>
<td>N₂O</td>
<td>0.00057</td>
<td>0.1763</td>
</tr>
</tbody>
</table>

Table 2-2: comparison of GHGs emissions (extracted from EPA, 2009)
A possible downside of excluding other emissions is that this study may lead to recommendations which reduce CO₂ emissions but increase other emissions. Furthermore, only emissions resulting directly from the transport itself (‘wheel-to-wheel’ emissions) are taken into account. In this study carbon dioxide is referred to as ‘carbon’.

Outbound ETP transport within Europe
The focus of this project is on emissions in transport. No emissions caused by production are taken into account. An advantage is that transport processes of companies, unlike production processes, can easily be compared, which provides the opportunity to draw both general and company-specific conclusions about carbon emissions resulting from transport. The transport of interest is the outbound transport within Europe, which is the same as the scope of the European Transport Procurement department (ETP). In other words, only products transported from production facilities within Europe are taken into account. For the inbound process raw material is transported from only a few harvesting locations to a limited amount of production facilities, while for the outbound process the products are transported from the production facilities to a large number of customers spread all over Europe. In other words the outbound transport network is finer meshed. Due to large volumes mainly clean modes of transport (especially water) are used for the inbound transport, while for the outbound process mainly road transport is chosen. Therefore the carbon dioxide emissions resulting from the outbound process are larger than for the inbound process and it is expected that the largest potential savings are included in the chosen scope. Of this transport only gate-to-gate transport is considered, excluding onsite logistics. Furthermore, only the delivery by Cargill to customers is taken into account, customer pick-up is excluded since this is out of control for Cargill.

Full Truck Load direct delivery bulk liquid goods
Full Truck Load (FTL) in this context refers to shipments where there is only Cargill cargo on the transport equipment. This is in line with the reality, since ETP does not apply transport sharing with other companies. ETP transport concerns direct delivery and is divided into three types: bulk powder, bulk liquid and packed. In Te Loo (2009) it was found that in the bulk liquid group the highest savings can be realized, because bulk liquid has a relatively high percentage of road transport and a relatively low average payload.

Business Unit Cargill Cocoa & Chocolate
A small business unit, Cargill Cocoa & Chocolate (CC), is chosen to narrow the scope, making it suitable for a detailed lane-per-lane analysis. An additional argument is that the Green Transport Project is funded by the four BUs mentioned in Section 1.3.1, but relatively little has been done so far for CC. CC is not only small in number of lanes but also in volume and distance per lane, as illustrated in Figure 2-1. One tonnekilometer is equivalent to one tonne of cargo transported over one kilometer. The consequence is that relative small absolute effects are expected to be found, compared to including all lanes and all types of transport. However the main goal of this report is to find methods for and insights in emission reductions. The methodologies designed can be applied to other BUs or FTL bulk transport in general, since only the product type under scope differs. However it is possible that for packed goods other emission reduction options exist than for bulk liquid.
2.3 Report structure

In Chapter 3, the data used for the emission calculations is briefly discussed. In Chapter 4, the business opportunities for reducing carbon emissions in transport are set out and are analyzed on their potential for the scope of this project. Next, a chapter is devoted to each selected carbon reduction opportunity (Chapter 5, 6 and 7). In these chapters methodologies for lane selection are designed and the emission reductions and effects on other transport parameters are calculated. In Chapter 8, the conclusions are drawn and recommendations for further research are provided. Finally, Chapter 9 discusses the implementation and monitoring of the carbon reduction options for Cargill. At the end of the report, one can find a glossary, which explains the specific terminology and abbreviations used in this report.
3 Data

The transport data is based on the bulk liquid award plan (Section 3.1), data collected in Te Loo (2009) (Section 3.2) and additional data collected in this project (Section 3.3). An award plan is an overview of contracts between Cargill and the logistics service providers. Section 3.4 provides an overview of the collected data and assumptions used.

3.1 Bulk liquid award plan

The transport procurement process of ETP is described in Appendix 7. Every year the contracts of one type of transport are renegotiated alternately; bulk liquid in 2008, bulk powder in 2009, packed in 2010, bulk liquid in 2011, etc. Ultimately, the procurement process results in the award plan in which, for every lane it is specified to which LSP(s) it is awarded. The award plan of bulk liquid dates from the end of 2008. For each lane the award plan contains data about the origin, destination, Business Unit, product and product group, cleaning requirements, required equipment, annual weight, distance for road transport, and the different bids. Each bid provides information about the LSP, bid price and the percentage of the lane which is awarded to this LSP. For this project only the bulk liquid lanes of CC are taken into account.

3.2 Data collected in first Cargill project

Because the award plan does not contain all the data required to make the carbon dioxide emission calculation, additional data has been collected by Te Loo (2009): transport mode, distance per mode and vessel type. The data collection process, parameters collected and assumptions made are described in Appendix 8.

The following assumptions on parameters made in the Te Loo (2009) are supported:

- Empty returns: in the CRSC methodology it is assumed that emissions from empty return trips are allocated to the customer, only if transport is dedicated to the customer on request. Since the CRSC methodology is used and Cargill uses almost no dedicated equipment, empty returns are not taken into account.

- Cleaning: because the transport under consideration is food transport, cleaning is always required, so the assumption of always cleaning is valid.

- Temperature control: Cargill uses almost no refrigerating and freezing transport. In case products should stay above a certain temperature, often products are loaded at higher temperature than required, such that no temperature control is needed. In some cases however, heating before unloading or heating during transport is required, mainly for chocolate. It is expected that heating has a significant impact on the fuel usage and thus on the emissions. The lack of reliable emission data as described in CRSC (2009) implies that it only makes sense to collect data on heating if the calculation methodology is improved. The emissions resulting from heating depend on many parameters, among others: product characteristics, loading and required unloading temperature, lower bound of allowed temperature, isolation of tank or container used, outside temperature, volume in the tank or container and lead time of the transport. The combination of amount of work to improve the method and the expected reliability of the emissions, results in not taking into account this parameter. The impact is that in reality emissions are higher on lanes which require heating.

- Truck type: there are only a few exceptions on the general rule of a truck with semi-trailer (<40 tonnes).

- Vessel type: information on detailed vessel specifications is often unavailable, as experienced by Te Loo (2009) and Schers (2009), so only type of vessel is taken into account. This only influences the water emissions.
Parameters on which no collection is needed are:

- Volume and pallets: the transport under scope is weight limited due to high densities.
- Road allocation: no shared transport with other companies is done, so road allocation is always ‘no’.
- Load factor road: not required, because all transport is weight-limited and FTL is assumed, i.e. no sharing of transport.

The number of twenty foot equivalent units (TEU) of a container is not available. However, this can easily be estimated using the density of the product and standard container sizes. CC has three product groups with different density ranges (Cargill, 2009e):

- Chocolate: 1.10 – 1.30 kg/l
- Cocoa liquor: 1.00 – 1.20 kg/l
- Cocoa butter: 0.85 – 0.95 kg/l

A standard ISO container (TEU = 1) has a typical maximum volume of about 26 m³ and a SWOP body (TEU = 1.5), which is an extended container, has a typical maximum of about 33 m³. For intermodal transport the general maximum payload is 28 tonnes. Dividing the maximum payload by the average product density results in the volume capacity required. In general for chocolate and cocoa liquor a standard ISO container with TEU = 1 is sufficient; for cocoa butter a SWOP body with TEU = 1.5 is required. These values are assumed here. Only for low density cocoa liquor products in reality a container with TEU = 1.5 could be necessary, however this is assumed to be not the case here. Note that TEU is only used for water allocation.

In the CRSC (2009) project it is shown that the following parameters have medium or large effects on the emission results:

- Positioning distance
- Traction type rail
- Gross weight of train
- Load factor rail and water

On these parameters currently no data is available. Therefore these parameters are investigated in more detail in Section 3.3 via a sensitivity analysis.

### 3.3 Additional data collection

Accurate and complete data collection is crucial for reliable emission calculations. While the impact on total emissions of a large data set may be limited, the differences per lane can be very large if detailed data is unavailable. A sensitivity analysis is conducted on the influence of several parameters on the emission results. This information is used as input to make the decision on whether or not to collect data on these parameters for the transport under scope.

#### 3.3.1 Sensitivity analysis of missing parameters

For each parameter an uncertainty level is chosen, resulting in three levels; the current CRSC assumption (reference level), a lower level and a higher level. Next, emission calculations have been executed using the three levels and the upper and lower level are compared to the reference level. For this analysis the complete bulk liquid data set is used to have a sufficiently large dataset.

**Positioning distance**

No positioning distance is assumed for other modalities than road. For road positioning distance for road the NTM (2008) assumption of 20% of the distances is used. High variability is expected due to the fact that there can be large differences in locations of LSPs. It is expected that there is always some positioning distance; 10% is chosen as a lower level. On the other hand it is expected that the positioning distance will not be too high, otherwise a LSP would not be competitive anymore; 30% is chosen as a higher level.
Gross weight of train
The standard assumption about the gross weight is 1,000 tonnes. NTM (2008) uses three standard types; 500, 1,000, 1,500 tonnes, which are used here to check the sensitivity.

Load factor rail
A load factor of 72% is assumed for rail bulk transport, which is based upon EcoTransIT (2008). EcoTransIT is developed in cooperation with several rail companies. Therefore the load factors for rail transport are assumed to be accurate. Both 10% lower and 10% higher levels are used. Note that the load factor for rail is only used in case no information is available about the gross weight of the train.

%-electrical traction
The general European value of 75.4% is used as an electrical / diesel split (based upon EuroStat, 2009). Here it is assumed that each lane is either executed totally with diesel or totally with electrical traction; both 0% and 100% are used in the sensitivity analysis.

Load factor water
A load factor for bulk water transport of 80% is assumed. This assumption is based upon NTM (2008), which uses estimations of ship owners, who have participated in the NTM work group. The assumptions are again assumed to be accurate; both 10% lower and 10% higher levels are used.

3.3.1.1 Results
The results of the sensitivity analysis are summarized in Table 3-1. In the table the expected average effect on total emissions and type specific emissions are calculated. Total emissions refer to total emissions per lane. Type specific emissions are: positioning distance for positioning; rail emissions for %-electrical traction, gross weight train and load factor rail; water emissions for load factor water.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Difference type specific emissions</th>
<th>Difference total emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning</td>
<td>reference</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>50%</td>
<td>-5.22%</td>
</tr>
<tr>
<td></td>
<td>30%</td>
<td>50%</td>
<td>5.22%</td>
</tr>
<tr>
<td>%-electrical traction</td>
<td>reference</td>
<td>75.4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>56.17%</td>
<td>24.35%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>-18.33%</td>
<td>-9.94%</td>
</tr>
<tr>
<td>Gross weight train</td>
<td>reference</td>
<td>1000 tonne</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>41.42%</td>
<td>16.60%</td>
</tr>
<tr>
<td></td>
<td>1500</td>
<td>-18.35%</td>
<td>-7.35%</td>
</tr>
<tr>
<td>Load factor rail</td>
<td>reference</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>62%</td>
<td>16.13%</td>
<td>6.46%</td>
</tr>
<tr>
<td></td>
<td>82%</td>
<td>-12.20%</td>
<td>-4.89%</td>
</tr>
<tr>
<td>Load factor water</td>
<td>reference</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70%</td>
<td>13.60%</td>
<td>3.73%</td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td>-11.64%</td>
<td>-3.20%</td>
</tr>
</tbody>
</table>

Table 3-1: sensitivity analysis, expected effect on type specific and total lane emissions

In this project we take a detailed lane per lane perspective, so not only the average effects on total emissions are interesting, but also the distribution of these effects, visualized in Appendix 9. The main insights are that the effects from different positioning, load factor rail and load factor water values have small variances, where the effect from different %-electrical traction and gross weight train values are wide-spread. For the latter two also lanes exist with very high deviations on the total emissions.

3.3.1.2 Decision on extra data collection
The decision on collecting extra data is a trade-off between the expected contribution to accuracy of the results, the amount of work and time required, and the likelihood of obtaining reliable data. With respect to expected contribution it is shown that especially the traction type and gross weight of the train are important input parameters for the result. The load factors and positioning distances seem of less importance, however the uncertainty cannot be fully denied.
In the CRSC case studies it is found that it is difficult to obtain reliable data on positioning distances, because the positioning distance is different for every shipment (dependent on the location of the truck before transport). Data on all shipments of a lane has to be available to be able to calculate the average positioning distance on a particular lane. Furthermore, the amount of work would be high, since all LSPs have to be contacted. Together with the limited contribution to accuracy of the emission result, it is decided not to collect this data. Furthermore, it is found that real load factors for water transport are hard, if not impossible, to retrieve, due to either unavailability or confidentiality of the data. In Te Loo (2009) it seemed almost impossible to collect data on the rail parameters, gross weight, traction type and load factor. However due to the high expected contribution and the limited number of LSPs, which have to be contacted it is decided to try to get additional data on gross weight and traction type. Currently only two lanes are executed by rail. Both LSPs could provide data about the traction type, only one of them was able to give an estimation of the gross weight of the train. It should be kept in mind that not collecting data has as a consequence that the total emission results can deviate, as shown in Table 3-1 and Appendix 9.

### 3.3.1.3 Refined assumptions

For the influential parameters it is desirable to refine the assumptions, which are used in case the real data is not available, to be better applicable to the average of Cargill. For gross weight of train this is assumed to be a difficult and very labour-intensive process with low probability of accurate estimations, since different rail operators have to be contacted and often accurate information will be unavailable. For %-electrical traction a new assumption is based on the current rail lanes of the bulk liquid dataset and the %-electrical traction per country as extracted from EuroStat (2009). The data of 2005 is used because of its relative completeness of data compared to more recent years. The number of tonnekkm per country in combination with the %-electrical traction per country for Eurostat, results in 76.57% as average %-electrical traction for Cargill bulk liquid. Although this is very close to the original assumption, the value is changed in TERRA’s parameters.

### 3.4 Data overview

It is expected that the collected data is accurate, since the majority of the data is internally collected. The externally collected data always underlies more uncertainty, however it is expected that transportation mode and routings are data which is standard available at the LSPs. For %-electrical rail traction and gross weight of the train the reliability is lower, because LSPs often depend upon rail companies for this data. The two contacted LSPs have mentioned that it is especially difficult to provide accurate data on the gross weight of the train. For future data collection decisions it is advised to collect data at least data on %-electrical traction. With respect to gross weight of the train, it is desirable to collect data, however only if accurate data is available. Table 3-2 provides a summary of parameters collected and assumptions made.

Calculations in this project are based on historical data, because the data of the award plan and data collected by Te Loo (2009) is used. Former experiences of the CRSC case studies have shown a lot of problems with external data collection, e.g. unavailability of data, unwillingness of LSPs to share data due to market sensitivity, long response time on data request, very time consuming. Therefore it is decided to not update the data unless explicitly required for analysis. The consequence is that the results may slightly differ from today’s situation.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source / assumption</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport mode</td>
<td>Te Loo (2009)</td>
<td>Required for calculation</td>
</tr>
<tr>
<td>Distance per mode</td>
<td>Award plan / Te Loo (2009)</td>
<td>Required for calculation</td>
</tr>
<tr>
<td>Weight</td>
<td>Award plan</td>
<td>Required for calculation</td>
</tr>
<tr>
<td>Number of shipments</td>
<td>Award plan</td>
<td>Required for calculation</td>
</tr>
<tr>
<td>Truck type</td>
<td>Assumption: always standard truck semi-trailer</td>
<td>Complies with reality</td>
</tr>
<tr>
<td>Load factor road</td>
<td>Not required</td>
<td>Weight-limited transport and FTL</td>
</tr>
<tr>
<td>Vessel specification</td>
<td>Assumption: only vessel type (collected Te Loo, 2009)</td>
<td>More specific data unavailable</td>
</tr>
<tr>
<td>Load factor water</td>
<td>Assumption: 80% (CRSC, 2009)</td>
<td>Minor influence on result</td>
</tr>
<tr>
<td>%-electrical traction</td>
<td>Collected</td>
<td>Large influence on result</td>
</tr>
<tr>
<td>Gross weight train</td>
<td>Collected if available</td>
<td>Large influence on result, however hard to retrieve reliable data</td>
</tr>
<tr>
<td>Load factor rail</td>
<td>Assumption: 72% (CRSC, 2009)</td>
<td>Minor influence on result</td>
</tr>
<tr>
<td>Empty returns</td>
<td>Assumption: assigned to LSP (CRSC, 2009)</td>
<td>Out of scope for Cargill</td>
</tr>
<tr>
<td>Positioning distance</td>
<td>Assumption: 20% (CRSC, 2009)</td>
<td>Medium effect, however hard to retrieve reliable data</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Assumption: always cleaning</td>
<td>Complies with reality</td>
</tr>
<tr>
<td>Temperature control</td>
<td>Excluded</td>
<td>Lack of reliable emission data and accurate calculation method</td>
</tr>
<tr>
<td>Volume</td>
<td>Not required</td>
<td>Weight-limited transport</td>
</tr>
<tr>
<td>Pallets</td>
<td>Not required</td>
<td>Weight-limited transport</td>
</tr>
<tr>
<td>Road allocation</td>
<td>Not required</td>
<td>No transport-sharing</td>
</tr>
<tr>
<td>TEU</td>
<td>Assumption: TEU = 1 for chocolate and cocoa liquor, TEU = 1.5 for cocoa butter</td>
<td>Based upon product density and capacity of standard equipment</td>
</tr>
</tbody>
</table>

Table 3-2: overview of parameters collected and assumptions made
4 Carbon Emission Reduction Opportunity Assessment

First, the carbon dioxide emissions for Cargill Cocoa & Chocolate have been calculated using the CRSC methodology and the collected data. Next, in Section 4.2 different carbon dioxide emission reduction options are reviewed. The potential of the options is judged based on their expected impact and practicability. Section 4.3 provides an overview of the carbon reduction options and their potential. This results in a selection of carbon reduction options to investigate further in the remainder of this study.

4.1 Emission calculation results of Cargill Cocoa & Chocolate

The total yearly carbon dioxide emission for CC is 7,326 tonnes. Figure 4-1 shows the division of the emission over different sources. One can see that the categories vary significantly. Road is by far the largest category here. Road includes also the emissions of road legs of intermodal transport. The emissions of rail, water and vertical handling are very small. This is due to the small percentage of intermodal rail and intermodal water transport compared to road transport, as is visualized in Figure 4-2. The division of emissions per modality is in line with the division of tonne kilometers. Note that modality road in Figure 4-2 includes the modalities ferry and Eurotunnel as well, because in general the largest distance of these modalities is covered by road transport.

![Figure 4-1: emissions per source](image1)

![Figure 4-2: emissions per modality](image2)
4.2 Business opportunities

This section provides a review of the carbon dioxide emission reduction options addressed in literature and the CRSC (2009) project. It is investigated which parameters, used in the CRSC calculation methodology (as described in Appendix 1), are influenced by which options. The main parameters are distance, emission factor, load factor and fuel consumption. The opportunities are classified into four areas: increasing transport efficiency, vehicle shift, technological innovation and supply chain (re)design.

An option which is not included in the list, but mentioned in literature is carbon offsetting, i.e. investing in projects that reduce carbon dioxide emissions somewhere else. However this is not seen as a reduction option, but as compensation and therefore not included. Every business opportunity is assessed based on the practicability and expected magnitude of emission reductions for transport under scope, as described in Section 2.2. The assessment is mainly based upon qualitative reasoning. Quantification for the selected reduction options takes place in the next chapters.

4.2.1 Increasing transport efficiency

Increased efficiency of transport leads to reduced transport related carbon emissions per m$^3$ of load. The transport can be made more efficient by increasing the payload, using combined transport, reducing the number of ‘empty’ kilometers, outsourcing transportation activities to logistic service providers, using carbon efficient vehicle routings and energy-efficient driving.

4.2.1.1 Payload increase

Payload is defined as the absolute weight in a vehicle and is restricted by law. Payload increase affects the load factor, which is defined as ‘the percentage of the capacity of the vehicle used, where capacity is expressed in weight, volume, pallets, lane meters or twenty-foot equivalent units’. Applying higher load factors in general requires fewer trips to transport the same amount of goods, and therefore will result in lower emissions. In this project payload increase focuses on putting more of the same product of one customer in a transportation vehicle. Weight is always the limiting factor with respect to load factor for the transport under scope. The maximum payload depends on the country where the transport takes place and the type of transport. For international transport in Europe, in general a maximum gross weight of a truck of 40 tonnes is allowed. This typically results in a maximum payload of about 25 tonnes (depending on the weight of the truck). An additional way to increase the maximum allowable payload of trucks is the use of intermodal transport. The maximum gross weight for trucks conducting road transport is 40 tonnes, while short distance transport to an intermodal terminal is in general limited at 44 tonnes. This can be an (extra) incentive to use of intermodal transport.

The current average payload of CC bulk liquid transport is 17.2 tonnes. A high number of lanes has a payload close to the average payload or even a very low payload. Based on the current payload and the legal restrictions, payload increase is seen as an option with high potential. Furthermore, Cargill can directly influence the payload via order quantity requirements to customers.

4.2.1.2 Transport sharing

Another way to increase the load factor is by combining cargo of multiple products or of multiple customers in one transport vehicle, i.e. by transportation sharing. Note that transportation sharing can go beyond a company’s borders. Whether orders can be combined depends on the order process.

Combining of cargo can be realized by requiring customers to order at the same time (or by requiring one customer to order different products at the same time) or by applying transport-efficient order cycles. The former currently happens at small scale for some small customers. Concerning the latter, Marklund (2008) has developed a model, which uses shipment intervals for different retailer groups, such that shipments can be consolidated in an efficient way. Orders can be combined for the same customer or for different customers and the single-item model can quite straightforward be extended...
to a multi-item situation. The model is originally designed for cost minimization, however emissions will also decrease when orders are consolidated. The model is based on a (S-1,S) order policy of customers, i.e. immediate base stock replenishment.

The potential of order sharing depends on the order quantities. For the transport under scope, only a small fraction (about 30%) of the orders is smaller than half of a truck capacity. However, these orders are done with low frequency. Furthermore, the majority of small orders represent short-distance lanes. This implies that small order lanes take up only a minor fraction of the total emissions. Therefore the expected impact of transport sharing is low. Moreover, the applicability on the transport under scope is problematic. Since we are dealing with bulk liquid transport, the products have to be transported in a bulk liquid tank or container. In case of different products, different compartments are necessary. Though scarce, these are available, but have all a fixed capacity per compartment, which limits the number of products and the volume ratios one can consolidate.

### 4.2.1.3 Reducing empty returns

Another way of combining shipments is by reducing the number of empty returns. If for a shipment from A to B a return shipment from B to A is found, two empty returns can be avoided as is illustrated in Figure 4-3. Although the emissions of an empty vehicle are lower than the emissions of a loaded vehicle, the expected impact on emission reduction is large, because the distance of the return leg is as large as the original leg (when assuming that the vehicle returns to the same location). CRSC (2009) assumes that emissions resulting from empty returns are assigned to the LSP except when the customer (Cargill in this case) requests dedicated transport. Since the CRSC assumptions are used in this project and Cargill has hardly any dedicated transport, this option is out of scope.

![Figure 4-3: effect of combining shipments on empty returns (CRSC, 2009)](image)

### 4.2.1.4 Reducing positioning distance

Emissions from positioning are assigned to the customer (in this case Cargill). The emissions from positioning represent a reasonable fraction of the total emissions, for the transport under scope about 11%. As found in Section 3.3.1, a decrease of positioning from 20% to 10% results in an average decrease of 5% in total emissions. The positioning distance depends on the load location and the location of the transport vehicle just before loading.

Cargill cannot influence the positioning distance directly. However by choosing a LSP close to the load location the positioning distance can be influenced. The practicability of this reduction option is expected to be low, since the choice of a LSP is influenced by many other more important factors, such as transport price, quality and reliability.

### 4.2.1.5 Outsourcing transportation

Outsourcing transportation activities to logistic service providers has the benefit that LSPs have a lot of customers and a larger fleet of vehicles. This enables them to plan transport more efficiently, e.g. they can find return loads more often or combine shipments of different companies. In this way the number of empty returns can be reduced or the load factor can be increased. ETP has already contracted out the main part of their transport activities.
4.2.1.6 **Carbon efficient vehicle routing**

Carbon efficient vehicle routing implies that carbon is taken into account as a decision variable next to lead times, service levels and transport cost when deciding on vehicle routings. Gabali (2009) established a framework for modeling and optimizing carbon emissions in a time-dependent Vehicle Routing Problem. Decrease in distance and decrease in emission factors, due to efficient driving speed, result in lower emissions. In this project this will have a minor effect, since the main part of the transport is based on direct delivery from factory to one customer (single destination). Furthermore, vehicle routing is under control of LSPs.

4.2.1.7 **Energy-efficient driving**

Fuel consumption can be reduced by ecological driving, which includes measures such as avoiding harsh acceleration and braking, using higher gears, observing speed limits and keeping the vehicle regularly serviced with correct tire pressures (SDC, 2006). SDC (2006) estimates an average reduction of fuel use of 8.5%, however this number applies to personal car use. Since the transport under scope is contracted out, this can only be influenced indirectly, e.g. via ‘Green driving’ contracts for LSPs.

4.2.2 **Vehicle shift**

4.2.2.1 **Modal shift**

Every mode of transport has a different fuel consumption and leads, accordingly, to different carbon emissions. In order to compare transport modes the carbon dioxide emissions of all modes are expressed using the same notation, gram CO$_2$ per tonne kilometer (g/tonnekm), which is the amount of CO$_2$ that is emitted for moving one tonne of cargo over a distance of one kilometer. Transport modes in order of increasing carbon intensiveness are (in general): water, rail, road and air transport. Shifting to another mode can decrease the carbon emissions, e.g. from road to water transport would generally lead to lower emissions. However, a modal shift might require the use of multiple transport modes, often referred to as intermodal transport. Intermodal transport uses rail or water transport as main transport mode and a truck to deliver the cargo at the departure terminal and pick it up at the arrival terminal for delivery to the final destination. Macharis and Bontekoning (2004) define intermodal freight transport as: “the combination of at least two modes of transport in a single transport chain, without a change of container for the goods, with most of the route travelled by rail, inland waterway or ocean-going vessel, and with the shortest possible initial and final journeys by road” (Figure 4-5). Chapman (2007) states that one of the most promising solutions for long distance freight transport is a modal shift from road to rail and water. In Figure 4-2 the current distribution over the modalities is shown based on tonnekm. Figure 4-4 provides the emission factor per modality. A wide range of intermodal LSPs exists, which provides sufficient alternatives to Cargill to choose from. The current modal split in combination with the differences in emission factors labels this option as high potential for the scope of this study.
4.2.2.2 Transport type shift

Not only switching to another mode can reduce emissions, using another type of transport within the same mode may be advantageous too, since this can influence the emission factor. In general it holds that transport types with larger capacity result in lower emission factors, assuming equal load factors. For road transport currently almost all transport is executed with trucks with a typically gross weight of 40 tonnes, with only a very limited number of exceptions. This implies that only minor savings are expected. For rail transport the choice between diesel and electrical train is often limited to the existing network, i.e. availability of electricity lines and the different providers operating on this network. Concerning water transport, it was found impossible to obtain data of the exact transport types with larger capacity used. Furthermore, Cargill could only influence these choices indirectly.

4.2.2.3 Use of double-deckers

An extra alternative is the use of double-deckers. This is especially useful for pallet goods, because double-deckers allow stacking of pallets on top of each other. Using this option for products for which volume is the limiting factor or combine heavy and light goods in one shipment increases the potential of this option to increase the load factor. However in this case we consider bulk liquid goods, which are weight limited, so this option is not relevant.

4.2.3 Technological innovation

4.2.3.1 Vehicle improvement

Carbon reduction can be achieved through other factors than capacity, e.g. through technological innovation. “Since 1980, fuel efficiency in the road freight transport sector has been increased by 20% by increasing engine performance and improving vehicle design. A further 15 – 20% can be achieved by implementing initiatives to ensure vehicles are operated in a fuel efficient manner” (Chapman,
2007). An example of vehicle improvement is the Euro classification. For trucks this has significant impact on other GHG emissions, the effect on CO\textsubscript{2} is limited to the decreases in fuel consumption (CE Delft, 2008). Cargill could design contract requirements for LSPs concerning the Euro type used. A practical downside is that strict requirements cut a large share of the available capacity.

4.2.3.2 Use of alternative fuels
Using low carbon fuels instead of high carbon fuels has both a direct and indirect effect. Not only using these low carbon fuels leads to a reduction of carbon emissions, but also to a reduction of emissions related to the transportation of these fuels. Most high carbon fuels are solid, which have to be transported by rail, sea or road. On the other hand the majority of low carbon fuels are liquid or gaseous, for which pipeline transport can be used.

Another option is the use of bio fuels; however opinions differ about the indirect effects caused by the increased demand for agricultural land. Converting forests and grasslands into agricultural land causes emission of the carbon content from the soil. Since there is no clear view about the magnitude of these indirect emissions it is not certain to state that bio fuels will reduce the amount of CO\textsubscript{2} (JRC, 2008). Further research is necessary to judge the applicability and effect of this option on a large scale. Furthermore, most vehicles are not developed far enough to apply this on a large scale. Moreover, fuel usage cannot be influenced directly by Cargill.

4.2.4 Supply chain (re)design
Parameters that have an impact on the supply chain structure and connections are expected to have a large impact on the emissions for Cargill and the transport within scope. Where other options attempt to reduce the emissions within a given structure, redesigning the supply chain goes one step further by reducing the need of transport. This is a more radical approach.

4.2.4.1 Inventory management
Inventory management should focus on determining the amount and location of every raw material, sub-assembly and final assembly, such that slower (less emitting) modes of transport can be used. In case of tight customer lead times it may still be possible to use a slower (less emitting) mode of transport for replenishment as long as inventory is kept close enough to the customer. Decisions on inventory management are obviously influenced by a tradeoff between inventory holding costs and transport and emissions costs.

4.2.4.2 Network redesign
Where inventory management focuses on the amount of products on current locations, network redesign focuses on adapting the supply chain structure, by creating or moving stock and production facilities, in order to put inventory closer to the customer. In this way transport distances are decreased. A possibility for bulk products is to use storage facilities which can be replenished on a low frequency with a bulk vessel, which covers the largest distance while other modes can be used for the short-distance transport to the customer.

4.2.4.3 Distribution center (DC) – customer assignment
Distribution center (DC) – customer assignment determines which DC(s) will serve which customer(s). Note that a DC in this case is a production plant since we are dealing with direct delivery from plant to customer. Including the green aspect here, these assignments should be designed such that the transport distances from the plant to the DCs and from the DCs to the customer are minimized.
4.2.4.4  **Plant – product assignment**

Determining which plant(s) will manufacture which products is a so-called sourcing decision. The general idea is similar to DC – customer assignment.

Although the supply chain redesign options are expected to have high potential, in accordance with Cargill the chosen focus of the project is transport, not supply chain redesign. The main reasons are that supply chain redesign options require high investments and decisions on these decision variables are influenced by many other important factors than carbon dioxide emissions. However, inventory management options which do not change the structure can be taken into account, as is explained in more detail in Chapter 7.

4.3  **Overview of business opportunities**

Table 4-1 summarizes the result of the carbon reduction opportunity assessment. As mentioned, in accordance with Cargill it is decided to exclude all supply chain design option except from inventory management. Several options, e.g. changing driving behavior and technological vehicle improvement, could be influenced via contract requirements for LSPs, however no detailed analysis of these options is given in this study. The further focus of this project will be on payload increase (Chapter 5), modal shift (Chapter 6) and inventory management (Chapter 7).

<table>
<thead>
<tr>
<th>Carbon reduction opportunity</th>
<th>Expected Impact</th>
<th>Practicability</th>
<th>Selected</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload increase</td>
<td>High</td>
<td>High</td>
<td>Y</td>
<td>Large share of medium and low payloads</td>
</tr>
<tr>
<td>Transport sharing / order consolidation</td>
<td>Low</td>
<td>Low</td>
<td>N</td>
<td>Candidate lanes represent small fraction of total emissions, sharing is limited by product characteristics / equipment requirements</td>
</tr>
<tr>
<td>Reducing empty returns</td>
<td>High</td>
<td>Low</td>
<td>N</td>
<td>Empty return emissions are assigned to LSPs, out of scope</td>
</tr>
<tr>
<td>Reducing positioning distance</td>
<td>Medium</td>
<td>Low</td>
<td>N</td>
<td>Cargill cannot affect directly</td>
</tr>
<tr>
<td>Outsourcing of transport</td>
<td>Low</td>
<td>High</td>
<td>N</td>
<td>Practically all transport is contracted out already</td>
</tr>
<tr>
<td>Carbon efficient vehicle routings</td>
<td>Low</td>
<td>Low</td>
<td>N</td>
<td>Mainly single destination lanes</td>
</tr>
<tr>
<td>Changing driving behavior</td>
<td>Medium</td>
<td>Medium</td>
<td>N</td>
<td>Cargill cannot affect directly</td>
</tr>
<tr>
<td>Modal shift</td>
<td>High</td>
<td>High</td>
<td>Y</td>
<td>Currently mainly road transport</td>
</tr>
<tr>
<td>Transport type shift</td>
<td>Low</td>
<td>Low</td>
<td>N</td>
<td>Either minor savings or limited to services offered</td>
</tr>
<tr>
<td>Use of double-deckers</td>
<td>Low</td>
<td>Low</td>
<td>N</td>
<td>Not applicable to bulk liquid</td>
</tr>
<tr>
<td>Technological vehicle improvement</td>
<td>Medium</td>
<td>Medium</td>
<td>N</td>
<td>Cargill cannot affect directly, strict requirements decrease available capacity</td>
</tr>
<tr>
<td>Use of alternative fuels</td>
<td>?</td>
<td>Low</td>
<td>N</td>
<td>Unclear effect on large scale, not developed far enough, Cargill cannot affect directly</td>
</tr>
<tr>
<td>Inventory management</td>
<td>High</td>
<td>High</td>
<td>Y</td>
<td>Allows payload increase and cleaner transport modes for replenishment</td>
</tr>
<tr>
<td>Network redesign</td>
<td>High</td>
<td>High</td>
<td>N</td>
<td>Reduces the transport distances, out of scope</td>
</tr>
<tr>
<td>Plant – customer assignment</td>
<td>High</td>
<td>High</td>
<td>N</td>
<td>Reduces the transport distances, out of scope</td>
</tr>
<tr>
<td>Plant – product assignment</td>
<td>High</td>
<td>High</td>
<td>N</td>
<td>Reduces the transport distances, out of scope</td>
</tr>
</tbody>
</table>

*Table 4-1: overview of carbon emission reduction opportunity assessment*
5 Payload increase

Payload is defined as the absolute weight loaded in a vehicle. Payload increase affects the load factor in terms of weight. Higher load factors result in higher emissions per trip, but fewer trips are required. In general this will result in a lower total emission, since the emission per tonnekm decreases. This is illustrated in Figure 5-1.

![Figure 5-1: emission factors for different load factors for road transport for a tractor with semi-trailer (CRSC, 2009)](image)

For rail and water transport, increasing the payload has only a minor effect on the emissions, since Cargill’s contribution to the total gross weight of a train or boat is negligible. If allocation for rail and water is based upon weight, the payload per shipment does not influence the total emissions, because the total weight shipped remains the same. However, in case of allocation based on TEU or lane meters, the emissions resulting from rail and water decrease as well. This is due to a reduction in number of shipments, which results in a reduction in total number of TEU or total lane meters used for the transport.

How much the payload can increase depends on several restrictions, which are discussed in Section 5.1. Next, based upon these restrictions the calculation of maximum payload is established. In Section 5.3 the calculation is applied to Cargill and the results are discussed.

5.1 Payload restrictions

5.1.1 Legal restrictions

The maximum payload is restricted by law. The law is rather complicated when it comes to the maximum payload in the different countries of the EU. On the one hand, there are some general European directives; on the other hand, every country has its own regulations and interpretation of the European principles.

For road transport every country has its own legislation regarding the maximum gross weight allowed on its road network. An overview of the maximum allowable gross weight per country is given in Appendix 10. With respect to intermodal transport, the road leg is the restricting leg for payload. For those countries where the maximum allowable gross weight is less than 44 tonnes, the EU adopted a directive. According to this directive (EU, 1992) 44 tons is allowed as maximum gross weight for intermodal movements, provided that the vehicle uses the road on the initial and / or final leg of the journey and, on the other leg, rail, inland waterway or maritime services, where this section exceeds 100 km as the crow flies and provided that:

- for maritime transport and inland navigation: the loading and unloading location is located within a radius of 150 km as the crow flies from the maritime or inland ports;
- for rail transport: the closest appropriate rail terminal to the origin and the closest appropriate rail terminal to the destination are used.
Also several non-EU countries have adopted this directive, e.g. Turkey. Where the directive for maritime transport and inland navigation is clearly defined, the rail directive leaves room for interpretation. Although some guidelines have been put up for ‘closest appropriate terminal’, it is not clearly defined. The Royal Belgian Road Haulage and Logistics Providers Federation shows that many exceptions exist on these rules FEBETRA (2009). One general exception is that some countries only allow a higher weight for 40’ ISO containers, e.g. Bulgaria, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia and Portugal. Furthermore, France has exceptions on the 44 tonne rule, which only allows 44 tonnes in several regions or requires that French loading or unloading terminals are used. Here 44 tonnes is assumed to be always valid.

5.1.2 Equipment restrictions
In case weight is the limiting factor for payload, the most important equipment restriction is the weight of the equipment. Subtracting the weight of the equipment from the maximum grossed weight allowed for a truck results in the maximum allowable payload. The weight of the equipment depends on whether a light or heavy truck is used, whether it is a tank trailer or tank container, included additional equipment (e.g. unloading equipment), etc. FEBETRA (2009) and Appendix 10 provide the detailed (mainly technical) requirements for weights and dimensions of road transport vehicles. In all countries the maximum gross weight is subject to the correct spread of the cargo and weight over the complete combination. These are the so called individual ‘axel weights’. Furthermore, distances between the individual axels are specified and differ per country.

5.1.3 Customer restrictions
The maximum amount of goods a customer can receive depends on the available storage capacity of the customer and further restricts the payload. However, not only the storage capacity itself is a limitation, but also product characteristics (like food quality and perishability) and the demand the customer faces influence the possibilities of payload increase.

5.2 Maximum payload calculation
To be able to calculate the potential of payload increase on each lane, a calculation is made of the maximum payload allowed per routing. Several assumptions underlie this calculation:

- All transport is weight-limited. This holds for the project under scope.
- In case of intermodal transport the road leg is the limiting factor for payload, this is perceived to be an adequate assumption in practice.
- LSPs comply with all the technical requirements, such that the maximum legal allowable payload can be reached.
- Since the intermodal directive for intermodal rail transport is not clearly defined it is assumed that a gross weight of 44 tonnes is always allowed in the countries where this rule is valid, independent of the distances to the loading and from the unloading terminal.
- Exceptions on payload rules of different regions within a country are not taken into account. Per country the rules which apply to the largest area are chosen as general rules for that country.

Subtracting the weight of the equipment from the maximum grossed weight allowed for a truck results in the maximum allowable payload, resulting in the following formula:

\[ PL = GW - EW \]

where

- \( PL \) = Max. payload
- \( GW \) = Max. gross weight
- \( EW \) = Total weight of transport equipment.
EW is constant, GW depends on the modality used and the countries crossed, as described in Section 5.1.1. Next, formulas to calculate the maximum gross weight allowed on a lane are described per modality. Each country \( j \) has its country-specific maximum gross weight, defined as \( GW_{j,\text{road}} \). If a lane is intermodal (IM), the maximum gross weight in country \( j \) equals the maximum of the country-specific and European (EU) ‘44 tonnes’ rule. For non-European countries the maximum gross weight is only determined by the country-specific maximum gross weight. In formulas:

For \( j \notin EU \):
\[
GW_{j,\text{IM}} = GW_{j,\text{road}}
\]

For \( j \in EU \):
\[
GW_{j,\text{IM}} = \max(GW_{j,\text{road}}, 44)
\]

Assume that on a lane \( i \) the countries crossed via road are \( \{1, 2 \ldots, j\} \). For road transport the maximum gross weight is simply limited by the maximum gross weight of all countries crossed, since there is only one road leg. In other words, the maximum gross weight on a road lane is the minimum of maximum allowable gross weights of all countries crossed \( \{1, 2 \ldots, j\} \). This results in:

\[
GW(\text{road})_i = \min\{GW_{1,\text{road}}, GW_{2,\text{road}}, \ldots, GW_{j,\text{road}}\}
\]

The same formula can be applied to lanes, which use multiple modalities, but are not intermodal, because it is assumed that \( \{1, 2 \ldots, j\} \) are the countries crossed by road. In this case no other rules apply than the country-specific rules. An example is when a ferry is used (Road_1 – Ferry – Road_2).

For intermodal transport (IM), a distinction is made between intermodal rail and intermodal water transport, because separate rules exist for the European ‘44 tonnes’ rule, as defined in Section 5.1.1. The ‘44 tonnes’ rule for IM rail transport is subject to the precondition that the total rail distance as the crow flies, here defined as \( D_{\text{rail}} \), should exceed 100 km. This implies that if the rail distance is shorter than 100 km, only the country-specific rules apply. This results in the following formulas:

For \( D_{\text{rail}} \leq 100 \):
\[
GW(\text{rail})_i = \min\{GW_{1,\text{road}}, GW_{2,\text{road}}, \ldots, GW_{j,\text{road}}\}
\]

For \( D_{\text{rail}} > 100 \):
\[
GW(\text{rail})_i = \min\{GW_{1,\text{IM}}, GW_{2,\text{IM}}, \ldots, GW_{j,\text{IM}}\}
\]

IM water transport faces the same precondition with respect to the distance of the water leg, denoted as \( D_{\text{water}} \). However, intermodal water transport has an additional restriction for the EU rules that each of the road distances of the pre- and post-carriage, here defined as respectively \( D_{\text{pre}} \) and \( D_{\text{post}} \), each do not exceed 150 km as the crow flies. The two preconditions combined results in:

For \( D_{\text{water}} \leq 100 \cup \min(D_{\text{pre}}, D_{\text{post}}) > 150 \):
\[
GW(\text{water})_i = \min\{GW_{1,\text{road}}, GW_{2,\text{road}}, \ldots, GW_{j,\text{road}}\}
\]

For \( D_{\text{water}} > 100 \cap \max(D_{\text{pre}}, D_{\text{post}}) \leq 150 \):
\[
GW(\text{water})_i = \min\{GW_{1,\text{IM}}, GW_{2,\text{IM}}, \ldots, GW_{j,\text{IM}}\}
\]

A country table has been set up, which provides the countries crossed if one goes from an arbitrary country \( A \) to country \( B \) by road. For every country a large central city has been taken as reference. In case of several countries where the population is clearly concentrated in the south, e.g. Sweden, Norway and Finland, a central southern city has been taken. The shortest distance is taken as routing using Google Maps (2009). Of course it is possible that in some cases different countries are crossed.
in reality, because of the position of origin and destination in the country, or different routings are taken. For distances as the crow flies (used for checking intermodal conditions) the great circle distance (GCD) is used in the method:

\[
D = 2 \cdot r \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\Delta lat}{2}\right) + \cos(lat_1) \cdot \cos(lat_2) \cdot \sin^2\left(\frac{\Delta lon}{2}\right)}\right)
\]

where

- \(D\) Distance in kilometers
- \(r\) Radius of the earth (= 6371 km)
- \(lat_1\) Latitude of origin
- \(lat_2\) Latitude of destination
- \(\Delta lat\) Difference between latitude of origin and destination
- \(\Delta lon\) Difference between longitude of origin and destination.

TERRA contains an overview of geo coordinates per postal code, which have been used for calculations. A macro is written in Excel which incorporates the calculations and country table as described.

5.3 Application to Cargill: scenario analysis
The maximum payload calculation is applied to Cargill and different scenarios are compared to get insights in the effect of payload increase on carbon emissions and costs. The specific assumptions made in the calculations and the scenarios are listed below.

- For the road transport under scope the most right column of Appendix 10 is used for the maximum allowable gross weight.
- After discussing the issue of average weight of equipment with several LSPs it is found that for the transport under scope a widely accepted rule of thumb is an average of 15 tonnes for tank trailer (road transport) and 16 tonnes for tank container transport (intermodal). These numbers are used for the calculations.
- In case of intermodal transport it is assumed that either 20’ ISO or 30’ ISO containers are used, which is in line with reality for the transport under scope. This implies that no extra payload is allowed for countries where the 44 tonnes rule only applies to 40’ ISO containers.
- The calculation does not take into account limitations of multiple product transport sharing for one customer, since no data about transport sharing is available.
- Customer restrictions of payload increase, as described in Section 5.1.3, are not included in the calculation. It is not realistic that customer with very low demand will order maximum payloads, due to e.g. storage limitations or perishability of the product. To exclude these customers, only lanes which have an annual volume of at least 650 tonnes are taken into account. 650 tonnes is equivalent to receiving a replenishment of 25 tonnes once every two weeks. These lanes represent 70% of the current total emissions.

Scenario 1: current situation (baseline)
The current situation assumes that on each shipment the average historical payload is used. Average historical payload implies that aggregate payload data is used for the calculations, since no data is available of exact payloads per shipment. This scenario serves as a baseline for comparison.

Scenario 2: maximum payload on all lanes
Combining the annual weight and maximum payload, the minimum number of shipments needed is taken and used as a basis for the calculation. This scenario results in the maximum emission saving possible.
Scenario 3: partial payload increase
In practice it is not always possible to increase the payload up to the maximum allowable level, e.g. due to customer restrictions as described in Section 5.1.3. This scenario is used to also get insight in the savings when the payload is only partially increased. Different percentage levels of the maximum allowable payload are used. The levels used for calculation are 50% and 75%.

Scenario 4: general 44 tonnes law
This is an extension of scenario 2 and the idea is based upon a study of the European Commission (2008) to adaption of rules on weight and dimension allowed for heavy commercial vehicles. It describes a situation in which a general law is implemented in Europe, which states that for road transport as well as intermodal transport always a gross weight up to 44 tonnes is allowed, independent of the country-specific limitations.

Scenario 5: different equipment weight
This is an extension of scenario 2. A general assumption is made about the weight of the equipment of 15 and 16 tonnes, respectively for tank trailers and tank containers. If lighter equipment is used and the allowable gross weight remains the same, the maximum allowable payload is increased. Significant savings are expected by using light-weight vehicles (IFEU, 2004). It is also interesting to investigate the effect of LSPs using (too) heavy vehicles, which limits the payload. This is an issue recently seen in practice in bulk liquid transport of ETP, where it has happened that the requested payload could not be loaded due to use of too heavy equipment. In this scenario both one and two tonne lighter, and one and two tonne heavier equipment are compared to the baseline level (i.e. current assumptions regarding equipment weight).

5.3.1 Results
For each scenario the effect on carbon emissions is calculated using TERRA. The savings in number of shipments is calculated based on the payload and the annual volume. Furthermore, the effect on transport costs is calculated, since on every lane the (historical) transport costs per shipment are known. ETP has agreements with LSPs based on lump sum prices, which means that independent of the payload per shipment (within the legal limits) a fixed price is charged. It is therefore up to Cargill to optimize their transport within the legal limits. This implies that each trip saved, automatically results in savings in transport costs as well. It is assumed that an increased payload has only a minor effect on the lead time resulting from increased loading and unloading time and possibly slower acceleration of a truck. Since we are talking about hours or even minutes on lead times of days, it is assumed that this effect is negligible.

At the moment companies are not charged for their emissions resulting from outsourced transport. However it is likely that costs will be linked to carbon emissions in the future. Besides transport cost, a carbon cost is calculated, estimated from the carbon price per allowance of one tonne. Although the carbon market has been far from stable, mainly due to implementation issues, a carbon price of 20 Euro per tonne seems reasonable (Appendix 11). Section 5.3.1.1 provides the results of the total selection of lanes. Next, individual lane results are given in Section 5.3.1.2.

5.3.1.1 Aggregate result
Table 5-1 and Figure 5-2 give an overview of the total results of the scenario analysis of the selected lanes. The cost shown in shown in Figure 5-2 is transport cost only. The total numbers and savings mentioned refer to the selected lanes only.
Table 5-1: aggregate results of payload increase scenario analysis

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Emission saving (%)</th>
<th>Emission saving (tonne)</th>
<th># trips*</th>
<th>Trips saving (%)</th>
<th>Transport costs* (EUR)</th>
<th>Cost saving (%)</th>
<th>Carbon cost (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (baseline)</td>
<td>5,113</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>102,251</td>
</tr>
<tr>
<td>2 (max)</td>
<td>4,073</td>
<td>20.3</td>
<td>31.9</td>
<td>27.7</td>
<td>81,463</td>
<td>3.2</td>
<td>99,855</td>
</tr>
<tr>
<td>3 (50%)</td>
<td>4,993</td>
<td>2.3</td>
<td>5.2</td>
<td>3.2</td>
<td>99,855</td>
<td>3.2</td>
<td>93,415</td>
</tr>
<tr>
<td>3 (75%)</td>
<td>4,671</td>
<td>8.6</td>
<td>16.5</td>
<td>12.1</td>
<td>93,415</td>
<td>12.1</td>
<td>81,463</td>
</tr>
<tr>
<td>2 (baseline)</td>
<td>4,073</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>81,463</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (44 tonnes)</td>
<td>3,739</td>
<td>8.2</td>
<td>9.8</td>
<td>11.5</td>
<td>74,778</td>
<td>7</td>
<td>77,563</td>
</tr>
<tr>
<td>5 (-2 tonne)</td>
<td>3,878</td>
<td>4.8</td>
<td>6.8</td>
<td>7</td>
<td>77,563</td>
<td>7</td>
<td>79,536</td>
</tr>
<tr>
<td>5 (-1 tonne)</td>
<td>3,977</td>
<td>2.4</td>
<td>3.4</td>
<td>3.5</td>
<td>79,536</td>
<td>3.5</td>
<td>83,910</td>
</tr>
<tr>
<td>5 (+1 tonne)</td>
<td>4,195</td>
<td>-3.0</td>
<td>-4.2</td>
<td>-4.3</td>
<td>83,910</td>
<td>-4.3</td>
<td>86,320</td>
</tr>
<tr>
<td>5 (+2 tonne)</td>
<td>4,316</td>
<td>-6.0</td>
<td>-8.4</td>
<td>-8.6</td>
<td>86,320</td>
<td>-8.6</td>
<td></td>
</tr>
</tbody>
</table>

* confidential

Payload increase can result in large savings on emissions and costs. The increased payload causes a decrease in number of trips, which is related to emissions and transport costs. The % saving in number of trips is larger than % saving of emissions, because the average weight per trip increases and consequently the emissions per trip decrease. The savings in trips go hand in hand with the savings in transport costs. Per lane this is a linear relationship, however in the total picture this depends on the price per trip reduced.

Scenario 2 results in an emission saving of 20% (1,040 tonnes) and a transport cost saving of more than 27%. This corresponds with an emission reduction of more than 14% compared to the total dataset of bulk liquid CC lanes. These are the maximum savings Cargill could realize on the selected lanes. Although much smaller, also partial payload increase results in significant savings. With respect to scenario 3 one would expect that the payload increase for lower weight is more significant than for higher weight, as we will see in the individual results (Section 5.3.1.2). However in this aggregate analysis only a small fraction of the lanes are currently below 50%, such that the total saving is relatively small compared to the 75% and 100% level. Scenario 4 leads to 8% emission savings and 11.5% savings on transport costs. As mentioned by McKinnon (2000) a possible
downside of scenario 4 is that it would possibly divert freight transport from cleaner modes, because it removes the incentive of allowed payload increase when using intermodal transport (Section 5.1.1). Furthermore, this rule could lead to safety issues, due to e.g. increased braking distances for higher weights or destruction of roads which cannot handle such heavy vehicles. The total effect of the equipment weight differences is quite large on carbon emissions, number of trips and transport costs, as shown in the results of scenario 5. Although it concerns small deviations of one and two tonnes, emission savings up to almost 5% and costs savings up to 7% can be generated (for two tonnes weight decrease). This demonstrates that it is really worthwhile for Cargill to stimulate LSPs to use lightweight vehicles.

From Table 5-1 it follows that the carbon costs are about 1% of the total costs. The carbon price should raise up to €90,- per tonne to represent about 5% of the total cost. It is not expected that the carbon price will develop as such in the near future. It is concluded that the carbon price as such does not give a significant incentive for payload increase.

5.3.1.2 Individual results

To illustrate the effect per lane, lane BL-0265 is chosen as illustration. This lane has a high volume, currently low payload, but is only short-distance. The results are shown in Figure 5-3.

![Figure 5-3: payload increase scenario analysis, results of lane BL-0265](image)

Similar results are found as in the aggregate analysis. Here, it can be seen that the savings in trips relate linearly to the transport costs. For lanes with very low payload, the first increase results in the highest savings in emissions, as expected. In this case scenario 2 and 4 are equal, because currently already >44 tonnes is allowed in The Netherlands and Belgium.

The same analysis can be executed for any arbitrary lane. For each lane the savings when applying maximum payload can be calculated by:

\[
UB_{i,\text{saving}} = TE_{i,\text{current}} - TE_{i,\text{MP}}
\]

\[
\%UB_{i,\text{saving}} = \frac{UB_{i,\text{saving}}}{TE_{i,\text{current}}} \cdot 100
\]
where

\( UB_{i,\text{saving}} \)  
Upper bound of absolute emission saving on lane \( i \)

\( \%UB_{i,\text{saving}} \)  
Upper bound of \% emission saving on lane \( i \)

\( TE_{i,\text{current}} \)  
Current total emissions on lane \( i \)

\( TE_{i,\text{MP}} \)  
Total emissions for maximum payload on lane \( i \).

The upper bound of the emission savings can be used as selection criteria of transport lanes for payload increase. It is found in this chapter that payload increase is an important emission reduction option and that high savings are to be expected. The practical limitations of payload increase should be investigated further. These limitations and recommendations regarding implementation of payload increase are discussed in Chapter 9.
6 Modal shift

The current modal split is such that about 95% of the lanes, representing about 90% of the total tonne kilometers of the BU Cocoa & Chocolate is road transport, as we have seen in Chapter 4. First, a methodology is designed to select lanes with high potential for a modal shift. In Section 6.2, the method is applied to CC transport to select lanes for a modal shift and investigate the effects on carbon emissions, cost and lead time. A second application of the method is done in Section 6.3, where the efficiency of the existing intermodal lanes is assessed. In Section 6.4 a savings index is designed, which can be used to make a quick selection of lanes on which to apply the modal shift identification method. This chapter ends with a discussion of additional insights of intermodal transport.

6.1 Modal shift lane identification method

Reviewing the CRSC methodology tells us that many parameters influence the carbon emissions in transport. Our method attempts to take into account the most important parameters. The focus of our method is on shifting from road to intermodal transport (IM). Note that air transport is out of scope for two reasons: air is not a suitable mode for bulk transport (the transport under scope does not contain any air transport) and shifting from road to air transport will not lead to emission reductions.

One of the most important parameters for emission calculation is the distance per modality, which is determined by the routing. The real routing when shifting from road to IM cannot be known in advance, since it depends on the routing offered by the LSP. However, the most carbon-efficient routing can be determined, i.e. the lower bound of the intermodal emissions can be calculated, leading to the upper bound of the emission reduction when shifting from road to IM. In the ideal situation, for an arbitrary road lane the calculation of the upper bound of emission savings is done by complete enumeration. Let $EM_{road}$ denote the current road emissions, $EM_{IM,i,j}$ denotes the intermodal emissions using modality $i$ and routing $j$ and $UB_{savings}$ is the upper bound of emission savings. Complete enumerations then results in:

1) Compute $EM_{road}$
2) Compute $EM_{IM,i,j}$ for all combinations of $i$ and $j$
3) $UB_{savings} = EM_{road} - \min(EM_{IM,i,j})$

Using this ideal approach requires a complete overview of intermodal terminals. This is discussed in Section 6.1.1. Complete enumeration is not seen as a suitable and efficient approach in combination with TERRA. Therefore, in Section 6.1.2 our approach is described to limit the number of calculations required in a smart way. In Section 6.1.2.4 the limitations of the method are discussed.

6.1.1 Terminal data

In order to find a complete overview of intermodal freight terminals, a large number of organisations have been contacted (Appendix 12 provides an overview). It is found that there is no single complete overview of intermodal freight terminals available (either not available or not shared), however a lot of initiatives are running and relatively complete overviews exist.

The decision which overview to use is based on the completeness and spread of the terminals over Europe and the amount of work needed to extract the location data.

- **Rail transport**: UIRR (2009) has the best completeness and spread and the terminal data has been shared by the organization. This dataset contains 251 terminals spread all over Europe.
- **Short-sea transport**: ESPO (2009) has the best coverage. However, the location data is not shared in a list, but has to be extracted manually from a map. TERRA’s dataset contains 116 terminals, which are based on Water Distance (2009). A visualization of short-sea terminals in ESPO and TERRA is provided in Appendix 13. Because TERRA consists of a list with less harbours, but has a similar spread and all the data is available, this list is chosen.
• *Inland waterways*: no complete list has been found and therefore inland waterways are excluded from the methodology.

### 6.1.2 Intermodal emission calculations

A simplified approach is designed to limit the number of calculations. The first simplification is that per modality a standard transport type is assumed to be used:

- **Road**: a standard truck with a typical gross weight of 40 tonnes, assuming 85% highway, 10% rural, 5% urban transport.
- **Rail**: a standard train of 1,000 tonnes with an average electrical / diesel split of 76.57% (average for Cargill bulk liquid) and an average load factor of 72% (assumption for bulk).
- **Short-sea**: a standard bulk water type Feeder with a capacity of 1,100 TEU and an average load factor of 80%.

To make a fair comparison both in case of road and IM transport the maximum allowable payload is used, based on the maximum payload calculation constructed in Chapter 5. This implies that:

- the emission reduction calculated is derived from modality shift only.
- the payload increase allowed if using intermodal transport (in general 4 tonnes extra gross weight) is incorporated in the analysis
- country differences with respect to payload increase for intermodal transport is incorporated

It is assumed that intermodal transport consists of three legs, one pre-carriage and one post-carriage via road and, in between, one rail or water leg. Furthermore, it is assumed that there is a connection between each pair of terminals in the terminal list. For emission calculation the real distance travelled is important. For road distance (only to loading and from unloading terminal) and water distances *TERRA’s* distance tables are used, complemented with some manual calculations. For rail, *Deutsche Bahn* (2009) is used. Next, a separate approach is taken for IM Rail and IM Short-sea due to differences in the network.

#### 6.1.2.1 IM Rail terminal selection

Of the 251 terminals, 17 terminal locations do not occur in the road distance tables. This has no large influence for this scope, since these terminals are either in countries, where CC has no origin or destination or where sufficient other terminals are located. These terminals are deleted from the list.

Since the emission factor of rail is on average significantly lower than the emission factor of road, the routing which minimizes the road distances as much as possible is in general the most carbon-efficient routing. Hence, the closest terminal from the origin and the closest terminal from destination should be chosen. In reality small deviations can occur here, if the closest terminal is in the opposite direction, however no large deviations are expected. A macro, which uses the distance tables of the *TERRA* tool, is written in Excel to find the terminals closest to the origin and destination. One of the most important parameters for rail is the electricity generation. Therefore it is important to know in which country the rail transport takes place. The exact distances per country have been looked up manually using *Deutsche Bahn* (2009). The advantage is that also the real rail network is taken into account, so real distances for the rail leg are used.

Of all the origins and destinations of the dataset of CC only two locations are not found in the distance tables. For these, the closest terminals have been chosen manually. Furthermore, three terminals were not found in *Deutsche Bahn* (2009). For these a close destination was chosen and only the country-specific distance has been changed, by taking the road distance from the border and multiply this by 1.2, which is the general assumption of *CRSC* (2009) regarding rail distances. For origins and destinations within the same country (except for Germany), *Deutsche Bahn* (2009) does not allow calculating rail distances. For these lanes also the road distance is taken from *Google Maps* (2009) and multiplied by 1.2.
6.1.2.2 IM Short-Sea terminal selection

For short-sea the closest terminals to origin and destination do not necessarily result in the most carbon efficient routing, because there is a large limitation of the network, i.e. short-sea transport can only use the waterways around the continent. So, selecting a terminal at the wrong side could result in very large distance increase. This is illustrated in Figure 6-1 with an example of a lane between The Netherlands and North-East of Spain. A large number of countries are surrounded by the sea on several sides, among others: Ireland, UK, Sweden, Denmark, (Northern) Germany, France, Spain, Italy and Greece. Therefore, this issue cannot be neglected.

![Figure 6-1: illustration of effect on routing of short-sea terminal choice](image)

Geographic coordinates are useful when incorporating directions. Here, geo coordinates from TERRA are used, complemented (mainly for UK) with GPS coordinates (2010). Combining geo coordinates with the method described for IM rail, the nearest terminal can be found in all four quadrants (North-West, North-East, South-West, South-East) for both the origin and destination. This results in four potential loading and four potential unloading terminals, resulting in 16 potential routings. The next step is to determine out of these 16 routings the most carbon-efficient one, i.e. the one resulting in the lowest total emissions. The total emissions are as follows (formulas are based upon CRSC (2009), as described in Appendix 1):

\[
\min J = \min (T_{\text{road}} + T_{\text{water}})
\]

where

- **TE** Total carbon dioxide emission
- **j** routing.

The road emissions are calculated as follows:

\[
T_{\text{road}} = F_{\text{CO}_2} \cdot D_{\text{road}} \cdot L_{\text{road}}
\]

where

- **FC** Fuel consumption at the specified load factor (litres per kilometre)
- **D** Distance (kilometres)
- **EF** Emission factor for fuel (kilogram carbon dioxide per litre fuel).

\[
F_{\text{CO}_2} = T_{\text{EF}} \cdot \left( F_{\text{empty}} + (F_{\text{full}} - F_{\text{empty}}) \cdot \frac{L_{\text{F}}}{100} \right)
\]
where

\[ FC_{\text{empty}} \] Fuel consumption of the empty vehicle (litres per kilometre)

\[ FC_{\text{full}} \] Fuel consumption of the fully loaded vehicle (litres per kilometre)

\[ LF \] Specified load factor

\[ TF \] Average terrain factor.

The equation for full consumption at a specified load factor, can be simplified, because a load factor of 100% is assumed, resulting in:

\[ FC_{LF} = TF \cdot FC_{\text{full}} \]

The average terrain factor in the European Union (1.05) and the fuel consumption of a standard truck are used. Incorporating the differences in fuel consumption between highway, rural and urban results in:

\[ FC_{\text{full}} = 1.05 \cdot (0.85 \cdot FC_{\text{full,highway}} + 0.10 \cdot FC_{\text{full,rural}} + 0.05 \cdot FC_{\text{full,urban}}) \]

= 1.05 \cdot (0.85 \cdot 0.36 + 0.10 \cdot 0.396 + 0.05 \cdot 0.504) = 0.3891 \text{l/km(DieselEurope)}

\[ TE_{\text{road}} = FC_{\text{full}} \cdot D \cdot EF_{CO_2} \]

= 0.389 \cdot D_{\text{road}} \cdot 2.624

= 1.022kg/km

The water emission for a standard feeder is calculated as follows:

\[ TE_{\text{water}} = FC \cdot D \cdot EF_{CO_2} \]

= 33 \cdot D \cdot 3.179

= 104.907kg/km

The total emissions of a feeder are allocated based on TEU using the assumption that the feeder can hold 1,100 TEU and has an average load factor of 80%. This results in:

\[ TE_{\text{water}} = \frac{104.907 \cdot TEU}{0.8 \cdot 1,100} = 0.1192kg/km/TEU \]

The total minimization then results in:

\[ \min TE = \min (1.022 \cdot D_{\text{road}} + 0.1192 \cdot D_{\text{water}} \cdot TEU) \]

This comparison excludes the factors positioning, cleaning, temperature control and vertical handling. It is assumed that these factors are more or less equal on all routings.

### 6.1.2.3 Emission savings calculation

For each modality the preferred routing is known if the terminals are determined. Knowing the routing allows us to calculate the emissions for each modality. The upper bound of the emission savings is obtained by choosing the modality with the minimum emissions. Note that we consider two modalities, intermodal rail and intermodal water. Let \( D \) denote distance. The approach is summarized as follows:
1) Compute $EM_{road}$
2) **Rail**: Determine routing $j$ for which $D_{road,j}$ is minimized
3) Compute $EM_{IM, rail,j}$ for $j$
4) **Short-sea**: Determine routing $j$ for which:
   \[ \min TE = \min(1.022 \cdot D_{road} + 0.1192 \cdot D_{water} \cdot TEU)_j \]
5) Compute $EM_{IM, water,j}$ for $j$
6) $UB_{savings} = EM_{road} - \min(EM_{IM, rail,j}, EM_{IM, short-sea,j})$

### 6.1.2.4 Limitations and recommendations

Here limitations of our method are briefly discussed. The emission savings can differ if other modal specific parameters apply than assumed. In case of Cargill it is expected that the modal specific parameters match to a large extent the reality. Furthermore, it is assumed that intermodal transport consists of three legs. In case of bulk liquid transport of Cargill this holds for 87% of the intermodal lanes. In reality it could be that a combination of more legs or modalities leads to lower emissions. Using complete overviews of terminals also leads to higher upper bounds of emission savings. The method does not include inland waterways, which would make it more complete. This implies that in reality the upper bound of emission savings could be even lower for lanes where inland waterways outperform intermodal rail and short-sea in terms of carbon emissions. If a list of inland freight harbours and a table with distances between these harbours is available, the method can be applied quite straightforward to inland waterway transport as well.

Due to problems with the distance tables of TERRA, as mentioned in Appendix 2, the real road distances can deviate from the distances in the distance tables. For the application of our method the absolute magnitude of these deviations is expected to be small, because the tables are only used for calculating short distances to and from terminals. Moreover, it is assumed that there is a connection between each pair of terminals in the terminal list. Although this represents reality to a large extent, frequencies of connections between terminals can be an important factor in practice when deciding on the intermodal routing, due to lead time.

### 6.2 Application to Cargill: modal shift options

First, current road lanes are analyzed for their potential of shifting to intermodal transport using the method described. Next, lanes are selected for further investigation via a mini-tender.

#### 6.2.1 Selection of potential lanes

Most lanes of CC bulk liquid are currently executed via road transport. Similar lanes executed by multiple LSPs are grouped together for the analysis. The emission reduction upper bounds are calculated for each lane based on the method described. A minor part of the lanes result in a (small) emission increase, these are typically very short distance lanes such that the total road distance of the pre- and post-carriage is larger than the current road distance from origin to destination. The lanes resulting in a positive emission reduction are ordered from highest to lowest emission reduction, resulting in Figure 6-2.

The maximum emission savings is 2,875 tonnes on selected lanes. Due to time restrictions further analysis is only conducted on a selection of the lanes. Pareto’s Principle, better known as the 80 / 20 rule, is applied here (Pareto, 1963). Here, 21.3 % of the total number of lanes accounts for 80% of the emission reduction and are selected for further investigation.
6.2.2 Mini Request For Quotation
The selected lanes are sent out to intermodal bulk liquid LSPs in a mini Request For Quotation (RFQ) to investigate the real emission savings and get insights on the effect of emission reduction on cost and lead time as well. Some of the selected lanes are high distance, but have a low annual volume. It will be difficult in practice to find a useful intermodal solution on these lanes, because if volume is low, LSPs do not want to invest in equipment (e.g. unloading equipment at a customer). Lanes with a smaller annual weight than 300 tonnes, which corresponds to one shipment per month of 25 tonnes, are deleted. Several other lanes have high annual volume but a short distance. In accordance with the Contract Freight Manager Bulk Liquid, lanes with shorter distance than 400 km are excluded as well. It is expected that relative small savings can be obtained on short distances, however it should be kept in mind that in reality saving can also occur on short distance, e.g. due to payload increase or very short pre- and post-carriage. A list of the selected lanes is given in Appendix 14.

Before sending out the selected lanes to the LSPs, data on annual volume is updated. Furthermore, extra data is collected from the BU CC about lane requirements (discharging equipment, cleaning and extra requirements), which is necessary for LSPs to provide a fair bid price. Furthermore, the current lead time on road is gathered. A limited amount of data per bid is requested to limit the amount of work for the LSPs and to increase the response rate, based on experience of the CRSC case studies. Train type (electrical or diesel) is requested, as it was found in Chapter 3 that this has a large effect on the calculations. After contacting several LSPs, it was found that they were unable to provide accurate data on gross weight of trains. Therefore it was decided to exclude this parameter. Chapter 3 describes the possible consequences of this. The data requested in this mini-RFQ is: price, offered payload, lead time, modality, train type (in case of IM rail) and routing (terminal locations). Furthermore, only one bid per lane is asked, to limit the amount of data. A bidder form is designed containing bid instructions, lane specifications and bid fields. Intermodal bulk liquid LSPs which have quoted intermodal on the last official bulk liquid RFQ are selected, excluding the ones which are currently out of business, merged with other LSPs or do not do any business with Cargill anymore. An announcement by phone was made to each of the 24 LSPs selected after which a guidance mail was sent including the bidder form. After two weeks a reminder was done by phone. The guidance mail, bidder form and list of LSPs are provided in Appendix 14.

6.2.2.1 Response
21 of the 24 invited LSPs have participated in the mini-RFQ. However one could not provide information about the routing, which is crucial for the emission calculation, and is therefore excluded. The effective response rate is 83.3%. Two LSPs are part of the same group and did a combined offer.
The three LSPs that could not participate mentioned unavailability of the required equipment as reason. Not all LSPs could indicate in case of rail transport, whether an electrical or diesel train would be used, for these the assumption of split is used, as made in Section 3.3.1.3. 5 lanes did not receive any bid. On average about 5.5 bids per lane are given. The spread of bids per lane, number of bids per LSP, number of bids per product type and number of bids per modality are visualized in Appendix 15.

Some interesting insights can be gained by analyzing the bid statistics. To get additional insights in the bidding outcome several LSPs have been interviewed by phone to comment on their bids.

- The majority of the bids is done on cocoa butter. Chocolate has a very limited amount of bids. Also the lanes without bids are either chocolate or cocoa liquor. According to the LSPs the main reason for this is that cocoa butter is a less sensitive product than cocoa liquor and especially less sensitive than chocolate. Furthermore, chocolate lanes have stricter requirements to temperature control and equipment used (e.g. sometimes multi-compartment). Moreover, chocolate has in general a smaller average volume and distance.
- 5 lanes have significantly more bids, which are all lanes from Netherlands to Italy. According to LSPs this is due to good railway connections. Furthermore, some Italian LSPs only offered prices on these lanes.
- The number of bids per LSP differs a lot. This is due to difference in size of the LSPs, the availability of intermodal equipment and the areas in which the destinations are.
- Clearly rail transport is the most offered modality. Some LSPs have mentioned that with rail one can reach most of the destinations, where short-sea is limited to locations close to the coast. Furthermore, in general rail transport requires shorter lead time than short-sea such that this is perceived to be more competitive. Barely any inland waterway bids are done. This has two reasons. First, because inland waterway is not included in the method for selecting the lanes. However quite some overlap is expected between interesting lanes for inland waterway and rail. Second, inland waterways are limited to the intermodal waterway network in North-West Europe, which limits the possibilities. While most CC plants are located in North-West Europe, excluding the short distance lanes has possibly decreased the potential lanes for inland waterway use.
- The split in electrical / diesel offered is about 74%, which is very close to the assumption made in CRSC (2009) and this project.

6.2.3 Scenario analysis

For every bid on every lane the emissions are calculated with TERRA. Next to emissions, transport cost and lead time are seen as the key parameters. Different scenarios are considered to get insight in the effect of modal shift on each of these key parameters. Distances are looked up manually for each bid, using for road Google Maps (2009), for rail Deutsche Bahn (2009) and for water Water Distance (2009). The lanes without any intermodal bids are excluded from the analysis. There are only two intermodal bids which result in a higher emission than road due to a pre and post-carriage distance of the same magnitude as the total distance between origin and destination.

Scenario 1: current situation (baseline)
The current situation is where all lanes are executed via road, serving as a baseline to compare with the other scenarios.

Scenario 2: maximum emissions savings
Per lane the bid is chosen which has the lowest intermodal emissions. This results in the maximum total emissions savings.

Scenario 3: maximum cost savings
Of all bids per lane the one resulting in the maximum cost savings is chosen in scenario 3. In case the road cost is lower than the minimum of intermodal options, road is selected. So, in this scenario only intermodal options are considered which result in a cost saving.
Scenario 4: maximum emissions saving with cost restriction (below today’s cost level)
Of all options the ones are chosen which lead to the maximum total emission savings, but have a similar or lower total cost than today’s cost level. On each lane the bid with the highest cost reduction per tonne carbon saving is selected. Next, the selected bids are ordered from highest to lowest cost saving per tonne carbon saving and accordingly included in this order.

Scenario 5: maximum emission saving with lead time restriction
The bids with the maximum emission savings are selected under a maximum lead time restriction. Any arbitrary level could be used for the analysis. Here four relevant levels are used for maximum lead time increase: 0%, 25%, 50% and 100%. Whether a longer lead time is suitable on a lane depends on the specific situation, e.g. agreed customer order lead time. Per lane the option resulting in the highest emission saving complying with the lead time restriction is chosen.

Scenario 6: non-dominated solution based on emission and cost savings
Where scenario 3 and 4 are extreme scenarios, scenario 6 focuses on the area between these scenarios. The ratio cost saving per tonne carbon saving is used for decision making here.

Scenario 7: multi-criteria solution of emission, cost and lead time
Where scenario 4, 5 and 6 incorporate only two parameters, scenario 7 describes a multi-criteria solution of three parameters: emission, cost and lead time. Here the emissions are minimized under a cost and lead time constraint. As an illustration a maximum cost increase per lane of 25% and a maximum lead time increase of 50% is chosen (i.e. the lead time may not be more than one and a half times the current lead time). However, any arbitrary combination of levels could be chosen for this scenario.

Another possibility is to use a weight factor for each of the parameters. Here, costs could be used as a weight factor. The market price of carbon (20 euro per tonne as estimated from Appendix 11) could be used to express the carbon emissions in cost. However, it seems almost impossible to attach an appropriate cost to lead time (in this study lead time costs are included in the transport price). Therefore no analysis has been executed regarding this option. In general it can be expected that increased cost for lead time favors road transport while increased cost for carbon promotes the use of intermodal transport.

Scenario 8: minimum total costs (transport cost and emission cost)
This scenario results in a minimization of the total cost, including transport cost and carbon emission costs. Both the market price of 20 euro per tonne and higher levels are taken into account to investigate which price level of carbon emissions will have an effect on the choice of modality. Scenario 3, which only takes into account transport costs serves as a baseline level.

6.2.3.1 Aggregate results
The result of the different scenarios is summarized in Table 6-1. Note that all numbers and percentages mentioned only refer to the lanes included in the mini-RFQ. Scenario 1 is used as a baseline. As in Chapter 5, a carbon price of 20 Euro is used to calculate the emission costs. Note that total costs in Figure 6-3, Figure 6-4 and Figure 6-5 are transport cost only.
Scenario | Emissions (tonne) | % emission reduction | Transport cost* (EUR) | % total cost change | % intermodal | Emission cost (EUR)  
---|---|---|---|---|---|---  
1 (baseline) | 3,343 | - | - | - | 100 | 66,860  
2 | 1,745 | 47.8 | 19.0 | 98.0 | 34,899  
3 | 2,412 | 27.9 | -9.5 | 52.9 | 48,232  
4 | 1,981 | 40.8 | -0.8 | 90.2 | 39,611  
5 (<= 0%) | 2,427 | 27.4 | 2.3 | 52.9 | 48,537  
5 (<= 25%) | 2,213 | 33.8 | 3.0 | 58.8 | 44,262  
5 (<= 50%) | 2,032 | 39.2 | 2.9 | 70.6 | 40,635  
5 (<= 100%) | 1,932 | 42.2 | 9.6 | 84.3 | 38,632  
6 | 2,230 | 33.3 | -8.1 | 70.6 | 44,591  
7 | 2,143 | 35.9 | -3.9 | 64.7 | 42,860  

* confidential

Table 6-1: overview of result of modal shift scenario analysis

![Figure 6-3: emission and cost comparison of modal shift scenario 1, 2 and 3.](image-url)

Figure 6-3 visualizes scenario 1, 2 and 3. Scenario 2 results in a maximum carbon emission saving of 1,598 tonnes (= 3,343 – 1,745), which is a reduction of almost 50%. This corresponds with a reduction of almost 22% of the current total emission level of bulk liquid CC transport. This emission reduction requires a cost increase of 19%, due to higher transport cost. In this case all lanes except one are executed intermodal. On the other hand, a maximum cost savings (scenario 3) of 9.5% can be obtained, while still changing more than half of the number of lanes to intermodal transport. At the same time this results in an emission reduction of 27.9%. Scenario 4 and 6 are visualized in Figure 6-4. Practically all emission savings (40.8% of 47.8% in total) can be done without an increase of total costs. All lanes can be changed except from five and still the total costs are lower than today’s total cost. As one can see in Figure 6-4, the cost increase is very steep from about -8%. This point is chosen for scenario 6. 5.4% more emission savings than scenario 3 can be achieved, while the cost decrease is only 1.4% lower and still 8.1% is saved on the cost.

One can find the results of scenario 5 compared to the baseline (scenario 1) and upper bound of carbon reduction (scenario 2) in Figure 6-5. The most important observation is that more than half of the carbon reduction can be done with a smaller or equal lead time. The less strict the lead time requirement, the more intermodal options are incorporated leading to lower carbon emissions.
Scenario 7 only serves as an illustration. As one can see, the emissions are higher than taking only a lead time restriction of 50% (scenario 5 (<= 50%)). However, due to the restriction on cost scenario 7 results in a cost saving of almost 4% instead of a cost increase of 2.9% (scenario 5 (<= 50%)). Scenario 8 results in Table 6-2.

It is concluded that carbon cost are relatively small compared to transport cost and therefore have a limited impact on choice of modality. Even unrealistic price increases of carbon have a limited impact. This is in line the conclusion from Hoen, et al. (2010), who state that “emission cost is only a small part of the total cost and introducing an emission cost for freight transport via a direct emission tax or a market mechanism such as cap and trade are not likely to result in significant changes in transport modes and hence will not result in a large reduction of emissions.”
<table>
<thead>
<tr>
<th>Carbon cost (EUR/tonne)</th>
<th>% intermodal</th>
<th>Emissions (tonne)</th>
<th>% emission reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (baseline)</td>
<td>52.9</td>
<td>2,412</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>54.9</td>
<td>2,403</td>
<td>0.37</td>
</tr>
<tr>
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<td>54.9</td>
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</tr>
<tr>
<td>100</td>
<td>56.9</td>
<td>2,281</td>
<td>5.43</td>
</tr>
<tr>
<td>120</td>
<td>56.9</td>
<td>2,281</td>
<td>5.43</td>
</tr>
<tr>
<td>140</td>
<td>58.8</td>
<td>2,238</td>
<td>7.21</td>
</tr>
</tbody>
</table>

Table 6-2: modal shift scenario 8

6.2.3.2 Individual results

In addition to an aggregate analysis, a lane per lane analysis is conducted in this section. Table 6-3 provides the different bids for lane BL-0334. All bids use modality intermodal rail. Assuming that the decision is taken on only three parameters (emissions, costs and lead time), options which score worse on all parameters than another option are dominated and can be deleted. Table 6-3 shows which options are dominated. No optimal solution (best score on three parameters) is found. To find the best option it depends on the value that is assigned by the decision maker to each of the parameters.

<table>
<thead>
<tr>
<th>Bidno.</th>
<th>Emissions (tonnes)</th>
<th>Transport cost* (EUR)</th>
<th>Lead time (hours)</th>
<th>Dominated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49</td>
<td>11</td>
<td>120</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>51</td>
<td>3</td>
<td>120</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>57</td>
<td>9</td>
<td>60</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>57</td>
<td>6</td>
<td>72</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>59</td>
<td>7</td>
<td>96</td>
<td>Y</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>2</td>
<td>96</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>64</td>
<td>5</td>
<td>96</td>
<td>Y</td>
</tr>
<tr>
<td>8</td>
<td>65</td>
<td>4</td>
<td>96</td>
<td>Y</td>
</tr>
<tr>
<td>9</td>
<td>65</td>
<td>1</td>
<td>96</td>
<td>N</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>14</td>
<td>48</td>
<td>N</td>
</tr>
<tr>
<td>11</td>
<td>79</td>
<td>12</td>
<td>36</td>
<td>N</td>
</tr>
<tr>
<td>12</td>
<td>82</td>
<td>13</td>
<td>72</td>
<td>Y</td>
</tr>
<tr>
<td>13</td>
<td>97</td>
<td>10</td>
<td>216</td>
<td>Y</td>
</tr>
<tr>
<td>14</td>
<td>104</td>
<td>15</td>
<td>120</td>
<td>Y</td>
</tr>
<tr>
<td>Road</td>
<td>140</td>
<td>8</td>
<td>48</td>
<td>N</td>
</tr>
</tbody>
</table>

* modified numbers

Table 6-3: emission, cost and lead time of different options for lane BL-0334

6.2.3.3 Additional costs and benefits

In the analyses no qualitative aspects of the LSP, such as reliability, are taken into account. This has to be investigated on a case by case basis. Some bids are not done with exactly the right unloading equipment, which are required for the transport, so a slight price increase can be expected in some cases. On the other hand, based upon former official RFQs, a price decrease is to be expected from the first bidding round to the final award step. Both aspects are excluded from analysis.

6.3 Application to Cargill: efficiency of intermodal lanes

Our method cannot only be used to investigate which lanes have potential to shift from road to intermodal transport; another application is to investigate the carbon emission efficiency of the current intermodal lanes. Since the method calculates a lower bound of intermodal emissions, this lower bound is compared here with the current level of intermodal emissions on existing intermodal lanes. The percentage difference is calculated for each lane. This approach is applied on two groups: bulk
liquid intermodal lanes of CC and bulk liquid intermodal lanes of all BUs. Note that bulk liquid CC currently has only a few intermodal lanes. The results of the analysis are visualized in Figure 6-6. A negative deviation from the intermodal emissions is due to several limitations of our methodology, as described in Section 6.1.2.4. As one can see this holds only for a very few cases. E.g. due to the incompleteness of the terminal lists, it could be that closer terminals exist which are not in this list, resulting in a more carbon-efficient routing. Also the use of a combination of multiple non-road modes could result in lower emissions than using our methodology.

The positive deviations from the upper bound show that the carbon efficiency of the current intermodal lanes can be enhanced significantly. Carbon emission savings are possible by either using another modality or by adapting the routing, often by using terminals closer to the origin and destination. In absolute numbers for CC the total current emissions of the intermodal lanes is 227 tonnes, while the lower bound is 155 tonnes. So a saving of 72 tonnes (31.7%) could occur. For bulk liquid, the emission can drop from 2,883 tonnes (current level) to 2,301 tonnes, which is a saving of 582 tonnes (20.2%).

![Figure 6-6: carbon efficiency of current intermodal bulk liquid lanes of CC (left) and all BUs (right)](image1)

The intermodal bids of the mini-RFQ can be analyzed in a similar way. On every lane the option resulting in lowest carbon emission (scenario 2) is used. The results are given in Figure 6-7. Using our method results in an upper bound of emission savings of 1,831 tonnes on the lanes selected with intermodal bids. The upper bound of emission savings of the real bids (scenario 2) is 1,598 tonnes (= 3,343 – 1,745), which is 12.7% lower than the upper bound. The results of the mini-RFQ deviate less from the upper bound than the current intermodal lanes, because on every lane the option resulting in lowest carbon emission is used.

![Figure 6-7: carbon efficiency of mini-RFQ bids](image2)
6.4 Savings index

Because our method requires quite some manual work, in case of large datasets it is useful to make a quick scan and select the lanes on which the largest carbon savings are expected when shifting from road to intermodal transport. For this purpose a ‘savings index’ is created, which expresses the expected %-savings of carbon emissions on a lane when shifting from road to intermodal transport. Note that the savings index will only serve as an indicator; it is not designed for prediction of emission savings. The savings index can be used to select the lanes with highest expected carbon savings. Next, one can apply our method to this selection to calculate the upper bound of emission savings when shifting from road to intermodal transport. To calculate the savings index (i.e. expected %-savings on carbon emissions) a multiple regression model is used. Two separate regression equations are designed, since per modality different parameters need to be considered; one for shifting to intermodal rail (Section 6.4.1.1) and one for shifting to intermodal short-sea transport (Section 6.4.1.2). The values on independent variables in the regression model must be known in the current situation (road transport) or must be easy to estimate, since no information is available about the routing taken when shifting to intermodal transport.

The dataset of Cocoa & Chocolate on which the model shift identification method is applied is used here as well. This dataset is complemented with bulk liquid intermodal lanes to get a better spread (geographically). These lanes are treated as if they are currently executed by road. The dataset is randomly split into two, such that one part can be used for fitting the model and the other one for validation (Section 6.4.1.3). Rules of thumb regarding the sample size for multiple regression differ between 15 and 40 times the number of parameters. The sample size is 272 and only 4 or 5 parameters are included, so is expected to be sufficiently large. SPSS 16.0 is used here as statistical analysis software.

6.4.1.1 Savings index intermodal rail

The %-savings of carbon emissions when shifting from road to rail is used here as dependent variable. This parameter is calculated for each lane using the model shift identification method. For rail the selected independent variables are:
- Distance
- Average electricity generation factor
- Sum of road distances to the closest terminals of origin and destination (0: >100 km and 1: ≤100 km)
- Allowed payload increase

Although it may be correct measurements, extreme values can dramatically change the result of the data analysis. The dataset is checked for both univariate and multivariate outliers. Hair et al (2006) recommends that if the number of observations exceeds 80, values with a standard score which exceeds ±3 are univariate outliers. Three cases have been identified and deleted. For multivariate outliers the Mahalonobis Distance ($D^2$) is calculated. This statistic can be analyzed as a Chi-square test. If $p<0.001$ the observation can be seen as a multivariate outlier (Hair et al., 2006). One additional case has been deleted.

Decisions regarding inclusion or exclusion of parameters are based upon their effect on the model fit. The same measures, as used for validation, are used as statistics for the model fit. These measures are described in more detail in Section 6.4.1.3. The relations between the continuous independent variables and the dependent variable (DV) are verified by visualization of scatter plots and, if necessary, the parameter is transformed. As can be seen in Appendix 16, the relation between DV and distance is clearly not linear. Hair et al. (2006) suggest several transformation possibilities $\log X$, $-1/X$ or $\sqrt{X}$. The natural logarithm outperforms the other transformation possibilities on model fit and is used here. Including payload increase only leads to a small increase of the model fit. The expected underlying reason is that the allowed payload increase is identical for the majority of the lanes (more than 60%), namely a payload increase of 3 tonnes (from 25 to 28 tonnes). A higher power of payload increase and the interaction of payload increase and distance do not result in a better fit. For electricity
generation factor a higher power and the interaction with distance do not result in a better fit neither. Altogether this results in the following model:

\[
Y = -96.852 + 23.468 \cdot \ln(X_1) - 42.526 \cdot X_2 + 16.304 \cdot X_3 + 0.520 \cdot X_4
\]

where

\[
\begin{align*}
Y & \quad \text{%-savings of carbon emissions when shifting from road to rail} \\
X_1 & \quad \text{Distance} \\
X_2 & \quad \text{Average electricity factor} \\
X_3 & \quad \text{Sum of road distances to the closest terminals of origin and destination (0: > 100km and 1: \leq 100km)} \\
X_4 & \quad \text{Allowed payload increase.}
\end{align*}
\]

The SPSS output of the final model can be found in Appendix 16. The direction of all relationships is in line with the theory. I.e. larger distance, smaller road distances to the terminals, smaller average electricity factor and higher allowed payload increase result in higher expected %-savings of carbon emissions when shifting from road to intermodal rail transport.

### 6.4.1.2 Savings index intermodal short-sea

A similar approach, as described in Section 6.4.1.1, is taken for shifting from road to intermodal short-sea transport. Here, the selected independent variables are:

- Distance
- Allowed payload increase
- Sum of road distances to the closest terminals of origin and destination (0: > 100km and 1: \leq 100km)
- Number of TEU
- Crossing water in straight line from origin to destination (0: no, 1: yes)

Ten univariate outlier and no multivariate outliers have been removed. A similar non-linear relationship between DV and distance is found (Appendix 16), as in Section 6.4.1.1. The same logarithmic transformation is applied. Payload increase does not result in a significant improvement in fit, even not if combined with distance. No other relevant interaction effects have been found. TEU has only a minor effect but results in a slightly better model. Powers of different parameter do not result in a better fitting model. Altogether this results in the following model:

\[
Y = -108,475 + 24,429 \cdot \ln(X_1) + 22,642 \cdot X_2 + 35,071 \cdot X_3 - 23,791 \cdot X_4
\]

where

\[
\begin{align*}
Y & \quad \text{%-savings of carbon emissions when shifting from road to short-sea} \\
X_1 & \quad \text{Distance} \\
X_2 & \quad \text{Crossing water in straight line from origin to destination (0: no, 1: yes)} \\
X_3 & \quad \text{Sum of road distances to the closest terminals of origin and destination (0: > 100km and 1: \leq 100km)} \\
X_4 & \quad \text{TEU.}
\end{align*}
\]

Appendix 16 provides the SPSS output of the final model. The direction of all relationships is in line with the theory. I.e. larger distance, smaller road distances to the terminals, water between origin and destination and a lower TEU result in higher expected %-savings in carbon emissions when shifting from road to intermodal short-sea transport.
6.4.1.3 Validation

For validation the randomly selected second half of the dataset is used. Validation is done in two separate ways. Validation 1 compares the top 20% of %-emission savings using the regression model and compares whether these lanes correspond with the top 20%, top 30%, top 40% and top 50% when using our method. The success rate describes the fraction that corresponds with our method. Validation 2 is similar to validation 1, however, it is an absolute validation. Validation 2 checks whether the lanes of the top 20% (as used for validation 1) have emission saving higher than a certain level (as calculated with our method). The levels of emission savings taken are 30%, 40%, 50%, 60% and 70%. Again success rates are calculated. The results one can find in Table 6-4 (column 2 and 4). The success rates are very high, implying that the regression equations can be used for a quick scan with high success score expected. The top 20% of lanes using the savings index matches more than 70% of the top 20% lanes, which one would find using our method. The 30% of lanes, which do not correspond with the top 20% of our method, are likely to be represented in the top 30%, 40% or 50% of our method. Moreover, the selected lanes all have an upper bound of emission savings of larger than 30%, often larger than 40, 50 and 60% as well. Because the savings index only requires a few input parameters, it allows us to apply it in an easy and quick way on large datasets.

<table>
<thead>
<tr>
<th>Validation</th>
<th>Success rate (rail) – real rail factor</th>
<th>Success rate (rail) – estimated rail factor</th>
<th>Success rate (short-sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validation 1 (top 20%)</td>
<td>0.714</td>
<td>0.625</td>
<td>0.750</td>
</tr>
<tr>
<td>Validation 1 (top 30%)</td>
<td>0.857</td>
<td>0.768</td>
<td>0.893</td>
</tr>
<tr>
<td>Validation 1 (top 40%)</td>
<td>0.929</td>
<td>0.839</td>
<td>0.964</td>
</tr>
<tr>
<td>Validation 1 (top 50%)</td>
<td>0.964</td>
<td>0.929</td>
<td>1</td>
</tr>
<tr>
<td>Validation 2 (&gt; 30% emission saving)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Validation 2 (&gt; 40% emission saving)</td>
<td>0.982</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Validation 2 (&gt; 50% emission saving)</td>
<td>0.964</td>
<td>0.928</td>
<td>0.964</td>
</tr>
<tr>
<td>Validation 2 (&gt; 60% emission saving)</td>
<td>0.732</td>
<td>0.643</td>
<td>0.946</td>
</tr>
<tr>
<td>Validation 2 (&gt; 70% emission saving)</td>
<td>0.304</td>
<td>0.304</td>
<td>0.786</td>
</tr>
</tbody>
</table>

Table 6-4: validation of savings index

For the use of the regression model, the electricity generation factor has to be estimated. It is hard to make a good estimation, since this depends on the distance per country, which is unknown. If we would use a simplified estimation of the average electrical factor of all countries crossed, not taking into account the distance per country, this results in the following scores in the third column of Table 6-4. With estimated electricity factor the regression performs worse, however the savings index still performs well.

6.5 Additional insights

Intermodal transport results often in a longer lead time than road transport. This implies that short customer order lead times limit the modality choice to a large extent. Cargill can deal with this by either extending the customer order lead time or by adapting its inventory management. The former option and implementation of modal shift for Cargill is discussed in Chapter 9. Inventory management is addressed in Chapter 7.

In several interviews with LSPs some additional insights on intermodal transport are gained. Note that these are based upon a few different viewpoints, so no general conclusions may be drawn here. One of the largest current problems for intermodal transport is competition with road transport. Due to economic circumstances there is a large overcapacity of trucks. This affects intermodal transport in multiple ways. First, prices for road transport have decreased, making intermodal transport relatively expensive. Secondly, companies demanding transport have to decrease their costs as well and choose the cheaper road option. Furthermore, lower demand of intermodal transport, reduces the frequency of rail and water connections, leading to increased lead times, making intermodal transport less attractive. Another main problem is the limitations and incompatibility of the intermodal transport
infrastructure, e.g. different rail sizes, electricity missing on several rail tracks, different railway operators, hindering passenger transport for freight rail transport, improper road network around and facilities at intermodal terminals. Several European projects are running to overcome these issues, e.g. the Trans-European Network project (TEN-T). The ultimate policy objective of TEN-T is the establishment of a single, multimodal network covering both traditional ground-based structures and equipment to enable safe and efficient traffic (EU, 2010a).

On the other hand some developments can be expected which are favorable for intermodal transport in the future. Increasing demand to transport in the future will result in a shortage of truck drivers (resulting in high wages), increased congestion of the road and safety issues. Moreover, increasing fuel prices result in a better position for intermodal transport. And of course policy makers are expected to focus more and more on the environment, e.g. via taxes, subsidies or laws, promoting the use of intermodal transport.
7 Inventory Management

One finding from the mini-RFQ in Chapter 6 is that intermodal transport results often in a longer lead time than road transport. Cargill could overcome this issue by changing the service agreement with the customers or via inventory management. For the latter the general idea is to put inventory closer to the customer and as such being able to supply the customer with the same service, but having emission reduction as advantage. The option of opening a distribution center close to the customer was mentioned in the business opportunity assessment, but it has been decided to leave this out of scope due to high investments. However, inventory management options which have similar effects, but do not require investments by Cargill, are the use of floating stock (FS) or applying Vendor Managed Inventory (VMI). To study the potential of these options a case study is conducted, which is described in Section 7.1. Next, the calculations are done in Section 7.2 and, finally, the results are discussed.

7.1 Case study

The case study focuses on transport from Benelux to Northern Italy, because multiple destinations are located in this region and were identified as high potential for a model shift. Furthermore, in the mini-RFQ the number of bids on these lanes was significantly higher than others, partly due to the good rail connections between these regions. More specifically the focus will be on cocoa butter lanes from Wormer to Northern Italy. One product is chosen, such that pooling effects are incorporated in the analysis. Only intermodal rail transport is considered in this case study, since it has been found that short-sea transport on these lanes results in higher emissions, longer lead time and higher costs. For rail electrical traction is used, which is in line with the offers on the RFQ.

7.1.1 Current situation

Figure 7-1 visualizes the current situation, which consists of four road lanes to four different customers.

Figure 7-1: current situation
7.1.2 Vendor Managed Inventory

In the VMI scenario Cargill is responsible for the inventory of the customer. Under the same service level, Cargill can hold more inventory at the customer, such that the stock replenishment can take place with a more carbon-friendly mode with longer replenishment lead time. The situation is visualized in Figure 7-2. Here the most carbon efficient options of the mini-RFQ are chosen. Although two destinations are supplied via the same rail terminal, no inventory sharing is assumed here.

![Vendor Managed Inventory Diagram]

Figure 7-2: Vendor Managed Inventory

7.1.3 Floating Stock

Since containers are used for intermodal transport, these units could be used as floating stock points by storing them in a rented depot, e.g. at a LSP. A big advantage compared to a truck is that the waiting costs for a truck are relatively high (this includes a driver’s wage) compared to the holding cost of a container (no driver required). The FS point chosen is an existing depot of one of the LSPs. The situation is illustrated in Figure 7-3.
7.2 Calculations

Several assumptions are made to simplify the calculations. The effects with lanes not included in the case study are left outside the analysis. Furthermore, the inventory level of the plant in Wormer is not considered, since it is influenced by demand from a large range of customers. 100% availability at the plant is assumed such that the lead times from the plant are assumed to be constant.

The calculation of emissions is done with TERRA, transport costs are based upon RFQ rates. Cargill has in general fixed order quantity agreements with her customers. Order quantity is denoted as \( Q \). It is assumed that customers order if the inventory drops below a reorder point \( s \). Furthermore, continuous review of the inventory at customers is expected, altogether resulting in a \((s,Q)\) policy. Since the products under scope are food products no overloading of containers is allowed between loading at the plant and arrival at the customer. To incorporate the inventory sharing effect at the floating stock point, it is assumed that every customer orders an identical order quantity, which equals the maximum payload allowed on the routing. Let us assume an equipment weight 15 tonnes for a tank trailer and 16 tonnes for a tank container (in line with Chapter 5). For this case study the order quantities become for road transport \( Q = 25 \) (= 40 – 15) and for intermodal rail transport \( Q = 28.5 \) tonnes (= 40 – 16 + 0.5). 0.5 tonnes is some slack, which is allowed in Italy. In this way also the extra payload increase of intermodal transport is included.

Basic inventory theory (Appendix 17) of De Kok (2002) is used for calculations. It is assumed that the net inventory after arrival of an order is always positive. No data about the demand distribution of the customer is available. For calculation reasons it is assumed that this demand is Poisson distributed, with rate \( \lambda \) (in tonnes per day). \( \lambda \) is calculated based upon average figures of 2008. The demand which is faced by the floating stock point is that of all four customers. The sum of Poisson distributed variables is also Poisson distributed. Hence, a Poisson distributed demand is assumed for the floating stock point as well. \( \lambda \) is converted to containers instead of tonnes. A \( P_2 \)-service level of 0.95 is assumed for each customer. For the floating stock point also a \((s,Q)\) policy is assumed and a \( P_2 \) service level of 0.95 is chosen. It is assumed that in 5% of the customer orders a rush order is required, which has to be done by road. It is assumed that rush orders are 25% more expensive than normal road transport. This represents a ‘lost sales’ situation. However, calculations for average inventory levels have been made assuming a ‘backorder’ situation. The calculated average inventory will therefore be slightly overestimated.
Pipeline inventory holding costs (resulting from goods still in transit to the stock points) are excluded from the calculations since these are included in the transport costs. In the VMI scenario Cargill is responsible for the inventory of the customer. Only the additional inventory cost at the customer compared to the current situation are taken into account. In the FS scenario the lead time to the customer has dropped by one day, the customer can have a lower inventory level and thus lower inventory costs. However the floating stock results in additional inventory cost. These additional inventory cost minus the inventory cost savings at the customer are taken into account. The holding costs at the customer are estimated from available holding cost information in the plant. The holding costs at the floating stock point are based upon real cost data provided by the LSP that owns the depot. The holding costs are given in Table 7-1. Note that the costs are not expressed in the same unit. The holding cost at the FS point are higher than the holding cost at the customer, which is not a standard situation.

<table>
<thead>
<tr>
<th>Location</th>
<th>Holding cost (EUR/day)</th>
<th>Holding cost (EUR/container/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>Floating stock point</td>
<td></td>
<td>65</td>
</tr>
</tbody>
</table>

*Table 7-1: inventory holding costs*

### 7.3 Results

For each scenario the emissions, change in transport and inventory costs are calculated. The results are given in Table 7-2.

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>VMI</th>
<th>Floating Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total emissions (tonnes)</td>
<td>274</td>
<td>90</td>
<td>142</td>
</tr>
<tr>
<td>%-emission saving</td>
<td></td>
<td>67.1</td>
<td>48.2</td>
</tr>
<tr>
<td>Transport cost* (EUR)</td>
<td></td>
<td>-48,940</td>
<td>-4,795</td>
</tr>
<tr>
<td>Change in transport cost (EUR)</td>
<td></td>
<td>6,167</td>
<td>4,405</td>
</tr>
<tr>
<td>Cost change (EUR)</td>
<td></td>
<td>-42,773</td>
<td>-390</td>
</tr>
<tr>
<td>% cost change*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* confidential

*Table 7-2: results case study of inventory management*

For both alternative scenarios large emission savings occur. However, the emission saving under VMI is larger than FS (67% compared to 48%, respectively), because for FS the total road distance is relatively large. The transport costs of VMI and FS are lower than in the current situation. FS has a relative high transport cost due to additional handling, an additional road leg and rush order transport costs. With respect to the additional road leg, putting the floating stock in the rail terminal of Bologna would overcome this, however, no temperature control is available there, which create a too high risk for the product under scope.

For VMI the increase in inventory holding cost is relatively small compared to the decrease in transportation costs. The additional inventory costs of VMI will be larger for higher service levels at the customer, since the magnitude of the effect of increased lead time becomes larger. In this case study FS results in almost the same total costs as the current situation. The inventory holding costs at the floating stock point are significantly larger than at the customer due to container hire cost. The more customers make use of the floating stock, the higher the potential of this option is, due to inventory pooling. Furthermore, if all lanes using the floating stock point are awarded to one LSP, a transport price decrease is expected. Implementation of VMI and FS is discussed in more detail in Chapter 9.
8 Conclusions & recommendations

In this chapter, the main findings and limitations of the study are summarized. Also, recommendations for further research are given.

8.1 Main findings

In response to a growing pressure on companies to pay more attention to the impact of their products and services on the climate, there has been an increasing stream of research with a focus on carbon dioxide emission assessment and reduction. So far, most attention has been paid to GHG emissions from manufacturing of goods. However, 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. A minor stream of research has focused on carbon dioxide emission assessment of transport activities. However, detailed insight is lacking on how to reduce carbon dioxide emissions and what its implications are. This study aims to fill this knowledge gap and to give practical insights in carbon emission reduction in Full Truck Load bulk transport (i.e. shipments where there is cargo of only one company on the transport equipment).

First, the current emissions of Cargill Cocoa & Chocolate (CC) bulk liquid have been assessed to construct an emission reference. The total yearly carbon dioxide emissions for CC are 7,326 tonnes for approximately 123 million tonnekm (equivalent to one tonne of cargo transported over one kilometer). The first objective of the study is to give an overview of carbon emission reduction options in transport and to select the reduction options with the highest potential for Cargill Cocoa & Chocolate bulk liquid transport. Carbon dioxide emission reduction options existing in literature are reviewed. Payload increase, modal shift and inventory management have been selected, based on expected impact and practicability for CC bulk liquid transport. Although depending on the current payload, modal split and transport network, these options are expected to have high potential for Full Truck Load bulk transport in Europe in general. Next, a separate approach has been taken per selected reduction option to answer the research question: “How can transport lanes be selected for carbon dioxide emission reduction?” Furthermore, the effects of carbon dioxide emission reducing activities on carbon dioxide emissions, costs and lead time are assessed.

Payload increase affects the load factor of a vehicle in terms of weight. Higher load factors result in higher emissions per trip, but fewer trips are required. In general this will result in a reduction of total emissions, since the emission per tonnekm decreases. The current regulations regarding maximum gross weight (EU and country-specific), combined with weight of equipment, have been translated into formulas to determine the maximum allowed payload on a routing, depending on the modality used. It has been found that the regulations are rather complicated and sometimes ambiguous, especially with respect to intermodal transport.

The current average payload at CC bulk liquid is 17.2 tonnes. In general a maximum gross weight of a truck of 40 tonnes is allowed, typically resulting in a maximum payload of about 25 tonnes. Note that, for the transport under scope, weight is the limiting factor with respect to capacity. It is not realistic that customer with very low demand will order maximum payloads, due to e.g. storage limitations or perishability of the product. To exclude these customers, only large volume lanes of bulk liquid CC (> 650 tonnes per year) have been selected. However, these lanes represent 70% of the current total emissions. Using a maximum payload on all these lanes results in a carbon emission saving of 20% (1,040 tonnes) and transport cost savings of 27%. This corresponds with an emission reduction of more than 14% compared to emissions of the total dataset of bulk liquid CC lanes. Each trip saved, automatically results in savings in transport costs as well. Furthermore, it is expected that an increased payload has only a minor effect on the lead time.

In practice, payload increase depends on the quantities customers can receive. Therefore, partial payload increase has been investigated as well. Even an increase of payload up to only 50% or 75% of the maximum capacity leads to significant savings in carbon emissions and costs. In general it holds that payload increase for lower weight is more significant than for higher weight. Moreover, it is demonstrated that the weight of the equipment has a significant effect on the potential of payload.
increase. The maximum carbon emission saving on a lane can easily be calculated by subtracting the emissions using maximum payload from the emissions using the current payload. This number can be used to select lanes for payload increase.

For modal shift, a method is developed to calculate the upper bound of carbon emission savings when shifting from road to intermodal rail or intermodal short-sea transport. This method attempts to choose the most carbon-efficient modality and routing on a transport lane. It has been found that modal shift to intermodal short-sea requires another approach than a modal shift to intermodal rail, due to differences in transport network. Our method can be used to select high potential lanes for a modal shift or to investigate the carbon efficiency of current intermodal lanes. When using large datasets it is recommended to make first a quick scan. This quick scan should result in a selection of lanes on which the largest carbon savings are expected, when shifting from road to intermodal transport. Next, one can apply our method on this selection to calculate the upper bound of emission savings. For this purpose, a ‘savings index’ has been created, which expresses the expected %-savings of carbon emission on a lane. The savings index can be used for a quick scan with high success scores expected, i.e. matching results of our method, only using a few parameters: distance, road distances to the terminals, allowed payload increase, average electricity factor of countries crossed (for intermodal rail), whether there is a sea in between origin and destination (for intermodal short-sea) and the number of TEU (for intermodal short-sea). Because the savings index only requires a few input parameters, it allows us to apply it in an easy and quick way on large datasets. Both the savings index and the method can be applied to FTL bulk transport in Europe.

The current modal split is such that about 95% of the lanes is road transport, representing about 90% of the total tonne kilometers of the BU Cocoa & Chocolate. Applying the model shift method to Cargill shows that about 20% of the lanes result in 80% of the maximum emission savings. I.e. the Pareto principle (1963) applies here. This implies that companies can focus their effort on a relatively small number of lanes, while still including the largest fraction of potential emissions savings. The selected lanes have been sent out in a mini Request For Quotation (RFQ), where logistic service providers (LSP) were asked to bid ‘intermodal’. The mini-RFQ has provided insights in the carbon emission savings, cost and lead time effects of modal shifts. The results of the mini-RFQ show that on the selected lanes a maximum carbon emission saving of 1,598 tonnes (48%) is possible, which is a reduction of 22% of the current total emission level of bulk liquid CC transport. However, this emission reduction requires a cost increase of 19%, due to higher transport cost. On the other hand, a maximum cost savings of 9.5% can be obtained in combination with an emission reduction of 27.9%. Furthermore, practically all emission savings (40.8% of 47.8% in total) can be done without an increase of total costs. The majority of the bids have a longer lead time. However, more than half of the carbon reduction can be obtained by using transport modes that currently use a smaller or equal lead time by selecting the right LSP. This means that it is not always true that intermodal transport requires a longer lead time. Moreover, via the mini-RFQ the assumption regarding electrical / diesel split of CRSC (2009) is verified. The split in the mini-RFQ is in accordance with the assumption.

Our method has also been applied to investigate the carbon efficiency of current bulk liquid intermodal lanes. The current intermodal emissions are more than 20% higher than the lower bound calculated with our method. It is concluded that large savings can be achieved by optimizing the routings and modality choice of intermodal transport.

The idea of inventory management is to put inventory closer to the customer. As such one can replenish the customer with the same lead time and service level, but with a more carbon friendly transport mode, having emission reduction as advantage. A case study to several lanes to Northern Italy has been executed to investigate the potential of floating stock (in containers) and Vendor Managed Inventory (VMI). It is not possible to draw general conclusions based on one study only, hence the main findings of our case study are briefly discussed. Both options result in large emission savings, (48% and 67% respectively) and lower transport cost. Compared to VMI, floating stock has a relative high transport cost due to additional handling, an additional road leg and rush order transport costs. For VMI the increase in inventory holding cost is relatively small compared to the decrease in
transportation costs. The inventory holding costs at the floating stock point are significantly larger than at the customer due to container hire cost. The more customers make use of the floating stock, the higher the potential of this option, due to inventory pooling.

In general it is found that carbon emission reduction often can be applied cost effectively, taking into account transport costs only. For both payload increase and modal shift it is concluded that carbon cost are relatively small compared to transport cost. At a current market price level carbon cost has a very limited impact on the choice of modality and hence will not result in a large reduction of emissions. The carbon price has to increase to an unrealistic level in order to make a significant difference.

8.2 Limitations & recommendations for further research

In this study only carbon dioxide emissions are taken into account. A possible downside of excluding other emissions is that this study may lead to recommendations which reduce carbon emissions but increase other emissions. It is interesting to get insight in these effects in future research. For calculations the TERRA tool is used, which implies that the results are subject to parameter and assumptions influences and limitations as described in the CRSC report (CRSC, 2009). Furthermore, the study is only applied to a relative small business unit, Cargill Cocoa & Chocolate. This has resulted in relatively small absolute findings; however the explored methods can be easily applied to a wider scope, e.g. the FTL bulk transport of other business units under control of the European Transport Procurement department. It is expected that similar savings can be found in other European FTL bulk transport (of Cargill) as well.

A recommendation for TERRA is to incorporate the maximum payload calculations and lane identification method for modal shift. As such decision makers can easily analyze the potential of both options on the emissions of their transport. For the calculation of the maximum payload several assumptions have been made, which can lead to slight deviations from reality. The method is designed for weight-limited transport; however it can be applied quite straightforward to volume-limited transport as well. In this case the volume of the equipment is the limiting factor. The modal shift identification method underlies several limitations as well. It is assumed that intermodal transport consists of three legs (two road legs and one rail or water leg). Furthermore, the overviews of terminals used are not complete. Besides, the method does not include inland waterways. However, if a list of inland freight harbours and a table with distances between these harbours is available, the method can be applied quite straightforward to inland waterway transport. All these limitations imply that in reality a higher upper bound of emission savings exist than calculated with our method. Another assumption is that there is a connection between each pair of terminals in the terminal list. Although this represents reality to a large extent, frequencies of connections between terminals can be an important factor in practice when deciding on the intermodal routing, due to lead time. The existing intermodal infrastructure was mentioned as a limiting factor for intermodal transport by several LSPs. It is recommended to explore how to (re)design the infrastructure to make intermodal transport more attractive. Furthermore, the effect of the frequency of connections between intermodal terminals on the choice of the routing is an interesting area for further research.

In this study supply chain (re)design is left out of scope. However, large carbon emission savings are expected for this option. It is recommended to include this area in further research to get better insight in the trade-off between carbon emission, transport cost and inventory holding cost. Moreover, inventory management is only investigated for one case study; more case studies should be conducted in order to draw general conclusions about this carbon reduction option.
9 Implementation

In this chapter, the implementation of the findings of this study for the ETP bulk transport of Cargill is discussed. Next, recommendations are given on how to monitor progress of carbon emission reduction in transport.

9.1 Implementation plan

The objective of the Green Transport Project is to reduce carbon dioxide emissions resulting from transport. So far, no official internal goal has been set on how much to reduce these emissions. However, since the carbon emissions in transport can be measured with TERRA, a clear quantifiable goal can be set. This goal should include at least a reduction quantity (absolute or %), a baseline year and a time span. Rather than solely evaluating the absolute emissions, the focus should be also on the amount of carbon dioxide per delivered tonne of product. Two types of goals are:

- Reduce CO₂ emissions from ETP transport with X percent by year Y compared to base line year Z.
- Reduce CO₂ emissions from ETP transport with X percent per metric tonne of delivered product by year Y compared to base line year Z.

The goals can be split up into sub-goals per reduction option or per BU, e.g. by setting goals for average payload levels or the percentage of transport which is executed intermodal. Furthermore, it must be clearly stated whether Cargill is willing to reduce carbon emissions while costs increase, or that only cost-effective solutions are taken into account. As has been analyzed in this project, the main reduction options are payload increase and modal shift. It is advised that these options should receive primary focus, although more reduction options should be investigated, e.g. supply chain redesign.

With respect to payload increase, it is not realistic that customers that face low demand will order maximum payloads. Therefore, it is suggested to focus on big volume lanes. The maximum payload calculation can be used to calculate the maximum savings in carbon emissions and costs. However, realizing payload increase is not straightforward. On every lane the practical limitations need to be studied, e.g. storage capacity of customers. Whether the payload can be increased depends on the ordering system. Cargill can stimulate customers in three ways to order maximum instead of partial payloads (Green ordering): 1) visualize the carbon emission effect of customers’ order behavior and show what can be saved when ordering maximum payload instead; 2) set contract requirements with respect to minimum order quantity; 3) use order quantity-based pricing, such that customers get a financial incentive to order maximum payloads. With respect to the latter option, since payload increase results in cost savings for Cargill, part of these cost savings could be used for price discounts when ordering maximum payload. Furthermore, it is demonstrated that the weight of the equipment has a significant effect on the potential of payload increase. It is worthwhile for Cargill to punish LSPs which use heavy equipment, e.g. heavier than 15 tonnes. This is currently done in bulk liquid transport. However, it is also recommended to stimulate LSPs to use light-weight vehicles, such that payload can be further increased.

With respect to modal shift, the savings index can be applied to make a quick selection of lanes to investigate further modal shifts for a wider scope than CC. On basis of the savings index an A, B, C classification can be made, expressing which lanes have ‘high’, ‘medium’ or ‘low’ potential for carbon savings. Next, our modal shift identification method can be applied to this selection to get more detailed insight in maximum carbon savings. Similarly to this project, a separate intermodal RFQ procedure can be executed including the lanes identified (labeled ‘high’ and ‘medium’). Next, decisions can be made on shifting from road to intermodal transport. In the current RFQ the option is offered to LSPs to quote ‘intermodal’, however this is not restricted. A more proactive approach towards intermodal transport is to set requirements (or give LSPs an incentive) to quote intermodal on the lanes, which have been identified as ‘high’ potential. The optimizer, which is used for awarding decisions, should be extended with emission as an extra decision parameter.

Our method can be used to analyze the carbon efficiency of current IM lanes as well. It is advised to Cargill to optimize the routing and modality used with the awarded LSPs. For those lanes which have
potential but are not cost-effective due to required investments, financial support can be requested, e.g. via the Marco Polo program (EU, 2010b). In this study it has been shown that on the majority of the lanes a cost-effective solution can be found, so it is advised to focus on these first.

It is expected that on average the lead times of intermodal transport are larger than of road transport. This implies that short customer order lead times limit the modality choice to a large extent. Cargill can deal with this in a similar way as payload increase can be realized; visualize carbon savings of extended order lead time (i.e. ‘awareness raising’), restrict the minimum order lead time in the contract (require ‘X days advance notice’) or apply order lead time-based pricing. Two additional options are Vendor Managed Inventory or the use of floating stock. For the latter, if a cluster of customers in the same area demands the same product the potential is expected to increase. VMI is a concept, which is currently applied for part of the transport of the BU Cargill Refined Oils Europe (CROE). A practical downside of VMI is that the customer must be willing to let Cargill manage their inventory. On the other hand, an advantage of VMI is that customers get connected to Cargill and will not shift easily to another supplier. It is advised to Cargill to investigate both VMI and FS further for lanes, which have high potential for modal shift.

Since it has been found that a lot of carbon reduction options cannot be influenced directly by Cargill, the choice of LSPs is crucial for Cargill’s carbon emissions in transport. Using a performance measurement score-card to judge how ‘green’ a LSP is can serve as a basis for these decisions and can be used to stimulate LSPs to reduce their emissions. By setting up contract requirements for LSPs, with respect to e.g. Euro truck type used and ‘Green Driving’, Cargill can reduce its emission for transport as well. However, the effects of these options have to be investigated in more detail. In the future, also supply chain redesign decisions to cut down on carbon emissions should be investigated in Cargill.

In order to make this implementation plan successful all different stakeholder groups have to be involved in the project. This will improve their commitment and can overcome borders due to low willingness to change or lack of trust. A project team should be established with members from all different groups and departments, among others: ETP (contract freight managers, RFQ team), Green Transport Project Manager, Sales, Customer Service and Supply Chain Management.

### 9.2 Monitoring

The progress can only be monitored if data is available and kept up to date. Obtaining the necessary data for carbon emission calculations from the RFQ is an easy way to do this. Transport mode, distance per mode, weight, number of shipments, % electrical traction (for rail) and gross weight of train (for rail) are the most important parameters to collect. Using TERRA on a regular basis provides feedback on the progress made towards the established goals. Other interesting parameters to keep track of are the average payload and % of intermodal transport (in number of lanes and tonnekm). This results in the following overview of Key Performance Indicators (KPIs):

- **KPI 1**: Absolute amount of carbon dioxide emitted as measured in tonne
- **KPI 2**: Efficiency of carbon dioxide emissions as measured in grams per tonnekm
- **KPI 3**: Average payload as measured in tonnes per shipment
- **KPI 4**: % intermodal transport as measured in percentage of lanes
- **KPI 5**: % intermodal transport as measured in percentage of tonnekm

The main part of the expected work is the investigation of practical limitations, negotiation with customers and LSPs, and adaptation of contracts.
# 10 Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>Business Unit Cargill Cocoa &amp; Chocolate</td>
</tr>
<tr>
<td>CO₂ / carbon</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>Emission factor</td>
<td>Emission per tonnekm</td>
</tr>
<tr>
<td>Empty return</td>
<td>Return of the means of transport without another shipment</td>
</tr>
<tr>
<td>eSCF</td>
<td>European Supply Chain Forum</td>
</tr>
<tr>
<td>ETS</td>
<td>European Trading Scheme</td>
</tr>
<tr>
<td>ETP</td>
<td>European Transport Procurement</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FTL</td>
<td>Full Truck Load, refers to shipments where there is cargo of only one company on the transport equipment</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse gases</td>
</tr>
<tr>
<td>GTP</td>
<td>Green Transport Project</td>
</tr>
<tr>
<td>GWP</td>
<td>Global Warming Potential</td>
</tr>
<tr>
<td>Intermodal</td>
<td>Transport of cargo using multiple modes without any handling of the cargo itself when changing modes</td>
</tr>
<tr>
<td>Lane</td>
<td>Combination of a certain origin, destination, product and period, possibly executed by different LSPs and / or different modalities (Figure 10-1)</td>
</tr>
<tr>
<td>Load factor</td>
<td>Percentage of the capacity of the vehicle used, where capacity is expressed in weight, volume, pallets, lane metres or twenty-foot equivalent units (TEU)</td>
</tr>
<tr>
<td>LSP</td>
<td>Logistic Service Provider, synonym of carrier</td>
</tr>
<tr>
<td>mT</td>
<td>Metric Tonne</td>
</tr>
<tr>
<td>NTM</td>
<td>Network for Transport and Environment (NTM: Nätverket för Transporter och Miljön), a Swedish non-profit organisation that developed a methodology for calculating CO₂ emissions in transport.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>Payload</td>
<td>Absolute weight loaded in a vehicle</td>
</tr>
<tr>
<td>Phase</td>
<td>Part of a lane that is done with a certain transport mode (Figure 10-1)</td>
</tr>
<tr>
<td>Positioning distance</td>
<td>Distance travelled by the means of transport in order to reach the cargo location</td>
</tr>
<tr>
<td>RFQ</td>
<td>Request For Quotation</td>
</tr>
<tr>
<td>Route</td>
<td>Combination of a certain origin, destination, product, LSP and modality (Figure 10-1)</td>
</tr>
<tr>
<td>Shipment</td>
<td>Combination of a certain origin, destination, product, LSP, modality and date and can also be called one transport operation (Figure 10-1)</td>
</tr>
<tr>
<td>TEU</td>
<td>Twenty-foot equivalent unit</td>
</tr>
<tr>
<td>Tkm / tonnekm</td>
<td>Tonne Kilometre, equivalent to one tonne of cargo transported over one kilometre.</td>
</tr>
<tr>
<td>TU/e</td>
<td>Eindhoven University of Technology</td>
</tr>
</tbody>
</table>
Figure 10-1: definition of a lane, route, shipment and phase (CRSC, 2009)
References


European Supply Chain Forum (2008). EU emission regulations: current situation, scenarios and impacts on supply chain, white paper eSCF.


FEBETRA (2009). Massa’s en afmetingen, Koninglijke Federatie van Belgische Transporteurs en Logistieke Dienstverleners (Royal Belgian Road Haulage and Logistics Providers Federation).


Marklund (2008). Inventory Control in Divergent Supply Chains with Time Based Dispatching and Shipment Consolidation, Lund University, Sweden.


Appendices

Appendix 1: CRSC calculation methodology
Source: based upon CRSC (2009)

Existing calculation methods

One may use an energy-based or an activity-based methodology to calculate transport emissions. Activity-based calculations require information about mode (truck, rail, marine, air), fuel type, and distance travelled. Energy-based calculations require vehicle emission rates, fuel economy factors, direct measurement data (e.g. fuel gauge records), fuel purchase records. Especially the data on fuel usage is hard to gather, either not measured or not shared due to market sensitivity of the data. In the CRSC project is chosen for an activity-based approach.

There are different research methods and tools available that are designed to determine carbon dioxide emissions in transport, each with a different scope, different background and different emission results. Five methods are compared; ARTEMIS, EcoTransIT, GHG Protocol, NTM and STREAM. Network for Transport and Environment (NTM: Nätverket för Transporter och Miljön) is a Swedish non-profit organization aiming at establishing common values to be used for calculating the environmental impact of different modes. For the calculation method in the CRSC project NTM (2008) is chosen as a basis, because NTM:

• has a high level of detail
• offers the possibility to calculate the emissions based on varying levels of detail
• offers the possibility of adding or changing parameters and values
• is aligned with several European studies
• is cooperating with the European Committee for Standardization (CEN) to set a standard for calculating emissions resulting from transport

Method description

The calculation method works as follows. First, the emissions for an entire means of transport are calculated and, next, these emissions are allocated to the cargo on it. Because allocation is not always straightforward two important assumptions are made:

• Carbon dioxide emissions resulting from positioning are included in the total emission calculation, so the customers (here: Cargill) are responsible. Positioning is defined as the distance travelled by the means of transport in order to reach the cargo location.
• If transport is dedicated to the customer on request of the customer, the emissions from empty return trips are allocated to the customer. 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. Empty return trips are when the means of transport are returning without another shipment.

Transport parameters

The different parameters taken into account are summarized in Table 11-1. The table also explains who developed the parameter (source parameter) and on what the assumption is based (source assumption). In the CRSC report the decision about which parameters to include, assumptions and their influence on the measurement are clarified. Note that assumptions are only used if no actual data is available, to assure the most accurate result possible.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source parameter</th>
<th>Source assumption(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning</td>
<td>CRSC project</td>
<td>CRSC project</td>
</tr>
<tr>
<td>Electricity generation</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Emission values for different transport types</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Empty returns</td>
<td>NTM</td>
<td>CRSC project</td>
</tr>
<tr>
<td>Load factor</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Positioning</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Road type</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Temperature control</td>
<td>CRSC project</td>
<td>CRSC project</td>
</tr>
<tr>
<td>Terrain factor</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Traction type (rail)</td>
<td>NTM</td>
<td>Eurostat (2009)</td>
</tr>
<tr>
<td>Train size</td>
<td>NTM</td>
<td>NTM</td>
</tr>
<tr>
<td>Vertical handling</td>
<td>CRSC project</td>
<td>CRSC project</td>
</tr>
</tbody>
</table>

Table 11-1: parameters included in the calculation method

Calculation method per mode
Here the rail, road and water transport calculation method are described. The air transport calculation is excluded, because it is not relevant for this project.

Rail transport method
Rail transport is defined as cargo transport over land using railroad tracks. There are two types of trains that can be used, either diesel or electricity powered locomotives. At the European continent rail transport is most often carried out by national railway operators active within national borders. In some cases, this means that the train has to stop at the border to switch locomotives. Furthermore, not all countries use the same track width and this means that the carts should be changed at the border (this is seen as vertical handling). There are several parameters that influence the emissions during rail transport and these are discussed below, followed by the calculation and the assumptions.

Calculation
This section gives the formulas for the emission calculation for both diesel and electrical trains. First the formulas for both calculations are given, followed by the explanation of the symbols used. The formula used for diesel transport:

\[ TE = \sum_{i=2}^{\infty} W_c \cdot D \cdot \frac{EF_{\text{CO}_2}}{1 \times 10^6} \cdot \frac{675 \cdot c_{\text{CO}_2} \cdot W_{r-18}}{LF} \]

For electrical trains, the formula is given by:

\[ TE = \sum_{i=2}^{\infty} W_c \cdot D \cdot \frac{EF_{\text{CO}_2}}{1 \times 10^6} \cdot \frac{675 \cdot c_{\text{CO}_2} \cdot W_{r-18}}{LF} \]

Where:

- \( TE \) Total emission for the customer’s cargo (tonne carbon dioxide)
- \( W_c \) Weight of the customer’s cargo (tonne)
- \( D \) Transport distance (kilometre)
The total emission for diesel trains is based on the weight of the company cargo multiplied with the distance travelled. This is multiplied with the emission factor for diesel. The last part of the formula is the calculation of the energy usage per tonne cargo. This is based on the load factor of the train and the total weight of the train.

For the electric rail emissions the formula is more or less the same, the only difference is that the emission factor is summed over all the countries. This is done because the emission factor is based on the method for electricity generation in each country. The other addition is the transmission loss, this is the electricity loss when transporting electricity.

**Eurotunnel train**

A special type of train is the Eurotunnel train between Coquelles (France) and Folkestone (Great-Britain) since the total emissions are more or less the same on each trip, slightly varying with the load of the train. The Eurotunnel has a length of 50.5 kilometres. There are two types of trains in the Eurotunnel: passenger trains and cargo trains. Both are electrical trains. Since the beginning of 2008 all electricity is fed from the French electric sub-station.

A cargo train in the Eurotunnel has an average length of 720 metres and weighs maximally 4000 tonnes when loaded. All of the cargo is loaded onto the train in trucks; the cargo is never unloaded from the trucks. The trucks can maximally be 18.75 meters long (with a maximum height of 4.2 meters and a maximum width of 2.6 meters) and the weight of the truck can maximally be 44 tonnes.

**Allocation**

In rail transport there are several types of transport possible and the most common are; rail car and container. In the first option, rail car, the unit that contains the goods is fixed. This type is often used for bulk goods, i.e. coal. The second option, container, is a container that is placed on the Conflat (Container Flat Wagon). This is often used in intermodal transport because the container can be placed on both a truck and the Conflat.

In both cases, the first step of allocation consists of allocating emissions to the total transport unit, either the rail car or the container. This is done by multiplying the total emissions with the weight percentage of the car. So if container A is responsible for 10% of the total weight, also 10% of the emissions are allocated to that container. After this initial allocation there are several options for further allocation:

- **No Allocation**: In this case the emissions of the entire wagon are allocated to the shipper. This can be the case when there are no other goods in that specific car.

- **Allocation**: In this case the emissions of the wagon are allocated to the cargo in the wagon. This can be the case when there are goods of multiple shippers in the same wagon. The allocation can be based on weight, volume or pallets. The method of determining which allocation will be used is described below.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>D_z</td>
<td>Transport distance in country z (kilometre)</td>
</tr>
<tr>
<td>EF_{CO2}</td>
<td>Emission factor for diesel (kilogram carbon dioxide per kilogram diesel)</td>
</tr>
<tr>
<td>EF_{z,CO2}</td>
<td>Emission factor for electricity generation in country z (kilogram carbon dioxide per kilowatt hour)</td>
</tr>
<tr>
<td>c_t</td>
<td>Terrain factor as explained above</td>
</tr>
<tr>
<td>W_{gr}</td>
<td>Gross weight of the total train (tonne)</td>
</tr>
<tr>
<td>LF</td>
<td>Load factor</td>
</tr>
<tr>
<td>TL</td>
<td>Electricity lost due to transportation losses</td>
</tr>
<tr>
<td>z</td>
<td>Country</td>
</tr>
</tbody>
</table>
If there is no information available on the volume and the number of pallets, the allocation is based on weight. If there is information available for either the volume or the number of pallets then the capacity utilisation of the different factors (weight, volume, pallets) is determined. These values are then compared and the factor with the highest capacity utilisation is used as the basis for allocation. The reasoning is that the factor with the highest utilisation will be the limiting factor in most cases.

**Road transport method**

Road transport is defined as transport over road. Road transport services are carried out around the world with vehicles ranging from small distribution vans to long road trains. Road transport has the advantage that it is very flexible and has the ability to reach remote locations. On the other hand, the loading capacity is limited by regulations and there are congestion problems in some regions.

**Calculation**

For each vehicle type on each road type, fuel consumption values for empty and fully loaded vehicles are given. To calculate the fuel consumption of the specific vehicle and load factor, the following formula is used:

\[
FC_{LF} = FC_{empty} + (FC_{full} - FC_{empty}) \cdot LF
\]

Where:

- \(FC_{LF}\) Fuel consumption at the specified load factor (litres per kilometre)
- \(FC_{empty}\) Fuel consumption of the empty vehicle (litres per kilometre)
- \(FC_{full}\) Fuel consumption of the fully loaded vehicle (litres per kilometre)
- \(LF\) Specified load factor

The total carbon dioxide emission is directly related to the fuel consumption:

\[
TE = FC_{LF} \cdot D \cdot EF_{CO2}
\]

Where:

- \(TE\) Total carbon dioxide emission
- \(FC_{LF}\) Fuel consumption at the specified load factor (litres per kilometre)
- \(D\) Distance (kilometres)
- \(EF_{CO2}\) Emission factor for fuel (kilogram carbon dioxide per litre fuel)

In case of heating, cooling or freezing during transport, the fuel consumption increases. The values have been described before.

**Allocation**

In road transport allocation is needed in case there is cargo of more than one shipper on the vehicle. In case of no allocation, the emissions of the entire truck are the responsibility of the shipper. In case of allocation the allocation can be done based on weight, volume or pallets. If there is no information about the volume and the number of pallets available, the allocation is always done based on weight. If there is information about either volume and/or the number of pallets available, the capacity...
utilisations of the different factors (weight, volume, pallets) are compared and the factor for which the capacity utilisation is the highest is used.

**Water transport method**

Water transport is defined as transport over sea or inland waterways with diesel-oil powered vessels. To calculate the carbon dioxide emissions from water cargo transport, several parameters are taken into account. These parameters are described in the next section.

**Calculation**

Based on the vessel type, the fuel consumption value is given. This fuel consumption value is multiplied by the distance and the carbon content of the fuel and this results in the carbon dioxide emissions for the vessel.

\[
TE = FC_{cf} \cdot D \cdot EF_{CO_2}
\]

Where:
- **TE**: Total carbon dioxide emission
- **FC_{cf}**: Fuel consumption (tonnes per kilometre)
- **D**: Distance (kilometres)
- **EF_{CO_2}**: Emission factor for fuel (kilogram carbon dioxide per tonne fuel)

**Allocation**

In water transport the allocation is different for different types of water transport. In this section, per type of water transport (container, bulk and ferry) the allocation is described.

**Container water transport**

In container transport the total emissions are always allocated to the different containers on board of the vessel. This means that in case of no allocation the emissions of an entire container are the responsibility of the shipper. In case of allocation, the total emissions are allocated to different cargo in the container. This can be done based on weight, volume or pallets and the allocation is done in the same way as the allocation for road transport (so first it is determined whether to allocate on weight, volume or pallets and then the actual allocation is done).

**Bulk water transport**

In bulk water transport in case of no allocation, the emissions of the entire vessel are the responsibility of the shipper. In case of allocation, this is always done based on weight.

**Ferry water transport**

In ferry transport the total emissions are always allocated to the different trucks on board of the vessel. This means that in case of no allocation the emissions of an entire truck are the responsibility of the shipper. In case of allocation, the total emissions are allocated to different cargo in the truck. This can be done based on weight, volume or pallets and the allocation is done in the same way as the allocation for road transport.
Appendix 2: Problems with TERRA

The calculation tool developed which uses the method described is the TERRA tool. TERRA can calculate emissions per lane as well as emissions per batch of lanes. Calculations per lane are performed manually by entering data for one or two lanes. This option also serves as a quick comparison between two lanes. Batch calculations can be done by importing company transport data from Excel into the tool. The result consists of total emissions for the whole data set, several reports and the possibility to export the data to Excel.

In this project the TERRA version of 20th of October 2009 has been used. To check whether the tool really works as described in the methodology of the CRSC report, the source code has been scanned and several test runs are done with different input values. Several bugs have been found, which are described in this appendix.

The main problem concerns the distance tables included in TERRA, which uses postal code information (country code and first two digits of postal code) to automatically calculate the distance between two locations. Both road distance tables exist, used for road and rail distances, and a separate water table. The completeness and correctness have been checked by comparing the calculated distances with the real distances as extracted from the internal data system of the ETP or looked up manually.

From the total number of lanes only 8 distances could not be calculated, because of missing postal codes in the tool. These destinations are Russia, Belarus and Ukraine, so countries which are not included in the country table. The completeness is assumed to be very good. The table of water distances is not complete, but only contains the main harbours in Europe. When additional water distances were required, these have been looked up manually in Water Distance (2009). Figure 11-1 shows the percentage difference in distance calculated by the tool and real distance. While for the majority of the cases the calculation deviates a small percentage, there is a reasonable large group for which the distance differs more than 50%. Partly these are short distance lanes, however many of larger distances deviate significantly as well. It is concluded that postal codes for road and rail distances should be used with caution and preferably real road distances should be used instead of postal codes. For water the accuracy is very good, since the values are retrieved from Water Distance (2009), so postal codes for water distance can be used without problems.

Not only the distance itself, but also the distance per country should be calculated automatically by TERRA. However this is not the case, since the table ‘Distance_PerCountry’ is far from complete. So far, in the majority of the cases, 100% of the distance is assigned to the departure country. This means, when using postal codes, country-specific parameters as road type, terrain factor and electricity generation, are not taken into account correctly in the calculation. For most road parameters this will have a minor effect as the differences on these parameters are small (see Appendix 6), however electricity generation differences are large and this parameter has a large impact on the emission result. It is concluded that for rail transport the real distances and distance per country should be used. This data has been extracted manually from Deutsche Bahn (2009). In this project real road and water distances and real rail distances per country have been used, unless explicitly mentioned.
Furthermore some minor issues, which have been found, are:

- Commas in the location names result in problems importing the data. In the data set all commas have been removed to overcome this problem.
- The standard fuel type of train type Chunnel to UK is set on ‘None’. This leads to errors in the calculations of the (vertical handling emissions) on all lanes using intermodal transport. The standard type has been set on ‘Diesel Europe’ to prevent this.
- If the TEU in the input file is not equal to one of the TEU values of standard container types in the tool, no rail and water emissions are calculated. Container types with the specific value need to be added to solve this issue. Due to density of the products under scope a container type of TEU = 1.5 is added in this project.
- The factor %-electrical traction is not imported automatically. This has to be done manually after importation.
- In the code of the tool it is assumed that rail and water transport allocation is always ‘yes’. In case of ships where allocation is based on TEU or lane meters, this is automatically translated to allocation within a container, which results in different allocated emissions dependent on weight. In case of Cargill no allocation within one container has to be done. For the scope of this project this has been changed in the source code.
- Flow conditions for inland waterways are not included in the tool. Inland waterways are barely used by ETP, so for the scope of this study this is not an important issue.
- If a blank lane is imported from Excel, this results in problems with importing. Using right mouse click in Excel prevents this.

Except from the described bugs, one general comment is that in a lot of cases an error occurs without a clear error message is given (run-time error instead of pop-up screen). Even in some cases no error message at all is given, but errors occur in the calculation. This makes it difficult to find out why things do not work as they supposed to do.

**Recommendations**

The tool is still not totally finished and requires some updates and corrections. Some parameters are not correctly incorporated in the tool, e.g. temperature control is not time-dependent. Furthermore the tool is not user-friendly and it will require quite some manual work to keep the tool updated. To make TERRA user-friendly and attractive for commercial usage, a web-based tool is desirable, incorporating the necessary redesign by IT specialists and continuously updating and improvement. Furthermore, a tool which automatically generates graphical results is a good expansion. A GIS application would provide additional improvements as well. Advantages of GIS are that a lot of different calculations can be made very fast, more complete overview of terminals can be included, a complete overview of routings can be included and better visualization options. Kronbak (2006) describes a research project where a GIS-based tool is used for illustration and assessment of transport costs, a similar approach could be taken for emissions.
Appendix 3: Company visualization
Sources: Cargill (2009a), Cargill (2009c)

OUR PURPOSE is to be the global leader in nourishing people.

OUR MISSION is to create distinctive value.

OUR APPROACH is to be trustworthy, creative and enterprising.

OUR PERFORMANCE measures are engaged employees, satisfied customers, enriched communities and profitable growth.
Appendix 4: Cargill’s commitment statements towards sustainability and CO2 reduction

“America’s largest food company is hungry to grow even larger. More global. More green. And more visible.”
(Greg Page, Chairman and Chief Executive Officer, Cargill News July – August 2007)

“On a corporate level, climate change touches on almost every part of our business, whether it is transportation, fertilization or acreage.”
(Greg Page, Chairman and Chief Executive Officer, Cargill News July – August 2007)

“I believe, in the absence of some startling new information, that the world is headed for a place where you are charged or penalized for putting carbon dioxide in the air, and you are going to be rewarded for removing it.”
(Greg Page, Chairman and Chief Executive Officer, Cargill News July – August 2007)

“At Cargill, minimizing our environmental footprint is consistent with our environmental policy and the right thing to do. Now, it is creating opportunities for us to bring solutions and services to all our customers.”
(LaRaye Osborne, Vice President of Environment, Health and Safety, Cargill News July – August 2007)

“Together with government, non-profit groups and our customers, we have a good chance to have a positive impact on the problem of climate change.”
(Scott Portnoy, Corporate Vice President, Cargill News July – August 2007)

“Cargill steps up efforts to address one of the foremost issues of our time: climate change.”
(Cargill News July – August 2007)

“Very few companies touch the carbon cycle and the carbon market in as many ways as Cargill. If these initiatives work the way Cargill hopes, the “green” associated with Cargill will refer to more than just the color of its logo.”
(Cargill News July – August 2007)

“Food and feed depend upon clean water, clean soil, clean air, and sunlight.”
(Cargill News, May-June 2009)

"Corporate responsibility is part of everything we do. We will develop ways of reducing our environmental impact and help conserve natural resources. Earth day, every day.”
(Cargill News, May-June 2009)

“We’ll continue to work to further reduce greenhouse gas emissions as part of our overall environmental and energy strategy”
(Cargill News website, June 8 2009)

“Energy efficiency, water conservation and reducing carbon footprints have become major cost-control mechanisms for business, Cargill included. Sustainability is a competitive advantage. (…) Now we are starting to look at environmental sustainability as an opportunity to build closer relationships with customers, offer more valuable products and create a competitive advantage for Cargill.
(Paul Conwayh, Senior Vice President, Cargill News, January-February 2010)
Appendix 5: Production process and production locations of Cargill Cocoa & Chocolate
Source: Cargill (2009b)
### Appendix 6: Country table in TERRA

Source: CRSC (2009)

<table>
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<tr>
<th>Countries</th>
<th>CountryCode</th>
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<th>Rural</th>
<th>Urban</th>
<th>Terrain factor railroad</th>
<th>Terrain factor road</th>
<th>Transmission loss</th>
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</table>
Appendix 7: Cargill Transport Procurement Procedure

Confidential
Appendix 8: Data collection in Te Loo (2009)
Source: Te Loo (2009)

Data collection
In order to make a carbon dioxide emission calculation for Cargill using the methodology described in the previous chapter, data of all Cargill’s transport movements is needed. This chapter describes which data was already available and which data needed to be collected externally. Next, the method used for collecting data and the problems encountered are described.

Data available and data collected
The calculations are based on the award plans available in the ETP. For each lane, these award plans contain data about the origin, destination, logistics service provider, number of transport movements, annual weight of cargo and transport material (trailer or container). For the bulk products, the award plans contain data about the distances for road transport. For packed goods this data is not available.

Method for collecting additional data
This section starts with an evaluation of which parameters to collect externally. The method for collecting these parameters is described in the second part.

Parameters to collect
As a first step in collecting additional data, a list of all parameters that could be used in the calculation was created. This list was split into two parts: the parameters that are required for the calculation and the optional parameters that increase the accuracy of the calculation.

The parameters that needed to be collected are the transport mode used and the distance per transport mode.

For the optional parameters, a trade-off needed to be made between collecting as many data as possible on a smaller number of lanes and collecting fewer parameters on all lanes. Collecting all data on all lanes provides the logistics service providers with a lot of work and therefore the response rate was expected to drop. To be able to make this trade-off, the impact of all parameters on the final results has been evaluated using data collected from two logistics service providers (both operating a large number of lanes for Cargill) prior to the data collection of all lanes. The next sections describe all parameters and the trade-offs made. These sections are summarised in Table 4.

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<th>Collect/assumption</th>
<th>Reason</th>
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</thead>
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</tr>
<tr>
<td>Distance per mode</td>
<td>Collected</td>
<td>Required for calculation</td>
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<td>Assumption: only type collected</td>
<td>More specific data unknown</td>
</tr>
<tr>
<td>Positioning distance</td>
<td>Assumption: 20%</td>
<td>Minor influence on result</td>
</tr>
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<td>Empty returns</td>
<td>Assumption: no empty returns</td>
<td>Almost real situation</td>
</tr>
<tr>
<td>Heating</td>
<td>Assumption: no heating</td>
<td>Unknown for aggregated data</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Assumption: all bulk</td>
<td>Almost real situation</td>
</tr>
</tbody>
</table>

Table 4: parameters to collect / assumptions

Positioning distances
The data on positioning collected from the two logistics service providers showed that their average positioning distance is slightly larger than the 20 percent used by NTM: 24 percent. The increase from 20 to 24 percent leads to an increase in the result of 2 percent. This small influence (20 percent positioning distance increase leads to 2 percent emission increase), together with the difficulty of obtaining this data because of the aggregated information used, resulted in omitting positioning distance from the parameters that needed to be collected.
Empty returns
Empty returns are only taken into account if dedicated equipment is used, so if the empty return is ordered by the company requesting the transport (Cargill). Cargill uses almost no dedicated equipment. Therefore, empty returns are not taken into account at all.

Heating and refrigerating
Cargill uses almost no refrigerating. For some chocolate products, refrigerating is used only when the ambient temperature exceeds 25 degrees Celsius.
Heating is used more often, to be able to unload the product at the destination. Heating can take place during or after transport. The product is loaded at high temperature to prevent heating or reduce heating times. If heating is required, most of the time the product is heated at the customer location. In case of longer transport times, for instance in case of intermodal transport, heating may also take place at terminals and even during transport. A container can be “plugged-in” while transported on a vessel.
The amount of work needed to obtain data on heating, the lack of reliable emission data (as described in the methodology section) and the aggregated data resulted in not taking this parameter into account.

Cleaning
Cargill does not use a lot of dedicated equipment. Therefore all containers and trailers need to be cleaned prior to the transport. This is especially important when food products are transported. Therefore, it is assumed that all bulk transport material needs to be cleaned and all packed transport material not.

Detailed transport vehicle specifications
For road transport, a truck with a typical gross weight (truck and cargo combined) of 40 tonnes (for international transport) is used on all lanes, with only a very limited number of exceptions. Therefore, the truck type used in the calculations is assumed to be this type of truck for all lanes.
For rail transport, the gross weight of the train and the type of traction (electrical or diesel) influence the calculation result. Based on the lanes of the two logistics service providers, it seems almost impossible to collect data on the gross weight of the train. The type of traction is difficult to obtain as well, especially because the lanes are aggregated.
In water transport, a large number of different types of vessels can be used. According to the two logistics service providers, information on the size of the vessel was not available. Therefore, only the type of vessel has been taken into account. Each logistics service provider has been asked to choose one of three ship types: container, ferry or RoRo cargo. Here, the difference between ferry and RoRo cargo is that on a ferry the complete truck is loaded and on a RoRo cargo ship, only the trailer is loaded. On a RoRo ship it is also possible to load a train cart.

Data collection method
Based on the above trade-off for all parameters, the lanes have been split into road transport and all other modes of transport. For road transport all data needed to make a calculation was present, but for all other modes of transport, additional data needed to be gathered.
The other modes of transport are road transport using a ferry or Eurotunnel and intermodal transport using either rail or water transport (or both). For these modes of transport, the routing and the distances per transport modality needed to be known, as well as the vessel type for water transport. Both the lanes of interest and the logistics service providers are known. To obtain the data, all logistics service providers have been contacted by phone. This initial phone call was intended to explain the aim of the study and to obtain contact information of the right persons. Directly after the phone call, an e-mail has been sent to the contact persons with information on the lanes of interest and a further explanation of the data requested. If needed, additional phone calls took place to clarify problems or to remind the logistics service providers of the request.
In total 55 logistics service providers (all operating intermodal transport lanes for Cargill) have been contacted. 45 logistics service providers provided the requested information. One LSP did respond but with data that could not be used (this is not counted as a response) and did not provide the requested information later on. The 10 logistics service providers that did not provide the requested information...
(either no reaction or wrong data) are logistics service providers that operate a small number of lanes for Cargill. Calculated by number of lanes the response rate was equal to 95.9 per cent. It was not possible to find other similarities between these 10 logistics service providers.

All 45 logistics service providers provided the geographical names of the terminals that are used but not the distances per modality. To obtain the distances, different route planners have been used. For road transport distances Google Maps© (Google Maps, 2009) has been used, but where necessary the distances have been calculated using Map 24 (Map 24, 2009), because the coverage of Map 24 is better in Eastern Europe. Rail transport distances per country have been gathered using the route planner from Deutsche Bahn (Rail Distance, 2009) and water transport distances for short sea navigation have been obtained using a World Ports Distances Calculator (Water Distance, 2009).

**Problems**

For most logistics service providers, obtaining the requested data was not a problem. Some logistics service providers, however, only shared the geographical names of the terminals and not the type of vessel used. In these cases, the type of vessel was taken from other logistics service providers operating on the same route. This approach has also been used for the lanes where no information was available, because the logistics service provider did not provide this. During the collection of the data, response times of the different logistics service providers varied a lot. To speed up the data collection, logistics service providers have been reminded of the request every two weeks. In the end, this resulted in a very high response rate.
Appendix 9: Effect of different parameters on emissions

- Positioning 10% vs 20% - effect on total emission
- Positioning 30% vs 20% - effect on total emission
- Electrical traction 0% vs 75.4% - effect on total emission
- Electrical traction 100% vs 75.4% - effect on total emission
- Gross weight train 1500 vs 1000 - effect on total emissions
- Gross weight train 500 vs 1000 - effect on total emissions
- Load factor rail 62% vs 72% - effect on total emissions
- Load factor rail 82% vs 72% - effect on total emissions
Load factor water 70% vs 80% - effect on total emissions

Load factor water 90% vs 80% - effect on total emissions
Appendix 10: Payload restrictions per country
Source: European Transport Forum (2009)

<table>
<thead>
<tr>
<th>Country</th>
<th>Weight per 1st axle</th>
<th>Weight per drive axle</th>
<th>Lorry 2 axles</th>
<th>Lorry 3 axles</th>
<th>Road Train 4 axles</th>
<th>Road Train 5 axles and +</th>
<th>Articulated Vehicle 5 axles and +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>10</td>
<td>11.5</td>
<td>18</td>
<td>26</td>
<td>36</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Azerbaijan</td>
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<td>10</td>
<td>18</td>
<td>24</td>
<td>36</td>
<td>40</td>
<td>44</td>
</tr>
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<td>Belgium</td>
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<td>12</td>
<td>19</td>
<td>26</td>
<td>39</td>
<td>44</td>
<td>44 (1)</td>
</tr>
<tr>
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<td>19</td>
<td>26</td>
<td>38</td>
<td>40</td>
<td>40</td>
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<td>36</td>
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<td>18</td>
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<td>42 / 48</td>
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<td>18</td>
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<td>42 / 48</td>
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<td>40</td>
<td>40 / 44 (10)</td>
</tr>
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<tr>
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<td>11.5</td>
<td>18</td>
<td>26 (2)</td>
<td>36</td>
<td>40</td>
<td>40 / 44 (10, 19)</td>
</tr>
</tbody>
</table>

Notes:
1. 2 axles tractor + 3 axles semi-trailer: mechanical suspension = 43t; pneumatic suspension = 44t
2. With air suspension or similar
3. Weight per drive axle: national traffic = 10t; international traffic = 11.5t; Lorry 3 axles: national traffic = 24t; international traffic = 26t
4. 3 axle tractor + 1 axle trailer = 35t
5. 3 and + axles tractor + 3 and + axles trailer = 44t
6. For vehicles registered in an EEA member country
7. 5 axles = 44t; 6 axles = 56t; 7 axles = 60t
8. 44t is applicable for 40 feet long ISO containers
9. Weight per drive axle: mechanical suspension (national traffic) = 10.5t; road friendly suspension (national traffic) = 11.5t; international traffic = 11.5t
10. For vehicles engaged in combined transport
11. Weight per drive axle: mechanical suspension = 11.5t
30-Jul-09
12. Under specific conditions EMS (European Modular System) combinations may have a maximum length of 25.25 m and maximum mass of 60t
13. 3-axle motor vehicle with 2 or 3 axle semi-trailer carrying a 40 feet ISO container as a combined transport operation
14. 2 axle motor vehicle with 3 axle semi-trailer carrying a 40 feet ISO container as a combined transport operation
15. 5 axles = 48t; 6 axles = 58t; 7 axles = 60t
16. With the conditions laid down in Regulation for type approval.
17. Container trucks 2 axles = 18t; 3 axles = 24t; road train 4 axles, 5 axles and + and articulated vehicles 5 axles and + = 44t; container trucks licensed by the state Motor Road service of Ukraine and State traffic Inspection Department: road trains and articulated vehicle 5 axles and + = 46t
18. For general operation at 44t, at least 6 axles are required. The drive axle(s) must not exceed 10.5t and have twin tyres / road friendly suspension. Vehicles not having road friendly suspension on the drive axle(s) must have twin tyres and a maximum axle weight not exceeding 8.5t. Each part of the combination must have at least 3 axles and the trailer must have road friendly suspension.
Appendix 11: EU ETS price development
Source: Ellerman & Joskow (2008)
Appendix 12: Organizations contacted for mapping intermodal terminals

<table>
<thead>
<tr>
<th>Rail</th>
<th>Short-sea</th>
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<tbody>
<tr>
<td>Deutsche Bahn</td>
<td>European Sea Port Organisation (ESPO)</td>
</tr>
<tr>
<td>Nationale Spoorwegen (NS)</td>
<td>Europan Shortsea Network</td>
</tr>
<tr>
<td>Raillion / Deutsche Bahn Schenker</td>
<td>FEPORT</td>
</tr>
<tr>
<td>European Railway Agency (ERA)</td>
<td>World Maritime University Malmo</td>
</tr>
<tr>
<td>International Union of combined Road-Rail transport companies (UIRR)</td>
<td>International Association of Ports and Harbors (IAPH)</td>
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<tr>
<td>Kombiverkehr</td>
<td>Port of Rotterdam</td>
</tr>
<tr>
<td>International Union of Railways (UIC)</td>
<td>Institute of Shipping Economics and Logistics (ISL)</td>
</tr>
<tr>
<td>Community of European Railway and infrastructure companies (CER)</td>
<td><a href="http://www.ports.com">www.ports.com</a></td>
</tr>
<tr>
<td>European Shippers Council (ESC)</td>
<td><a href="http://www.worldportsource.com/">http://www.worldportsource.com/</a></td>
</tr>
<tr>
<td>RailNetEurope</td>
<td>TERRA tool</td>
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<table>
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<tr>
<th>Inland waterways</th>
<th>Intermodal</th>
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</thead>
<tbody>
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<td>Inland navigation Europe (INE)</td>
<td>European Intermodal Association (EIA)</td>
</tr>
<tr>
<td>European Federation of Inland Ports (EFIP)</td>
<td>Trans European Network Agency (TEN-T)</td>
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<tr>
<td>Voorlichtingsbureau Binnenvaart</td>
<td>Europan Intermodal Research Advisory Council (EIRAC)</td>
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<td>Eurostat</td>
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<td>Rail Cargo Information Netherlands</td>
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<td>Ministerie van Verkeer en Waterstaat</td>
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<td>BE LOGIC</td>
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</tr>
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<td><a href="http://www.hollandintermodal.com">www.hollandintermodal.com</a></td>
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</table>
Appendix 13: Visualization of short-sea freight terminals in ESPO and TERRA

**ESPO**

![ESPO Map]

**TERRA**

![TERRA Map]
Appendix 14: Mini-RFQ files

Overview of selected lanes

Confidential

Guidance mail

Dear LSP,

This email is an invitation to participate in a mini-Request For Quotation (RFQ) executed as part of the Green Transport Project, which is a project within the European Transport Procurement department of Cargill and focuses on reduction of CO2 emissions in transport. One of the most promising possibilities is to shift from road to intermodal transport.

To investigate the potential of intermodal transport, a number of current road lanes have been identified to investigate further via this mini-RFQ. All these lanes concern the transportation of bulk liquids for the business unit Cargill Cocoa & Chocolate. Please note that this is NOT an official RFQ, but a separate study with which we seek to get more insight in the possible reduction of CO2, the effect on costs and the impact on lead times.

In the attachment you will find the Bidder Form to place your bids. Please download and save the Excel file on your own PC (choose your assigned folder and save as Excel 2003 or 2007 version). First carefully read the instructions in the first worksheet called “Bid instructions”. Then fill out your bids in the second worksheet called “Bidder form”. Once all is done then please reply to this email and attach the completed and saved Excel file.

All bids have to be entered taking into account the Cargill Terms & Conditions, the Bulk Liquid Transport Booklet and Transport Agreement, as valid today. It may be that the list contains lanes on which you already have bid on intermodal basis in the last Bulk Liquid RFQ. In such cases we would like to ask you to enter your (same) bid with the additional data requested.

Please return the completed Bidder Form latest before February 12th. In case of any question related to this invitation please do not hesitate to contact us.

With great interest we are looking forward to receive your completed Bidder Form.

Best regards,

On behalf of Niels Juel Hansen

Stefan Boere
Green Transport Project Trainee, Cargill European Transport Procurement

Cargill Nordic A/S
Ordrupvej 101, 2nd - 2920 Charlottenlund - Denmark
Tel +45 4546 9024

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**Bidder form (content)**

**GENERAL**
- Please only enter Intermodal bids
- Please only bid on lanes where you are interested in.
- Please enter only one bid per lane
- There is no possibility for combination bids, bids with other equipment or discount for specific turnover
- Your bids should be excluding the fuel surcharge
- Mandatory fields are marked with 'required'
- The bidder form you find in the second worksheet named 'Bidder form'

**GLOSSARY**

**LANE SPECIFICATIONS**

<table>
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<th>Description</th>
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<td>Lane ID</td>
<td>Unique reference for the lane.</td>
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<tr>
<td>Origin country</td>
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</tr>
<tr>
<td>Origin area</td>
<td>Origin area postal code (Country code + 2 digit postal code)</td>
</tr>
<tr>
<td>Origin city</td>
<td>Origin city name</td>
</tr>
<tr>
<td>Destination country</td>
<td>Destination country name</td>
</tr>
<tr>
<td>Destination area</td>
<td>Destination area postal code (Country code + 2 digit postal code)</td>
</tr>
<tr>
<td>Destination city</td>
<td>Destination city name</td>
</tr>
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<td>BU</td>
<td>Cargill Business Unit, always Cocoa&amp;Chocolate (C&amp;C)</td>
</tr>
<tr>
<td>Lane risk classification</td>
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<tr>
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<td>Product description</td>
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</tr>
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<td>Density kg/l</td>
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<td>Historical volume shipped per year</td>
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**BID FIELDS**

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<td>Enter lump sum price in Euro based on the lane specifications given</td>
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<td>Indicate your payload in mT, taken into account the empty truck weight and the national and European regulations, without tolerance</td>
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<td>Needed transportation time from departure from plant to arrival at customer location (excluding loading and unloading time)</td>
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<td>Train type (required if IM)</td>
<td>Only for IM rail. Indicate whether diesel or electrical train is used (pick from list)</td>
</tr>
<tr>
<td>Field</td>
<td>Description</td>
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</tr>
<tr>
<td>Loading country (required)</td>
<td>The country where the loading terminal is located (where the goods are put on the train or boat)</td>
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**Intermodal LSPs invited**

Confidential
Appendix 15: Mini-RFQ response statistics

Confidential
Appendix 16: Savings index statistics

Scatter plots

**Intermodal rail**

**Intermodal short-sea**
### SPSS output intermodal rail

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a. Dependent Variable: DV

### SPSS output intermodal short-sea

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a. Dependent Variable: EmissionSaving
Appendix 17: Basic inventory theory
Source: De Kok (2002)

The basic inventory formulas used are:

$$E[X] = \frac{1}{2}Q + s - \lambda L$$

$$P_2 = 1 - \frac{1}{Q}E[(D(\tau_i, \tau_i + L_i) - s)^+]$$

Where:

- $E[X]$ Expected net stock
- $Q$ Order quantity
- $s$ Reorder point
- $\lambda$ Demand intensity (Poisson)
- $L$ Replenishment lead time
- $P_2$ Probability of no stock out just before the arrival of an order

- $D(\tau_i, \tau_i + L_i)$ Demand during lead time of a replenishment order placed at time $\tau_i$