

Outbound transportation and its environmental impact.
Case company: Drilling Mud Corporation (Vietnam)

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<p>This thesis aims to evaluate the environmental impacts of outbound transportation in the case company. The evaluation focuses on transporting Bentonite within Ho Chi Minh City. Bentonite is the most important product of the company.</p> <p>The objective of this thesis is to investigate the theories behind the environmental impacts of road transportation, including greenhouse gas (GHG) emission calculations and outbound transportation systems so as to identify problems in the company. Information was sought through interviews with the company's representative and its outsourced Third Party Logistics's representatives. In addition, concepts around GHG emissions are also investigated.</p> <p>This thesis project took place between January 2013 and October 2013, with the empirical research conducted from April 2013 to May 2013. The research has found remarkable problems in the case company when it comes to environmental management in road transportation.</p> <p>The thesis concluded with a recommendation on linear programming related to transportation problems and CO₂ calculation methods. Another recommendation is a GHG protocol, which is about emission calculating, analysing and reporting. Moreover, in order to reduce CO₂ emissions, it is highlighted that the company should integrate its GHG protocol and CO₂ emission calculation.</p>	
<p>Keywords Outbound transportation, greenhouse gas emissions (GHG), GHG protocol , environmental impact, optimizing resources, transportation emissions</p>	

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1 Introduction

This chapter presents background of thesis topic and research problem setting. The case company named Drilling Mud Corporation is also included in the chapter. More, key concepts and structure of report are explained.

1.1 Topic background

This case study concentrates on outbound transportation, which is defined as movement of final products from a point of origin to a point of consumption through different modes of transportation (Lai 2009, 96). In addition, the study focuses on environmental influence when transporting Bentonite, which is the most important drilling fluid in Drilling Mud Corporation (DMC). The company's business focuses on the sale of drilling fluid, oil exploitation, oil refinery, water treatment and others. Its main product is Bentonite and the whole corporation has three main distribution centres which are from the North, the Central and the South of Vietnam. In order to save logistics cost, provide fast delivery to customers, the company outsources main part of logistics to several Third Party Logistics (3PLs). The 3PLs have emissions report but it is not enough for DMC to consider how much transportation's energy consumption they should reduce.

Environmental issues relating to transportation are what company have been trying to avoid as much as possible for years. From one side, transportation activities support mobility demands for delivering raw materials to factories as well as delivering products to customers. On the other side, it has resulted in growing levels of motorization. As a result, transportation sector is increasingly linked to environmental problems. In addition, fossil fuel emissions are rising dramatically and most of Vietnamese companies are not measuring greenhouse gas (GHG) emissions, as they think their business do not have a significant climate change impact or they assess its importance differently. Therefore, the most common first step towards action on climate change is to conduct an inventory of GHG emissions as companies need to know their current situation for a start. (Sundin & Ranganathan 2002, 137-144.)

As discussed, the company agreed that they should have a broader view of their outbound transportation's inventory of carbon dioxide (CO₂) emissions, the most significant emission, then find possible solutions for reducing it.

1.2 Research problem

As noted in the previous section, DMC focus on the sale of drilling fluid, oil exploitation, oil refinery, water treatment. The company's strategy is to provide the best qualified product with suitable price in the way that products need to be optimal for customer needs. DMC are always looking for developing technology, technique, management system of perfect logistics and supply services.

The aim of this study is to get a broader understanding of GHG emissions, specially CO₂ and optimization of distribution system in outbound logistics of Bentonite. More, I will provide recommendation for the company, where applicable and different stages of outbound logistics need to be identified. The inventory of GHG emissions is defined according to the transportation modes, amount of tonne- kilometres and routes and type of fossil fuel used. By doing so, the goal is to find possible solutions for reducing the emissions by optimizing resources or other ways if needed.

The chosen case company represents a Vietnamese enterprise engaged in international business. The company's management allowed me to study closely the outbound transportation structure in the company, which provides the opportunities for coming up with real solutions to found problem. This gives further validity to the study at hand and also makes the analysis work more interesting.

The research question for this thesis can be stated as follow:

How to decrease CO₂ emissions of DMC's outbound transportation of Bentonite ?

In order to answer the main research question, more questions need answering. Thus, the investigative questions address the following issues:

Q1: How is the current level of CO₂ emissions of DMC's outbound transportation?

Q2: How to minimize transportation's energy consumption?

Q3: How to reduce CO₂ emissions?

The purpose of the first question is to investigate the current level of CO₂ emissions of outbound transportation of Bentonite based on company's information, 3PLs's response and secondary data. From the current level of emissions, I will find the best solutions to minimize transportation's energy consumption. The final step is to reduce CO₂ emissions according to results. These relationships are collected in the matrix below:

Table 1. Overlay matrix

Investigation questions	Theory chapter	Data collection tools	Informant group	Results and discussion chapters
How is the current level of CO ₂ emissions of DMC's outbound transportation?	3.1; 3.2 3.3	Secondary data Structured Interview	Company's representative Public resources	7.1; 8.1
How to minimize transportation's energy consumption?	5.1; 5.2	Secondary data Structured Interview	3PL's representative Public resources	7.2 ; 8.2

How to reduce CO ₂ emissions?	5.1; 5.2	Data combination	Results from IQ1&2	7.2 ; 8.2
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1.3 Scope of the research

At this stage it is important to outline the demarcations of this study. Firstly, this research will focus on collecting CO₂ emissions inventory of road transportation in outbound logistics from the perspective of the case company and its 3PLs since the company want to have data relating to those emissions and this fact is the answer for the first investigative question. From the view of measuring greenhouse gas emissions, the study focuses on scope 3 in GHG protocol, which is about supply chain emissions, such as fertilizers and packing materials, along with emissions from transporting products to markets. (ghauri et al. 2010, 9-11,16-17.)

Secondly, outbound logistics includes warehousing and transportation. In the research, I only focus on its road transportation. This study will not look into the case company's warehouse layout and the optimization of space usage through the design of the warehouse shelves and other relating features.

Finally, the aim of this research is to optimize outbound logistics system by analyzing locations of supply bases, demand bases, amount of fuel consumed and routes to find possible routes with minimum energy consumption for the company. Investigation into tools with which costs can be reduced, e.g. pricing, forecasting and discount systems, are outside the scope of this research.

1.4 Key concepts

In this study, the key concepts are outbound transportation, sustainable transportation and optimizing resources. These terms are explained below.

Outbound transportation- movement of final products from a point of origin to a point of consumption through different modes of transportation (Lai 2009, 96).

Greenhouse gas emissions in transportation– “the emissions from the combustion and evaporation of fuel for all transport activity, regardless of the sector, but excluding international aviation and maritime transport.” (European Environmental Agency 2013).

Resource optimization- use Linear Programming (LP) problem to show maximization or minimization of some quantity, which is the objective in all linear programming problem (Anderson et al 2009, 30).

1.5 Theoretical framework

The theoretical framework begins with GHG in general concerning transportation.

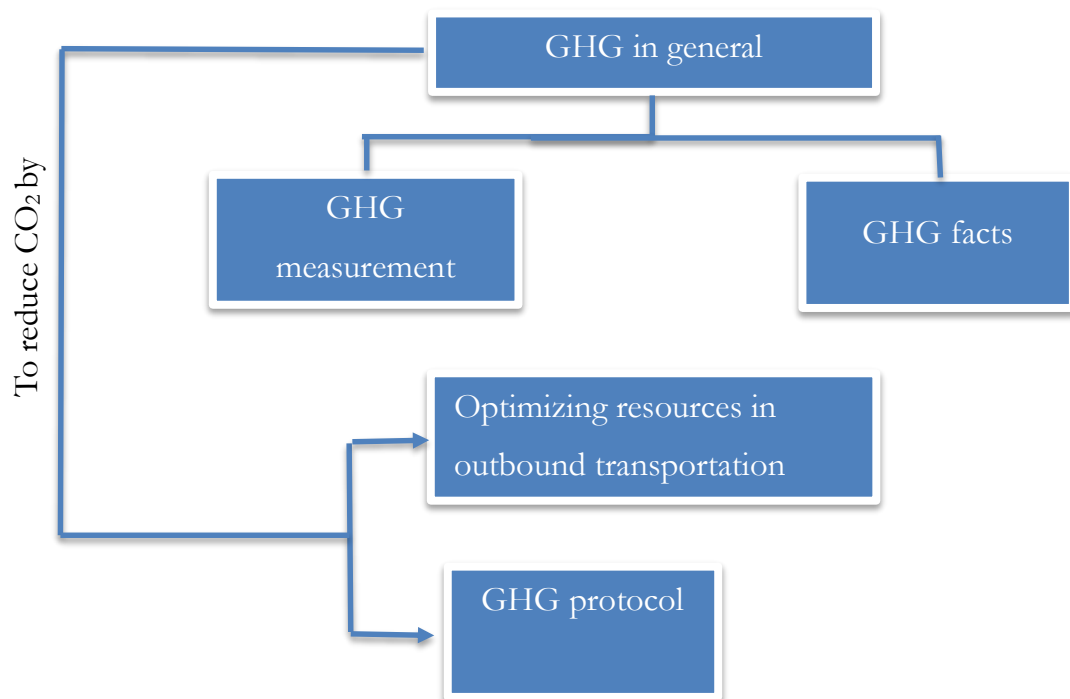


Figure 1. Theoretical framework

From there, it comes to three main researches in this study, which are GHG measuring and GHG facts. As explained in the previous chapter, the goal of this study is to

reduce CO₂ and transportation's energy consumption, optimizing resources and GHG protocol are considered as tools to achieve the goal. In addition, outbound transportation is set as limitation in DMC's supply chain.

1.6 Drilling Mud Corporation

The commissioning company for this study is Drilling Mud Corporation (DMC), were found in 1990, more specifically DMC are the first subsidiary to supply chemicals and drilling fluids service for Vietnam petroleum industry. It is an international corporation, operating mainly in Vietnam and other countries such as Taiwan, India, and China etc. Current personnel size is around 500 including professionals. The main production at DMC is chemicals product for petroleum and other industries. Bentonite is the main chemical product that DMC imported from India, Australia and supply to end-users (Company representative 10 January 2012).

The main thesis beneficiaries in the company are the business department, technical and environmental department are highlighted in red colour on the organizational chart showed in the attachment 1. There is no specific logistics department in the company because its activities based on different projects or contracts. DMC also outsource one part of the activities to 3PLs. Currently, the company have three main supply bases across Viet Nam for Bentonite : Vung Tau, Quang Ngai, Ha Noi (Company representative 10 January 2012).

2 Outbound transportation

Transportation is defined as physical movement of goods between points and it is important since it carries goods along the supply chain. The transportation is influenced by transportation costs, inventory management, transport modes, type of carrier etc. In this chapter, some significant transport modes and its greenhouse gas emissions produced will be expressed. (Tracy 2004, 31.)

Outbound transportation allows final products to move from a point of origin to a point of consumption through different modes of transportation. Delivering products to customers at the right time, quality and quantity requires a high level of planning and cooperation a firm, customers and many distribution elements such as warehousing and break-bulk or repacking services. Further, the outbound transportation function creates time utility by determining how fast final products are delivered. Place utility is created when customers get products delivered to the design location. Further, outbound transportation is important and has to be controlled well since products have little value to customers until they are moved to them for consumption. (Lai 2009, 96.)

In the whole business logistics, it is the combination of inbound movements and physical distribution and the connections between two parts are indicated in figure 2. In the figure, the circles represent buildings where inventories are stored and the lines with arrows represent movement performed by carriers or transport modes. In the supply chain, logistics coordinate inbound logistics, material management, and physical distribution in cost- efficient manner. There, inbound logistics refers to primary process of logistics, which concentrate on purchasing and arranging movement of materials, spare part etc. In addition, material management deals with the tangible components a supply chain. Total cost approach is the way logistics managers use to coordinate the system. The aim of this approach is built on the fact that all relevant activities in moving and storing products should be considered as a whole. (Murphy &Wood 2008, 11-13.)

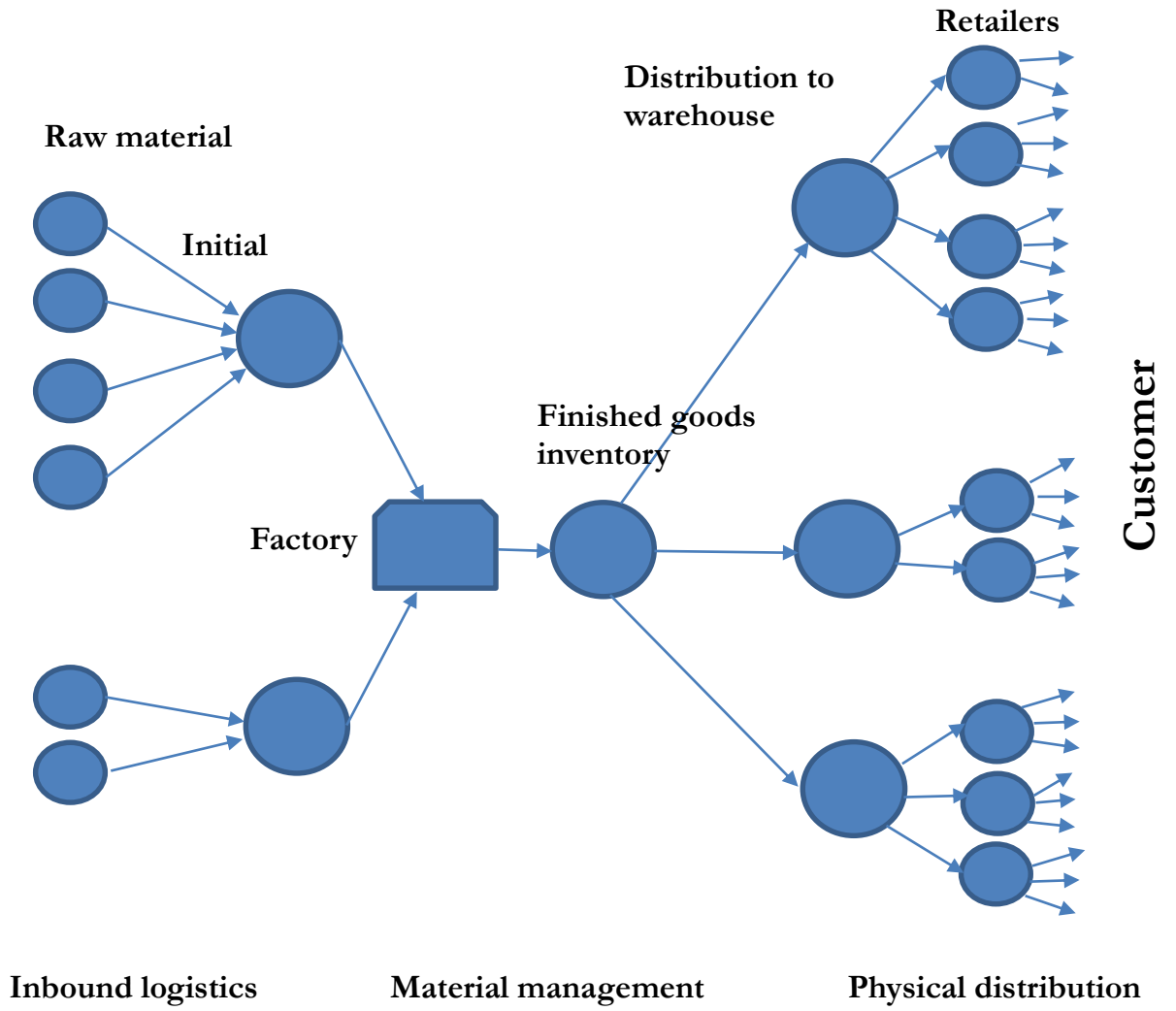


Figure 2. Control over the flow of inbound and outbound movements (Murphy & Wood 2008, 11-13).

3 Greenhouse gas emissions (GHG) of transportation

In this chapter, an overview of greenhouse gas emission will be expressed in details of spectacular emissions. Measuring the emissions is the main part in this chapter which is explained according to different energy fuels. Some facts of greenhouse gas emissions give a big picture of how organizations handle their emission inventory.

3.1 Greenhouse gas emissions

All businesses, large and small, from the industrial sector to services, produce greenhouse gas emissions. Heating and cooling office spaces, powering electronic equipment, transportation are main activities that produce greenhouse gas emissions and contribute to climate change. In this research, I only focus on greenhouse gas produced from transportation which includes the movement of people and goods by cars, trucks, trains, ships, airplanes, and other vehicle.

Carbon dioxide (CO₂) is the main contributor to climate change, especially through the burning of fossil fuels like coal, oil and gas. In addition, the majority of greenhouse gas emissions from transportation are CO₂ emissions. Consequently, it is my main focus in the study. Besides, there are small amounts of methane (CH₄) and nitrous oxide (N₂O) and hydro fluorocarbon (HFC) emissions are emitted during fuel combustion. These emissions result from the use of mobile air conditioners and refrigerated transport. The global greenhouse gas emissions by gas are expressed in figure 3. (EPA 2010b.)

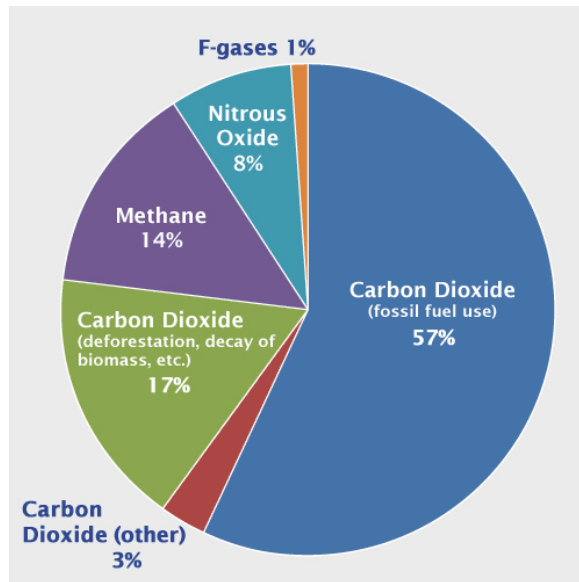


Figure 3. Global greenhouse gas emissions by gas (EPA 2010b).

Global greenhouse gas emissions can also be broken down by economic activities. In the figure 4 below, the emissions from transportation involve fossil fuels burned for road, rail, air and marine transportation. Almost all (95%) of the world's transportation energy comes from petroleum- based fuels, largely gasoline and diesel (EPA 2010b)

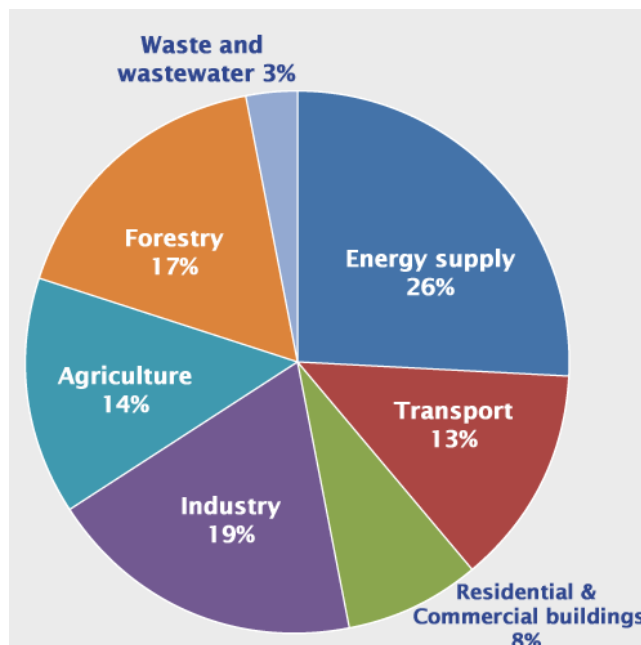
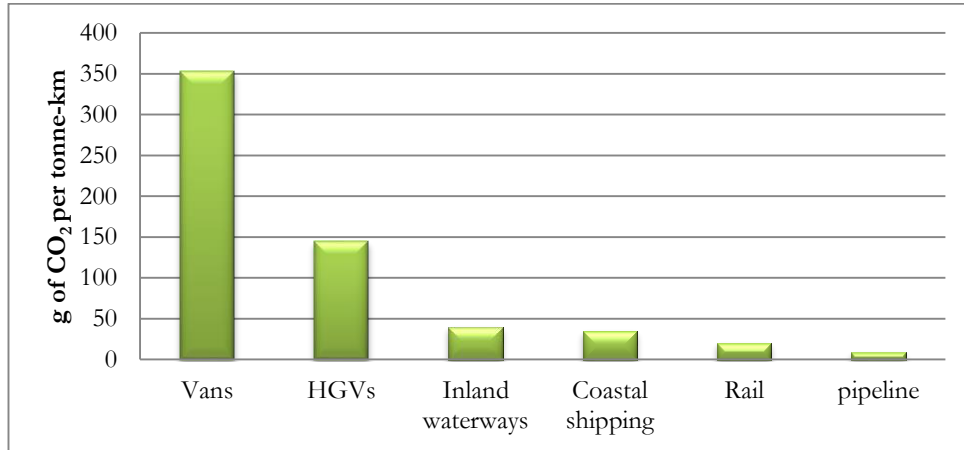


Figure 4. Global greenhouse gas emissions by source (EPA 2010b)

As different transport modes have significant impacts on environment, figure 5 presents assessment of the CO₂ emissions per tonne-km for a range of transport modes. It showed that rail and waterborne modes of transport are less effecting to environment than road haulage.



HGV: Heavy Goods Vehicles

Figure 5. Estimated average CO₂ intensity values for freight transport modes (McKinnon et al 2010, 129.)

3.2 Measuring greenhouse gas emissions

In order to measure transportation emissions, Greenhouse Gas Protocol is one method that can report greenhouse gas emissions and it is used by companies, governments and non-government organizations (Bhatia et al 2011, 4).

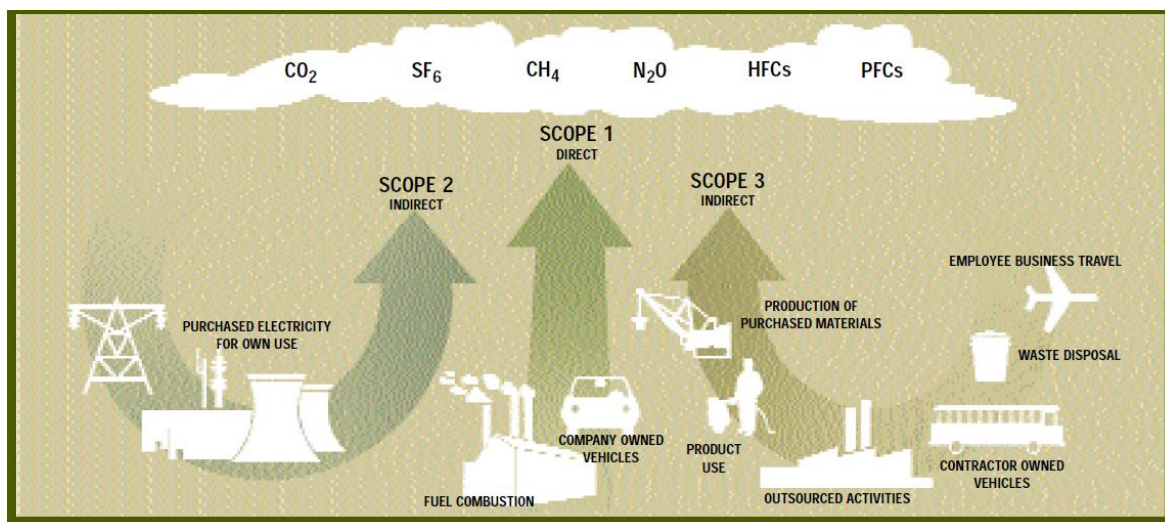


Figure 6. Breakdown of GHG emissions sources according to the GHG Protocol (Bhatia et al 2011, 5).

In the figure above, scope 1 represents for fuel consumption of water heaters, boilers and farm equipment. Scope 2 represents for purchased electricity, heat and steam and scope 3 is about supply chain emissions, such as fertilizers and packing materials, along with emissions from transporting products to markets. Organizations gradually pay more attention to manage their greenhouse gas emissions inventory and scope 3 emissions are the main target. More, the transport of goods in vans would be classed as scope 3 emissions. (Lingl et al 2010, 9-11,16-17.)

After establishing an emissions boundary by choosing which is the main scope of emissions to focus, companies will collect activity data or information about emission source within the boundary. The accuracy of data is very important because it depends a lot on activities. Therefore, the data should be collected carefully and if some data is not available for some emission sources, companies have to use their estimates. In transportation, companies base on typical units or data type such as kg/lbs/tonnes and km/miles transported, and modes of transport to find activity data. (Lingl et al 2010, 9-11,16-17.)

Emissions from freight transportation depend on type of fuel consumed. Diesel and petrol are considered to be the main fuel types. They have slightly different

environmental impacts as their mix of pollutant emissions varies. In addition, according to Clean Air Task Force (2005) diesel engines release harmful substances including directly emitted organic and elemental carbon. The standard fuel CO₂ conversion factors for different types of fuel are showed in the table 2.

Table 2. Standard road transport fuel conversion factors (McKinnon et al 2010, 33).

Fuel type	Total units used	Units	x	Kg CO2 per unit	Total
Petrol		Litre		2.3154	
Diesel		Litre		2.6304	
Compressed national gas (CNG)		Kg		2.7178	
Liquefied petroleum gas(LPG)		Litre		1.4975	

Compressed national gas (CNG): natural gas under pressure which remains clear, odorous and non-corrosive (California Energy Commission).

Liquefied petroleum gas (LPG): clear, natural form of energy that burns extremely cleanly without any soot, releasing only CO₂ and water (Neste Oil).

In the results chapter, I will use this table to calculate the total amount of emissions CO₂ of DMC's outbound transportation. The reason why I only chose CO₂ as the main emission to calculate will be explained in next chapter.

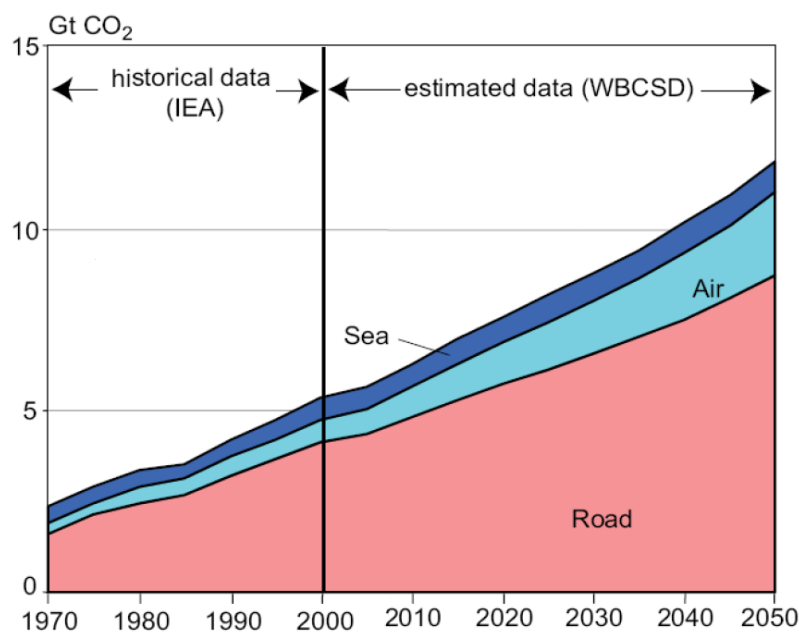
The GHG inventory must include a base year, which provides a consistent reference for comparing emissions over time and the choice of a base year varies by company. If companies have not previously identified a base year and for which historical data is difficult to obtain, the current year should serve as the base year. (Bauer et al 2007, 87.)

According to United Nations , the base year should be begun in 1990 or 2000. Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. Since there are high levels of GHG emissions in the atmosphere in developing countries, the Protocol places a heavier burden on those countries.

Furthermore, in the case that a company undergoes internal changes such as acquisitions, divestments and mergers, the base year need to be recalculated. The recalculation is based on the transfer of control of emissions generated from activities from one company to another. In addition, base year emissions are not recalculated for organic growth. “Organic growth” refers to changes in production output, production mix and operating units. (Bauer et al 2007, 87.)

3.3 Greenhouse gas emissions of road transportation

Road transportation has played an important role in freight transport market and it has several impacts on the environment such as air pollution, climate change and health risks. Further, GHG of road transportation has the highest share in the transport CO₂ emissions and it is expected to double between 2000 and 2050 as showed in figure 7. The main growth is to be expected from road transport and aviation. (EPA 2010b.)



IEA: International Energy Agency

WBCSD: World Business Council for Business Development

Figure 7. Historical and projected CO₂ emissions from transport by mode (EPA 2010b.)

3.4 Greenhouse gas emissions facts

This chapter draws attention to environmental impacts of freight transport's emissions by showing significant figures, data. First of all is the pollutants emitted by transport is divided into local, regional and global effects as reflected in table 3. The global effect has become the main cause of environmental concern since scientific researchers found that it causes more climate change than before. Consequently, climate change spread out to regional and local areas. CO₂ is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere). It affects the ability of natural sinks, like forest to remove CO₂ from the atmosphere. (McKinnon et al 2010, 34.)

Table 3. Geographical extent of pollutant effects (McKinnon et al 2010, 33).

Effect	PM	HM	NH ₃	SO ₂	NO _x	NMVOC	CO	CH ₄	CO ₂	N ₂ O
Global										
Greenhouse indirect					X	X	X	X		
Greenhouse direct								X	X	X
Regional										
Acidification			X	X	X					
Photochemical					X	X	X			
Local										
Health and air quality	X	X	X	X	X	X	X			

PM- particulates, HM- heavy metals, NH₃- ammonia, SO₂- Sulphur dioxide, NO_x- Oxides of nitrogen, NMVOC- non-metallic volatile organic compounds, CO- carbon monoxide, CH₄- methane, CO₂- carbon dioxide, N₂O- Nitrous Oxide.

Acidification: “When CO₂ combines with seawater, chemical reactions occur that reduce the seawater pH, hence the term ocean acidification.” (Woods Hole Oceanographic Institution)

Photochemical: “a chemical reaction initiated by the absorption of energy in the form of light”. (Encyclopaedia Britannica).

Global Warming Potentials (GWPs) is important term relating to GHG. They are defined as:

The ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas. Direct radiative effects occur when the gas itself is a greenhouse gas. (EPA 2013, 25.)

It is said that greenhouse gas emissions are the total mass of a GHG such as kilograms, pounds, metric tons and so on, not units of volume such as cubic meters, cubic feet, litres, released to the atmosphere over a specified period of time. Each gas has different GWP and the GWP of a given GHG is calculated “ by multiplying the radiative forcing impact of one mass-based unit of this gas relative to an equivalent unit of carbon dioxide over a given period” .(McKinnon et al 2010, 34.)

GWP values are only for gases that have long atmosphere lifetime (e.g. in years) since these gases last long enough in the atmosphere to mix evenly and spread throughout the atmosphere to form a relative uniform concentration. The international standard is to express greenhouse gas in units of carbon dioxide equivalent, commonly written as CO_{2e}. It is more difficult to estimate freight transport of emissions of CH₄, N₂O, and HFCs than of CO₂ since emissions of CH₄ and N₂O depend on vehicle kilometres travelled rather than fuel consumption per kilometres. Table 4 is an official set of GWPs published by DEFRA, which is Department for Environment, Food, and Rural Affairs. More, the amount of HFC leakage from air conditioners depends on many

factors such as system design, amount of use and maintenance. (McKinnon et al 2010, 35.)

Table 4. The global warming potential (GWP) of the six Kyoto greenhouse gases (McKinnon et al 2010, 35.)

Greenhouse gas	Global Warming Potential (GWP) DEFRA	Global Warming Potential (GWP) IPCC
CO ₂	1	1
CH ₄	21	25
N ₂ O	310	298
Hydrofluorocarbons (HFCs)	140-11,700	124-14,800
Perfluorocarbons (PFCs)	6,500-9,200	7,390-12,200
Sulphur hexafluoride (SF ₆)	23,900	22,800

4 Greenhouse gas protocol

Greenhouse gas protocol (GHG protocol) launched in 1998, which is used in business, non- governmental organizations (NGOs), government and so on. Its mission is to develop GHG accounting and reporting standards. The purpose of this standard is to provide standards and guidance for companies to report a GHG emission inventory from value chain activities. (Bhatia et al 2011, 2.) Figure 8 reflects overview of steps in scope 3 accounting and reporting.

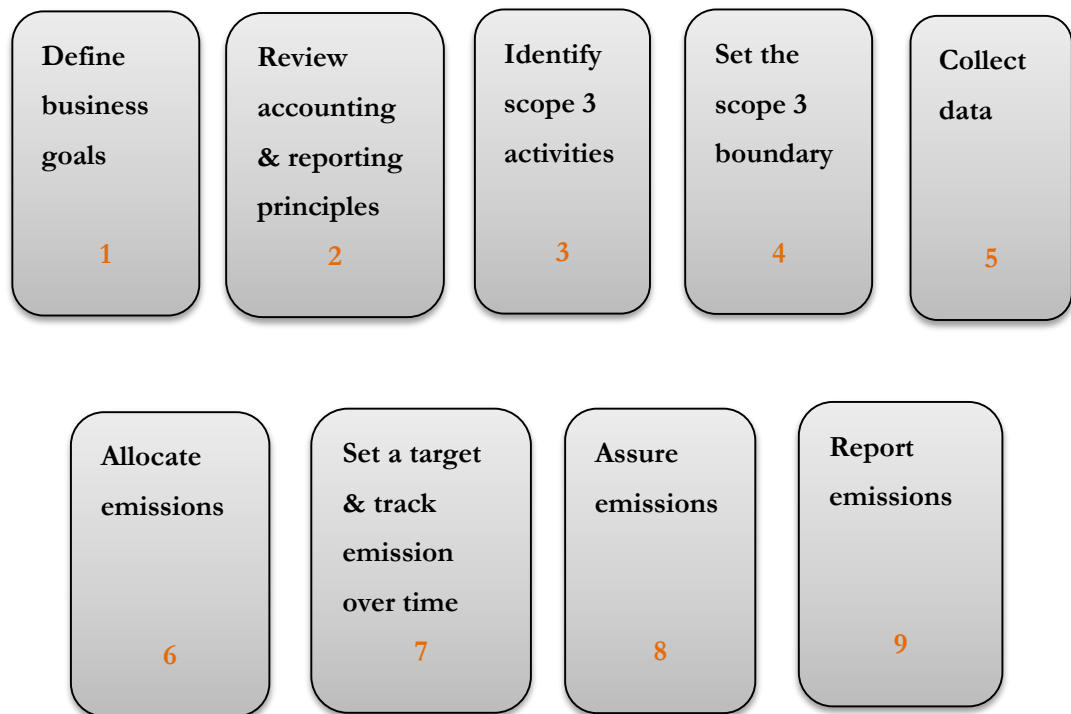


Figure 8. Overview of steps in scope 3 accounting and reporting (Bhatia et al 2011, 19.)

First of all, companies have to define their business goals in order to understand their value chain GHG emissions as a step to manage emissions- related risks and opportunities (Bhatia et al 2011, 12). There are business goal served by scope 3 GHG inventory which is showed in attachment 4. The second steps is reviewing accounting and reporting principles. In addition, this step should be based on following principles:

- Relevance: GHG inventory have to reflect GH emissions of the company;

- Completeness: report all GHG emissions sources and activities;
- Consistency: use trusted methodologies to track emissions over time;
- Transparency: report all relevant issue in a coherent manner;
- Accuracy: the quantification of GHG emissions has to be judged emissions.
(Bhatia et al 2011, 23.)

The third step identifies scope 3 emissions and there are two types of emission: direct emissions and indirect emissions. Direct emissions are defined as “emissions from sources that are owned or controlled by the reporting company”. (Bhatia et al 2011, 27.) Indirect emissions are “a consequence of the activities of the reporting company, but occur at sources owned and controlled by another company” (Bhatia et al 2011, 27). Besides, a complete GHG inventory includes scope 1, scope 2 and scope 3. In scope 3 emissions, it includes emissions owned by other entities in value chain such as material suppliers, third- party logistics providers, waste management suppliers etc. Furthermore, scope 3 emission is divided into upstream emissions and downstream emissions which can be seen in attachment 5. (Bhatia et al 2011, 27.)

The fourth step is setting the scope 3 boundary. Companies should set a minimum boundary according to upstream scope 3 emission and downstream scope 3 emission. In downstream transportation, the minimum boundary would be the emissions of transportation providers, distributors and retailers that occur during use of vehicles and facilities from energy use. (Bhatia et al 2011, 36.)

The fifth step is collecting data based on the most significant GHG emissions that companies should prioritize related data collection in scope 3 activities. In this way, it allows companies to focus resources on the most significant GHG emissions in the value chain. (Bhatia et al 2011, 87.) Moving on is the sixth step which is allocating emissions. It’s defined as “the process of partitioning GHG emissions from a single facility or other system (such as activity, vehicle, production line, business units, etc.) among its various output” (Bhatia et al 2011, 87). Companies need to allocate emissions by using primary data from suppliers or other partners. Equally important,

allocation is only necessary when a facility produces multiple outputs and emissions are only quantified for entire facility.

The seventh step is setting a GHG reduction target and tracking emissions over time. The first thing is to choose a base year and determine base year emissions. Base year is the year in history against which an organization's emissions are tracked over times. However, in case there are some changes such as merger, acquisition, investment in the organization, they should recalculate the base year because these changes may have a significant impact on the inventory. Next thing is quantifying changes in scope 3 emissions overtime, which is defined as following (Bhatia et al 2011, 99.):

Current year emissions from scope 3 category – base year emissions from scope 3 category.
(Bhatia et al 2011, 99.)

The eighth step is the requirement of assurance since this is a prove that the GHG inventory is complete, accurate without any material misstatement. The last step in GHG protocol is that company will report present information based on the principles of relevance, accuracy, completeness, consistency and transparency. (Bhatia et al 2011, 114, 121.)

There are emissions standards for diesel engines of heavy duty vehicles (HDV) which tell that those vehicles should meet certain emissions standards it is applied very between countries. Most of them apply the European standards. Figure 9 shows standards for particle pollution (PM10) in various parts of the world.

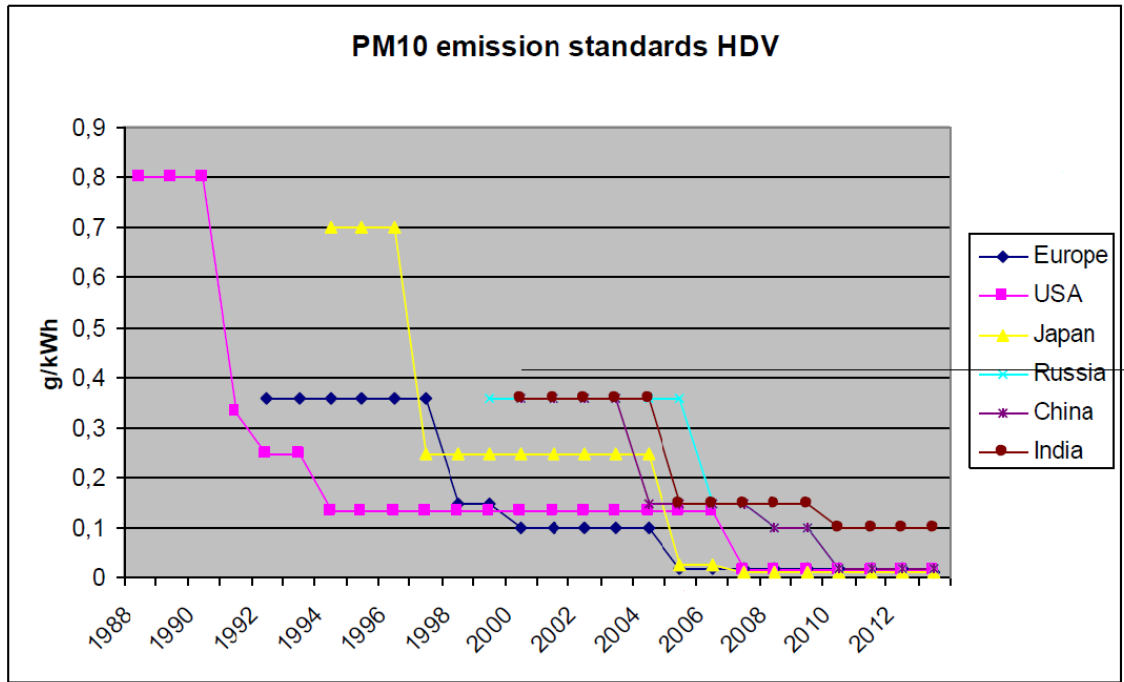


Figure 9. PM10 for HDV in selected countries (Essen et al 2008, 19).

5 Optimizing resources

In this chapter, basic concepts of linear programming, its formulation and ways to solve linear programming problems are indicated. Due to the fact that this research focuses on minimizing GHG as well as energy consumption of DMC's outbound transportation, minimization of some quantity and transportation problems are the main objectives. More, there is no final result for examples expressed in this chapter.

5.1 An introduction to linear programming (LP)

In this research, the main results come from solutions of linear programming. Linear programming is defined as “a model consists of certain common components and characteristics. The model components include decision variables, an objective function, and model constraints, which consist of decision variables and parameters.” (Taylor 2010, 48.)

Decision variables are symbols representing level of activity by the company while objective function represents relationships between it and decision variables. The objective function consists of either maximizing or minimizing value. For example, the company can maximize the profit or minimize some costs of production. The model constraints are relationships of decision variables in the way that they represent the restrictions placed on the company. The restrictions can be limited resources or restrictive guideline. The last factor in the program is parameters which are numerical values that are included in the objective functions and constraints. (Taylor 2010, 48.)

Due to the complication of LP, an example from M&D Chemicals Company is analysed according to minimization problem:

M&D Chemicals is based in Germany and manufactures a variety of chemical products that are sold to other companies who produce bath soaps and shower gels. Based on an analysis of current inventory levels and potential demand for the coming week, M&D's management specified that the combined production for the product A and B must total at least 350 litres. Separately, a major customer's order for 125 litres of product A must also be satisfied. Product

A requires 2 hours of processing time per litre and product B requires 1 hour of processing time per litre. For the coming week, 600 hours of processing time are available. M&D's object is to satisfy these requirements at a minimum total production cost. Production cost are 2€ per litre for production A and 3€ per litre for product B. (Anderson et al 2009, 57).

According to Anderson (et al 2009, 57) in order to minimize production cost in this case, decision variables and objective function are defined as follow:

A= number of litres of product A

B= number of litres of product B

The objective function is formed according to minimization of the total production cost when production cost is 2€ per litre for production A and 3€ per litre for product B (Anderson et al 2009, 57). :

$$\text{Min} = 2A + 3B$$

Next consideration is the constraints which are based on the fact major customer's demand for 125 litres of product A; the combined production for both products is at least 350 litres and the limitation of 600 hours on available processing time. Overall, we have 3 constraints as following (Anderson et al 2009, 57.):

$$1A \geq 125$$

$$1A + 1B \geq 350$$

$$2A + 1B \leq 600$$

Finally, we have a complete linear programming with nonnegativity constraints (A, B ≥ 0) (Anderson et al 2009, 57). :

$$\text{Min } 2A + 3B$$

Subject to (s.t)

$$1A \geq 125$$

$$1A + 1B \geq 350$$

$$2A+1B \leq 600$$

$$A, B \geq 0$$

There are two main solutions for this case, one of those is graphical solution and another one is computer solution using excel program. In this research, I only use computer solution since it is quick and easier to understand.

5.2 Transportation

The transportation problems usually happen in planning for the distribution of goods and services from supply bases to demand locations. The main objective in transportation problem is to minimize the cost of shipping goods. Taking one more case from Foster Electronics which manufactures memory cards, there are three different manufacturing plants: in the Czech Republic, Brazil, and China (Anderson et al 2009, 294). The production capacity for each plant, distribution centers and the demand for each center are showed in the tables below:

Table 5. Production capacity for each plant in Foster Electronics (Anderson et al 2009, 294).

Origin	Plant	Production capacity (units)
1	Czech Republic	5000
2	Brazil	6000
3	China	2500
		Total 13,500

Table 6. Distribution centers and demand forecast in Foster Electronics (Anderson et al 2009, 294).

Destination	Distribution Centre	Demand forecast (units)
1	Boston	6000
2	Dubai	4000

3	Singapore	2000
4	London	1500
		Total 13,500

In transportation problem, graphical distribution routes are needed in order to form formulas easily. The graph is called network in the figure below includes circles and connecting lines are known as nodes and arcs.

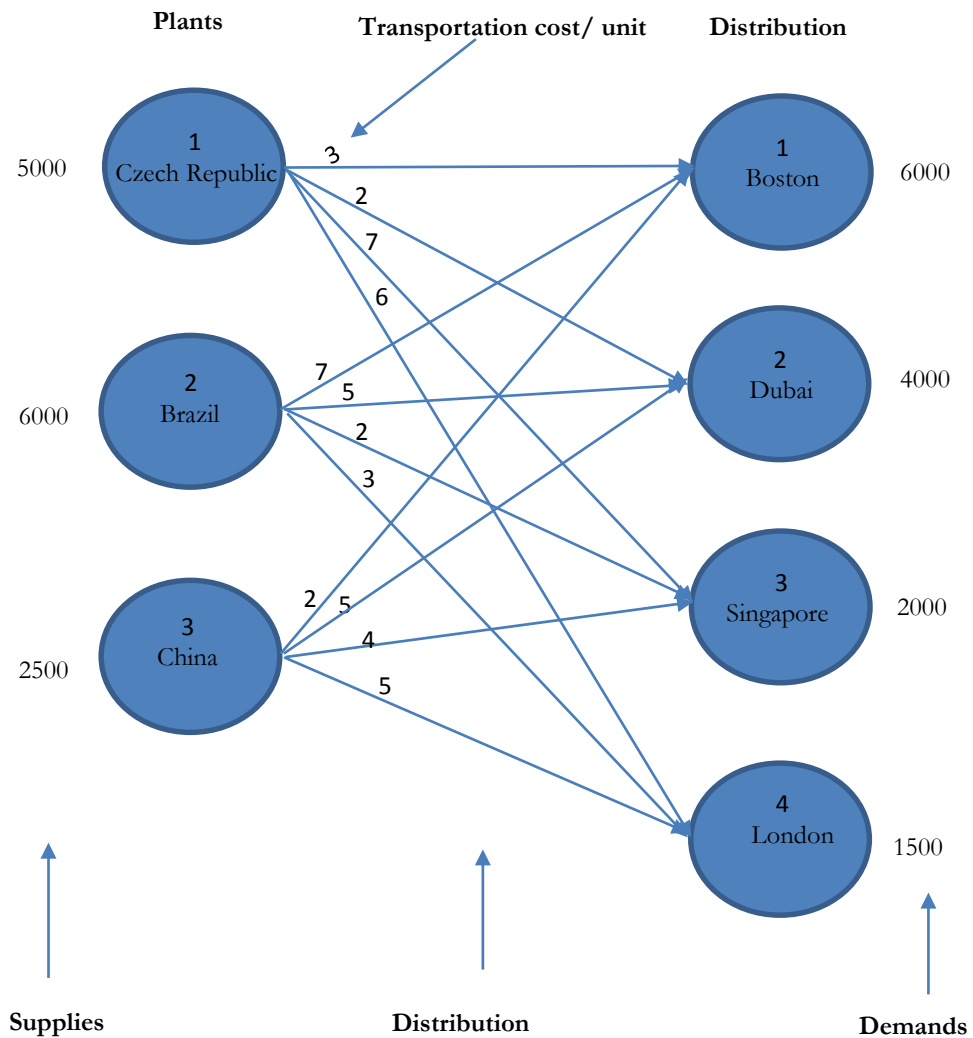


Figure 10. The network presentation of the Foster Electronics transportation problem (Anderson et al 2009, 295).

The numbers on the lines in figure 10 represent for transportation cost per unit which is showed in the below table.

Table 7. Transportation cost per unit for the Foster Electronics transportation problem (Euros) (Anderson et al 2009, 296).

	Destination			
Origin	Boston	Dubai	Singapore	London
Czech Republic	3	2	7	6
Brazil	7	5	2	3
China	2	5	4	5

The objective of this case is to determine the routes to be used and the quantity to be shipped that provides the minimum total transportation cost. Call X_{ij} is number of units shipped from origin i to destination j , where i is 1, 2, 3... and j is 1, 2... (Anderson et al 2009, 296.)

At this point, we can develop following cost expressions (Anderson et al 2009, 296). :

Transportation costs for units shipped from Czech Republic =

$$3X_{11} + 2X_{12} + 7X_{13} + 6X_{14}$$

Transportation costs for units shipped from Brazil = $7X_{21} + 5X_{22} + 2X_{23} + 3X_{24}$

Transportation costs for units shipped from China = $2X_{31} + 5X_{32} + 4X_{33} + 5X_{34}$

Next are constraints expressions (Anderson et al 2009, 296). :

The supply constraints for the Czech Republic plant: $X_{11} + X_{12} + X_{13} + X_{14} \leq 5000$

The supply constraints for the Brazil plant: $X_{21} + X_{22} + X_{23} + X_{24} \leq 6000$

The supply constraints for the China plant: $X_{31} + X_{32} + X_{33} + X_{34} \leq 2500$

Boston demand: $X_{11} + X_{21} + X_{31} = 6000$

Dubai demand: $X_{12} + X_{22} + X_{32} = 4000$

Singapore demand: $X_{13} + X_{23} + X_{33} = 2000$

London demand: $X_{14} + X_{24} + X_{34} = 1500$

Finally is the complete linear programming formulation (Anderson et al 2009, 296). :

$$\text{Min } 3X_{11}+2X_{12}+7X_{13}+6X_{14}+7X_{21}+5X_{22}+2X_{23}+3X_{24}+2X_{31}+5X_{32}+4X_{33}+5X_{34}$$

s.t

$$X_{11}+X_{12}+X_{13}+X_{14}\leq 5000$$

$$X_{31}+X_{32}+X_{33}+X_{34}\leq 2500$$

$$X_{21}+X_{22}+X_{23}+X_{24}\leq 6000$$

$$X_{11}+X_{21}+X_{31}=6000$$

$$X_{12}+X_{22}+X_{32}=4000$$

$$X_{14}+X_{24}+X_{34}=1500$$

$$X_{13}+X_{23}+X_{33}=2000$$

$$X_{ij}\geq 0$$

6 Methods

This chapter introduces the methods used in this study. It indicates the reasoning why particular tool was used and the practical steps of the data collection process. More, there is explanation how the chosen tools contributed to the investigative questions.

6.1 Research method and design

In this study I gathered information on what support DMC expect to receive. The information from data will be compared, analysed and calculated according to greenhouse gas facts and optimizing resources. The quantitative research was chosen since it concerns with gathering data that is structured and presented numerically. (Matthews & Ross 2010, 141.)

The research's target group are one representative from DMC and two people from 3PL and secondary resources. The representative from DMC is manager of commercial division, who has more than five year experiences in commercial and outbound logistics. Besides, two representatives from 3PL are both logistics managers who can provide me information about outbound transportation services hired from DMC. The figure 11 illustrates how documentary data and interview will be gathered from the three sources. Based on my discussion with them and materials I received I acquired data to investigate question 1.

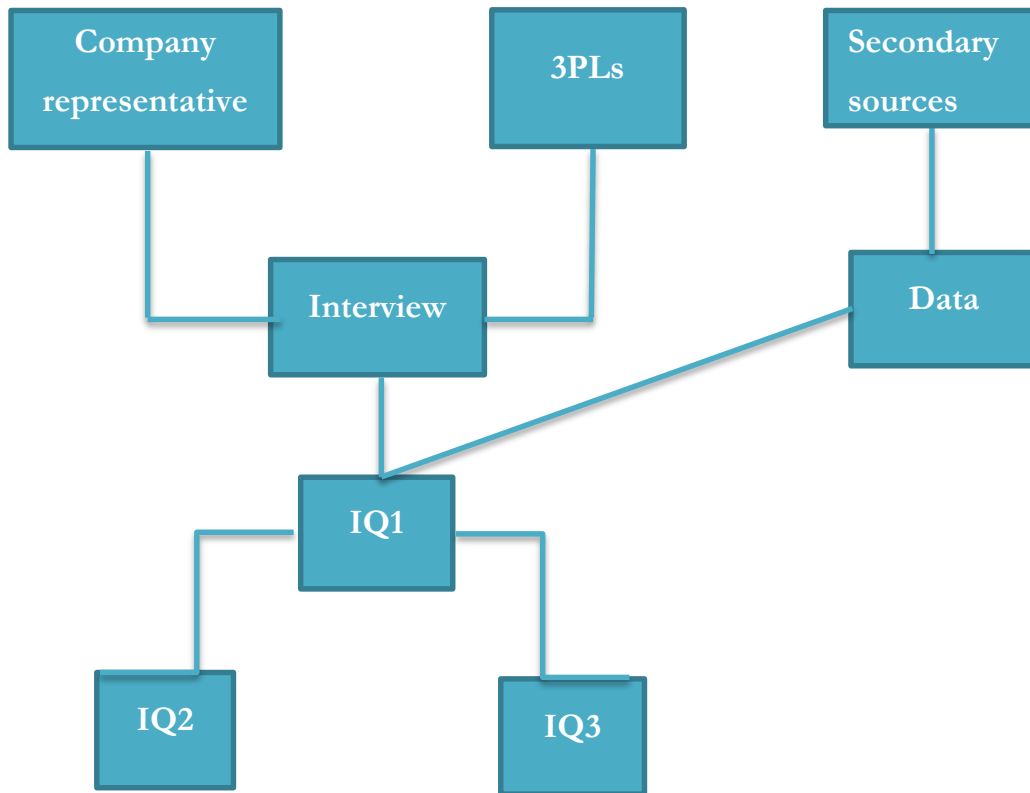


Figure 11. Informant group’s contribution to investigation questions

6.2 Data collection tools

Structured interview was used to gather background information about situation of outbound transportation of Bentonite. Additionally, the interview includes points to find out what are the most common routes to transport Bentonite from supply bases to end customers, what transport modes used. The second method of research was from secondary data. The secondary data is table showing ways to calculate GHG emissions. Both data collections tools were conducted in English as this is an international company.

6.2.1 Structured interview

The first part of data collection was through structured interview. The choice of tool was based on the amount of expected data and the purpose of the tool. I interviewed the company’s representative to gain information on outbound transportation of Bentonite in Ho Chi Minh City and her opinions on green transportation. In addition,

I had phone interview with 3PL's representative in order to get figures of outbound transportation.

With the purpose in mind, the interviews attempted to have questions formulated in standard format which requires a fixed response categories from respondent.

Additionally, the interview had opened ended questions rather than multiple options since they provide a large amount of data to analyse. I acknowledge that I made the choice for purpose of receiving real objective data and use it to find an accurate and clear picture of outbound transportation and respondent's opinion on green transportation.

As seen in the attachment 2, the interview questionnaire with company's representative had three parts to it. The first part was basic background information of the company. The second part was about outbound transportation of Bentonite. Third part sought to point out greenhouse gas emissions perception. The interview was face to face conversation. Besides, the attachment 3 showed the questionnaire used to interview 3PL had only one part which is about figures of outbound transportation.

In both interviews, we used English as a language to communicate the knowledge and understanding to each other. English is used commonly in the company since there are many business connections between DMC and other international companies. Since the respondents do not have any specific data relating to the topic, interview is the main data collection method used to gain the most important resource for accounts. It is said conversation between two or more people helps researcher find out more issues by asking question in a wide range of contexts (Matthews & Ross 2010, 219).

6.2.2 Secondary data

The interviews aided me to collect information on the outbound transportation. The interviews alone was not enough to acquire deep knowledge about two main topics of this study: environmental impact of outbound transportation and resource optimization. The second data collection tool was secondary data from public resources, which was used to calculate and analyse greenhouse gas emissions.

I combined primary data which is information gained from two interviews and secondary data. In addition, I used table 1, 2, 3 as secondary data to analyse environmental impact. “Researchers can also use secondary data as a supplement to the data they will collect themselves.” (Matthews & Ross 2010, 289). In this case, I examined secondary data firstly in order to consider what information I should collect from two interviews.

The analysis of data itself was quantitative in the way that it focused on testing and verification. “The research may code the data collected in such a manner that would allow statistical analysis. In other words, it is quite possible to quantify qualitative data” (Ghuri & Gronhaug 2002, 86).

7 Results

This chapter will describe results of the empirical research. As there were several sources of data, to make it easier to follow, this chapter will be divided into subchapters according to investigative questions.

7.1 Current level of CO₂ of DMC's outbound transportation

In order to measure the current level of CO₂, information such as transport mode, type of fossil fuel used, and total km of the routes when transporting Bentonite from supply bases to final customers need to be collected. Those information is partly collected from DMC because they mainly outsource the transporting from several 3PLs.

Firstly, the interview with DMC's representative was started with questions about general information of the company. Further, he was asked to explain about outbound transportation of Bentonite. There are two supply bases: Binh Chanh District (BC) and Cu Chi District (CC) and final destinations are Thu Duc District (TD), District 1 (1), 4 (4), & 11 (11). DMC have been approaching sustainable targets in transportation and they want to coordinate with 3PL to evaluate transportation performance. Recently, they only check 3PL's performance through some papers showing types of truck 3PLs using and their activities every 6 months. Therefore, there is not enough information for them to measure and control environment emissions (DMC's representative 22 May 2013).

Secondly, I had phone interview with 3PL's representatives and they offered me facts that they are using 20 tons trucks to transport products from BC and CC to four destinations. Furthermore, with that kind of truck, the fossil fuel used is diesel and it consumes 45 liters/100km. The representatives drew attention to the fact that the demand forecast in TD, 1, 4 and 11 is as following: 140 tonnes, 200 tonnes, 100 tonnes and 200 tonnes (3PL's representatives 23 May 2013).

Table 8 shows the amount of CO₂ produced in DMC's outbound transportation. The calculation was based on travelling times from supply bases to destinations, amount of km travelled and figures in table 2 in section 3.2. According to different demand at destinations and type of truck used, there are different travelling times at each route. For example, TD requires 140 tonnes Bentonite from two supply bases, DMC uses four 20 tons truck to transport the product from each supply base to TD. Therefore, there are 8 times travelling including 4 times returning to supply base from TD.

Following is formulation showing the amount of CO₂ produced for the route BC-TD:

Total km: 8 times travelling x 46 km = 368 km

Total diesel litters consumed: (368 km x 45 litters)/ 100 km = 165, 6 l

Total CO₂ produced: 165, 6 l x 2, 6304= 435, 6 kg

Table 8. Amount of CO₂ produced in DMC's outbound transportation in each route

100km/45 litters (20 tons truck)	BC - TD (46km)	BC-1 (27 km)	BC-4 (33 km)	BC-11 (28 km)	CC-TD (44 km)	CC-1 (37 km)	CC-4 (38 km)	CC-11 (33 km)	Total (286 km)
Total diesel used (litter)	165,6	121,5	148,5	75,6	158,4	166,5	171	59,4	1066,5
Amount of CO₂ produced(kg) in each route	435,6	320	390,6	199	416,6	438	450	156	2805,8

7.2 Linear program for transportation

According to all information in the data collected and the results calculated about CO₂, I used linear program to find solution for reducing it as well as energy consumption. Since this is transportation problem, it would be minimization of linear program for DMC case.

DMC is based in Ha Noi and supply a variety of oil & gas products and service that are sold to other industrial companies. There are two different supply bases in Ho Chi Minh City: Binh Chanh District (BC) and Cu Chi District (CC). In addition, the

destinations are TD, 1, 4, 11. The capacity for each supply base and demand for each destinations are showed in the tables below:

Table 9. Supply bases and destinations figures in DMC in Ho Chi Minh City

Supply bases	Capacity (tonnes)
BC	400
CC	300
Destinations	Demand forecast (tonnes)
TD	140
1	200
4	100
11	200

According to above facts, the graph is called transportation network in the figure below demonstrates nodes and arcs.

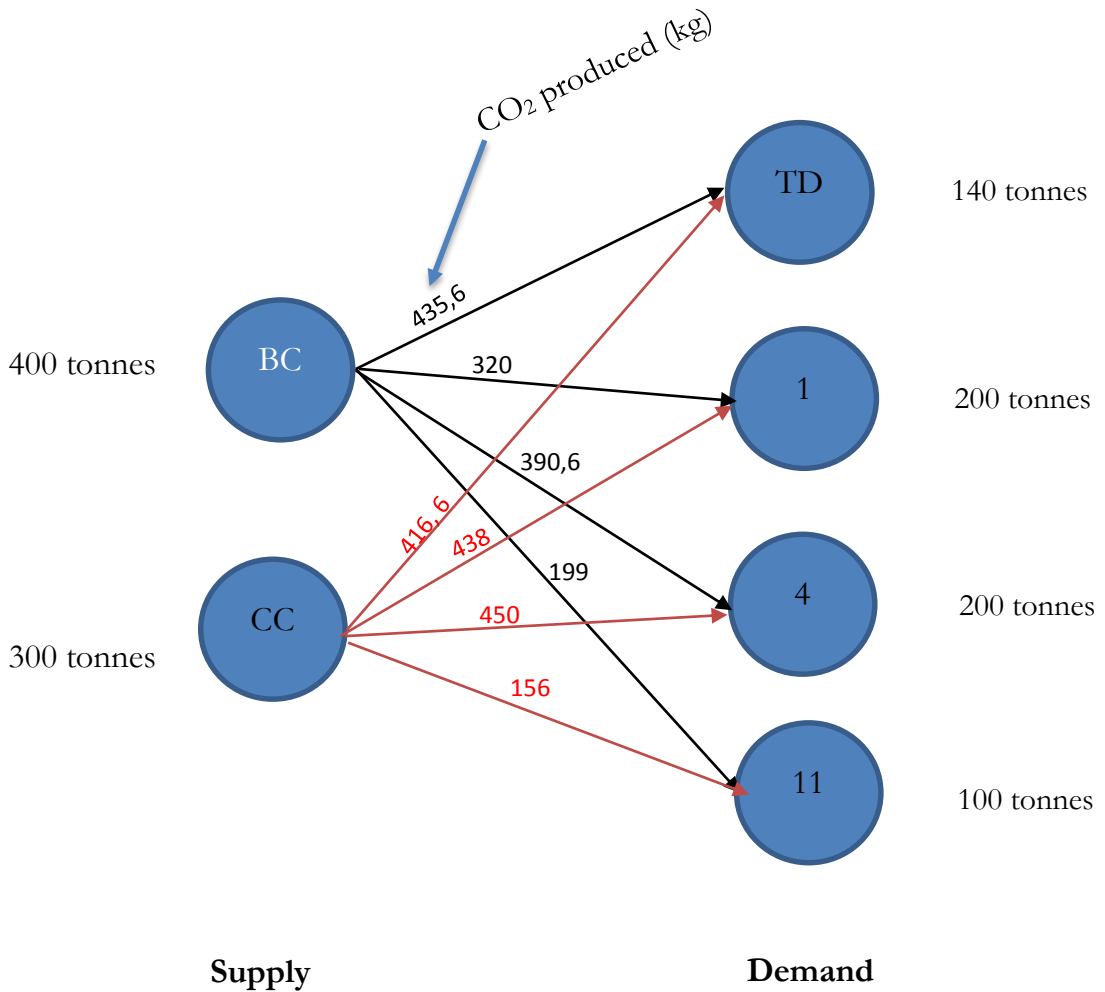


Figure 12. DMC's outbound transportation network

In the above figure, amount of CO₂ is showed according to this table:

Table 10. Amount of CO₂ produced in each route

Amount of CO ₂ produced in each route (kg)				
Supply bases	TD	1	4	11
BC	435,6	320	390,6	199
CC	416,6	438	450	156

The objective of this case is to determine the routes to be used and quantity to be shipped that produce the minimum total amount of CO₂. Call X_{ij} is number of units shipped from supply base i to destination j where i is BC, CC and j is TD, 1,4,11. At this point, we can develop the amount of CO₂ expression:

Amount of CO₂ produced from BC = $435,6 X_{BC\text{TD}} + 320 X_{BC1} + 390,6 X_{BC4} + 199 X_{BC11}$

Amount of CO₂ produced from CC = $416,6 X_{CC\text{TD}} + 438 X_{CC1} + 450 X_{CC4} + 156 X_{CC11}$

Next are constraints expressions:

The supply constraints for the Binh Chanh supply base:

$$X_{BC\text{TD}} + X_{BC1} + X_{BC4} + X_{BC11} \leq 400$$

The supply constraints for the Cu Chi supply base:

$$X_{CC\text{TD}} + X_{CC1} + X_{CC4} + X_{CC11} \leq 300$$

Thu Duc District demand: $X_{BC\text{TD}} + X_{CC\text{TD}} = 140$

District 1 demand: $X_{BC1} + X_{CC1} = 200$

District 4 demand: $X_{BC4} + X_{CC4} = 100$

District 11 demand: $X_{BC11} + X_{CC11} = 200$

Finally is the complete linear programming formulation:

$$\text{Min } 435,6 X_{\text{BC1D}} + 320 X_{\text{BC1}} + 390,6 X_{\text{BC4}} + 199 X_{\text{BC11}} + 416,6 X_{\text{CC1D}} + 438 X_{\text{CC1}} + 450 X_{\text{CC4}} + 156 X_{\text{CC11}}$$

$$\begin{aligned} \text{S.t } \quad & X_{\text{BC1D}} + X_{\text{BC1}} + X_{\text{BC4}} + X_{\text{BC11}} \leq 400 \\ & X_{\text{CC1D}} + X_{\text{CC1}} + X_{\text{CC4}} + X_{\text{CC11}} \leq 300 \\ & X_{\text{BC1D}} + X_{\text{CC1D}} = 140 \\ & X_{\text{BC1}} + X_{\text{CC1}} = 200 \\ & X_{\text{BC4}} + X_{\text{CC4}} = 100 \\ & X_{\text{BC11}} + X_{\text{CC11}} = 200 \\ & X_{ij} \geq 0 \end{aligned}$$

Further, I brought this linear program to Excel and used solver to find the optimal solution. Unfortunately, there was not any feasible solution because solver in Excel could not find a point for which all constraints are satisfied. It meant optimizing resources is not a suitable solution for DMC.

8 Discussion

This chapter will summarise the results for the first investigation questions and discuss with literature review. Afterwards, the last two investigation questions will be answered as recommendation for the case company based on the discussion with previous investigation questions. Furthermore, reliability and validity, research ethics and self-learning assessment will be included. Finally, I will suggest for further research.

8.1 Q1: How is the current level of CO₂ emissions of DMC's outbound transportation?

The first investment question asked about the current level of CO₂ emission in DMC's outbound transportation when transporting Bentonite in Ho Chi Minh City. The answers were provided in section 7.1 and 7.2 via the interview with the manager of commercial division from DMC and logistics managers from 3PLs.

CO₂ is the main contributor to climate change, especially through burning of fossil fuels like oil, gas and coal. In addition, diesel is the fossil fuel used to transport goods in DMC. Consequently, its engine releases substance including the most harmful emission which is CO₂. (EPA 2010a.) In section 3.2, Bhatia (et al 2011, 2) provided a fact as to measure transport emission, Greenhouse Gas Protocol is one method and it is used by companies.

According to Lingl (et al 2010, 9-11, 16 -17), there are three scopes of GHG emission sources in the Protocol and scope 3 is about supply chain management, along with emissions from transporting products to markets. As this case study is about outbound transportation, it belongs to scope 3. Moreover, companies will collect specific data about transportation within the boundary of the chosen scope. The data collected through interviews with representatives from DMC and 3PLs includes type of transport modes used, type of fossil fuel consumed, amount of tonne-km traveled from origins to destinations.

According to McKinnon (et al 2010, 33) all details of data mentioned above is the key to calculate total amount of CO₂ produced by using table 2. Furthermore, Jerry (et al 2007, 87) states that GHG inventory must have a base year in order to track CO₂ emission annually. Since DMC have not previously identified a base year, the current year should be their base year. In addition, road transportation has played an important role in freight transportation market both in Asia and around the world. More, GHG of road transportation has the highest share in CO₂ emission and it is expected to grow higher and the current level of CO₂ emission in DMC's outbound transportation is considered as a high rate. Therefore, DMC need to concentrate more on measuring and keeping track of CO₂ emission. (EPA 2010b.)

8.2 Q2 & Q3 How to minimize transportation's energy consumption? And How to reduce CO₂ emissions?

As planned in the beginning of the research, linear programming was the solution I chose to reduce energy consumption and CO₂ emissions from transportation. According to Anderson (et al 2009, 294), transportation problems in linear program happen in planning for the distribution of goods from supply bases to destinations. The main objective is to minimize the cost of shipping goods. This study is about outbound transportation and the objective is to minimize CO₂ emission as well as energy consumption when delivering Bentonite from two supply bases to destinations.

The constraints of DMC's case are from supply bases, demand from destinations and amount of CO₂ produced which is understood as the costs of shipping product in the case of Foster Electronics in section 5.2. Those constraints are enough to complete a linear programming formulation. However, the solver in Excel could not find feasible solution for DMC's constraints. This means DMC need another way to reduce CO₂ emission.

Since there is no significant results came out from LP, DMC can still follow GHG protocol to account and report CO₂ emission in order to track the emission over the outbound transportation system. According to Bhatia (et al 2011, 2), there are nine steps helping companies understand their value chain GHG emissions, set scope 3

boundary, then collect necessary data and report it. The standard also help them develop effective strategies for managing and reducing scope 3 emissions in order to analyze risks and opportunities. The main idea is DMC need to understand the overall emissions profile of their downstream activities so that they can credibly communicate to their stakeholders the potential impacts of these emissions. Moreover, the company can also use the results of the scope 3 inventory to identify new market opportunities for producing and selling goods and services with lower GHG emissions.

8.3 Reliability and validity

Reliability is defined as the consistency of a measure over time, over instruments and over group of respondents. Stability is one of influential factors of reliability in the research. It is about results of the research over time. Results are stable when we conduct a measure in a group at a time, then retest it, similar results would be obtained and there will be less difference in the results. (Bryman & Bell 2011, 158.) Therefore, researchers have to decide the length of time to conduct a research in order to test and retest because the time period between two tests should not be so long that situational factors may change. More, the time period should not also be too short so that respondents can remember the first test (Cohen et al 2008, 146).

In this research, I did not use this method. Instead, I showed the company's representative the questionnaire three days before the interview so that she could read it thoroughly. About the phone interview with 3PLs's people, the questions asked were about numbers, so they only need to check their data base and give the answers right away. This research is carries out for improvement purpose so the results in the future is expected to be improved and could be employed to assess the extent of betterment.

Validity is referred "to the issue of whether or not an indicator (or set of indicators) that is devised to gauge a concept really measures that concept." (Bryman & Bell 2011, 159). In interview, face validity is considered to be the main basic. The questions asked have to be measurable and one way to validate questions is to compare the interview measure with other measure that has been showed to be valid. (Cohen et al 2008, 150.)

Since I worked as a trainee for the company when the research was conducting, I was able to interpret the results reliably with practical experiences together with theoretical knowledge from study and literature review.

8.4 Research ethics

The participants of this research were not suffered by any physical harm nor mental harm. They were happy and enthusiastic to be interviewed as they had opportunity to share their problems and expectation that would be showed in some extent by the research. Furthermore, the name of interviewees is not revealed, only their position in the company was mentioned to ensure the reliability and validity.

Every participant was informed about the core of the research. Therefore, they can understand deeply the whole process of the research. In addition, the recording and taking notes while interviewing was visible to respondents. There is some information regarded as business's secret, so they are not reported in this report.

8.5 Self- learning assessment

As I am interested in green logistics, I wanted to research more about it. In this thesis, I decided to focus on GHG emissions especially CO₂ since it is the most significant emission in transportation. Fortunately, there was a course about linear programming, which was suitable for my topic.

At first, I thought linear programming could help my case company find optimal solution for their outbound transportation. However, the results came out without any feasible solution. Therefore, I had to look for another solution in last two weeks. In the meantime, I read a lot of books, articles concerning reduction of CO₂ emission in road transportation. It really took time to consider which way was the best for my case.

Sometimes, I read one article and felt that it would be useful, then I started to write about it. Yet, the more I wrote, I more I thought it was not the one I was looking for.

After that, I began reading another sources. In this period, I was really frustrated since I was not sure if I can find any other solution than linear programming.

Finally, one report was found regarded as a guideline for companies to keep on track of CO₂ emission. The guideline was explained in details and easy to follow, however, it a new concept for me. Consequently, I decided to dig into it deeper and changed one chapter just to discuss about it. In addition, I could use that research as a suggestion for improvement and it could be a framework for implementation. In the end, it has been a long learning journey and I have review so much knowledge that will be useful for my future career.

Regarding the empirical research process, thanks to my specialization knowledge and understanding of the case company, I managed to design research methods and content in a logical and reliable way. During the time, I learnt how to conduct a research process, data analysis, and reporting. Managing, such a long project was given me a valuable experience to challenge my organization skills. Even though, I had problem when the result was not as precise as I thought, I could still manage to find alternative way to solve the problem. It required so much patient as well as ability to remain motivated and focus until the end.

8.6 Further research

There are always rooms for further research regarding environmental impact of road transportation even though the goals of this thesis were reached. From the results of this thesis, linear programming may not be suitable for the company, so they could research more on calculating and keeping on track of GHG emissions. There are some other research that DMC can continue to study such as alternative energy sources, high technology truck and methods of calculating CO₂.

This study only focus on CO₂ emission as a main environmental impact in road transportation. A further research on other GHG emissions may be useful for the company. Many new technologies that are currently under development. Biofuels are one of the most controversial topics in recent times. These techniques pants a brighter

future for their successful implementation, but there is still a high level of uncertainty. More research into the lifecycle emissions of different biofuels could help DMC upgrade their product value.

Last but not least, this research only concentrated on outbound transportation, however DMC can also consider the whole supply chain system in order to set a larger GHG emissions boundary or build a new model shift for green logistics such as moving from road transportation to rail- road transportation.

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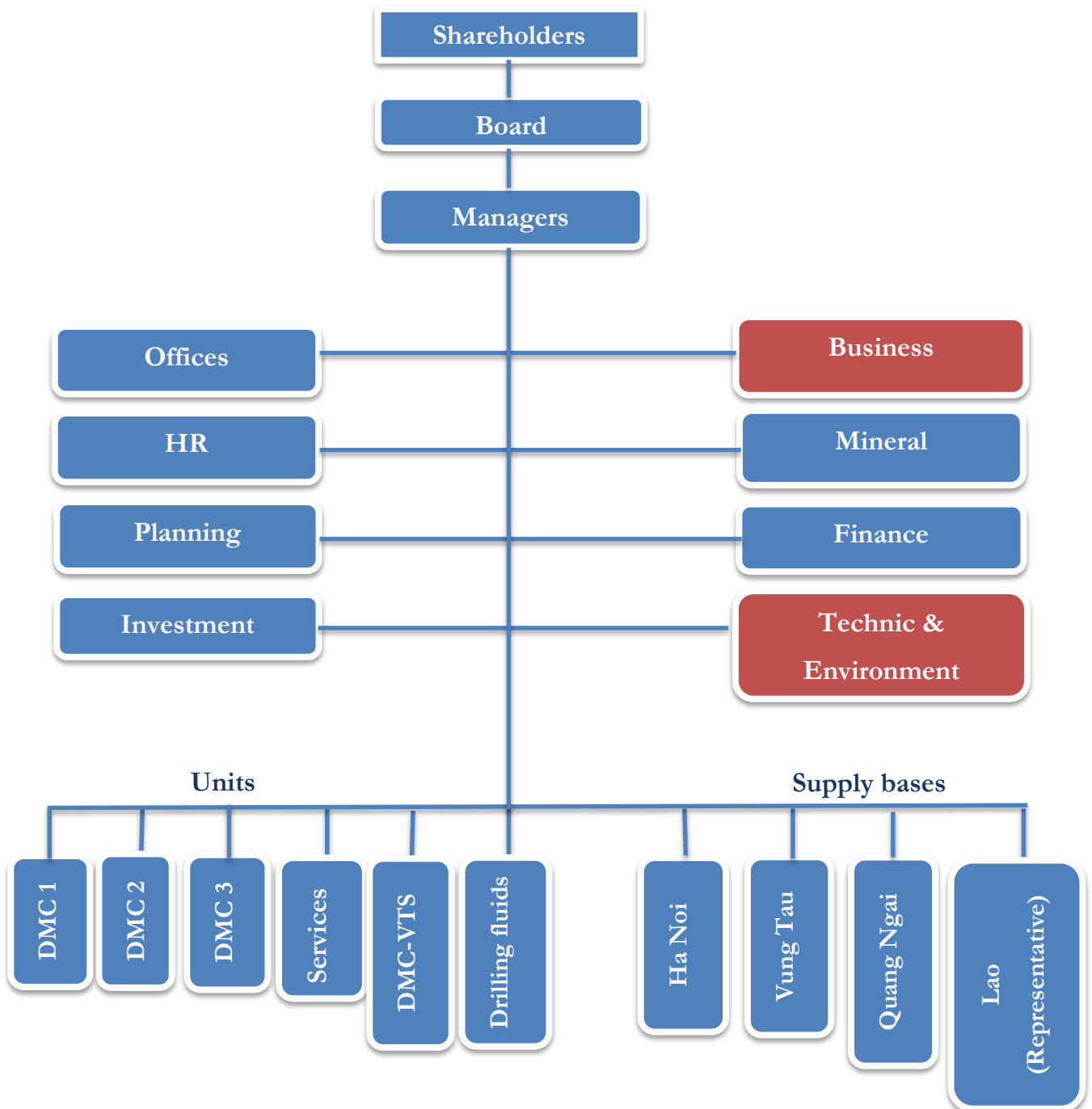
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Attachments

Attachment 1. DMC's organizational structure (The chart was modified from the internal DMC source)



Attachment 2. Interview questionnaire for company's representative

Part 1. General information

1. Can you describe the company structure?
2. What is your company strategy?
3. How does DMC perceive the concept of green transportation?

Part 2. Outbound transportation of Bentonite

4. Where are supply bases and end customer's locations in Ho Chi Minh City?
5. What kind of transportation outsourced to 3PLs?
6. How does DMC evaluate 3PL's performance?

Part 3. Greenhouse gas (GHG) emissions

7. What kind of environment standards does DMC use to evaluate transportation activities?
8. How does DMC measure and control emissions in transportation?
9. Do you have any criteria that DMC base on to evaluate GHG emissions?

Attachment 3. Interview questionnaire for Third Party Logistics (3PL)

1. Please name supply bases and end final destinations that you transport Bentonite in Ho Chi Minh City for DMC.
2. What kind of truck used to transport?
3. What kind of fuel used?
4. How many times per month you have to transport Bentonite?
5. How long is the delivery time?
6. How long is the distance from supply bases and final destinations?
7. How much do you have to transport the product averagely from each supply base per day?
8. Please state the capacity and demand forecast in each supply base as well as each destination.

Attachment 4. Business goals served by a scope 3 GHG inventory (Bhatia et al 2011, 12)

Business goal	Description
<p>Identify and understand risks and opportunities associated with value chain emissions</p>	<ul style="list-style-type: none"> - Identify GHG- related risks in the value chain. - Identify new market opportunities. - Inform investment and procurement decisions.
<p>Identify GHG reduction opportunities, set reduction targets, and track performance.</p>	<ul style="list-style-type: none"> - Identify GHG “hot spots” and prioritize reduction efforts across the value chain. - Set scope 3 GHG reduction targets. - Quantify and report GHG performance over time
<p>Engage value chain partners in GHG management</p>	<ul style="list-style-type: none"> - Partner with suppliers, customers and other companies in the value chain to achieve GHG reductions. - Expand GHG accountability, transparency and management in the supply chain. - Reduce cost through improved supply chain efficiency. - Etc.
<p>Enhance stakeholder information and corporate reputation through public reporting.</p>	<ul style="list-style-type: none"> - Improve corporate reputation and accountability through public disclosure. - Meet needs of stakeholders, enhance stakeholder reputation, and improve stakeholder relationships through public disclosure of GHG emissions. - Etc.

Attachment 5. List of scope 3 categories (Bhatia et al 2011, 32)

Upstream or downstream	Scope 3 category
Upstream scope 3 emissions	<ol style="list-style-type: none">1. Purchased goods and services2. Capital goods3. Fuel-and-energy-related activities4. Upstream transportation5. Waste generated in operations6. Etc
Downstream scope 3 emissions	<ol style="list-style-type: none">1. Downstream transportation2. Processing of sold products3. Use of sold products4. Franchises5. Investment6. Etc.