MSc in Climate Change: Impacts and Mitigation

2011

**Reducing CO$_2$ emissions from the Freight
Transport sector:
Lessons for Mexico from the UK Experience
and Future Policy**

By

Itzel Morales Lagunes

H00022442

Presented for the award of MSc.

Heriot-Watt University

Acknowledgements

I will like to thank Professor Alan McKinnon for his guidance to write this dissertation. His work inspired me providing me a priceless experience that helped me achieve the goals established in the beginning of the research. I also will like to thank Professor James Mair for his academic support along the year.

My sincere appreciation goes to Cristina Lagunes, José and José Manuel Morales for their unconditional support.

Declaration

I declare that the thesis embodies the results of my own work and has been composed by myself. Where appropriate within the thesis I have made full acknowledgement to the work and ideas of others or have made reference to work carried out in collaboration with other persons. I understand that as an examination candidate I am required to abide by the Regulations of the University and to conform to its discipline and ethical policy.

Signature of student …………………………… **Date:** January 31, 2012

Word count: 24606

Abstract

The United Kingdom and Mexico have established goals to reduce CO_2 emissions. With the publication of the Climate Change act in 2008 Britain acknowledges that is technologically ready to implement changes to bring important reductions of CO_2 emissions. Mexico included Climate Change abatement in its 2007 development program. UK aims to achieve a reduction of 80% and Mexico a reduction of 50% in their CO_2 emissions by the year 2050. To achieve these reductions both countries face the challenge of improving activities such as better use of fuels, for example natural gas for energy production or diesel used in road freight transport vehicles. Freight transport currently accounts 25% of global carbon emissions; with road freight as the fastest growing sector for both countries. The use of biofuels or clean energy powered vehicles is far from a 100% implementation in the fleet. Because of this improving the fuel efficiency in the current operation signifies an opportunity to reduce emissions. The United Kingdom is ahead in legislation through taxation, market incentives and research to encourage reductions from freight transport. Mexico is in its way to the creation of a Climate Change Law. This dissertation aims to determine which lessons Mexico can learn from the United Kingdom in its improvement of freight transport sector in two levels. The Macro level looks at legislation and private sector initiatives, and the Micro level simulating 11 scenarios using real data from operation of a food manufacturer provided by the StarFish Project. The scenarios simulate the implementation of a series of best practice recommendations to reduce emissions and improve operation. The results evidence that at a Macro level Mexico can implement legislation mechanisms to stimulate the reduction of CO_2 emissions in the transport sector. At a Micro level the simulations show that even for developed countries like the United Kingdom there is a big potential to reduce carbon emissions from the freight transport sector. The outcome of the dissertation is that learn from experiences from other countries applies not only for Mexico and other developing countries but for every country aiming to improve the reduction of CO_2 emissions.

Content

List of Figures

List of Tables

List of Equations

Chapter 1: Introduction

This dissertation examines efforts to reduce CO_2 emissions from the freight transport at both Macro and Micro levels. The Macro level study, analyze and evaluate different strategies and options for reduction of CO_2 emissions from the freight transport sector in the United Kingdom and Mexico. It focuses on the review of the governmental policies, strategies and projections for abatement of carbon emissions from the freight transport sector. The Micro level studies the options to reduce the emissions in the freight transport specifically by road. It will evaluate the impact of a selection of measures by modelling a set of real transport data provided by a large food manufacturer.

The Introduction chapter will explain back front this research and its objectives: The introduction is organize in three sections. The first section explains the nature of the environmental problem and its relevance for the United Kingdom and Mexico. The second section describes the research objectives and the third section gives an outline of the dissertation.

1.1 Nature of the environmental problem

As humanity started its chapter in earth's history, it started changing the environment. Every human activity requires natural resources, for food, energy, and building materials. Natural resources after being use for primary purposes produce different kinds of residues that in most cases alter the environment, polluting the soil, water and atmosphere.

Knowledge about the environment has increased bringing understanding to the causes and effects of human activities. Several main topics have concerned the world as much to make several countries to sit together to discuss the existence and possible solutions to common environmental issues. Countries expect to set up agreements, find solutions and design strategies to conquer the challenge of environmental problems.

Climate Change is the topic that contemporary society is concerned the most. Scenarios modelled forecast effects that would bring significant changes in several countries. The changes observed are desserts tending to expand, severe droughts, sea

level rise, more frequent hurricanes, warmer summers and colder winters. These modifications in global climate compromise multiple aspects of the way of living.

The global ecosystem is self regulating, but as we produce more residues and the demands of resources increase, the planet might reach a tipping point where the results of Earth's self regulation could change considerably the world and human's life as we know it.

From a geological point of view, we can appreciate that the World has always been in change. Since the atmosphere, oceans and continents were formed, the beginning of life and with it the effects of its inclusion to the global ecosystem. One example of the influence of life in the ecosystems is forests contributing to regulate temperatures and rainfall.

Currently there are variations in Climate. Are these alterations symptoms of natural changes in Earth? The Intergovernmental Panel on Climate Change (IPCC) gathers the results of the research about Climate Change, its causes and impacts, as well as the mitigation and adaptation to it. Reports are published every four years, with every report the uncertainty if the current Climate Change is due human causes has been getting clear. In the fourth report in 2007, evidence shows clearly that Climate it is changing as an effect of human activities (Parry, Canziani et al. 2007).

During the research to understand global climate, and the causes driving it to change along history, it has been found evidence that there is a direct relation between atmosphere's concentrations of Green House Gases (GHG), especially CO_2 and increase of temperature (Burroughs, 2007). Since the beginning of industrial revolution, human activities in the production of energy and goods, along with material residues in water and soil also have put in the atmosphere an amount of GHG along with other pollutants previously locked in forests and fossil fuels in the soil. One might think that the atmosphere and oceans (as part of the Carbon cycle) are big enough to hold the amounts of CO_2 that we have been continuously sending year after year. In fact they are capable of doing it but not without changing their nature. As atmosphere holds more CO_2, its capacity to absorb solar radiation increases, in other situation the radiation would be send back to space. Oceans also show effects since the amount of CO_2 they absorb increases acidification, damaging the growth of life structures that are sensitive to changes in the pH in water (Burroughs, 2007).

The amount of CO_2 as result of human activities such as energy supply, production industries, transportation and deforestation has a growing tendency. Because of this we can only expect to experience more effects of Climate Change.

Climate is difficult to predict, currently there are General Climate and atmosphere-ocean global circulation models. These models can simulate climate from past eras and help to forecast the future world and how would be if CO_2 emissions decrease or continue the growing trend. The Stern Review published in 2007 carries an evaluation of the possible cost of adaptation to an increase in the global average temperature of more than 2°C. The economical analysis reveals that the cost of not taking action will be higher than if countries decide to reduce their emissions (Stern 2007).

Because CO_2 has a mid life of a hundred years, we are still going to experience the effects of an increase in temperature. How much are we going to limit the temperature increase? Countries faced the previous question after the irrevocable evidence of Climate Change.

The United Nations Framework Convention on Climate Change (UNFCCC) agreed to limit the temperature increase to 2°C, to achieve this, CO_2 emissions will have to be reduced 80% by 2050 compared to 1990 levels. This is an agreement made by industrialized and developing countries. Each of them has to design a strategy to succeed in their own goals (UNFCCC members, 2010).

This dissertation looks at the United Kingdom and Mexico. The UK has included tackling Climate Change as their main topics in its legislation. Observing the proportion of the emissions the sector with the biggest share is energy production, completely cut the emissions from this sector without using nuclear power is a big technological challenge. That is why reducing small shares from other sectors have become the main strategy to decrease CO_2 emissions.

México is a developing country that has not such a long history contributing with CO_2 emissions. Nowadays as it has been increasing its economical activities is producing big amounts of CO_2. Recently has included reducing its carbon emissions as main topics in its development programs and legislation. Mexico is aiming to reduce its emissions 50% by 2050 compared to 2000 levels.

Both countries have in common that produce a large amount of emissions coming from the freight transport, especially by road. In 2010 the emissions from road transport in the United Kingdom account for 121 Mt representing around 25% of the total emissions (DfT, 2011c). For Mexico the emissions from transport represent 146 Mt representing 34% of the 2006 CO_2 emissions (SEMARNAT, 2009). This sector represents a big opportunity to decrease emissions because currently there is enough technology available to make a significant change. Both countries recognize this potential and have legislation and programs to promote reductions in CO_2 emissions from this sector.

Mexico and the United Kingdom have different economies, energy supply, climate and natural resources but share vulnerability to climate change impacts. In addition, both have decided that invest resources in mitigation now will prevent them from expending more in the future due to adaptation. That is why governments from both countries are stimulating through legislation to follow a pathway of sustainable development.

The United Kingdom is a developed country that has invested time and resources planning and implementing actions in how to reduce its CO_2 emissions, including the transport sector. Mexico is in the beginning of its legislation about Climate change abatement, learn from the UK experience could be beneficial. This brings us to the central question: *What lessons can Mexico learn from the UK in trying to reduce CO_2 emissions from its freight transport sector?*

1.2 Research Objectives

In order to achieve the objectives the research is divide in two major levels of study. The Macro level looks at legislation and planning to reduce CO_2 emissions from the freight transport sector. The Micro revises the options to reduce emissions in the transport operations of one company, followed by a simulation of the implementation of them. The simulation of the implementation of options is using a real data set from a food manufacturer.

The dissertation aims to understand how are the United Kingdom and Mexico facing the challenge of reducing considerably their CO_2 emissions from the freight transport

at Macro and Micro level. And find the lessons that would be helpful to the Mexican situation.

The research has the four main objectives listed below:

1. To review macro level initiatives in the UK and Mexico to reduce CO_2 emissions from freight transport.
2. To review the various ways in which companies can cut CO_2 emissions from freight transport operations.
3. To model the impact of a series of decarbonisation measures on a large company transport operator.
4. To consider what lessons the Mexican government and business can learn from UK efforts and plans to reduce CO_2 emissions from freight transport.

1.3 Outline of the dissertation

Different information is required to accomplish the objectives at Macro and Micro level. In the Macro level the objectives are achieved through the search and examination of secondary data exclusively. This required an extensive search of the relevant information from each country, including legislation, development programs, carbon abatement strategies from the government and the private sector. The information gathered, was analyzed qualitatively in order to establish the state of mitigation achieved by both countries and the lessons that Mexico can learn from de United Kingdom.

The macro study limited the data to the information published by both governments and scientific journals about Climate Change abatement plans, freight transport, energy policy, pathways for development and private sector initiatives. The study did not include the analysis of International Standard Organization (ISO) guidelines for quantification of CO_2 emissions. It also does not consider national standards such as the British Standards and the Mexican Norms for measurement of carbon emissions. The study does not include an analysis of the monetary resources invested by each country, or an economical evaluation of the result of the implementation of the options for reducing carbon emissions.

The micro study required the use of secondary data and primary data. The review of secondary data started with the consideration of a series of recommendations provided

by the Institute of Grocery Distribution (IGD) to further expansion with other sources. The recommendations represent options to reduce the carbon emissions and improve process from freight transport operation companies. In order to evaluate the strategies and give an example of its potential for carbon emission abatement and improvement in operation, the micro study uses a set of real transport data from a food manufacturer from the United Kingdom. A number of 4 recommendations were chosen: reallocation of customers, centre of gravity, use of biofuels and expanding vehicle capacity. The data modelling aimed to obtain results of the savings in CO_2 emissions and fuel consumption using conversion factors provided by Department of Environment, Food and Rural Affairs (Defra).

The Figure 1 is a map of the steps followed to achieve the research objectives for both levels of study. The Literature Review phase is divided in various sections to help separate the information from of the macro study the Macro (From section 2.1 to 2.8) and Micro study (Section 2.9). The chapters of the research methodology, results, discussions and conclusions are always divided in different sections for each level of study.

Research map

	Macro Study	Micro Study
Literature Review	Review of Policies and governmental strategies	Review of academic research papers
Researoh Methodology	Development of theresearch philosophy → Data resources and collection	Development of the research philosophy → Data resources and collection → Data modelling methodology
Results	Evaluation of trends	Results of the data modelling
Discussion	Discussion of the results	Discussion of the results
Conclusion	Outline objectives → Main findings → Project limitations → Directions for the future reseacrh	Outline objectives → Main findings → Project limitations → Directions for the future research

Figure 1 - Research map

Chapter 2: Literature review

This chapter is analysis of the literature both levels of study. The literature review is divided in nine sections, from section 2.1 to 2.8 the review is for the Macro study and section 2.9 is for the Micro level. The chapter studies the existing literature about how Climate Change has become a serious topic in the agenda of countries around the globe, and what actions have been designed to avoid climate change. The Macro study starts analyzing the Climate Change importance due to its possible impacts followed a section about the mitigation responses. At this point of the literature review there has been set a framework to start examining the relation between energy, CO_2 emissions and the freight transport sector. From section 2.4 to 2.8 there is the review of the freight transport situation view from the European Union, the United Kingdom and Mexico. This sections breaks down the Business as Usual trends, how every country measures its CO_2 emissions from the freight transport and the policies to reduce emissions for the United Kingdom and Mexico. Section 2.9 is for the Micro Study, looking at the options for reducing CO_2 emissions that can be applied to freight transport operators.

2.1 Climate Change, Causes and projections of future climate changes and their impacts

The climate is always in change. Understanding the global climate requires the study of complex systems such as atmospheric circulation patterns, radiation balance, hydrological cycle, biosphere, and hydrosphere. The interactions between all the elements as a result contribute to the climate conditions. It is important to establish that the conditions of the atmosphere at any specific time are called weather and the result of statistic use to predict what could happen in any time of the year is climate. The natural causes of climate change are: the atmosphere and ocean interactions, ocean currents, volcanoes, sun spots and solar activity, tidal forces, orbital variations, continental drift and changes in the atmospheric composition (Burroughs, 2007).

Nowadays the global climate is going through change. The proof it is not only in the news telling us about how temperatures have been getting to their maximum or lower in decades, is in the results of hard scientific work gathering more than a century of temperature records. Currently the continuous state of the atmosphere is updated

using information from stations in land, ships, and buoys; in the atmosphere in aircraft, balloons and satellites. All the information helps modelling the atmosphere in 70 different layers. Regional models can be created from the global models, this aloud to give forecast on a grid scale of 12 km and 4 km on a down level grid scale. Each point provides information of the temperature, humidity, pressure and wind. The models can deliver forecast for ten days in advance. Nowadays a forecast for three days is as reliable as the predictions for one day twenty years ago (Walko et al., 2000).

Running an analysis to the global weather information, results show a rise of more than 0.7°C in the medium surface air temperature of the planet along the last century (Henson, 2007). Keeping track of the present composition of the atmosphere, study the sea currents, use satellite images to keep track of glaciers, clouds and forest around the globe consist the research of the present climate. But in order to understand the future changes in it is necessary to study geological evidence of plants and animals fossilised remains, organic material, pollen, and the shells of creatures lock in sedimentary rocks. Geology also studies sediments from the ocean; analyzes the composition of atmosphere in the past using samples of ice from the poles or sediments in the air bubbles trap in them (Burroughs, 2007). With the information gathered is possible to create computer models that simulate the variations of temperature across time. For example a study conducted at the US National Centre for Atmospheric Research, looked at five different factors: sulphate aerosol pollution, volcanoes, solar activity, greenhouse gases and ozone depletion, to model the effects of its greenhouse emissions, it is important to say that without the account of the human emissions of green house gases, the model cannot reproduce the most recent warming trends (Henson, 2007).

With the aim of assessing available scientific and socio-economic information on climate change, impacts and options to mitigate and adapt to it, in the year of 1988, was established the Intergovernmental Panel on Climate Change (IPCC) by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). Scientist can contribute with the results of their research on a voluntary manner in order to asses on demand scientific/technical/socio-economic advice to the Conference of the Parties (COP) to the United Nations Framework Convention on

Climate Change (UNFCCC). From 1990 the IPCC has produced several reports, methodologies and other products that are widely use for policymakers, scientist and other experts (Metz et al., 2001) . In the Fourth IPCC report is stated that there is strong evidence that proves that most of the reported increase in global average temperatures in the second half of the 20th century is caused by the increase in the GHG emissions from human activities and development (Toman and Sohngen, 2001, Metz et al., 2001).
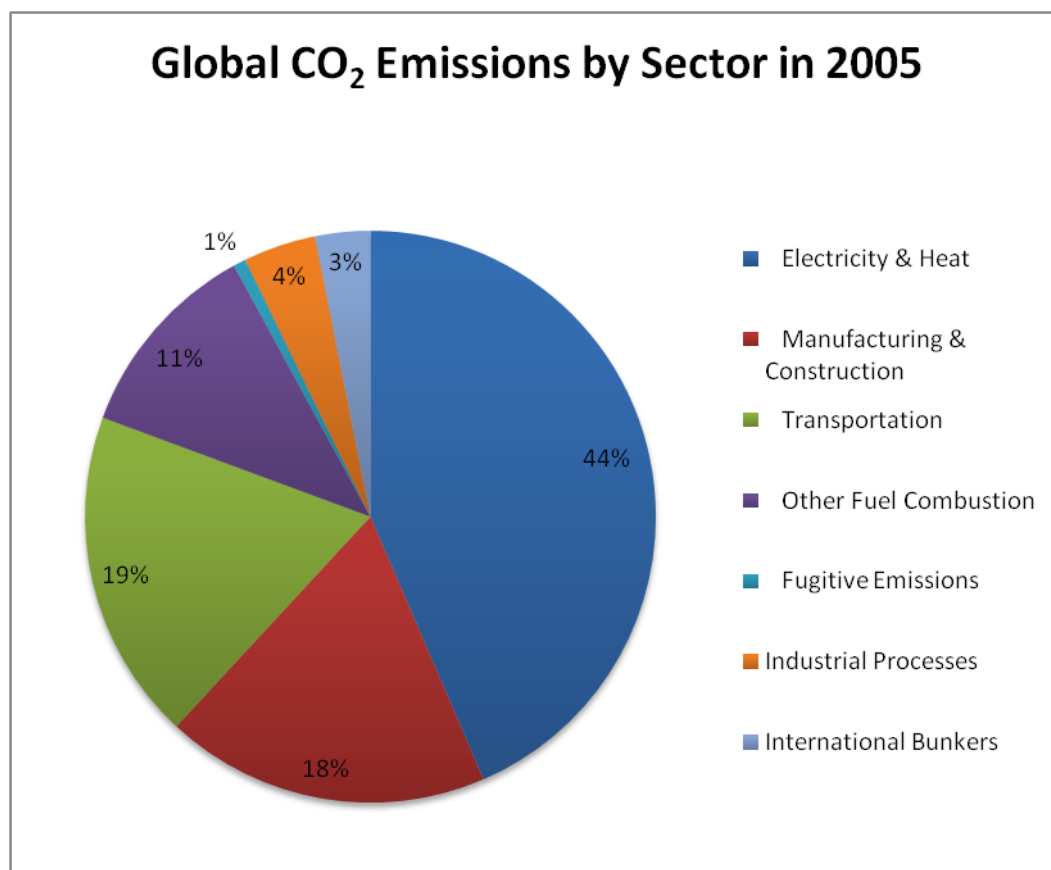
Figure 2- Global CO$_2$ emissions by sector. Source (WRI, 2012)

Not only the averages temperatures have been changing, but others aspects in climate; it has been observed:

- Increments in global average air and sea temperatures and average sea levels (Houghton, 2001).
- Melting of snow and ice. It has been reported an enlargement or increase in the quantities of glacial lakes; this situation causes soil instability in permafrost regions and avalanches in mountain areas (Parry et al., 2007).

10

- Several ecosystems on all continents and oceans are affected; there is "high confidence" that there have been alterations in ranges and changes in algal, plankton and fish abundance in high latitude oceans ((UNEP, 2009).

- Seventy percent growth of greenhouse gas emissions in the global temperate increase potential between 1970 and 2004 (UNEP, 2009).

- Greater than before runoff and sooner spring discharge in glaciers and rivers fed by melting snow. Warming in lakes and rivers in many regions have effects in water quality (Frederick and Major, 1997)

- Earlier spring planting yields and variation in forests caused by fires and plagues (Houghton, 2001).

Economics of Climate Change is a report elaborated by Sir Nicholas Stern, for the United Kingdom Treasury. This report estimates the consequences of specific levels of temperature change (Burroughs, 2007).

T rise	Water	Food	Health	Land	Environment
1°C	Glaciers in Andes melt threatening water supplies to 50 million people.	Cereal crops rise in temperate zones	At least 300 thousands from climate change related diseases.	Permafrost in Arctic regions thaws compromising buildings and roads	10% of land species may face extinction; coral reefs suffer 80% bleaching.
2°C	20 to 30% less water available in Southern Africa and the Mediterranean	Crop yields drop in tropical regions (by up to 10% in Africa)	Up to 60 million more Africans would be exposed to malaria	Coastal flooding affects 10 million more people each year.	15-40% of species may face extinction, including polar bears and caribou.
3°C	Serious droughts in southern Europe; up to 4 billion suffer water shortages.	Up to 550 million people are likely to go hungry.	Up to 3 million people would die of malnutrition.	Coastal flooding affects up to 170 million people each year.	20-50% of species face extinction; the Amazon rain forest begins to die.
4°C	Up to 50% less water available in the Mediterranean and Southern Africa	Agriculture stops in parts of Australia and crop output in Africa drops 35%.	Up to 80 million more Africans would be exposed to malaria.	A coastal flooding would affect up to 300 million more people each year.	Half the Arctic tundra disappears.
5°C	Himalayan glaciers might disappear altering on a negatively people in China and India.	Ocean acidity alters marine environment and probably fish stocks.		Cities like London, New York and low coastal areas endangered by rising sea.	

Table 1 - Predicted outcomes of global temperature rise. Source: (Burroughs, 2007)

The possibility of the occurrence of the scenarios in Table 1 will depend in the interaction of different forcings in diverse combinations. If the Global GHG emissions follow the Business as Usual (BAU) trend, they will continue to rise over decades unless there are new policies to reduce climate change and to promote sustainable development. A warming of around 0.2°C a decade is forecast for the next twenty years, with greater increase of temperatures over sea and land in high latitudes of the northern hemisphere. There is a positive feedback between the different elements that influence climate; this means that events set off changes that in consequence influence the initial trigger (UNEP et al 2009). For example the more the planet warms, less CO_2 it can absorbed naturally (Albritton and Barker, 2001). In addition, as much as the glaciers in the poles melt, there is less energy reflected to the space causing an increasing trend in the melting of the ice caps. Warming and rising sea levels would continue for hundreds of years, even if GHG emissions are reduced and concentrations stabilized, due to the feedbacks and the time-lag between cause and effect (Hare and Meinshausen, 2006). This means that there are not many possibilities to keep the global average temperature to an amount less than 1.5°C weigh against times before industrial revolution (Parry et al., 2007).

According to the modelling scenarios based on the Stern Review, the cost of doing nothing may perhaps be equal to lose among 5% and 20% of the annual global GDP but in the case of taking action the loss can be restricted only to 1% of annual global GDP (Stern, 2007).

2.2 Global efforts to abate the problem

In 1992 in Rio de Janeiro was held the United Nations Convention on Climate change, even when in those days there were not as many scientific information, the parties agreed in the fact that climate was changing and something had to be done. The Convention sets a decisive goal of stabilizing greenhouse gas atmosphere concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system" (UNFCCC, 1994).

In 2010 in the sixteenth session in Cancun it was recognized that there Climate Change is undeniable. With most of the reported increases in climate are due to human greenhouse gas emissions as advised by the Intergovernmental Panel on

Climate Change in its Fourth Assessment Report in 2007 (UNFCCC members, 2010). Another agreement was to set a limit for the global increase of temperature below 2°C under preindustrial levels (Barker et al., 2009). This agreement is a long term goal, in order to reach it is precise to take immediate attention rational with science and equity (UNFCCC members, 2010).

Mitigation of climate change search for a reduction in the speed and scale of climate change. Trying to delay the mechanisms triggering it and avoid several of its impacts (UNEP, 2009)

Electricity generation and road transport sectors have the biggest increasing trend in growth of their CO_2 emissions. From 1970 the greenhouse gas emissions from the energy supply sector have experienced growth of 145%. For transport the increase has been above 120%. Because of this there are policy mechanisms to promote an increase in energy efficiency. Even when some of these policies are not directly design for freight transport, they have an impact reducing the emissions from this sector (Parry et al., 2007).

2.3 Energy and CO_2 emissions

Energy is what powers and keeps society growing. The society's development, economic stability and quality of life depends in how is energy currently provide, and how it will be ensure that there will be a continuous supply, without greater cost (DECC, 2007).

The amount of carbon emissions has increased intensely from the year 1970 to 2000. This coincides with a growth in the GDP/capita and population (Parry et al., 2007). The connection between energy and economic growth has been studied since two energy crisis in the 70's (Zachariadis, 2009). At a global level the actions to reduce carbon emissions are not enough to overcome the effects of the constant increasing energy demand. The demand has this trend because the population is growing and with it the CO_2 emissions. The International Energy Agency (IEA) expects that this path will continue until 2030 (IEA, 2011a).

Energy is transformed into work. The amount of energy that is transformed into useful work is known as efficiency conversion and it is expressed mathematically with a number between zero and one. The connection between useful work and economic growth is result of a process of supply and demand driving one to the other. These means that as technology allow being more energy efficient, the energy offer increases making the production cost to decline and with this prices also fall. This causes an increased demand for useful work that will require capital investment. Demand from consumers influences employment that produces income that drives demand. Some environmental policies tend to tax heavily the use of fossil fuels to cut demand because in the big picture the gross national expenditures represent not a big share. But as the capability to produce useful works is an important driver economy growth the mechanism could also be set on reverse. That is why in order to stimulate economic growth while reducing fossil fuel use abate climate change, three options that should be apply at the same time: increase economic efficiency of useful work, increased conversion efficiency, keep lower cost (Ayres et al., 2007).

Energy efficiency in governmental policies is bond to commercial, industrial performance and energy security advantages, in this case the cutting down carbon emissions (Patterson, 1996).

The level of energy related CO_2 emissions are the product of four indicators: (1) Carbon intensity (CO_2 emissions per unit of total primary energy supply (TPES)), (2) energy intensity (TEPS per unit of GDP), (3) Gross domestic products per capita (GDP/cap) and (4) population. Between 1970 and 2004 the annual medium global rate of carbon emissions was 1.9%. This percentage is a product of the annual growth rates in population 1.6%, GDP/cap 1.8%, energy-intensity of -1.2% and carbon intensity - 0.2% (Parry et al., 2007).

According to the IEA in 2011 the price per barrel of crude oil in 2011 is fluctuating around 101 USD. Due to the recent events in the North of Africa and Middle East, IEA expects a tightening in the oil markets in the next two years (IEA, 2011b). The fluctuation of prices affects gasoline, natural gas, coal, uranium and other fuels. Making energy security a top topic in the agenda of countries (Birol, 2007).

2.3.1 Energy consumption and policy in the United Kingdom

The Final energy consumption by type of fuel for the United Kingdom is 218.5 million tonnes of oil equivalent (DECC, 2011a). The distribution by type of fuel in Figure 3 shows that the type of fuel with the biggest share is gas with 42.3%. While Figure 4, about the European final energy consumption shows that value for gas use is 23.2% (EU, 2010).
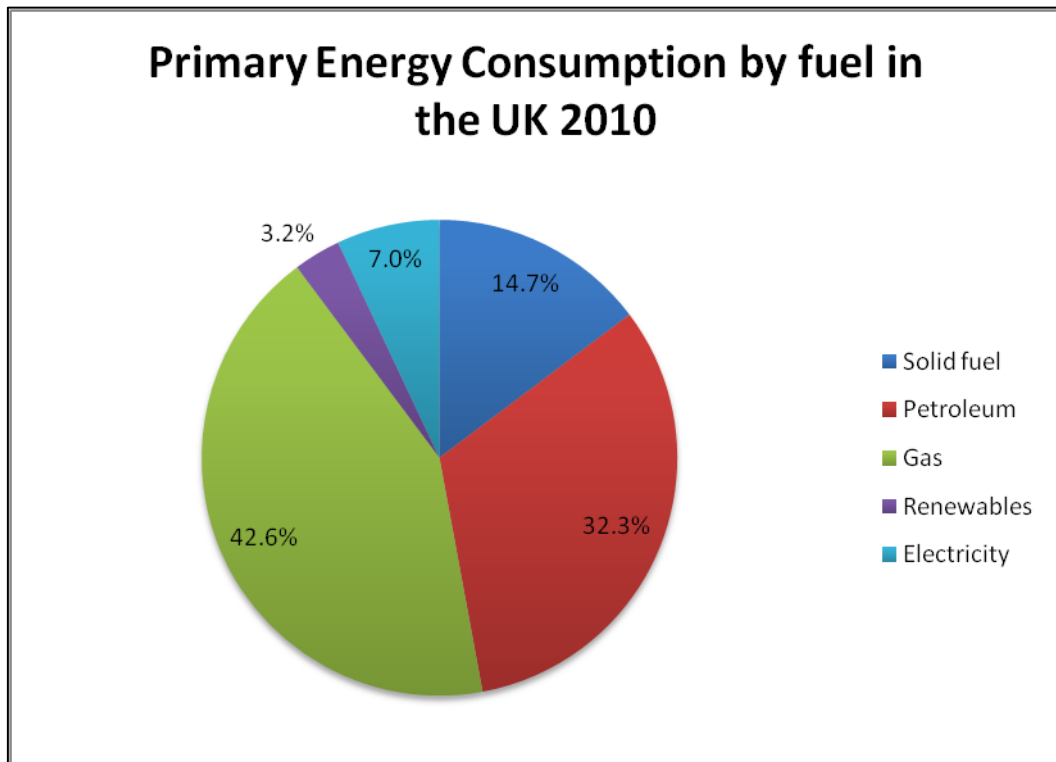
Figure 3 - Primary Energy Consumption by fuel in the UK 2010. (DECC, 2011a)
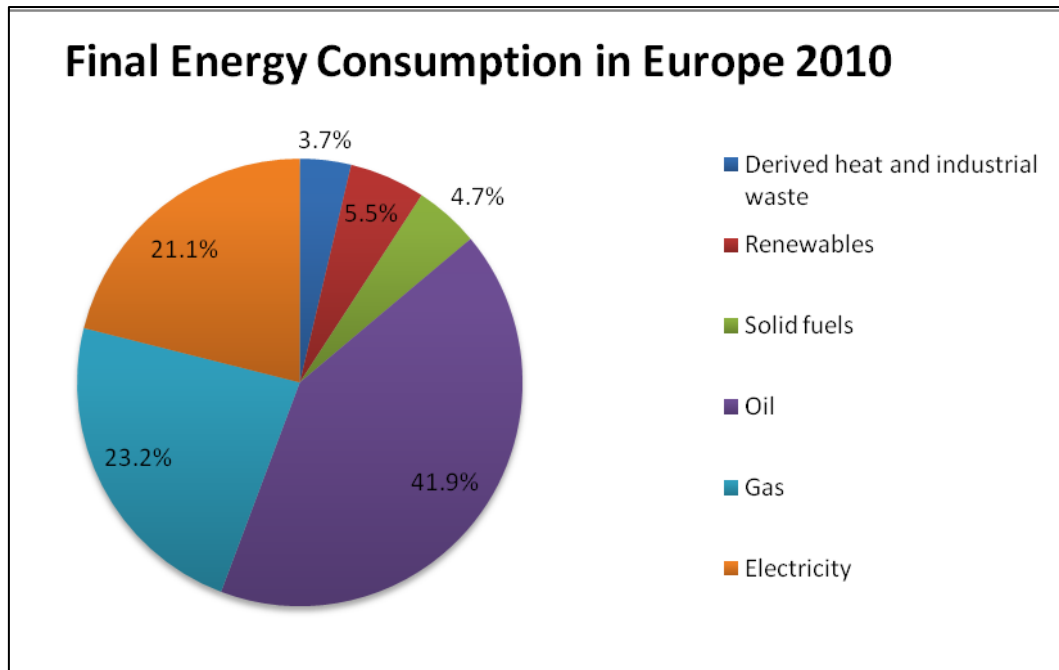
Figure 4 - Final Energy Consumption in Europe 2010

In 2007 the United Kingdom published a White Paper on Energy. The strategy in the White Paper has three major points: avoid energy waste, implementation of cleaner energy supplies, and assurance of reliable energy sources at competitive cost in the market. The Paper recognizes the evidence of climate change impacts and the extend thrusting on this fact in various other countries. The first point set in this strategy is tackling Climate Change, by reducing CO_2 emissions in Britain and abroad at the same time securing clean, reliable and fair energy supply (DTI, 2007).

There is a challenge in the increase of fossil fuel prices and a measured opening of EU energy markets. Within this time, the UK is becoming more reliant on imported energy such as gas. The two policies establish a concern about the dangers of the concentration of the concentration of oil and gas resources in not many places around the world, for example, Middle East, North Africa, Russia and Central Asia (FTA, 2011).

Companies in the UK will have to make a considerable investment in power stations, electricity and gas infrastructure in order to adapt to the new energy situation. Decrease energy consumption through savings; it is the fastest way to reduce emissions. The market for vehicles and electrical appliances is international, so there is a need for higher standards on energy efficiency, in order to achieve the reduction of 20% in emissions through saving it is necessary to stimulate the people and

17

business awareness in the importance of reducing the energy consumption to tackle Climate Change (DECC, 2007).

Two thirds of the UK's heat energy come from natural gas (DECC, 2007). Natural Gas essentially consist in methane, a compound formed with four molecules of hydrogen for every carbon atom (Kvenvolden, 1996), this means that when burning methane the exhaust contains a lower proportion of carbon dioxide compared for example with octane atoms, which is a hydrocarbon found in gasoline, and contains less than two hydrogen atoms for every carbon atom (Choudhary et al., 2002). Figure 5 shows how the gas consumption has evolve for the UK.
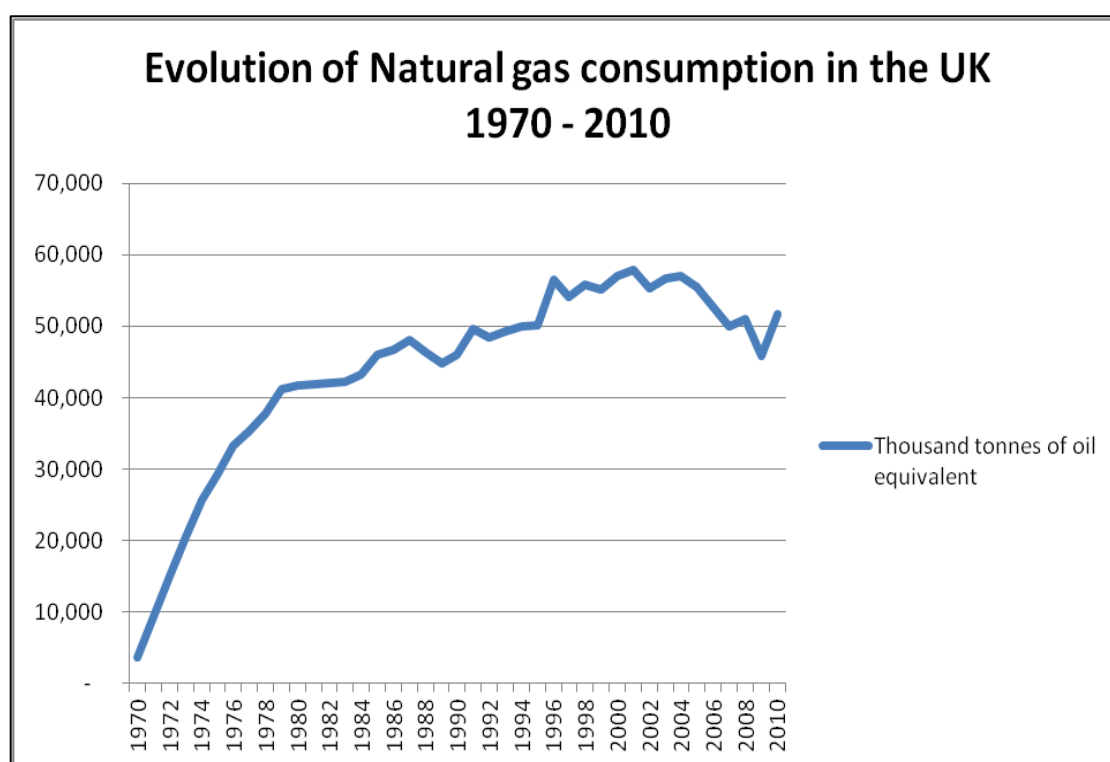
Figure 5 - Evolution of Natural gas consumption in the UK 1970 – 2010. Source (DECC, 2011c)

Other options to use as a fuel for heating are Hydrogen and low carbon electricity. Implementation of these systems will require changes in the electricity grid to install the use of electricity produce at a local level, for example, the one that could be produce by biomass (DECC, 2007).

It is obvious that in the future will be some reliance in fossil fuels to deliver all the energy demanded by the population for heating, transport and electricity. That is why find a way to make Carbon Capture and Storage (CCS) economically viable the

reduction coming from electricity generation using fossil fuels and coal could cut the emissions by 90% (DECC, 2007).

Nuclear Power is also a low carbon source of energy, 18% of the electricity generated and 7.5% of the total energy supplies came from it. Without Nuclear power, the carbon emissions for the UK would have been 5 to 12% higher (DECC, 2007). Nuclear Power stations are at the end of their useful life and there is a public debate if more stations should be installing or not (DECC, 2007). Nuclear Power stations have long lead times and when it comes to provide new capacity to the supply, nuclear is slow. The 2007 Energy White Paper estimates that it will be in 2020 when probably the first Nuclear Power Station could be in operation (Watson and Scott, 2009).

According to estimations it is possible to reduce 60% of the carbon emissions by 2050 without including Nuclear Power to the strategy but there are some risks to be take into account in that scenario. Not having nuclear power will make UK more dependent in other technologies to reduce carbon emissions like Carbon Capture (that is not ready yet for implementation with economic success) (DECC, 2007). One important argument use by Ministers in favour of nuclear power is that it will decrease UK's dependence on energy imports such as gas from Russia (Blair, 2005).

In the year 2008 the British Government created a new department called Department of Energy and Climate Change (DECC), in order to integrate the activities related to Climate Change policy and actions in other Departments like Department for business and Regulatory Reform (energy) and Department for Environment Food and Rural Affairs (Climate Change). It is directed by the Secretary of State for Energy and Climate Change. DECC has goals for tackling Climate Change along with securing the energy supply. The Department is aware of the complexity of the situation, not only because of the technological challenges that it represents achieving reductions of 80% of CO_2 emissions by 2050 (HM, 2008) but also because the UK has to establish the best guidance to rearrange the way the country is going to develop the upcoming generation of electricity and through which ways it is going to supply the fuels needed (DECC, 2011b).

To provide guidance to policy makers, the industry and general public, DECC published a document called 2050 Pathways Analysis. It is hard to predict how technology will develop, if the technology will achieve all the improvements needed

in the modelling of the pathways, due to the entropy of all stakeholders. DECC finds that most of the scenarios face the same uncertainties (HM, 2010):

- Reduction per capita in the energy demand
- The electrification of heating, transport and industry
- Electricity needs to be decarbonised
- The energy generation need to diversify
- The continuation in the use of biofuels will be influenced in how far other energy sources could develop

2.3.2   Energy consumption in Mexico

For Mexico in 2008 fossil fuels represented 91% of the total primary energy production, while hydroelectric, nuclear and renewable together had a share of 5% (Figure 6). Indeed while as a country Mexico produces a big amount of crude petrol for exportation, buys a percentage of the gasoline, diesel and gas required for the energy production (SENER, 2011).
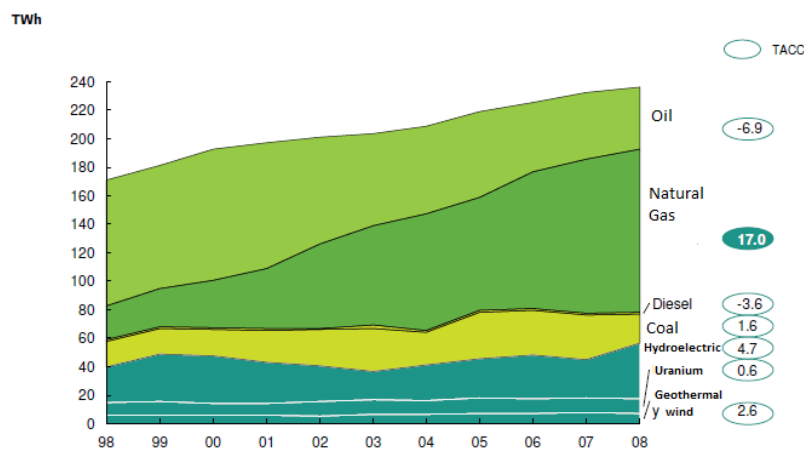
Figure 6 - Energy generation by type of fuel. Source (SENER, 2010b)
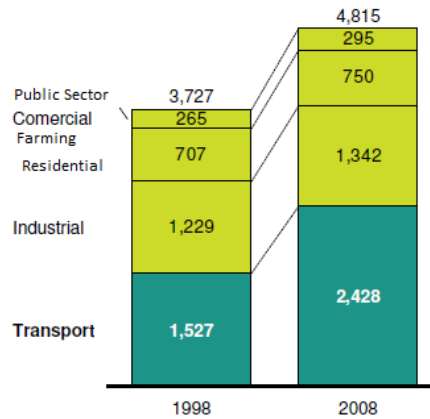
Figure 7 - Final Energy Consumption. Source (SENER, 2010b).

The energy consumption had an increasing growth of 2.6% between 1998 and 2008 (Figure 7). In the transport sector the rate is of 4.7% per year, this means the grow rate is above other sectors like agriculture, farming and the GDP. In 2008, the final energy consumption of transport was of 50% (SENER, 2010a).

For both countries, it is crucial to create an energy supply network that can provide sustainable energy security; also it is important to find ways for better usage of the energy currently in use by every sector. Energy efficiency is the profitable choice to reduce emissions while enhancing energy security and competitiveness (SENER, 2011) (DECC, 2007).

The Mexican energy strategy has a vision to 2024 with three base axes: energy security, economic and productive efficiency and environmental sustainability. Having as primary goals to restore the reserves, reverse the declination of the crude oil production and maintain the production of natural gas, followed for the aim of diversify the energy supplies, increase efficiency levels and reduce environmental impact (SENER, 2011).

2.4 Transport sector

There is an essential dependence in mobility because the movement of people and goods are key factor in human wellbeing and society's interaction (Parry et al., 2007). Transportation establishes the ground basis for the location planning of cities and industries, also helping in the economical success of regions (Greene and Wegener, 1997). Transport accounts for a whole industry that makes possible trade in the means

of providing cheap and efficient movement (Parry et al., 2007). Globally transport's share in the energy related carbon dioxide emissions is about 25% (IEA, 2009). The fuel in which vehicles rely is fossil, which is not renewable and prices are unstable. Because of this the future for the sector is challenging (Parry et al., 2007).

The automotive industry, aircraft construction and operation industry, train construction and railway operations, ship building and operation industry and suppliers is probably the biggest sector in the globe in terms of economic revenue, employment of personnel and resource use. The direct value that aggregates to the global GDP is between 3-5% and typically transport contributes to 5-8% of a country's total paid employment (UNEP, 2001). The economical bonds and type of energy consumption makes difficult to set a concrete strategy to reduce energy demand and carbon dioxide emissions (Stern, 2007, Parry et al., 2007, Enkvist et al., 2007, Brand et al., 2010).

Transportation has important environmental impacts in air, land, water. These impacts affect ecosystems and human health at all levels of the life cycle. The major affectations come from the energy consumption (UNEP, 2001). Over the past decade, GHG emissions from transport have showed a fast rate of growth that compared to other sectors is of the fastest (Mckinnon and Piecyk, 2009a).

Reducing the amount of fuel consumed by the transport sector represents not only an opportunity to save costs; it also helps to secure the enormous amount of socio-economic activities related to transport. Currently there are available technological improvements that if applied can help reducing the fuel consumption and the CO_2 emissions related to fossil fuels. Governments recognizing this potential have started formulating carbon abatement strategies for freight transport (McKinnon and Piecyk, 2009b).

2.5 Freight Transport Sector

The continuous growth of freight transport contributes to economic growth and job generation (EU, 2006). The development of freight transport puts in CO_2 emissions to the atmosphere that contribute to Climate Change. The environmental effects of transport are directly related to the amount of kilometres travelled and the specific

conditions of the operation. Freight transport activity is indirectly related to its negative environmental consequences (Pastowski, 1997).

2.5.1 Freight transport in Europe and the United Kingdom

The use of petrol as major fuel of the freight transport sector cannot continue its growth; there is a concern from policy makers in developed countries to stimulate changes in technology, design, operation and financing of transport operations. This makes energy efficiency an important issue in policy objectives. One useful indicator for energy efficiency in freight transport is the tonne-kilometres, which are the amount of freight in tonnes carried by a distance in kilometres (Greene and Wegener, 1997). The trend for the global tonne-kms in Business as Usual expects a growth of 2.3% per year from 2000 to 2050. This trend is driven for the market production and consumption as well to an increase in the distance that products would have to travel to get to their final destinations (McKinnon, 2010).

A plan has been outline to increase transportation and diminish GHG emissions in Europe. In March 2011 the European Commission approved an ambitious strategy, the White Paper "Roadmap to a Single European Transport Area" looking forward to create a efficient in the use of economical and energy resources transport system that will increase transportation movements, eliminating remove commercial barriers, promoting fuel growth and employment. This will mean the reduction of dependence in foreign fossil resources at the same time cutting carbon emissions from transport 60% by 2050 (EU, 2011).

The White Paper sets different goals for every type of travel and according to distances, inside cities, between cities and long distances across countries (EU, 2011).

For inter-urban movements:

- By 2020, create the structure for a European multimodal transport information, supervision and payment system.
- By 2030, 30% of road freight over 300 Km should shift to more fuel efficient transport modes such as rail or waterborne transport, and more than 50% by 2050.
- By 2050, unite network airports to the rail network. Also provide proper connection between seaports to the rail freight.

23

- Establish a "user pays" and "polluter pays" system to promote engagement of the private sector while generating revenues and resources for future investment.

Air travel and waterborne will continue they dominance in transportation for long-distance movements and intercontinental freight. Improved engines, fuels and traffic management systems will raise effectiveness and decrease emissions (EU, 2011)

It is estimated that globally the CO_2 emissions from the aviation sector accounts for between 2.3% and 3% (Scheelhaase and Grimme, 2007), high-altitude emissions of NOx causes ozone production along with leading to formation of cirrus clouds (Lee et al., 2009). Because the aviation sector is international and there are several countries involved, one of the strongest points in the European government strategy to reduce the GHG emissions is to promote a well-designed emissions trading scheme. Along with this, the strategy also seeks to improve the fuel economy of the aviation fleet (EU, 2011). In the last 40 years, there has been an improvement of 70% in the aircraft fuel efficiency that is why renewing aviation fleet part of the strategy. The Advisory Council for Aeronautic Research in Europe (ACARE) set goals for reducing the environmental impact of aviation: Reducing the CO_2 emissions by 50% through improvements applied to the engines, operations and air traffic management is forecast to reduce Nitrous Oxide by 80% and noise by 50% by 2012 compared to 2000 year levels (DfT, 2007a) (Bows et al., 2005).

For the Rail Sector, carbon emissions are low, accounting 1% of UK of emissions (DfT, 2007a). When comparing the energy efficiency in kilo joules per tonne-km, rail freight is two times more efficient compared to road (Bonnafous and Raux, 2003, RCEP, 1994, McKinnon, 1999). However, as all the previous modes of transport, rail needs to improve its fuel efficiency and carbon emissions profile (DfT, 2007a).

The Department for Transport leads the Intercity Express Program (IEP) that seeks to improve the cost efficiency for train replacement and growth needed to provide services in important long distance routes. This can be achieved by using high speed, hybrid trains that combine diesel and battery power (DfT, 2011b).

Waterborne is an efficient method to transport goods being the lowest carbon option to transport freight over long distances and is considered to be the cheapest and more

environmentally friendly (Chapman, 2007). A study was commissioned to assess the technological options to reduce carbon emissions produced by shipping. The study carried by AEA Energy and Environment and Newcastle University showed that there is potential to reduce emissions through the improvement of engines, implementation of the use of biofuels and the use of kites and skysails to enhance propulsion systems (DfT, 2007b).

2.5.2 Freight Transport sector in Mexico

Freight transport is called Federal Auto transport and it is the main mode for freight transport in Mexico. Mexico is country with an economy based on exportations and has 12 Free Trade Agreements with 44 countries, United States as its bigger partner. Most of the freight movement goes by road, despite the big movement of freight along the country; the freight transport sector faces the following problems (SCT, 2007).

- There is a need to reinforce the supervision and actualization of legislation
- There are several irregularities in the service and unfair competition
- There is a high index of accidents due to psychophysical problems of the drivers and mechanical fails in vehicles
- Uncompetitive vehicle fleet
- Not enough finance programs or tax incentives to help improve the fleet
- Excessive fragmentation of service providers
- Excess of weight and dimension of trucks
- Need to implement program for the reduction of GHG emissions.

Several of these issues are big challenges to improve Mexico's freight transport system, but it also represents opportunities for the development of other transport modes. It is imperative to change the distribution of transport modes to enhance the efficiency and sustainability of the country. That is why the Ministry of Communications and Transport has as priority the following themes (SCT, 2007):

- Improvements in legislation
- Creation of regulatory institution for road freight transport.
- Divide normative functions from operational, and lead to a reinforce supervision areas.
- Coordination with other government departments to decrease crime.

- Establish verification centres of vehicles to measure their GHG emissions.

- Promote sustainable policies.

- Driver training

- Integrated modernization of freight transport.

The rail system it is also not develop facing a lag in modernization and infrastructure coverage, there is not enough loading capacity in ports as well insufficient accessibility to connections in cities, boarders, the interconnection services are poor, and the trade policies are not attractive enough. In order to improve the rail transportation the Ministry is aiming to build railway lines in new development areas, implement efficiency schemes along with security programs, promoting policies to enhance participation of companies (SCT, 2007).

2.6 Road Freight Transport

2.6.1 Road Freight transport in the UK

According to the statistics and the Freight Transport Association (FTA) the transport sector has already make progress in reducing the carbon emissions. In the Figure 8 is represented the share of CO_2 emissions of mode of transport, rail, road, aviation and shipping (DfT, 2011c).
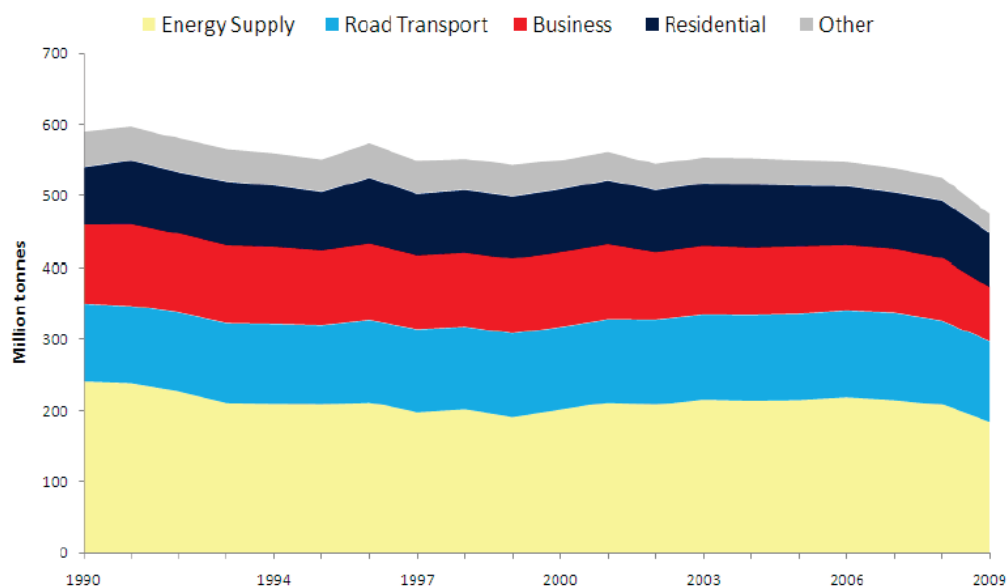
Figure 8 – Carbon Dioxide emissions by source, 1990-2009. (DfT, 2011c)

Emissions from HGVs accounted for almost 51% of Carbon Dioxide Emissions from freight transport in the UK in 2009 and emissions from vans 28%. This shows an increase of 6.3% between 1990 and 2008 (DfT, 2011c). The total amount of emissions in 2008 from road transport was 123 million tonnes. Figure 9 shows the distribution of this amount according to transport mode. Heavy Goods Vehicles contributed with 20%, cars made 59% and Light Goods Vehicles 11% (DfT, 2011c).
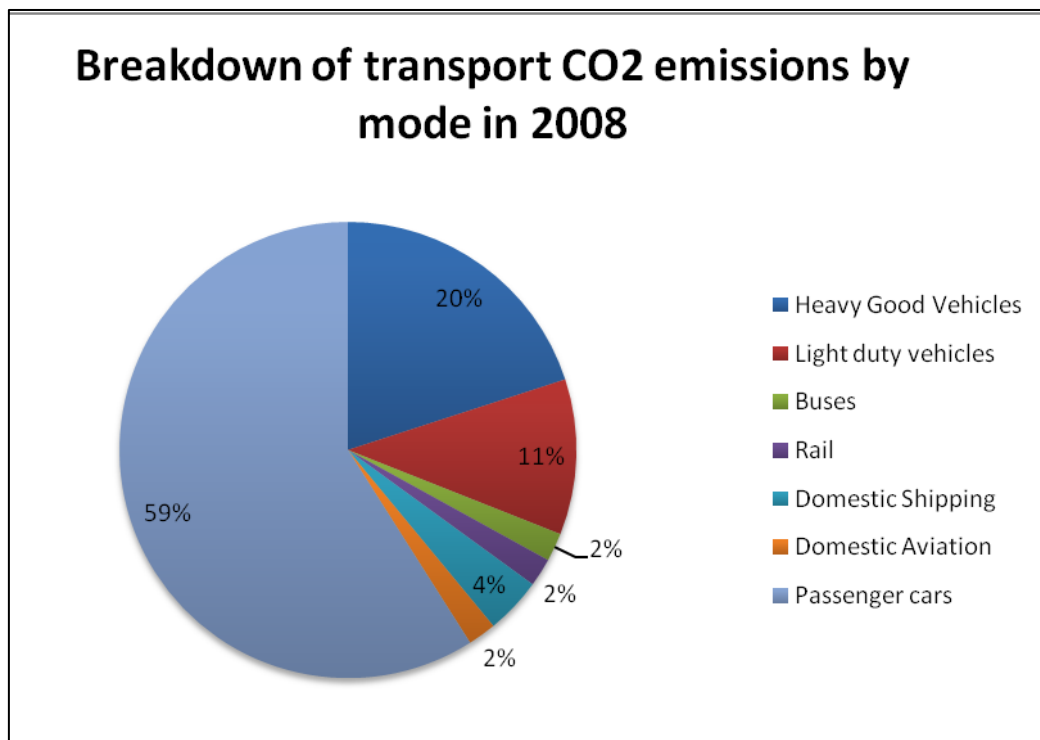
Figure 9 - Breakdown of transport CO$_2$ emissions by mode in 2008. Source (DfT, 2011c)

The expectation is that emissions from surface transport will still have a big share (22%) of the total amount of emissions in 2030 but the forecast indicates that these amounts will fall as the use of electrical vehicles increases (FTA, 2010).

The Low Carbon Transport Innovation Strategy along with the Government's Energy White Paper gives to technological development a critical role to achieve the carbon reductions needed from the freight transport sector. The strategy recognizes that there are several market malfunctions and obstacles to commercialize low carbon technologies. That is why the Government plays a crucial role to encourage the improvement of transport expertise promoting all stages of the innovation chain for modes of transport (DfT, 2007a).

In 2008/2009 the Government, the UK automotive sector, the Technology Strategy Board, the Department for Transport (DfT) and the Engineering and Physical Sciences Research Council (EPSRC) contributed financing a new Low Carbon Vehicle Innovation Platform that provided coordination and investments up to £30 million (DfT, 2007a).

2.6.2 Road Freight transport in Mexico

The Ministry of Communications and Transport (SCT) and the Ministry of Environment, Natural Resources and Fisheries (SEMARNAT) created the Clean Transport Program, as a voluntary initiative for Freight transport companies and service users from freight transport companies (SEMARNAT, 2011).

In 2006 the emissions by mode of transport were: 91% road, 6% air, 2% shipping, 1% rail. Road freight transport moves 56% of all the goods and 98% of passengers, according to figures from the Mexican Federal Motor Carrier General Directorate (SEMARNAT, 2011).

One of the biggest challenges is renew the vehicle fleet. According to the basic statistics of the DGAF 2007, 34% of the approximately 310 000 units that make up the freight transport fleet are older, equal or less than 9 years, 26% is between 10 and 19 years, 23% between 20 and 29 and the remaining 7% have an equal or over than 30 years (SEMARNAT, 2011).

The program Clean Transport Program aims to make road transport more efficient and safe by reducing the fuel consumption, green house emissions and pollutants like NOx and PM_{10} and cost and has the target to reduce two million tons of CO_2 by the year 2012. As is a voluntary program every company or fleet owner has to decide the amount they want to invest, in what, and when to invest. The strategies the program promotes are for the Freight transport companies are: Speed control on the road, driver training and intermodal shipping. Giving to option of the use of the following technologies: idle reduction, battery use, diesel heating, electrification of the loading and unloading stations, improved aerodynamics, broadband individual tires, tire automatic inflation systems, lubricants, truck weight reduction, and emission control devices (SEMARNAT, 2011).

For users of transport services gives suggests: intermodal transportation, stations for drivers, policies for reduction of idling, preferential loading and uploading for program users, improvement in the reception and delivery schedules, empty running, improvements in internal fleet of shippers, warehouse improvements and use of electric forklifts (SEMARNAT, 2011).

For the evaluation of CO_2 reductions it was used a model called FLEET. The technologies that were evaluated following: aerodynamics (tractor with aerodynamic profile, cab over engine truck, the protective cabin roof, wind deflector mounted on the front of the cab, the cab aerodynamic mirrors, skirts lateral aerodynamic trailer), individual tires wide base, automatic inflation of tires, motor oil low friction, lubricant power train low friction and speed of 100 km / h (SEMARNAT, 2011).

The modelling predicts that with the incorporation of 6% from the freight and passenger fleet there will be a reduction of 10% of and 40% reductions in CO_2e, if 70% of the fleet joins the program (Figure 10). As it can be observe in the following figure (SEMARNAT, 2011).
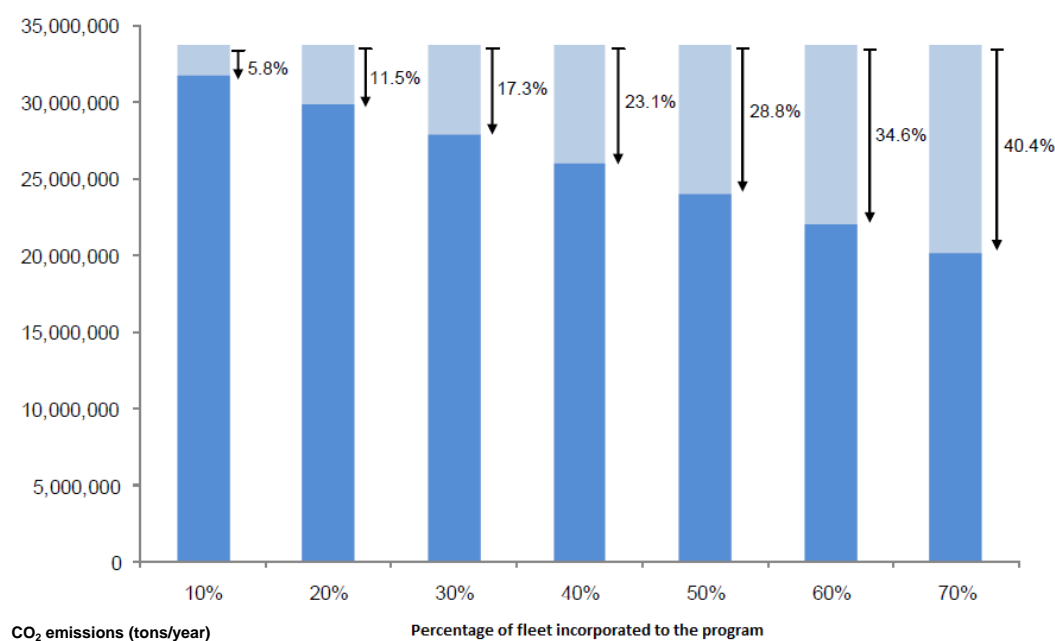
Figure 10 - CO_2e reduction percentage by the size of the vehicle fleet. Source: (SEMARNAT, 2011)

The pilot program started with 38 companies in June 2010, with a number of 5001 vehicles. This accounted for the reduction of 313 536.5 tonnes/year. By August 2011 the program had included more members reaching a number of 55 freight and passenger transport (SEMARNAT, 2011).

2.7 Measurement of CO_2 emissions from freight transport in the UK

In the view of the projected trends of growth in the freight transport sector, Mexico and the United Kingdom have formulated strategies to reduce the CO_2 emissions. The first face in the development of reduction strategies is to carry an analysis of greenhouse gas (GHG)/CO_2 emissions produced by the transport operation by mode (Mckinnon and Piecyk, 2009b). From the UK experience it has been observed that different calculation of the emissions can be obtained by using different data and procedures (McKinnon and Piecyk, 2009b). As a result there are different measures and trends. In order to provide a common system to measure the emissions and compare the trends Carbon footprint methodologies have been develop. Several methodologies have been published, the most relevant for the transport sector are: PAS 2050, Specification for the assessment of the Life Cycle Greenhouse Emissions of Goods and services (BSI, 2011b), the Green House Protocol: A corporate accounting and reporting standard (WBCSD, 2011), ISO 14064:1, Greenhouse Gases, Specification Guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals (ISO, 2006). There is also a BSI 16258, Methodology for calculation and declaration on energy consumption and GHG emissions in transport services (good and passenger transport) currently at a draft stage (BSI, 2011a). In order to standardize the measurement of CO_2 emissions from the transport sector the UK's Department for Environment, Food, and Rural Affairs (Defra) published a document with guidelines for GHG Conversion factors for passenger and freight transport. The emission factors are necessary to calculate CO_2 impact per km by tonne-km. These factors are use in various policies including, such as Defra and DfT CO_2 calculators and to update guidelines to Defra's GHG Conversion Factors, setting the present official government emission factors (Defra, 2011).

The Freight Surface Transport factors are estimated according to statistics from the DfT. In 2005 DfT carried a survey to calculate the average loading factor for Heavy Goods Vehicles (HGVs) both rigid and articulated. The results from the survey were combined with the outcome of the European Artemis project studying fuel efficiency and CO_2 emissions according to variations in the load of load. For Light Goods Vehicles (LGVs) the factors were based on the emission factors of average load factor of 50% or .5 tonnes for petrol vans (up to 1.25 tonne gross weight) and 1 tonne for

diesel/LPG/CNG vans (up to 3.5 tonne gross weight) (Defra, 2011). The value for rail freight is based the information about fuel consumption and CO_2 emissions produced by diesel trains in 2005. The data about the medium fuel consumption was provided by the UK Greenhouse gas Inventory and DfT data from the tonne-km transported by rail in 2005. Factors have a variation depending on the speed, traffic in the route scheduled and weight. For RoPax Ferry Freight the factors for calculation of emissions were determined using information from the Best Foot Forward (BFF) for the Passenger Shipping association (PSA). An analysis of data coming from freight and passenger ferries in UK routes, distance move people and goods, total freight units and fuel consumption. The carbon dioxide emissions were set between passengers and freight because of the tonnes transported and including freight vehicles and passengers. For other Marine Freight Transport, the values used come from EMEP-CORINAIR Handbook (2003) and a report by Entec (2002). The values in the table are in gCO_2 per ton km by deadweight. This means that the vessel should be loaded to its maximum capacity and not necessarily means that when the vessel is at half of its capacity the emissions will reduce by half. This means that the values provided in the table should be consider as the lower limits (Defra, 2011).

Freight Surface Transport Factors			
Body Type	Gross vehicle weight	% weight laden	gCO$_2$ per vehicle km
Rigid	<7.5t	0	525
		50	571
		100	617
		41 (UK average)	563
Rigid	7.5-17t	0	672
		50	768
		100	864
		39 (UK average)	747
Rigid	>17t	0	778
		50	949
		100	1119
		56%(UK average)	
All rigid	**UK average**		**865**
Articulated	<3.3t	0	672
		50	840
		100	1008
		43% (UK average)	817
Articulated	>3.3t	0	667
		50	889
		100	1111
		59% (UK average)	929
All articulated	**UK average**		**917**
All HGVs	**UK average**		**906**

Table 2 – Freight Surface Transport Factors for HGVs. Source (Defra, 2011)

Light Good Vehicles (LGVs)			
Van fuel	**Van size**		**gCO$_2$ per tonne km**
Petrol	Up to 1.25 tonne		448.8
Diesel	Up to 3.5 tonne		271.8
LPG or CNG	Up to 3.5 tonne		271.8
Average			**283.3**
		gCO$_2$ per tonne km	
Rail Freight		21	
Large RoPax ferry		384.3	
Shipping	**Weight class (dead weight)**		gCO$_2$ per tonne km
Small tanker	844 tonnes		20
Large tanker	18,371 tonnes		5
Very large tanker	100,000 tonnes		4
Small bulk carrier	1,720 tonnes		11
Large bulk carrier	14,201 tonnes		7
Very large bulk carrier	70,000 tonnes		6
Small container vessel	2,500 tonnes		15
Large container vessel	20,000 tonnes		13

Table 3 - Freight Surface Transport Factors for LGV's, Rail and shipping. Source (Defra, 2011)

Follow the guidance it is not an obligation for businesses so they are free to decide if they want to share the information to the government. The direct benefits of measuring the CO$_2$ emissions are to have the information about how is a business contributing with CO$_2$ emissions, in this way they will be able to identify which areas can start reducing its contribution, for example by saving energy. Saving resources is not the only benefit; also, it will show a responsible leadership by taking actions to tackle Climate Change, encouraging other businesses to also measure and reduce their CO$_2$ contribution (Defra, 2011).

Preventing the Government enforcement through legislation or taxation the Freight Transport Association (FTA) decided to start keeping track of the emissions, in order to be able to report progress in the reduction of CO$_2$ emissions. The FTA represents transport interest of companies moving goods by rail, road, sea, rail and air in the UK.

The Logistics Carbon Reduction Scheme (LCRS) was published in 2010, as a voluntary initiative from the industry as an action response to the Climate Change Challenge. To achieve the data recollection that FTA needs to carry the LCRS the 60 FTA members have to provide the number of vehicles and simple fuel consumption data, this information will be converted to CO_2" using the conversion factors approved by Defra. Then the FTA aggregates data from the scheme members, reports totals and keep records in CO_2 emissions and fuel efficiency over time. This allows the UK logistics sector to report for the first time its contribution to achieve the national targets to cut CO_2 emissions (FTA, 2011).

What should be the target in reduction of carbon emissions? That is question that the FTA asked to its members. The importance of the target relies in the significance of have a goal in decarbonisation the freight transport that will help to demonstrate that the sector is working towards objectives and achieving them. The first agreement by the group members was to first set a target of 5 years, setting a reduction trajectory for 2015 using 2010 as a the start line. The members considered several pathways and the efficiency factors available to the technological state are as it follows: Freight modal split, empty running, average payload weight, fuel efficiency, carbon intensity (FTA, 2010).

Once the duration and the five pathways were established the group members needed a target to achieve. All the LCRS and Logistics Working group members where surveyed on how their emissions would change from 2010 to 2015 following the 5 logistics efficiency indicators. FTA also surveyed the wider industry as part of its logistics industry survey 2011. Heriot Watt University helped by developing a model from "Moving Freight by road in a very low carbon world" to add individual company returns from both samples to provide an industry view of the likely level of CO_2 reductions from its logistics activities. The results were analyzed separately (Mckinnon and Piecyk, 2009a). After this came a second part of the study where the members were asked to review the previous results, by doing this it was founded that a small number of companies where setting high targets, and that most of the companies where being more realistic setting smaller ones. The result of both phases of the analysis suggests that when all the 5 logistics efficiency factors are applied the anticipated reduction is 8% by 2015 comparing it to the 2010 starting line (FTA, 2011).

2.8 Projected Trends of CO_2 emissions from Freight Transport

2.8.1 Projected trends of CO_2 emissions for the United Kingdom

Transport shows an increasing activity trend, and apparently, it has decoupled from economical growth. From 1997 to 2007 UK's GDP grew 37% while transport activity only did it by 11%, this can be due to several factors but it is hard to predict if this might be a continue trend in the future. The Drivers in the 2050 Pathways analysis for transport identified are: Population, GDP, cost of travel, location of economic activity, population growth, land use and population density (DECC, 2011b).

Reduction in the carbon dioxide emissions are enabled through a mixture of demand and supply that depends on actions in other sectors like: technological breakthroughs, conductive relative cost between different fuels and vehicles, supporting policy framework with public acceptance, and the consumer confidence in the use of new technologies. While representing the evolution of transport activities in the four different action scenarios there are three different factors that vary (HM, 2010):

- Transport activity
- Changes in technology and power source
- Changes in efficiency

In Figure 11, it can be appreciate the development of freight transport in 2050 under the four levels. Decreasing the share of road transport, electrify the rail systems and more use of shipping, as technological and commercial challenges achieve.
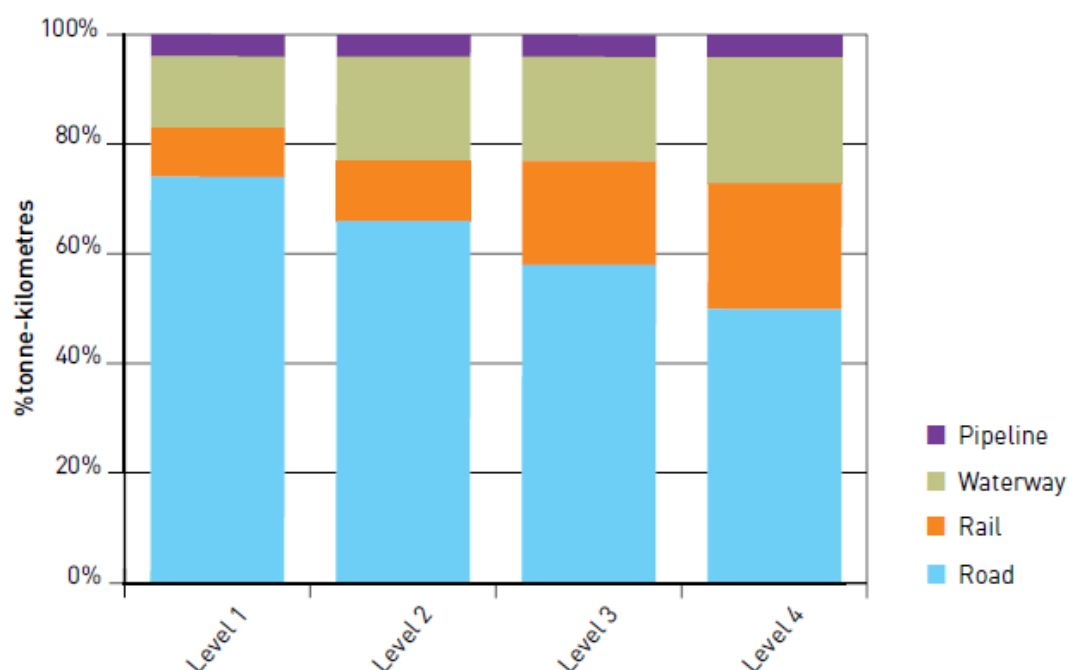
Figure 11 - Freight Transport mode shares in 2050 under four levels of change. Source (HM, 2010).

2.8.2 Projected trends of CO_2 emissions for Mexico

The Mexican Institute of Petroleum (IMP) had a project to elaborate GHG emissions Scenarios in the Medium and Long Term, 2020, 2050 and 2070. Three transport sectors were considered: road, rail and waterway. In the next Figure it can be observe the Business as Usual emission scenarios till the year 2050 (IMP, 2009).
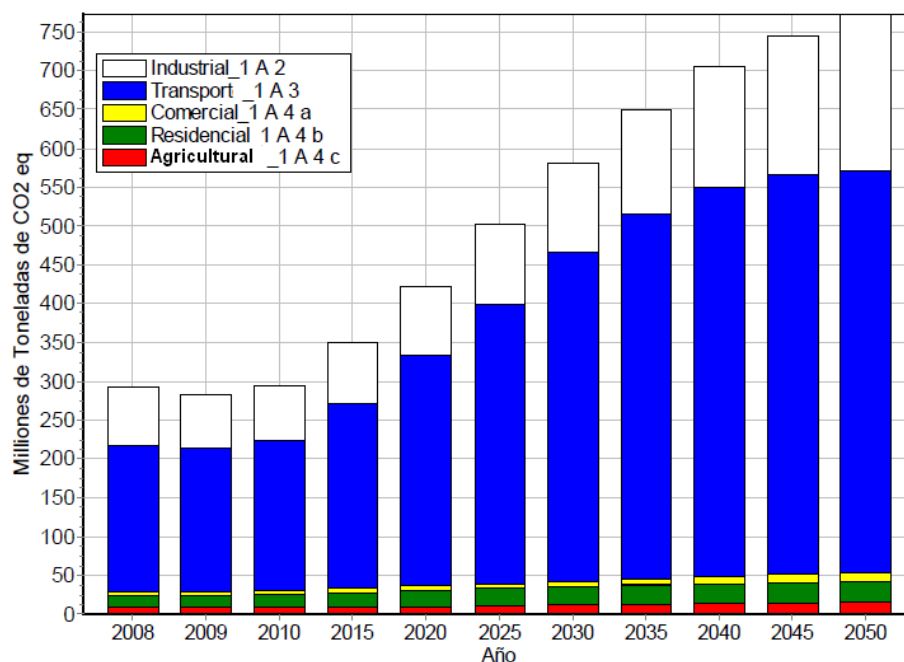
Figure 12 - Baseline Scenario of GHG Emissions. Source: (IMP, 2009)

For the year 2030 the mitigation potential for the transport sector is estimated between 130 to 140 Mt of CO_2eq per year, which represents a reduction around 4% against emissions in the year 2006 (IMP, 2009)

2.9 Options for reducing CO_2 emissions on freight transport

Improvement in the transport business operation leading to obtain economic profit is what companies look for. These aspirations are also called "green" and gold" (McKinnon, 1996). In the year 2006 the Food Industry Sustainability Strategy (FISS) published a series of six measures of best practice for the industry, including computerised vehicle routing and scheduling/telematics, use of higher capacity vehicles, collaboration between companies, out-of-hours deliveries, improved engine specification and logistics system redesign. In 2007 Defra commissioned a study to look at the options to reduce external cost of food distribution. Using software tools the study simulated, the application different best practice options to freight transport data from four supermarket retailers and other sources. The study was supported by the Food Industry Champions Group and after the good results of the data modelling the recommendations were used by the IGD as part of the ECR. This permitted the extension of the knowledge of the options, as a result 40 UK important brands implemented the recommendations in their freight operations. The after effects of the

implementations were savings of 124 millions of road miles from UK roads and around of 60 million litres of diesel fuel (Fisher et al., 2009) which accounts for around 153 million Kg of CO_2 (DEFRA, 2007).

From the year, 2006 to 2011 there has been a change in the scope of the reduction measures; in the beginning of the study it was the reduction of the external cost of the domestic food transportation. Nowadays there is an aim to focus the measures in the reduction of CO_2 emissions. It is important to say that the implementation of the series of recommendations by FISS helps reducing cost improving the daily operation.

The United Kingdom imports from other parts of the world almost 50% of all the fruits and vegetables consumed daily and food distribution represented 28% of all the road freight kilometres. In their campaigns, environmental groups have leaded to think that transporting food over long distances is not sustainable. However, as research has shown it is not only a matter of distance but also the kind of transport used to deliver. Movements over long distances in fully load modern articulate lorries by road are not as environmental damaging comparing it to distribution of goods along short distances by van on urban roads (Fisher et al., 2009). There are two basic ways to reduce the environmental impact of food distribution (IGD, 2008):

 ➢ Fewer miles. Reducing the distance for transportation reduces environmental impacts such as congestion of urban roads, greenhouse gas emissions, incidents and noise.
 ➢ Friendlier miles. Changing the transport mode might reduce the environmental impact of the miles travelled to deliver goods or by the implementations of technological developments in engine optimization and fuel consumption technologies.

2.9.1 Expanding Vehicle Capacity

Efficiency in the road freight transport is a key factor in the environmental aspect of delivery (McKinnon and Edwards, 2010). Cubic capacity of vehicles set a limit in the carrying capacity. In every 10 km that a truck transports food products 6.5 are under the restriction of capacity and not under the weight constraint (Fisher et al., 2009). In the United Kingdom the length limit is 18.75 metres, and the width limit is set to 2.55

metres. Everything within the current gross vehicle weight limit of 44 tonnes (Penning, 2011).

Expanding vehicle capacity will benefit companies transporting lighter or bulkier products because vehicles could carry more load without go above the weight limit. For transport operators carrying heavy products this would not be beneficial because load a vehicle with bigger cubic capacity would "weight out" the truck (IGD, 2008).

In much of mainland Europe truck height in lorries is restricted to 4 or 4.2 m, in the UK there is no legal limit on the maximum height but five metres is consider to be the restriction in the truck road network (Penning, 2011). This has permitted the use of double deck trailers in companies transporting low density products. Double deck trucks allow transporting two layers of pallets. The fuel efficiency in double deck vehicles is higher because carries more pallets per litre of fuel. This happens even when a double deck lorry is heavier and with a less aerodynamic design (Fisher et al., 2009).

2.9.2 Alternative fuels

The prices of fossil fuels are in continuous increasing change. That is why alternative fuels are becoming an increasingly attractive option (IGD, 2008).

Some vehicles are design to use fuels different from fossil. This are called alternative fuel vehicles (AFV) and also could be flexible-fuel allowing to use more than one type of fuel (IGD, 2008). The variety of alternative fuels goes from alcohols such as methanol and ethanol, liquid nitrogen, electric batteries, biodiesel, natural gas, hydrogen, fuel cells, solar power and others (Astbury, 2008). When using alternative fuels in motor engines they produce a lower amount of emissions of hydrocarbons, carbon monoxide and particular matter, than diesel engines (Ahouissoussi and Wetzstein, 1998) and according to the type of fuel use the CO_2 emissions can be reduce (IGD, 2008). For example emission factors using diesel (retail station biofuel blend) the emission factor is 2.5530 Kg of CO_2 per litre of fuel consumed while using 100% of mineral diesel the emissions are 2.648 Kg of CO_2 per litre (Defra, 2011).

A number of important food transport operators are changing their vehicle fleet to vehicles that can use a biodiesel mix. This means that there will be an increase in

demand of biofuels. According to the Industry Sustainability Strategy Champions' Group on Food Transport benefits from the use of alternative fuels are reduced; accounting less than 1% of the total external cost (DEFRA 2007). Biofuels seemed not to be an efficient cost method to reduce carbon emissions because they are more expensive to produce than petrol or diesel (Johansson, 1999).

2.9.3 Logistics system redesign

Is it known that the position of a facility establishes and has influence in the distribution system parameters such as time, cost and efficiency (Sule, 2001). Evaluate the logistic network and take the opportunities to optimise it is the objective of redesign the logistics system (IGD, 2008). There are two main areas of consideration(IGD, 2008):

- The requirements for retailing or manufacturing, such as the size, location and capability of one company. For example to set the location of several facilities for distribution of products, the depots should be located in order to serve customer demands taking into account the distances, times and cost. The redesign of the system should provide the best location of facilities to open, and which customers should be supplied from which depot to minimize cost (Melo et al., 2009).
- The use of consolidation in order to decrease road freight traffic, increase the efficiency of the urban freight transport operations, reduce cost and requirements for storage of goods (Browne et al., 2005).

2.9.4 Technology and operational processes

Vehicle telematics and computerized routing and scheduling (CRS) are considered good options to increase freight transport efficiency. To enhance the efficiency means to improve transport performance along with reduce environmental negative effects (Baumgartner et al., 2008). Scheduling is the procedure of generating a time-based presentation co-ordinated events and planned routes to deliver orders establishing resources and time limits. CSR uses computers and software to create the schedules before done manually (Baumgartner et al., 2008). Vehicle telematics are systems used for fleet management also allowing remote communication (Baumgartner et al., 2008, IGD, 2008). In means of sustainable distribution a better route planning will help to

avoid traffic congestion, decrease kilometres travelled and as a result there would be less fuel consumption and CO_2 emissions (IGD, 2008).

Vehicle telematics is applied in several ways (IGD, 2008, Baumgartner et al., 2008):

- Vehicle tracing and tracking
- Navigation and route planning
- Data communication
- Pricing insurance
- Recovering stolen vehicles
- Up to date traffic information and notification of issues such as road accidents and lane closures.

2.9.5 Fuel efficiency measures

From a logistical point of view there are three critical ratios that influence the energy-intensity of road freight transport. These are: road tonne-kilometres, total tonne-kilometres: output, vehicle kilometres (McKinnon, 1999).

To decrease fuel consumption and increase fuel efficiency two other aspects need to be taken into account: driving technique and maintenance of the vehicle to continue performance at its best (IGD, 2008, Ruzzenenti and Basosi, 2009). Some examples are:

- Monitor tyres pressure and air filters. It is reported that correct tyre pressure would improve rolling resistance 6%. This will decrease the tyre wear and fuel consumption (IGD, 2008).
- The way vehicles are driven has a strong influence in the efficiency and fuel consumption (Nader, 1991). If driving techniques are taught the potential to reduction of environmental impacts is promising (Wåhlberg, 2007). The general methods of Heavy EcoDriving are (Wåhlberg, 2007):
    - Strategic driving to lessen the amount of breaking
    - Engine breaking
    - Swift changes to higher gears, strong accelerations and low rpm (revolutions per minute).

The initiatives might not have an strong impact in cost and CO_2 emissions reduction but are consider a good practice because its easiness to implement and capability to bring savings without a considerable investment (IGD, 2008)

2.9.6 Vehicle utilization

Maximize the vehicle utilization brings cost benefits and improvements in the freight transport operation (Sarkar and Mohapatra, 2008). The maximum utilization of the cubic capacity should not exceed the weight limit. This also reduces the distances travelled to deliver goods (IGD, 2008).

The use of pallets and alternative transit units such as roll cages, totes or reusable trays or half pallets helps organizing the goods, reducing the misuse of space (Morabito et al., 2000). In order to determine which combination of pallets and alternative transit units could improve the space usage it needs to be take into account the type of product, dimensions and weight (IGD, 2008).

The following are measurements and parameters helping monitor and improve vehicle utilization looking forward to look at weight or volume:

- Tonne-kilometres per vehicle per annum which is not helpful to calculate the proportion of vehicle capacity (Mckinnon et al., 2010).
- Weight-based landing factor is the proportion of the freight moved to the maximum tonne-kilometres and full capacity (McKinnon, 1999).
- Space-utilization. Is calculated in two or three dimensions using the percentage of space used or the ratio of area covered (McKinnon and Edwards, 2010). There is software available that helps in the planning of the physical processes for loading goods into containers, trucks, trailers and rail wagons, and this kind of software delivers clear loading instructions to help you carry out loading process, in this way resources needed can be planned and the loading times kept to a minimum (SAP).
- Empty running. The parameters used expresses the proportion of vehicle-km run empty as a result of unilateral movement of goods and the challenge to find balance in the flux in the reverse way (McKinnon and Edwards, 2010).

2.9.7 Modal Shift / Inter-modality

This option means to change distribution of goods to more efficient and environmentally friendly types of transport (Woodburn and Whiteing, 2010). Intermodal transport can combine two or more modes of transport such as rail or waterborne (Macharis and Bontekoning, 2004), planning to use the less efficient freight transport mode in minimum. Air freight can be substitute with the use of inland waterways, and road transport replace with rail. Waterborne and rail are more energy efficient to move goods producing less CO_2 emissions per case unit (Ricci and Black, 2005).

2.9.8 Out of hours deliveries

Traffic conditions cause delays in transport of goods. More time in the road means more fuel consumption and CO_2 emissions. Evading heavy traffic trucks can move the goods with an on time and reliable schedule this improves fuel efficiency and reduce carbon emissions, bringing also positive effects for the road users (Browne et al., 2006). The scheme of out of hours deliveries need to solve the problems with restrictions on movements of cargo at specific times during the evening to avoid discomfort of local population (IGD, 2008). Despite this challenge policies are stimulating the implementation of the evening schedule (Sathaye et al., 2010).

2.9.9 Transport Collaboration

In economies of scale is important to reduce cost and improve operation. Cooperation and out sourcing have attract attention as an option to improve performance (Zhou et al., 2011)

Transport collaboration can be done in backhaul and fronthaul (IGD, 2008):

- Backhaul occurs when a freight service agent collects cargo from a supplier in its return from a delivery, to transport freight to the Distribution Centre.
- Fronthaul is when, the supplier picks up and delivers a store load in the way back from its journey

The challenges in the implementing of this collaboration are (IGD, 2008, Zhou et al., 2011):

- The complications of matching the necessities of various service agents for the deliveries.
- Combining collaborative practices
- Information sharing
- Service level agreements

2.10 Summary

Irrefutable evidence of Climate Change existence makes countries like Mexico and the United Kingdom to take action in order to avoid suffer the impacts of a global increase of temperature of 2°C. The first step in the Literature Review is to analyze the biggest sources of CO_2 emissions and the actions from them to quantify and forecast the trends in reduction of CO_2 emissions against BAU. Freight transport represents an important sector to reduce emissions for various reasons. First of all road, aviation, rail and shipping are consumers of fossil fuels. Using them as primary energy source or because they use electricity generated by fossil fuels. Fossil fuels are not renewable. Dependence on them causes not only economic risks but also environmental affectations, externalities as noise, air pollution and contributes with CO_2 emissions that are directly related to Climate Change. According to the IEA in 2009 the global emissions from transport accounted 25%. Figures show that the sector is expected to increase its activities and continue using fossil fuels. After carrying a consultation an emissions reduction target of 8% by 2015 has been set by the FTA. Mexico has a Climate Change law initiative and the transport sector still has infrastructure challenges to conquer. Mexico is aware of its situation and is starting to include reducing CO_2 emissions in initiatives such as the Clean Transport Program, which aims to start involving the private sector. Defra published a series of best practice recommendations to reduce carbon emissions while also improve daily activities on a freight transport operator. Each of them can be applied according to the economical capabilities of the companies and the ambition to achieve higher targets in the reduction of emissions coming from the operation of vehicles for transportation.

Chapter 3: Research Methodology

The present chapter describes the research methodology followed, which helped to direct the research for the Macro and Micro study. The chapter begins stating the reasons for the selection of the countries of study and explaining the foundations of the philosophy of research.

The dissertation has two levels of study, Macro and Micro, which is why the chapter is divided in two major sections, one for each level. The section for the Macro study is divided in two subsections, the first one to discuss the philosophy of the research methodology and the second to describe the data sources and collection. The section for the Micro study was divided in four subsections, the first one to discuss the philosophy of the research methodology, the second is dedicated to the discussion of the data resources used for the research, and the third section describes the data collection process and the last section to describe the methods of data analysis.

The United Kingdom and Mexico were selected for the comparative study for the reasons listed below:

- The United Kingdom was the first country to set a long term framework to tackle dangers of climate change (DECC, 2011b). In the year of 2008 with the publication of the Climate Change Act, the UK started strong action to include abatement to climate change as primary subjects in its governmental policies, making the UK a good example of strong legislation encouragement to create a change the sectors involved in the emission of CO_2. In the UK's Climate Change act, the Secretary of State considers that: there are enough technological developments about climate change since June 2000, as well that a more complete European law. These are conditions that allowed setting a target to abate a portion of Britain's CO_2 emissions. Leading to a designation of resources for research and climate change mitigation programs. This makes the UK situation a good example to look at the investment on research and the results in the improvement of technology and operation, towards a sustainable development implying reduction in carbon emissions.

- Mexico was the first non Annex I country in the UNFCCC to submit a report about its CO_2 reductions. In 2010 Mexico has also started an initiative of

legislation in the need of a proper framework to face climate change, which makes the country a great example to look at the starts of legislation on a developing country that without obligation is taking initiatives to assume the responsibility of its CO_2 emissions. In 2009 the National Institute of Ecology, carried an evaluation of Mexico's capacity of mitigation looking to a 2020 scenario. The results were that Mexico could reduce its CO_2 emissions 10% by its own resources and that with the share of technological improvements and economical resources from countries in the Annex I of the UNFCCC the reductions could be of 20%. In December 2009, the Mexican government declared to be ready to embrace the commitment to reduce the emissions up to 30% by 2020. In the Article 4.7 of the UNFCCC is established that in the amount that developing countries achieve their commitments in reducing their emissions, develop countries will start the share of technologies and resources. This implies that there is a need from the Mexican government to achieve reductions in its carbon emissions to be able to prove is ready to implement more ambitious strategies with help of the UNFCCC.

The development of the research philosophy is as crucial as the methods to achieve the objectives because the researcher needs to have a clear view of the nature of reality and which information is acceptable to the study, this ways of thinking about the research philosophy are Ontology and Epistemology, respectively. From an ontological point of view the research philosophy relies in the need to achieve the research objectives providing to the researcher a better perspective and understanding of the situation for the United Kingdom and Mexico about their abatement strategies of CO_2 emissions from the freight transport sector. The establishment of the philosophy of research required to follow a mixture of steps from the Research Onion by Saunders and Lewis and Thornhill (2008) and the research the paradigms by Burrell and Morgan (1982). The Onion helped as a map to find the best perspective, philosophy and approach. To complete the philosophy the paradigms by Burrell and Morgan (1982) where used as a guide to chose the conceptual dimension and paradigm. The following figure shows the mixture between them that directed the philosophy of research.
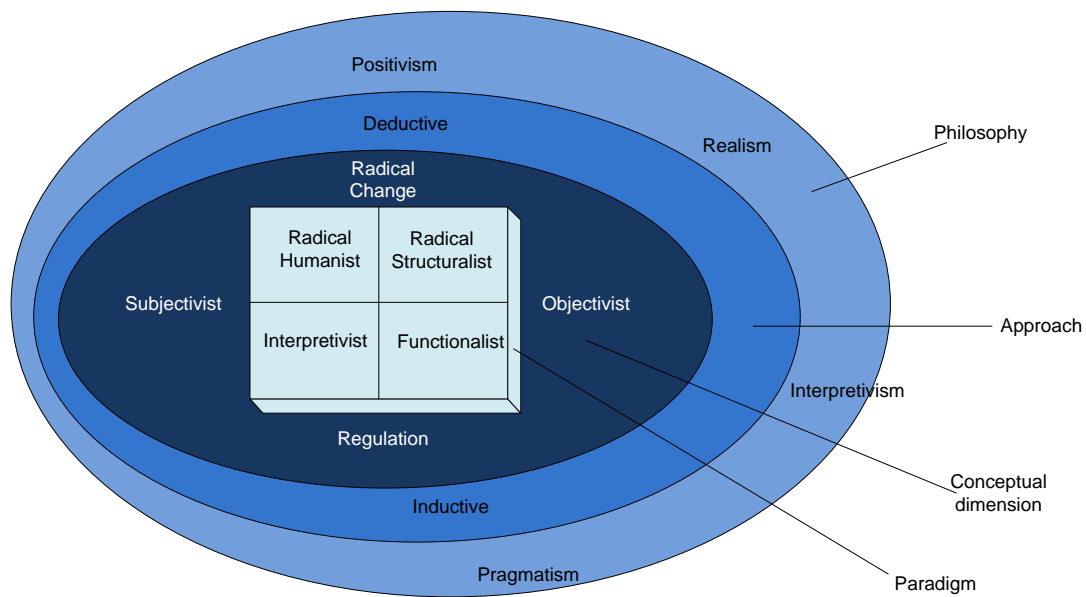
Figure 13 - Steps to develop the Philosophy of research. Source (Saunders et al., 2009, Burrell and Morgan, 1979)

3.1. Macro Study

3.1.1. Philosophy of research

The Macro level aims to review the strategies in legislation and projections implemented by the United Kingdom and Mexico to reduce the CO_2 emissions from road freight transport and determine if at this level there is a reduction in the carbon emission. In Figure 14 is observed in detail the options for each level of the development of the philosophy, the boxes in yellow indicate the option chosen.

Philosophy of the research methodology

Philosophy	Approach	Conceptual dimension	Paradigm
Positivism		Radical change	Radical Humanist
Realism	Inductive	Objectivist	Radical Structuralist
Pragmatism	Deductive	Regulation	Interpretative
Interpretivism		Subjectivist	Functionalist
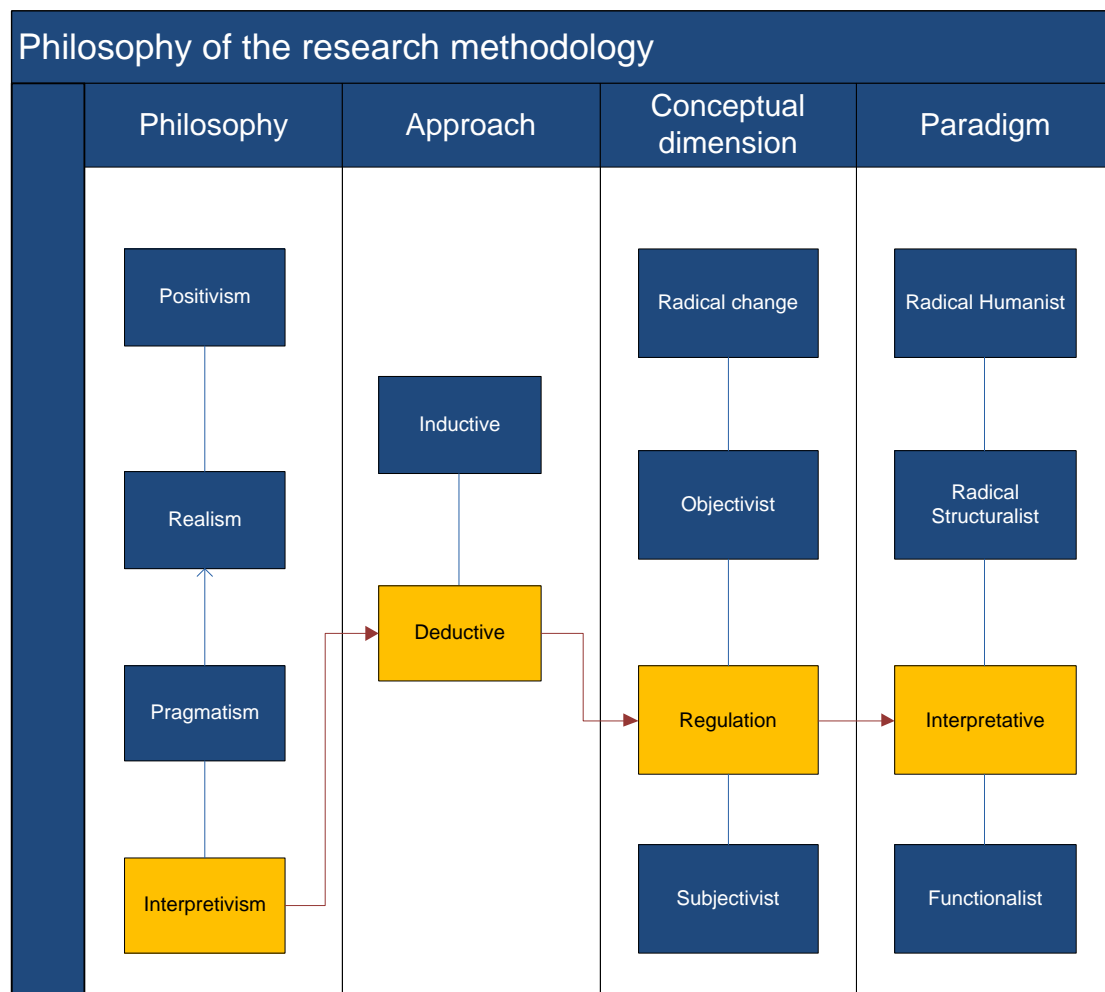
Figure 14 - Research Philosophy for the Macro Study. Source (Saunders et al., 2008, Burrell and Morgan, 1979)

In the first phase there are four options for the selection of the philosophy: Positivism, Realism, Interpretivism and Pragmatism. The Interpretivism philosophy focuses in that each situation is unique, because of a specific state of circumstances and actors involve combined together at a specific time (Saunders et al., 2009). The United Kingdom and Mexico are countries facing a common problem but with specific characteristics, such as their different levels of economic and technological development, different business as usual scenarios. In order to achieve the objectives of the research there is a need to understand the nature of each situation, how it works and the engagement to the particular perspectives from both countries, that is why for this first step of the development of the philosophy of research the interpretativism was the most suitable.

The second step is to choose to best approach for the investigation. The options for the approach are Deductive or Inductive. The deductive approach was chosen because searches to describe casual relations between variables, going from a general

perspective a specific view , starting with scanning of theory and giving logical conclusions (Spens and Kovács, 2006) which is needed to achieve an understanding of the information in matters of legislation, development plans and strategies to reduce CO_2 emissions from the freight transport sector for the countries in question.

To find the conceptual dimension and paradigms is important because these elements outline how we perceive the research universe guiding the investigation (Guba and Lincoln, 1994). For the analysis of social theory Burrell and Morgan (1982) set a framework of four dimensions and paradigms. The dimensions are: Radical Change, Regulation, objective and subjective. The Regulation dimension looks forward to explain and to make clear the premises in which organizational matters are conduct and offer options for improvement (Saunders et al., 2009). The present dissertation seeks to clarify assumptions about the strategies to the freight transport sector for climate change abatement, through the study of governmental and private sectors policies. The research also has the purpose of make suggestions about how to bring progression to the strategies and policies. Because of this the view needed to carry the study is in the Regulatory dimension. This dimension helps the researcher to deduce the premises about the points of view of the nature and society. As well gives advice about the importance of understanding how is that other researchers approach the same problem (Saunders et al., 2009).

For the selection of paradigm it was needed to find one to appreciate the fundamental meanings attached to the governmental, private sector behaviour, and its irrationalities about their climate change abatement strategies for the freight transport sector in both countries. This nature of knowledge it is found in the interpretive paradigm. The objective of this paradigm is to help understand the essential bottom line bind to organizational life, dealing with what is being observe with subjective eyes (Flemming, 2010).

3.1.2. Data sources and collection

The macro study relies exclusively in secondary data. This level of research starts identifying that even when both countries have different economies, Mexico and the United Kingdom share that the biggest amount of CO_2 emissions come from the electricity generation and another considerable part from freight and passenger transport.

The United Kingdom has set different programs and strategies and has designated from its budget resources to invest in the creation and execution of legislation to reduce emissions. What strategies is the Government planning and implementing? How is the freight transport sector accepting they share in responsibility to reduce the emissions? Is the freight transport sector gathering information about their emissions and setting targets to reduce them?

Seeking to answers this questions it was carried the data collection in the following sources for the United Kingdom:

- The UK legislation site to look at the Climate Change Act 2008
- White Paper on Energy
- Department of Energy and Climate Change, DECC
- Department for Transport, DfT
- Department for Environment, Food and Rural Affairs, Defra
- The Carbon Trust
- Freight Transport Association, FTA

Mexico is a more vulnerable country to the effects of Climate Change than many others; it has a big variety of climates that go from dessert, tropical evergreen forest, grassland, thorn forest, wetland, cloud forest, xeric shrubland. Some effects of climate change as droughts, excessive rain and hurricanes put population and natural resources in danger. The country has a policies to promote sustainable and clean development including mitigate and adapt to Climate Change as important goals in its planning and legislation. How is Mexico facing the challenge of reducing its CO_2 emissions from freight transport? How is the industry sector coupling with the policies? How is the government and private sector gathering information of its emissions and setting targets to reduce them?

Finding information about Mexico was not as simple as for the United Kingdom, mostly because there is not an approved Climate Change Act, there is a Law Initiative. This has started slowly the availability of information about the strategies being implemented. The sources for the search of data were the following:

- National Institute of Ecology, INE
- National Development Plan

- Energy Policy

- Mexican Institute for Transport

- Sectorial Program for Communications and Transport

- Clean Transport Program

- National Association of Freight Transport

After selecting the data sources, most of the main sources were consulted to find the information related to Climate Change and strategies to reduce CO_2 emissions from the freight transport sector.

The review of the information from both countries can be found in Chapter 2.

3.2. Micro Study

3.2.1. Philosophy of research methodology

As said in the first section of the chapter, questions of methods are as important as the philosophy guiding the research to achieve its objectives (Saunders et al., 2009). The Micro study aims to evaluate the implementation in operation of 4 different options of carbon emission reduction. Figure 15 shows a scheme of every step to develop the research philosophy.
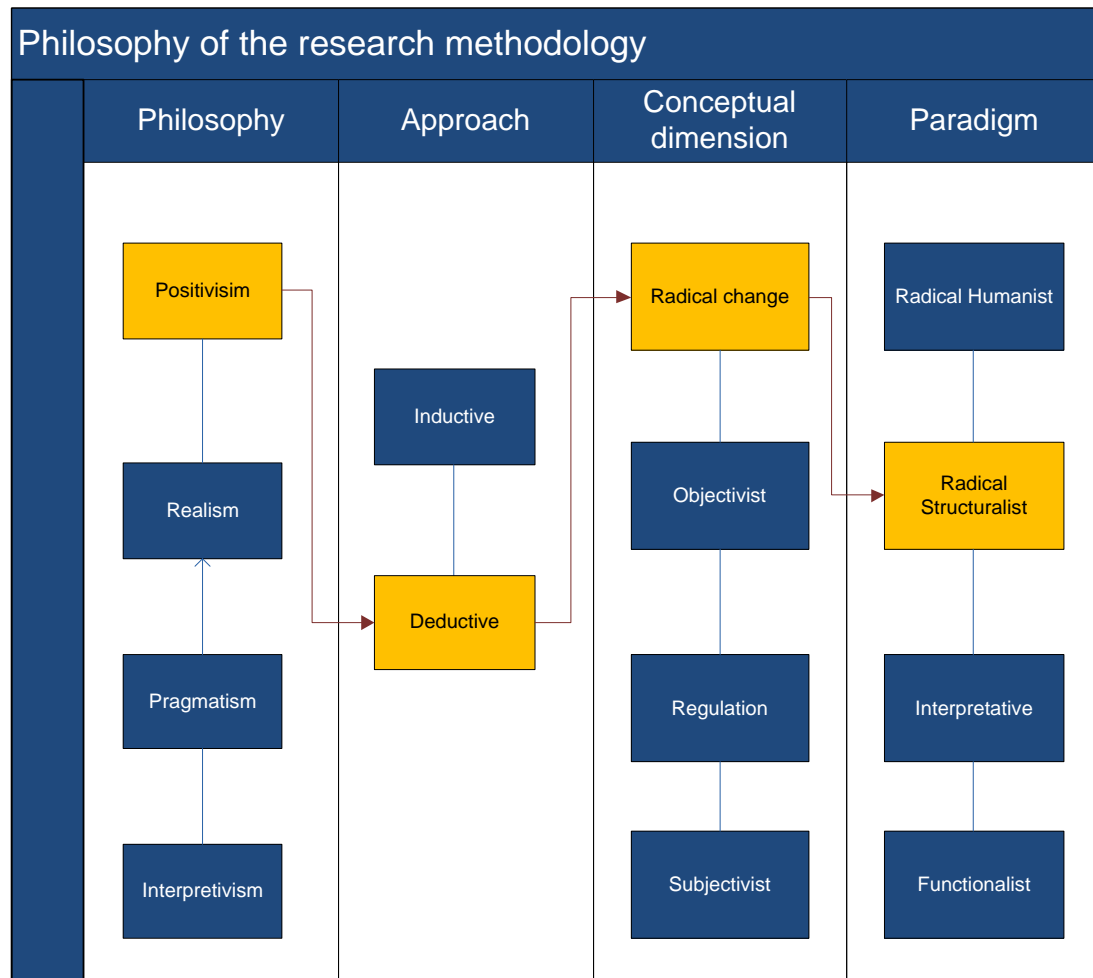
Figure 15 - **Research philosophy of the Micro study. Source (Saunders et al., 2008, Burrell and Morgan, 1979)**

The Micro Study required a qualitative analysis of secondary data to identify the CO_2 reduction measures to apply to primary data. Once the options to reduce emissions were selected, the information was modelled to simulate the application of the procedures in the operation.

For the Micro study the most appropriate philosophical view is the positivism. In order to model the data and simulate changes   in the transport of goods operations from customers to depots, and depots to customers, the information needs to be real and trustable. Positivism believes that reality is abiding, that can be observe and delineate from an objective aspect (Levin, 1998). This comes from the initial idea that science needs to count on detectable and measurable events and not through subjective perception such as feelings or intuition (Dilanthi Amaratunga and Baldry, 2001).

The second phase for the development of the research philosophy is to look at the approach. The Micro study does not begin an inexistent area of research, it relies in previous studies and seeks to use to information of the Starfish project to apply carbon reduction options, this way of starting from a general point of view that originated the Starfish project, going on the direction to focus just in one food manufacturer. Going from general to a specific point of view is one of the characteristics of the deductive approach (Spens and Kovács, 2006).

After defining the approach the next step is to find the conceptual dimension and paradigm that suits the best in order to achieve the objectives of the Micro study (Section 1.2). The modelling of data will simulate changes in the operation. According to Burrell and Morgan (1982) the conceptual dimension of Radical Change makes a judgement about how organizational situations should be conducted and makes suggestions to alter the normal order of things bringing positive changes to the organization (Saunders et al., 2009). That is why Radical Change is the dimension that helps the research to move towards modifying the operation of the food manufacturer transport of goods looking for improvement.

In the Radical Change dimension there are two paradigms, radical humanist and radical structuralist, the first one seeks to offer a critical point of view about organizational life, the second helps to approach the research to achieve fundamental modifications. The change will be base on an analysis of specific events and situations of conflict (Saunders et al., 2009). As the modelling of data implies fundamental modifications to the operation, the paradigm that helps the best to the research is the structuralist.

3.2.2. Data resources

The Micro study uses both secondary and primary data. The qualitative data comes from the options to improve operation and abatement of CO_2 emissions from freight transport. The best practice options were founded in reports about food distribution by the Food Industry Sustainability Strategy (FISS), the Department of Environment, Food and Rural Affairs (Defra, 2011) the Institute of Grocery Distribution (IGD, 2008), and the Green Logistics: Improving the environmental sustainability of logistics book (Mckinnon et al., 2010), the review of them can be found in Chapter 3.

In October 2010 after the positive results of the implementation of the Efficient Consumer Response (ECR), the ECR UK decided to start another evaluation of transport efficiency improvements. The ECR UK Sustainable Distribution Steering Group and consultants from the Logistics Research Centre in the School of Management and Languages of Heriot Watt University decided that a large amount of transport data was needed to evaluate the operation as well as a bigger number of participants. Manufacturers, retailers and wholesalers in the UK Fast Moving Consumers Goods (FMCG) sector were invited to take part in a new study 27 companies accepted this invitation and provided one month of UK transport data. These 27 companies consisted of 6 retailers, 3 wholesalers and 18 manufacturers (Figure 16). The participants had a total UK annual turnover of about £200 billion per year, the aim of the study was to analyse the opportunities for improving Transport Efficiency through Multi-lateral Collaboration in FMCG supply chains.
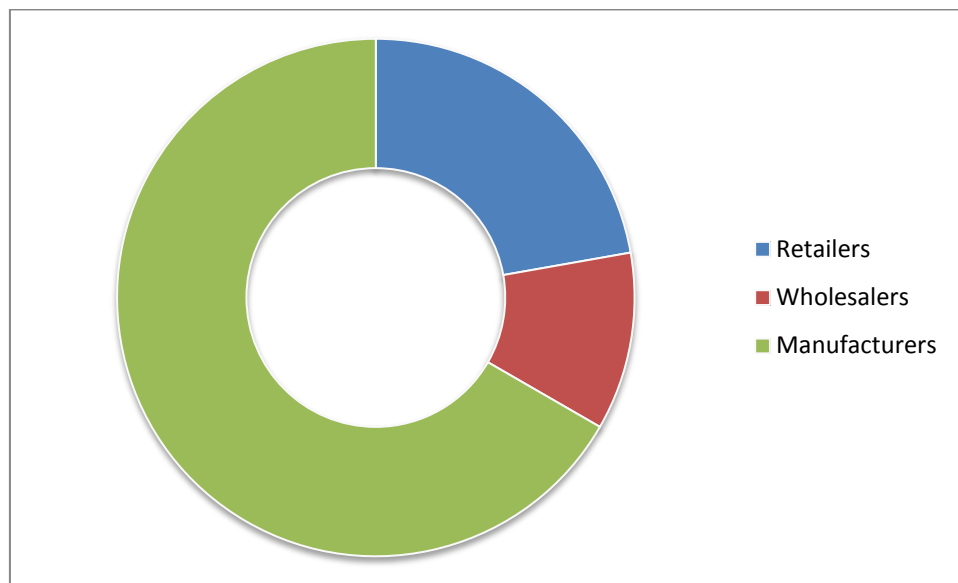
Figure 16 - Project Starfish participants. Source (Palmer and McKinnon, 2011)

Because of the involvement of Heriot Watt University in the research, it was possible to provide data to students aiming to use it to model the information applying efficiency improvements in the operation of the companies as a project for their Master's Dissertation. As all the information is real and reliable, it represented a great opportunity to use it to carry the quantitative part of the Micro study. The information for the present dissertation comes from a food manufacturer, which will remain anonymous and in the present dissertation will be referred as Manufacturer 1.

After the qualitative study knowing what kind of information was available to carry the micro study the following options of best practice recommendations and efficiency improvement were selected to carry the modelling:

- Logistics system redesign: Optimize the location of the depot, or reallocate the customers to reduce the distances travelled by the lorries.
- Expanding vehicle capacity: use of double-deck and larger vehicles, according to the product's characteristics, will enhance the capability of transportation decreasing the amount of journeys needed reducing fuel consumption and the tonne-kilometres.
- Use of biofuels. It has been reported by Defra that the use of biofuels can reduce the cost of externalities in 1%, but as it is part of the strategies from the UK and Mexico to increase the use of alternative fuels, it is interesting to apply a change of fuel to calculate the amount of CO_2 save.
- Modal shift: the use of less energy intensive modes of transport will allow evaluating the potential for modes like rail and shipping to reduce the CO_2 emissions and improve fuel efficiency.

3.2.3. Data collection

The information provided included all transport movements between depots and customers inter depot returns from customers, and supplier's collections under control of the companies. It was necessary data specification to minimize the risk of double count the movements between manufacturers and retailers also being excluded collections by customers from the depots of the companies. The location of depots, customers and suppliers was provided with postcode locations and longitude and latitude coordinates type of the vehicles used, amounts moved and the incidence of delivery. The volumes of deliveries were mostly provided in pallets and the information that was provided in quantities such as roll cages or case volumes were also converted into standard pallets. In order to have a basis for comparison of cost it was needed to apply a fixed and variable cost to the different vehicle types used by the companies so RHA tables were used (RHA, 2008). It was estimated than the transport operation of the 27 companies represented a large share of the total movements of the FMCG distribution in the UK, probably in excess of 50% (Palmer and McKinnon, 2011). The information of Manufacturer 1 it consisted on a month of

UK transport data, including: location of suppliers, customers and depots by postcodes and coordinates, volumes in pallet quantities, frequency of the movements and information of the vehicles used for the transportation. The summary of the information provided from the food manufacturer is in Table 4:

Parameter	Data
Weeks	4
Working days per week	6
Average height of pallet	2.6 m
Average weight of pallet	0.4 tonnes
Number of suppliers	23
Number of Customers	509
Number of Depots	16

Table 4 - Summary of data

3.2.4. Methods of analysis

This section will describe the methods and different scenarios used to model the data set and the parameters that will help measuring the performance of the simulations.

The key data to model the data set can be seen in Figure 17.
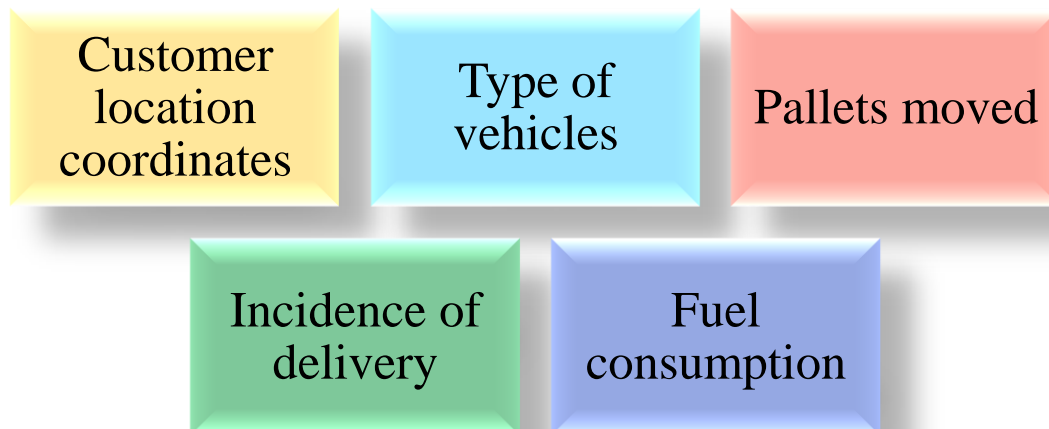
Figure 17 – Key elements of the data set

In the data collection section are stated the options for the data modelling, the combination of the different options provides 11 simulations; they are listed in Table 5.

Modelling scenarios	Centre of Gravity	Reallocation of customers	Expand vehicle capacity	Use of Biofuels
Simulation 1	X			
Simulation 2		X		
Simulation 3			X	
Simulation 4				X
Simulation 5	X			X
Simulation 6		X		X
Simulation 7			X	X
Simulation 8	X		X	
Simulation 9	X		X	X
Simulation 10		X	X	
Simulation 11		X	X	X

Table 5 - Modelling scenarios

The results of the modelling will be compared against the Business-as-usual operation using the parameters in Figure 18.

Distance travelled (vehicle-km)	Fuel Consumption (litres)
Energy Efficiency (Tonne-km)	Carbon emissions Kg of CO_2
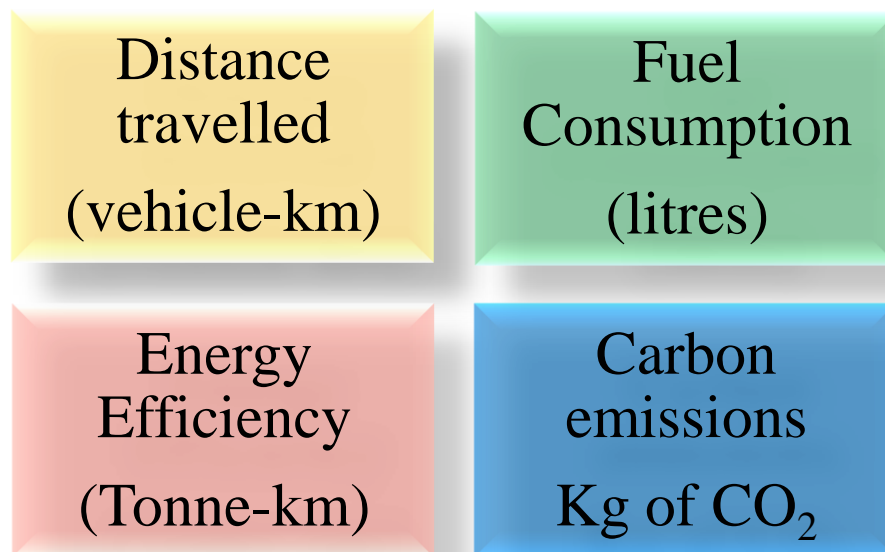
Figure 18 - Parameters

Reallocation of customers

The reallocation of customers is part of the logistics system redesign options. The data required to simulate the reallocation of customers is in Figure 19.
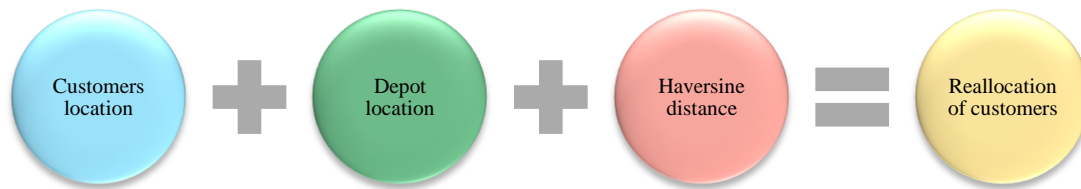
Figure 19 - Data and formulas to reallocate customers

Distance is one of the most relevant parameters taken into account to optimize the location of facilities. This is achieve through finding the median or minimal distance (Schilling et al., 1993). Taking into account the spherical shape of earth the formula to calculate the distance needs to consider this fact. In Euclidean geometry, the distance between two points is calculated measuring the length of a direct line between one point to the other. While in spherical geometry the direct line is substitute with great circle paths (Mwemezi and Youfang, 2011). The great circle distance can be determined by calculating the spherical angle between two points; the result should be multiplied by the radius of the earth as seen in Figure 20.
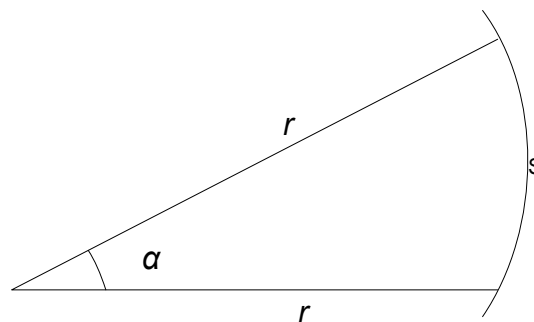
Figure 20 - Arc length (S) and Central angle

Where $S = \alpha r$

S = Arc length (great circle distance on the sphere)

r = Radious of Earth which is: 6372 km

α = Central angle measure in radians

Spherical triangles and the shortest distance between two points located on a geographical surface can also be calculated with the Haversine formula.

The central angle in radians is expressed as:

$$\alpha = 2\arcsin\left(\sqrt{\sin^2\frac{\Delta\theta}{2} + \cos\theta^1\cos\theta^2\sin^2\frac{\Delta\emptyset}{2}}\right)$$

Equation 1 - Central angle

$\Delta\theta = \theta_1 - \theta_2 =$ Difference in latitude

$\theta_{1=}$Lat at position 1

$\theta_2 =$ Latitude at position 2

$\Delta\emptyset =$Ddifference in Longitude

Excel is a good tool for the distance calculations, in order to make the calculations easier the coordinates should be in decimal places and radians (Pearson, 2009). The location of the facilities in the data are already in decimal positions, the set also takes into account the hemisphere in which are located with negative values for south latitudes and west longitudes (Mwemezi and Youfang, 2011). As the locations are in decimals in order to have radians it needs to be apply the following equation:

$$\boldsymbol{Radians = \frac{deg}{180} * \pi}$$

Equation 2 - Radians calculation

As a result we have the following Equation 3 adapted to Excel.

$$distance = 6372(2)\arcsin\sqrt{\sin^{2}\left((lat2 - lat1) * \frac{\pi}{360}\right)^{2} + \cos\left(lat1 * \frac{\pi}{180}\right) * \cos\left(lat2 * \frac{\pi}{180}\right) * \left(\sin\left((long2 - long1) * \frac{\pi}{360}\right)\right)^{2}}$$

Equation 3 - Distance calculation formula

The steps for the reallocation of customers using the Haversine distance formula are the following:

1. Calculate the distance between each depot and customers.
2. Using Excel find the Depot that is the closest to each customer.
3. Set the new network for each Depot
4. Calculate the parameters for measuring the operation.
5. Evaluate the effects of reallocation of customers through different parameters including carbon emissions.

Centre of Gravity

This option of modelling is part of the logistics system redesign. With the information of the location of customers, the number of pallets and the Centre of Gravity formula, it is possible to calculate the reallocation of the depot (Figure 21) to compare it with the depots already established.
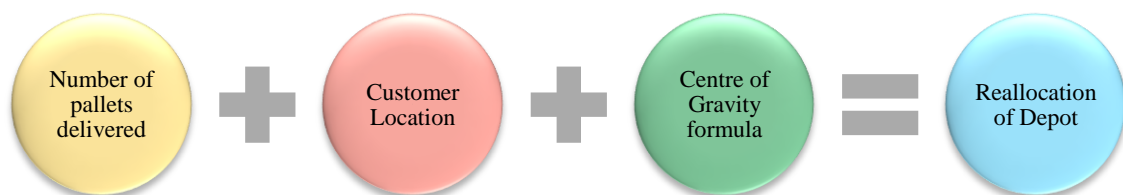
Figure 21 – Data and formulas to reallocation of depots

In order to reduce the environmental and economic costs of transportation, the depots should be located where the travelled distance is the minimal (Mwemezi and Youfang, 2011). If the cost of delivering to the customers is directly related to the

quantity of cargo transported and the distance between the depot and the customers, the entire cost can be obtained by Equation 4:

$$C = \sum_{j=1}^{n} w_j d_{0j}$$

Equation 4 – Cost of transportation

Where:

w_j = Weight of goods required by customer j

d_{0j} = Distance between depot and customer

$$j = \sqrt{\left[(x_0 - x_j)^2 + (y_0 - y_j)^2\right]}$$

Equation 5 – Distance formula

To determine x and y coordinates for a new depot using the Centre of Gravity Equation the next formulas are use:

$$x = {\sum w_i x_i} \Big/ {\sum w_i}$$

Equation 6 - Formula to calculate 'x' coordinate

$$y = {\sum w_i y_i} \Big/ {\sum w_i}$$

Equation 7 - Formula to calculate 'y' coordinate

The steps for the calculation of the Centre of gravity are the following:

1. The data of de locations of each Depot and the customers it delivers should be in the same spread sheet in Excel.
2. Run the calculations in Excel to find the Centre of gravity of each depot.
3. Evaluate the performance of scenarios involving the Centre of Gravity though different parameters including CO_2 emissions.

Expanding vehicle capacity

The data provided included a standardized vehicle and pallet size, with this information is possible to simulate the use of double-deck and larger vehicles.

Figure 22 - Data to simulate the expansion of vehicle capacity

The Starfish project data included the type of vehicles use to carry the deliveries as well as the number of pallets. The lorries to carry the deliveries have a capacity of 26 metric tonnes, 3 axles and are articulated. The weight limit in the road is of 44 tons. Using this data it was carried a simulation about the number of pallets that a 26 mt artic can carry and the use of a Double Deck lorry that would help improve the space utilization to carry more pallets per delivery.

The size of the pallet is 1.2 x 0.8 metres, height of 2.6 m and average weight 0.4 tonnes. A 26 metric tonnes lorry can carry 16 to 18 pallets with a maximum weight of 44 tonnes. Using a Double Deck lorry can allow to carry up to 44 pallets.

In order to re-arrange the cargo it will be necessary to change the height of the pallet to 1.3 metres, this will set the weight of the pallet to 0.2 tonnes.

The simulation of use of double deck vehicles was applied to the movements to deliver at least 44 pallets, deliveries up to that number will be carried by using 26 MT artic vehicles.

Use of biofuels

Simulate the use of biofuels requires the results of the kilometres travelled from the simulations and fuel consumption using the RHA factors for fuel consumption of the vehicles. Once the calculations of total distance and fuel consumption are made, the CO_2 emissions are calculated using the factors in the Freight Transport conversion tables Annex 7 by Defra/DECC 2011 GHG Conversion Factors for Company Reporting. The factor expresses the CO_2 emissions in Kg CO_2 per litre of Diesel and per litre of Diesel/biofuel blend.
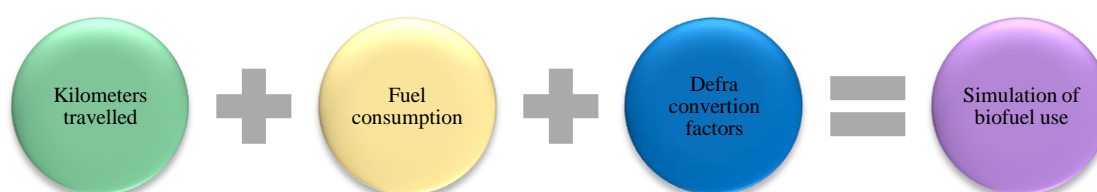
Figure 23 - Data to simulate the use of Biofuels

3.3. Summary

The research philosophy was develop following the steps of the Research Onion by Saunders, Lewis and Thornhill (2008) and the research paradigms by Burrell and Morgan (1982), looking forward to construct a philosophy to sustain in the most adequate way the achievement of the research objectives. For the Macro Study is Interpretivist for the Macro Study because of the need to understand the information in policies from the Mexican and Britain governments. The requirement of analyse real data in the Micro Study the philosophy needs to be positivist.

The quantitative data for the Micro Study comes from the Starfish Project, which gathered information from 27 UK companies, 6 retailers, 3 wholesalers and 18 manufacturers. Information of 4 weeks of transport data from a food manufacturer was chosen to carry the Micro Study. The data set included the locations of customers, suppliers and depots, as well the information of the vehicles used, the amount of goods moved and frequency of delivery. The Micro study seeks to simulate an implementation of four options to improve the operation reducing distances travelled between distribution centres, customers and suppliers. The options are: find the centre of gravity of the customers, using the centre of gravity formula; reallocation of customers, using the Haversine distance formula; expand vehicle capacity simulating the use of double deck vehicles and use of biofuels using the values of fuel

consumption by the RHA. Combining the four options 11 scenarios will be simulated and the evaluation of the results will be through 4 parameters: total distance travelled, total fuel consumption, and kilograms of CO_2.

Chapter 4: Results

The present Chapter contains the results of the Macro and Micro Study; it is divided in 2 major sections, one for each level of study. The Macro study results consist in the analysis of trends in of the CO_2 emissions from the freight transport sector for Mexico and the UK. The Micro study section is subdivided in two subsections, the first section for the Pareto Analysis of the data set of Manufacturer 1 and the second section is dedicated to the analysis of the results of the 11 Simulation scenarios decided in the Methodology Chapter (Methods of Analysis).

4.1 Macro study results

The Department for transport from the United Kingdom released Road Freight Statistics on October 27 2011, including road freight economical, environmental and safety statistics with figures from 1990 to 2010. Looking at the statistics from an ecological point of view there is a need to have ecological benefits instead of economic ones coming from an anthropological perspective (Patterson, 1998). From 1990 to 2008 (Figure 21 and 22) the tonne-km did not experienced a critical arise in its numbers even when UK's GDP had a growing trend, the same occurs with the CO_2 emissions coming from the freight transport sector. This decoupling could be due to the influence of factors like the change in the composition of the GDP. Currently the service sector has experienced such an increase that financial businesses and public services are half of Britain's GDP. These kind of economical activities do not require a big amount of movement of goods. Another factor considered very significant is the attrition of the industry to other countries as well as a decrease of spatial concentration (Mckinnon, 2007). Looking at statistics between 2007 and 2009 is observed a reduction in the tonne-km from the road freight transport as well in the CO_2 emissions, this reduction in emissions seems to be not directly link to positive effects of policies and legislation to reduce emissions from the freight transport sector, the phenomenon appears to be related to effects of the economical recession during the years 2008 and 2009 (Figures 24 and 25) that reduced considerably the amount of goods moved in UK roads. There is a traditional approach to reduce carbon emissions by increasing the use of biofuels (Tapio et al., 2007), one example of this initiatives is the Renewable Transport Fuel Obligation (RTFO) with the objective of reach the proportion of biofuel supplied in recharging stations to a 5% in 2013 (DTI, 2007). The

use of biofuels does not makes a considerable difference against the optimistic view from the UK government that will accomplish the objectives of the EU Biofuels Directive requirements (Banister, 2007). This shows there is a need for reinforcement of policies for the reduction in road tonne-km, empty running, higher vehicle load factor, improvements in fuel efficiency (Mckinnon, 2007). The United Kingdom has forecasted that in order to achieve the target of 80% reduction in the CO_2 emission are necessary important technological improvements (DECC, 2010) for the vehicles to have more energy efficiency and meet the environmental standards that will also have to be tighter (Gasparatos et al., 2008).
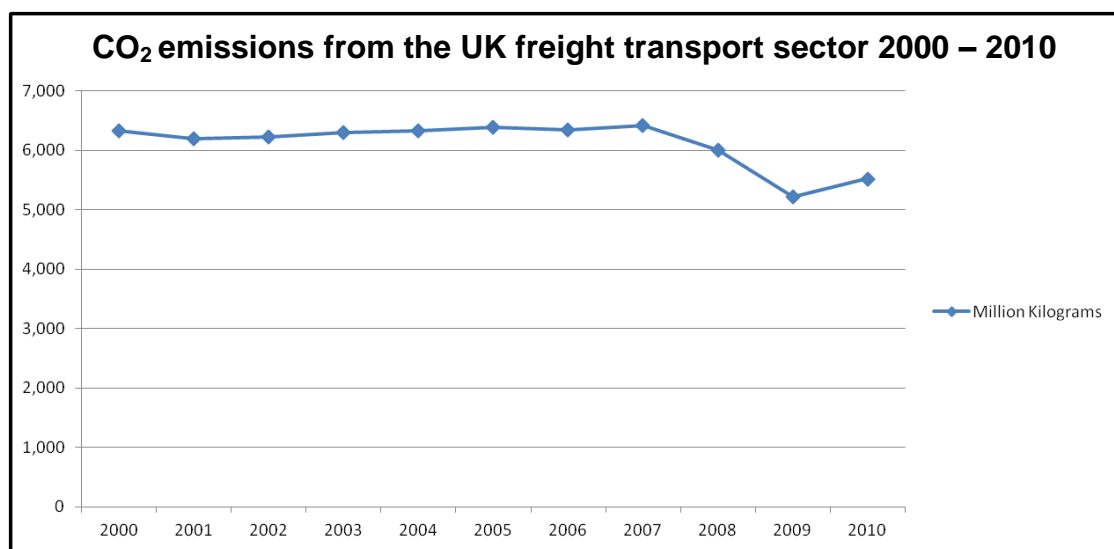

Figure 24 - CO_2 emissions from the UK freight transport sector 2000 – 2010. Source (DfT, 2011c)
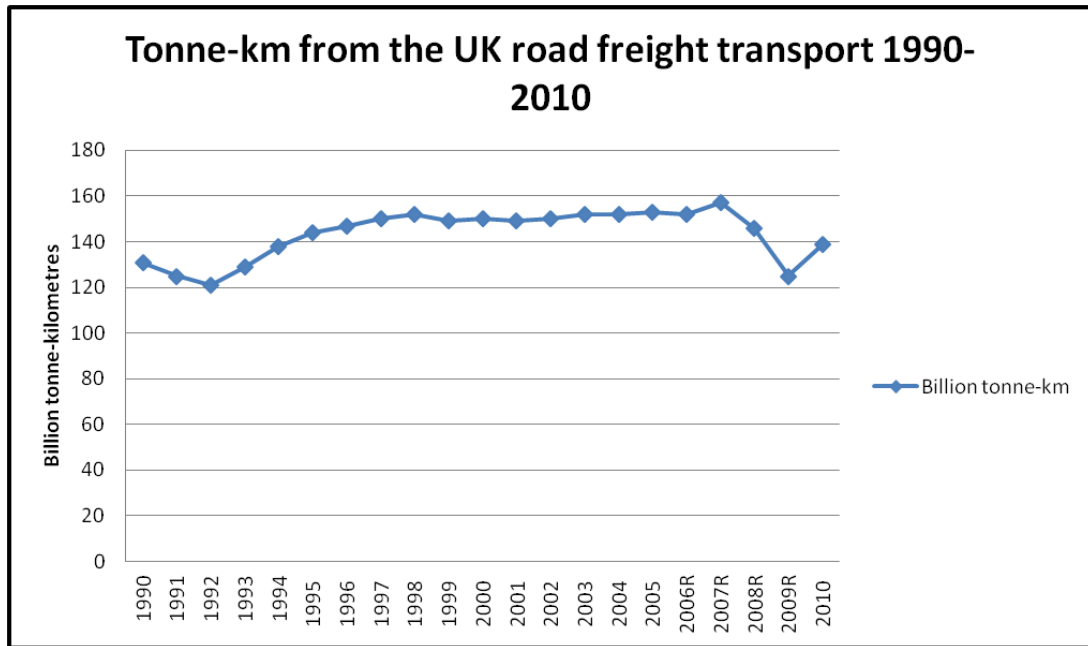
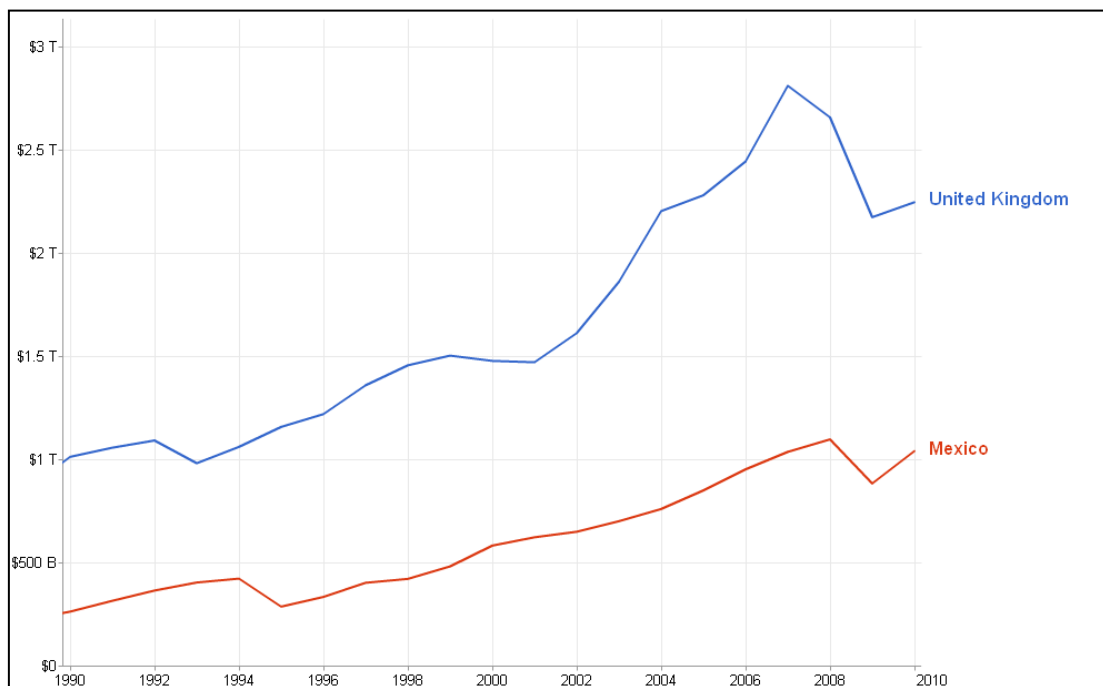**Figure 25 - Tonne-km from UK road freight transport 1990-2010. Source (DfT, 2011c)**

Figure 26 – Gross Domestic Products for the United Kingdom and Mexico. Source World Bank, World Development Indicators 2011 (WB, 2011)

The statistical releases for Mexico are quite different; there is not enough information from the road freight transport sector using the parameters of vehicle-kilometres, tonne-kilometres or fuel consumption. The statistics releases from the Mexican National Institute of Statistics and Geography (INEGI) include information about the type of vehicles, tonnes moved by transport mode and the length of roads. But there are figures of the freight movements by rail expressed in tonne-km (Figure 27). The information shows a continuous growing trend from 1995 to 2007, just before the recession that also had severe effects in the Mexican economy reducing the GDP around 6% (Figure 26). The situation for the road freight transport is different from the UK. The road freight transport is done by "man-vehicles" which means that most of the cargo is transported in vehicles that are not part of a big commercial fleet but by one person that might own one vehicle only. The revenue of the transportation will not allow the owners to renew their vehicles and meet the standards for emissions. The Ministry for Communications and Transport and the Ministry of Environment and Natural Resources are aware of the problematic. One of the initiatives to tackle the problem is the Clean Transport Program that aims to reduce the figures of 34% of the vehicles being having an antiquity or up to 9 years, increasing the fuel efficiency of the vehicles (SEMARNAT, 2011). It is expected that the initiatives from the Government and its influence in policies from the Ministry of Ecology and Ministry of Environment and Natural Resources will improve the kind of parameters report in statistics, allowing having a better knowledge of the trends in the CO_2emissions from numerous sectors, including the freight transport sector.
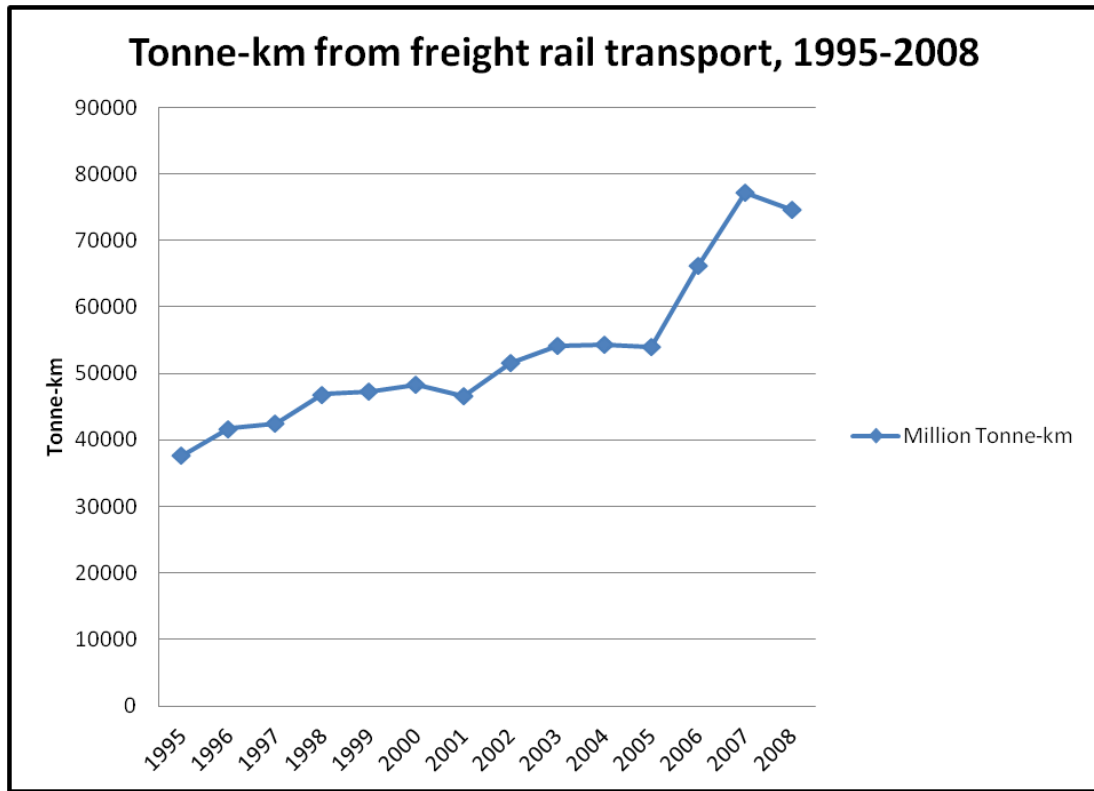
Figure 27 - Freight movement by rail, 1995-2008. (INEGI, 2009)

4.2 Micro study results

4.2.1 Outbound orders

Manufacturer 1 has 15 Depots distributed across the United Kingdom (Figure 28). The Depots receive goods from suppliers (Input movements) and sends goods to customers (Output movements).
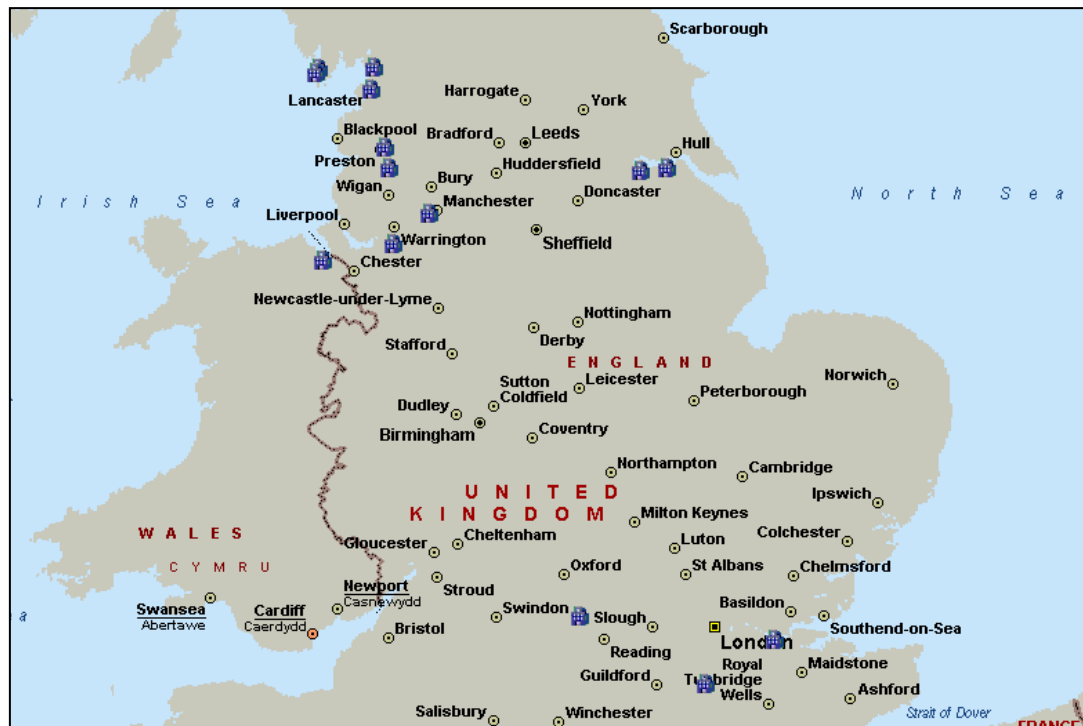
Figure 28 - Distribution Centres for Manufacturer 1

Two different vehicles are used to distribute the goods for the Customers for the suppliers. It is summarized in the following table:

Code	Vehicle description	Vehicle use	Capacity
1	26 MT artic	Customer	26 tonnes
2	30 RT artic	Customer	30 tonnes

Table 6 - Vehicles use by Manufacturer 1

4.2.2 Movements from Depot to Customers (Outputs)

The total amount of pallets sent to customers for the month of distribution in the data set provided is 58151.93 pallets which equals to 23260.77 tonnes, in a total of 485 flows or 3452 movements. In Table 7 it is seen that the average load per movement is of 14.6 pallets.

	Min	Max	Median	Sum	Average
Number of movements	1.00	72.00	3.00	3,452.00	7.12
Total quantity per each flow	0.28	1,412.88	26.00	58,151.93	119.90
Average load per movement	0.28	28.60	12.50	7,085.65	14.61

Table 7 - Pareto Analysis for Manufacturer 1

Movements from Depot to Suppliers

Manufacturer 1 receives 36,282 pallets in a total of 1399 movements or 22 flows. By looking at Figure 30, we appreciate that Flow 3 represents a considerable amount of pallets compared to the average number of pallets per flow.

Input movements	Min	Max	Median	Sum	Average
Number of movements	1	888	18.5	1,399	63.59
Total quantity per each flow	19.25	23,253	497.5	36,281.96	1,649.18
Average load per movement	0.001	27.85	25.8	532.62	24.21

Table 8 - Pareto Analysis of input movements
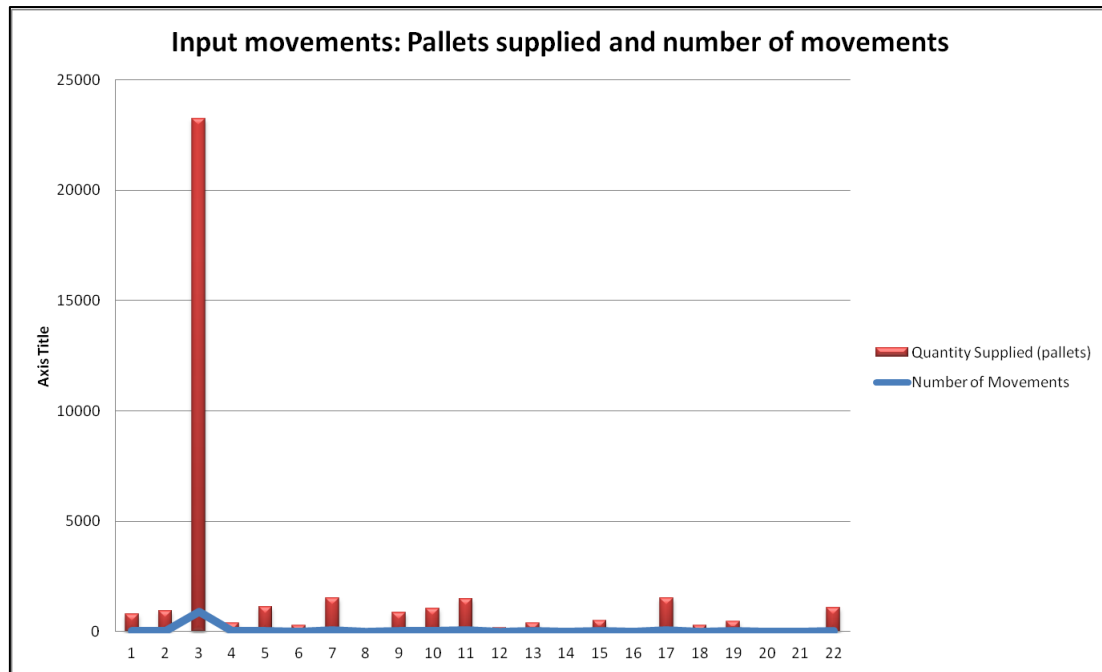
Figure 29 - Input movements in pallets

Centre of Gravity

Manufacturer 1 has 15 different depot locations but the Distribution Centres sending goods to customers are the numbers 1, 3, 4, 5, 7 and 13 that is why the Centre of gravity was only calculated for these depots, Figure 31 shows in a map the change in location for the Distribution Centres. The depot with the biggest change in its location is Depot 5 moving 192 km from the original location (Table 9).

		Real location		Centre of Gravity		Distance between real location and centre of gravity
Depot Code	Depot Location	Longitude	Latitude	Longitude	Latitude	
1	LA14 4QX	-3.2117	54.1447	-2.43	54.00	53.59
3	DN18 5RX	-0.4276	53.679	-1.36	52.73	122.12
4	DA11 9AD	0.3231	51.4447	-1.09	52.14	124.34
5	CH6 5EX	-3.1459	53.2412	-0.81	52.25	192.03
7	PR6 7AJ	-2.6348	53.6799	-1.40	52.81	127.03
13	M17 1ED	-2.3197	53.4669	-1.72	53.29	44.66

Table 9 - Changes in depot location according to Centre of Gravity
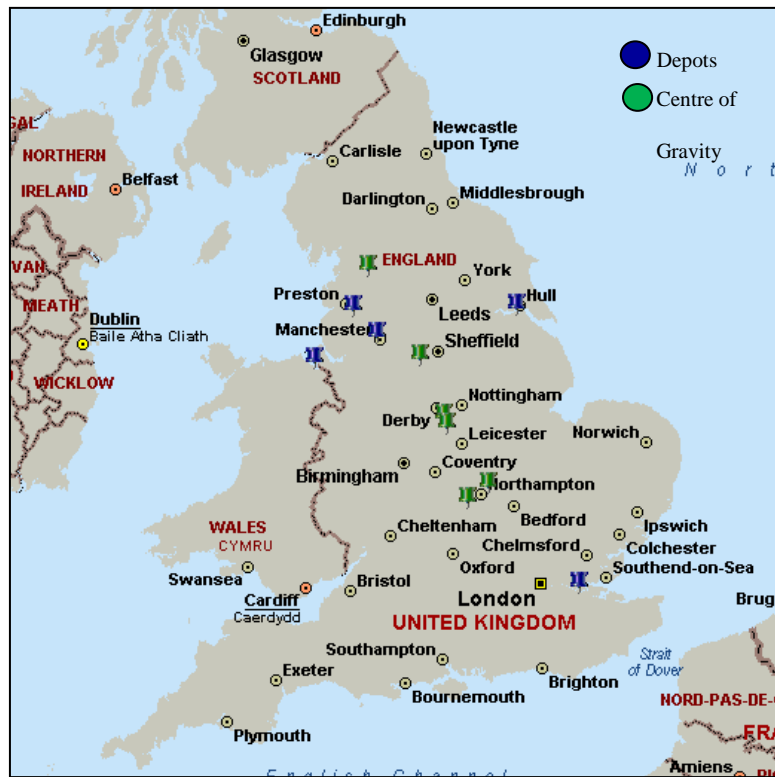
Figure 30 - Distribution centres and Centres of Gravity

The results of the simulation are for the total distribution including input and output movements. Because the changes in the depot location are considerable it is expected to have a reduction in the parameters of efficiency.

	Total Distance	Total fuel consumption	Total tonne-km	Kg of CO_2 using mineral diesel
BAU	721,097.05	226,347.33	663,645,229.59	599,367.74
Simulation 1	729,722.18	229,051.86	1,684,742,224.81	531,452.34

Table 10 - Results of Centre of gravity and Business as Usual

The Simulation 1 gives as a result an increase in all parameters (Table 10) especially in the tonne-kilometres, this occurs due to the influence of Flow 3 (Figure 30) that delivers 23,253 pallets in 888 movements to Depot 7 (Table 8). Movements to suppliers are not considered in the calculation of the Centre of Gravity, which only includes the quantity and location of customer's movements. The graphic in Figure 32 shows the considerable increase in the tonne-kilometres and the graphic in Figure 33 shows that for the output movements with the changes of depot locations there is reduction in the tonne-km, but the influence of the Flow 3 is not permitting the scenario to deliver a reduction of this parameter.
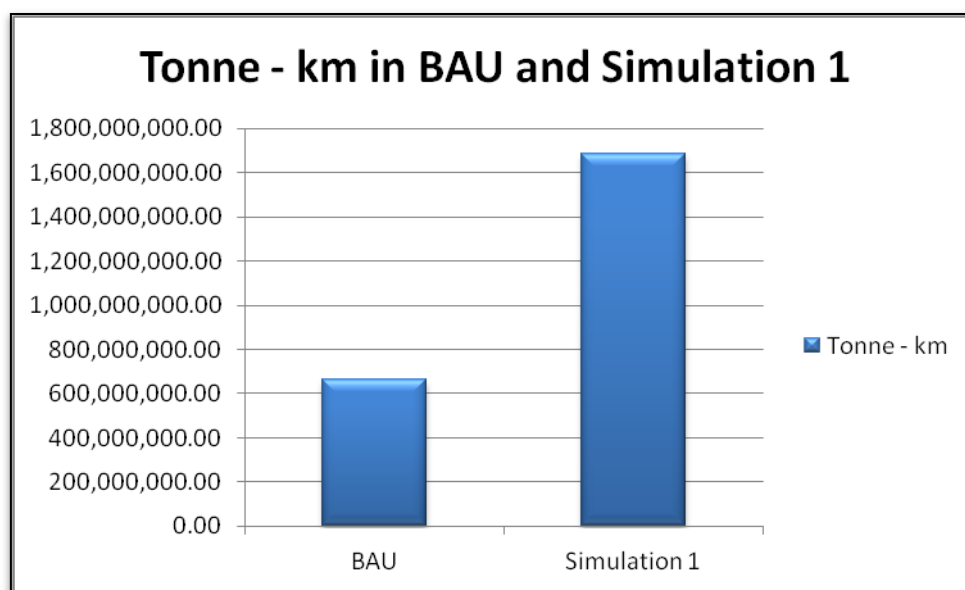
Figure 31 - Tonne-km comparison between BAU and Simulation 1
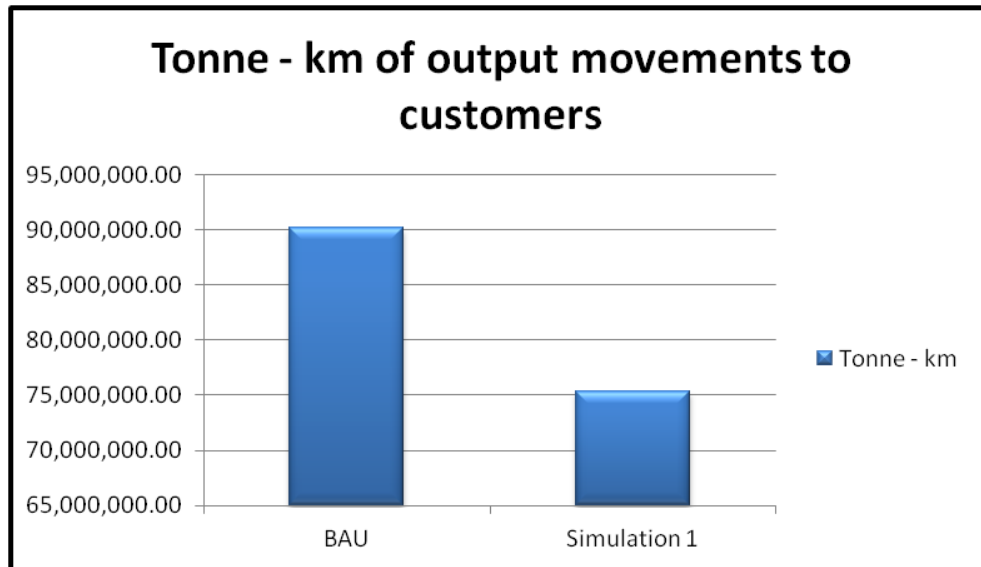
Figure 32 - Tonne - kilometres for output movements
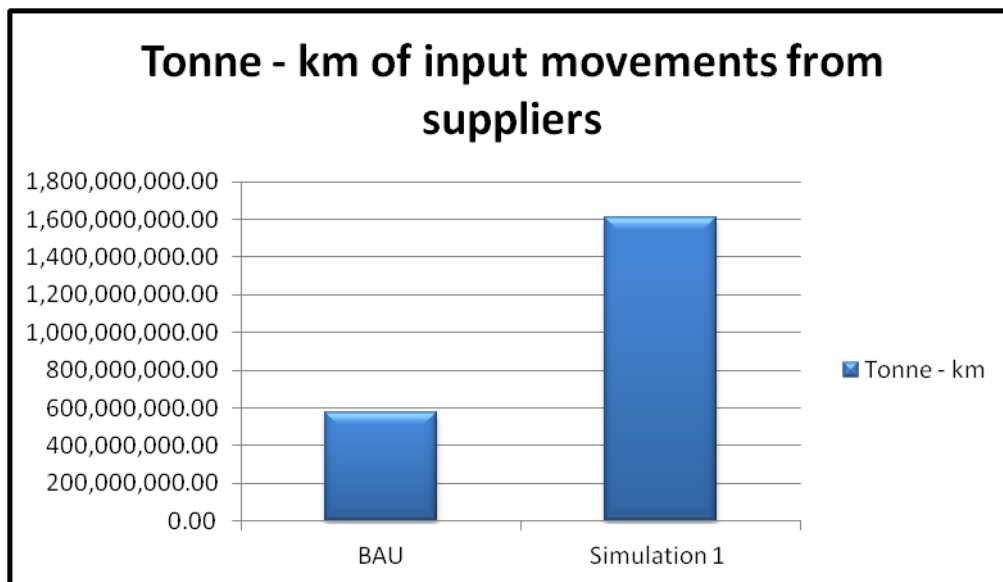
Figure 33 - Tonne - km for input movements

Because the objective of simulating different scenarios is to improve the operation, the location of Depot 7 will remain the same as in BAU for the following simulations involving the Centre of gravity modelling, which are Simulations 1, 5, 8 and 9. The locations for the Distribution Centres in the Simulation of Centre of Gravity will be the ones in Table 11 where location of Depot 7 remains the same.

Centre of Gravity		Real location		Centre of Gravity2		Distance between real location and centre of gravity
Depot Code	Depot Location	Longitude	Latitude	Longitude	Latitude	
1	LA14 4QX	-3.2117	54.1447	-2.43	54.00	53.59
3	DN18 5RX	-0.4276	53.679	-1.36	52.73	122.12
4	DA11 9AD	0.3231	51.4447	-1.09	52.14	124.34
5	CH6 5EX	-3.1459	53.2412	-0.81	52.25	192.03
7	PR6 7AJ	-2.6348	53.6799	-2.6348	53.6799	0.00
13	M17 1ED	-2.3197	53.4669	-1.72	53.29	44.66

Table 11 - Location of Depots for Centre of Gravity simulations

When returning Depot 7 location to the BAU there is a reduction of around 10 million tonne-km (Figure 35) between BAU and Simulation 1, this equals to savings of 67,425 km and 42,232 Kg of CO_2 (Table 12).

	Global distance	Global fuel consumption	Global tonne-km	Kg of CO_2 using mineral diesel
BAU	721,097.05	226,347.33	663,645,229.59	599,367.74
Simulation 1	653,681.74	205,186.20	653,568,697.33	557,134.99

Table 12 - BAU and Simulation 1
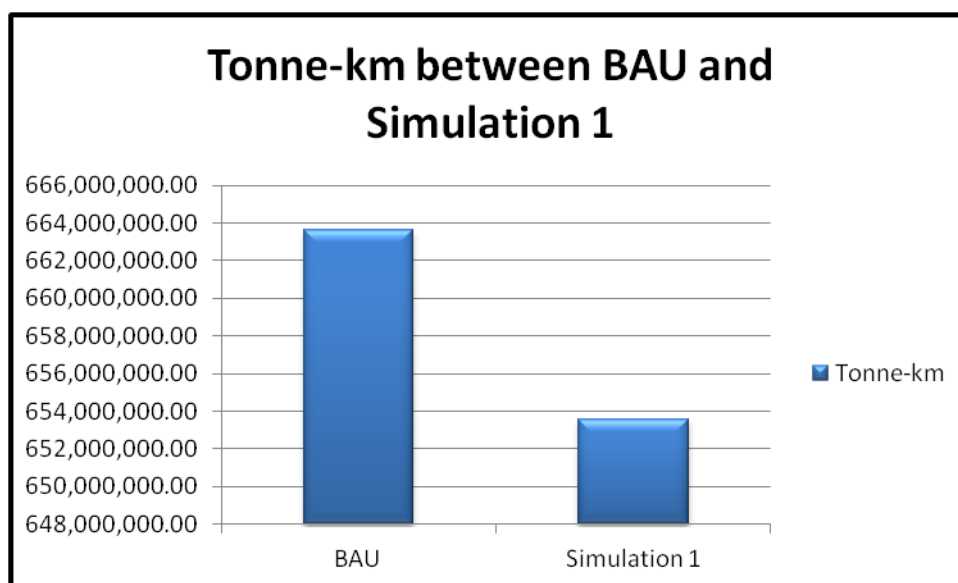
Figure 34 - Tonne-km from BAU and Simulation 1

4.2.2 Modelling of the Carbon reduction scenarios

The results of the 11 simulations are summarized in Table 13 the last column compares the percentage of reduction in carbon emissions between BAU and the 11 simulations. The performance of the simulations will be look through the comparison between parameters.

Simulation	Global distance Km	Global fuel consumption	Global tonne-km	Kg of CO_2 using mineral diesel	Kg of CO_2 using biofuel/diesel blend	% of savings in CO_2
BAU	721,097.1	226,347.3	663,645,229.6	599,367.7	N/A	
1	653,681.7	205,186.2	653,568,697.3	557,135.0	N/A	7.0
2	400,719.1	125,772.9	609,396,800.3	333,046.5	N/A	44.4
3	661,872.9	231,516.9	248,033,303.5	610,041.9	N/A	-1.8
4	721,097.1	226,347.3	663,645,229.6	599,367.7	577,864.7	3.6
5	653,681.7	205,186.2	653,568,697.3	557,135.0	537,147.1	10.4
6	400,719.1	125,772.9	609,396,800.3	333,046.5	321,098.1	46.4
7	661,872.9	231,516.9	248,033,303.5	610,041.9	588,156.0	1.9
8	596,063.7	208,218.0	257,934,686.0	551,361.3	N/A	8.0
9	596,063.7	208,218.0	257,934,686.0	551,361.3	531,580.6	11.3
10	369,151.3	121,504.2	228,150,679.7	318,728.3	N/A	46.8
11	369,151.3	121,504.2	228,150,679.7	318,728.3	307,293.5	48.7

Table 13 - Results from BAU and 11 Simulations

Looking at the numbers in Table 13, it is important to notice that results for Simulation 3 give percentage of -1.8% in savings of the emissions. This occurs because even when there is a consolidation of loads and reduction of distance travelled between BAU and Simulation 3, double deck trucks are more energy intensive consuming 4.83 more litres of fuel per every 100 km making the CO_2 emissions to be higher. An important reduction in the distance travelled like the one in Simulation 11 is needed to obtain the benefits of the consolidation of loads.
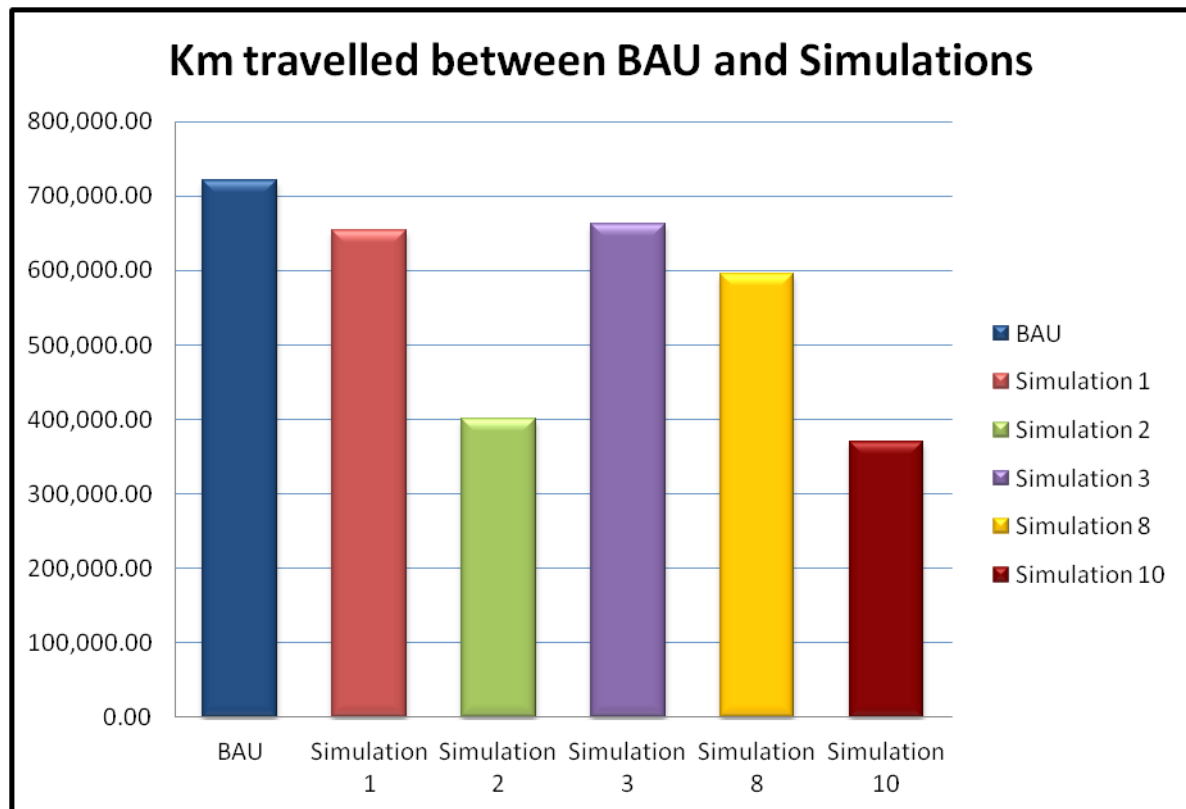
Figure 35 - Total km travelled by simulations

According to the amount of kilometres travelled, Simulation 10 (reallocation of customers + expand vehicle capacity) gives the best performance (Figure 36). This occurs because the reallocation of customers reduces 320 thousand kilometres compared to the Business as Usual operation.

Reallocation of customers is simulated in scenarios 2, 6, 10 and 11, giving savings of more than 40% in the emissions. It is interesting to notice that the reduction of 48% in Simulation 11 occurs despite the negative values as a result in scenario 3. When adding the expansion of vehicle capacity, 350 thousand kilometres are saved (Simulation 10). When comparing the values from Simulation 10 to the BAU scenario

there is a reduction of 46% in carbon emissions. The consolidation of loads seems to have an important impact in the reduction of emissions over short distances.

The visual explanation in Figure 37 shows that there is a constant proportion of the reduction from the scenarios using 100% mineral diesel and the scenarios using biofuel blend, the exact percentage of reduction in CO_2 emissions is 3.58%. The total kilometres travelled have a direct influence in the fuel consumption. Because of this, all simulations that include the reallocation of customers gave as result the fewer amounts in fuel consumption (Simulations 2, 6, 10 and 11). Analyzing the Kg of CO_2 produced as result of the use of fuel, Simulation 10 (Reallocation of customers + expansion of vehicle capacity) is the one producing less amount of carbon emissions using 100% of mineral diesel. While adding the Simulation of use of the Diesel/biofuel blend in Simulation 11 (Reallocation of Customers + Expansion of vehicle capacity + use of biofuels) gives the best performance saving 292 thousand kilograms which is a reduction of 48% in CO_2 compared to the BAU scenario using 100% of mineral diesel (Figure 37).
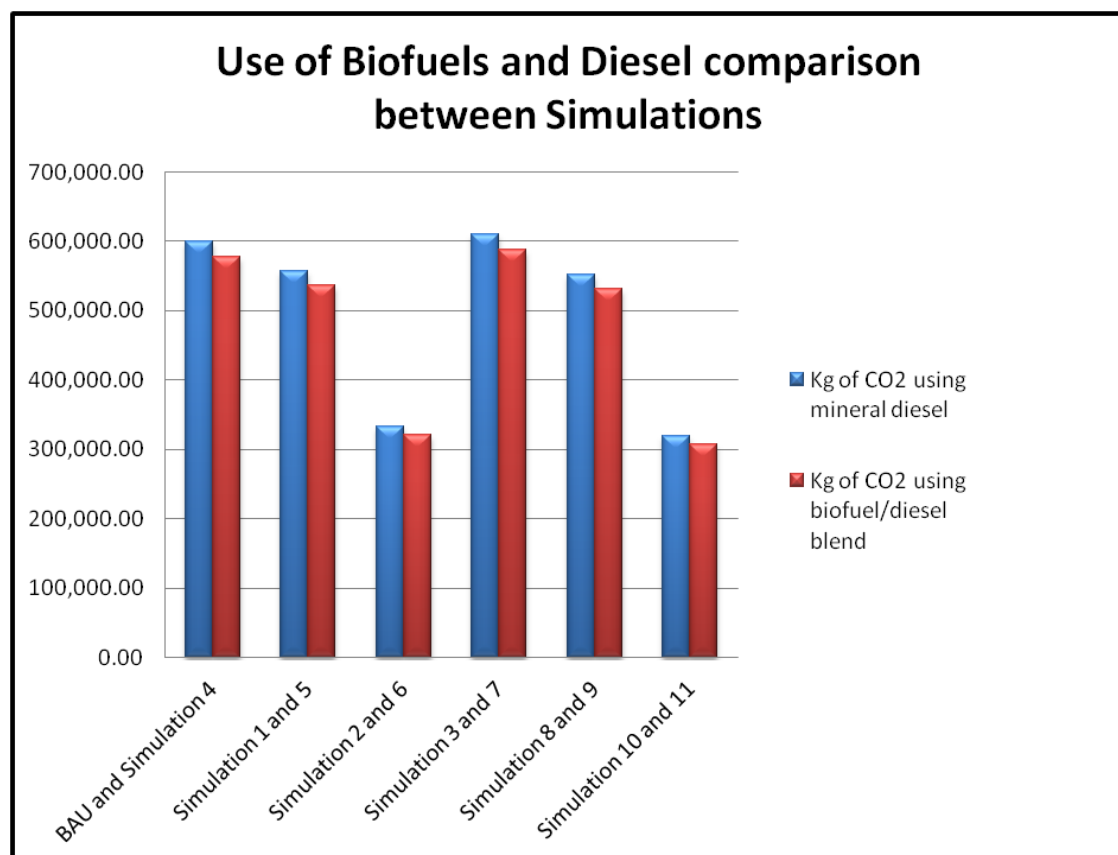
Figure 36 - Use of Biofuels and Diesel comparison between simulations

Finally at looking at the tonne-km, the results of the simulations of expansion of vehicle capacity (Simulations 3, 7, 8, 9, 10 and 11) give the biggest achievement in reduction of tonne-kilometres (Simulations 3, 8 and 10) showed in Figure 38. This is because of the fact that while simulating the expansion of vehicle capacity the simulation is assuming that most of the trips will be at its maximum load capacity, making the distribution more energy efficient.
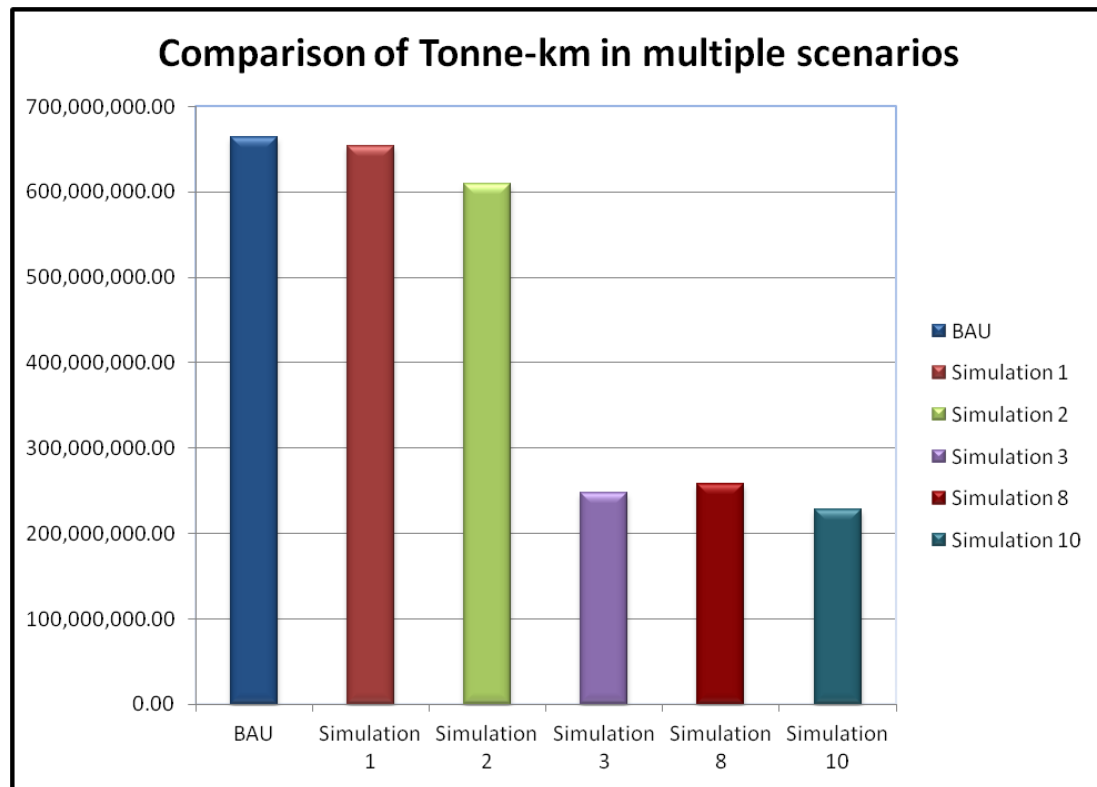
Figure 37 - Comparison of Tonne-km between BAU and multiple scenarios

Simulation 10 and 11 proves to be the best option to reduce emissions by reducing the kilometres travelled. Also give the best results in the tonne-km simulation scenarios. The reallocation of customers is the factor that leads to the important reductions in distance. When comparing the resources that will be needed to implement the simulation in the reality, the reallocation of customer represents also the best option due to the fact that there is no need to invest resources in new vehicles or construction of new distribution centres.

4.3 Summary

The results of the Macro Study show that there is a reduction in the tonne-km and CO_2 emissions from the freight transport sector not necessarily due to the success of

the implementation of governmental policies or means that the freight transport is becoming more sustainable (Mckinnon, 2007) the decrease in the emissions seems to be more related to effects of the economic recession between 2008 and 2009, and as the economy recovers the tonne-km and the fuel consumption statistics arise in its figures. There is a need of reinforcement of the policies and standards dedicated to increase the fuel and vehicle efficiency, average loading factor and decrease the empty running, as well to continue with the plans in the Renewable Transport Fuel Obligation to reach a proportion of 5% in the use of biofuels.

The 11 simulations give positive results in the reduction of total distance travelled, fuel consumption, tonne-km and Kg of CO_2. The simulation with more beneficial results for the operation is Simulation 11. Scenario 11 combines the reallocation of customers, the expansion of vehicle capacity and the use of biofuels. Reallocation of customers reduces considerably the amount of kilometres travelled for output movements, reducing the quantity of fuel use for transportation. The expansion of vehicle capacity is the scenario that produces the fewer amount of tonne-km. The effects of the three simulations give the fewer amounts of kilometres, tonne-km and CO_2 emissions (Figure 39). Simulation 11 is not the best just because is the one that produces less amount of carbon emissions but because the reallocation of customers does not requires the investment of a considerable amount of resources in the construction of new distribution centres as in the Centre of Gravity option.
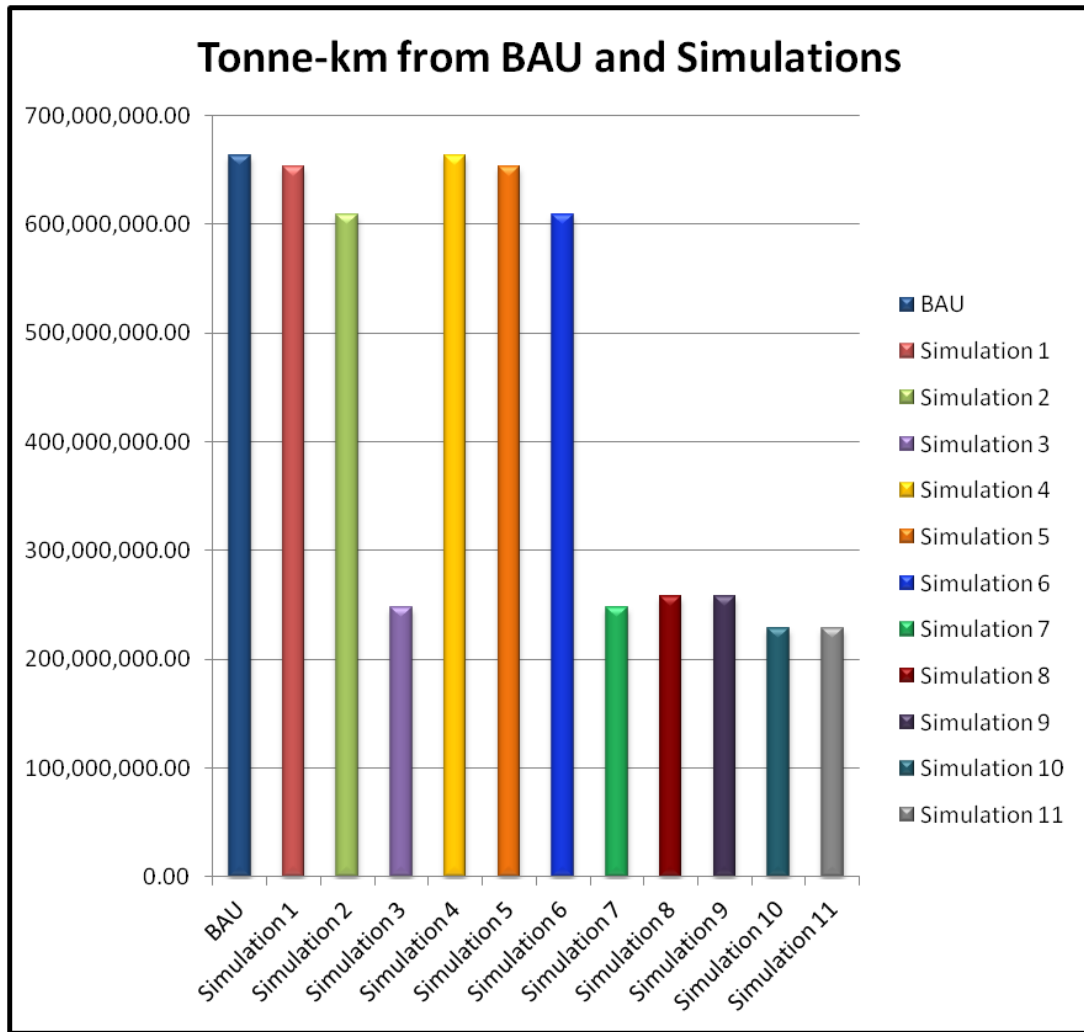
Figure 38 - Tonne-km comparison between BAU and 11 simulations

Chapter 5: Discussion

The present chapter links research objectives to the findings from the literature review and the results for the Macro and Micro Study. The chapter begins by restating the research objectives. This is followed by a discussion of the importance of transport sustainability policies.   The Macro strategies implemented by the Government to stimulate a low carbon freight transport are then reviewed. There is then a section focusing on best practice options for companies at the Micro level to reduce their emissions.   The chapter ends with a brief summary of the whole discussion.

The research objectives for the dissertation are:

1. To review macro level initiatives in the UK and Mexico to reduce CO_2 emissions from freight transport.
2. To review the various ways in which companies can cut CO_2 emissions from freight transport operations.
3. To model the impact of a series of decarbonisation measures on a large company's transport operations.
4. To consider what lessons the Mexican government and business can learn from UK efforts and plans to reduce CO_2 emissions from freight transport.

Transport is an important gear in the growth mechanism of countries because it determines the location of industries and the level of prosperity in cities where accessibility and mobility are closely linked with economic and social progress. However, at the end of the 20th century was recognised that freight traffics cannot grow indefinitely and transport's trends are not sustainable in the longer term. Transport consumes many non-renewable resources, such fossil-fuel energy, human and ecological habitats, atmospheric loading capacity and time (Greene and Wegener, 1997).

Several countries, including the United Kingdom and Mexico, have sustainable development policies for sustainable growth. These policies are attractive because sustainable development sets a clear direction, being flexible enough to adapt to new situations. In the case of transport, sustainable policies are difficult to establish

because of the complexity of the social, economic and technological aspects that involve. When sustainable policies are implemented they usually affect only limited fractions of the total spectrum of the ways in which transport is integrated to contemporary society (Goldman and Gorham, 2006).

One of the key aspects of sustainable development policies is reduction in CO_2 emissions, as Climate Change has become one of the top issues in the Agenda. By the end of the century, Carbon dioxide is expected to hold 70% of the radioactive forcing of climate. The transport sector can have an important role in reducing the carbon emissions to the targets (Tight and Bristow, 2005).

In order to set transport on an environmental friendly pathway there are needed essential changes in technology, design, finances and operation of the transport sector. The transport sector has its biggest challenges in minimising the resources it needs, both renewable and non-renewable. In the case for the non renewable ones, transport has petroleum as its principal energy source. This does not imply that oil should not be used any more as a fuel. Fuel sustainability should seek the improvement of energy resources, along with a wise use to ensure that future generations would have mobility and a preserve environment (Greene and Wegener, 1997).

5.1 Britain's incentives to reduce emissions from freight transport

The United Kingdom is at a more advanced stage in its plans and strategies to decarbonise freight transport. This study outlines the lessons that Mexico can learn from the UK experience.

The United Kingdom has made several projections of CO_2 emissions in business as usual scenarios. As well, the Government has set clear targets to reduce carbon emissions, establishing policies and strategies to stimulate t industry to achieve the targets. Examples of the policies from government (Macro level) and industry options (Micro level) to reduce carbon emissions are summarized in Table 14.

84

Macro: Governmental strategies	Micro: options to reduce environmental cost by freight operators
Taxes on fuel	Greater Capacity vehicles
Regulation of size and weight of trucks	Out of hours deliveries
Financial incentives	Vehicle developments
Government advice and guidance	Technology and operational processes
Support of research and development of technologies	Transport collaboration
Infrastructure	Logistics system redesign
Statistics	Alternative fuels
Industry initiative	Modal shift
Logistics Carbon Reduction Scheme	

Table 14 - Initiatives to reduce carbon emissions in freight transport at Macro and Micro level

Developed countries like the United Kingdom have implemented market based policy instruments, such like the Hydrocarbon Oil duty or Fuel tax. The fuel duty in 2011 £0.5795 per litre plus a Value Added Tax of 20% (HMRC, 2011). Taxing heavily users of road freight transport is a way to encourage companies to be more fuel efficient and to use more fuel efficient freight transport modes such as rail and waterborne. By expressing fuel efficiency in kilo joules per tonne-km rail is twice as efficient compared to road (Bonnafous and Raux, 2003, RCEP, 1994, McKinnon, 1999) and waterborne which is mostly used for freight transport overseas is considered to be efficient and environmentally friendly (Chapman, 2007).

As road freight transport accounts for close to 25% of the total share of CO_2 emissions in the United Kingdom the sector needs policies and regulation to diverge from the Business as Usual trend. This starts with having limits for maximum weight, length, width and height of the vehicles. For the United Kingdom, the length limit for rigid vehicles/drawbar trailer combination is of 18.75 metres, there is no legal limit for the height and the width limit is set to 2.55 metres. There is currently a gross vehicle weight limit of 44 tonnes (Penning, 2011). The truck weight limit is the result of a consultation of the British Government in 1999 to increase the maximum weight from 41 to 44 tonnes. The results of the study indicated a reduction in the cost of road

haulage in tonne-km for weight constrained loads of 11%. The increase of the maximum weight limit, caused rail freight companies to concern about a modal switch. The cost reduction in favour to road transportation will cause in a short period the increase in movement of goods by road and not rail. Still the UK government introduced measures to compensate the railways for the increase in maximum truck to 44 tonnes in 2001. Overall it was found that the increase in maximum truck weight yielded both economic and environmental benefits in the UK (Mckinnon, 2005).

Rail and water freight transport are the ones with more fuel efficiency and have economic incentives such as the Mode Shift Revenues Support (MSRS) Scheme to support their use. The MSRS gives financial support to companies for intermodal shift when rail or inland waterways are more expensive than road transport. The Scheme will last until March 2015 when it will be evaluated (DfT, 2009).

There is a strong bond between economic development, fossil fuels and green house emissions (Schäfer and Jacoby, 2006). Transport of goods is a "derived demand" of the production or use of goods and services (Cole, 1987). The same situation occurs with transport infrastructure that is result of public capital investments, for example in the construction of roads, and private investment in the vehicle fleet (Bell and Feitelson, 1991). In order to direct transport infrastructure to the use of low carbon technologies is logic to stimulate technological developments and market incentives (Schäfer and Jacoby, 2006). One important initiative in the United Kingdom is the Low Carbon Vehicle Innovation Platform (LCVIP), with the financial support from the UK automotive sector, the Technology Strategy Board, the Department of Transport and the Engineering and Physical Sciences Research Council. The LCVIP has two major internal programs, the Low Carbon Vehicles Integrated Delivery Programme that aims to help the implementation low carbon vehicles in UK's roads and the Ultra Low Carbon Vehicle Demonstrator to support industry-led innovations of low carbon technologies such as internal combustion engines, energy storage and management, lightweight vehicle and power train structures (TSB, 2011).

The quality of the transport infrastructure also influences the level of carbon emissions from freight transport. Transport infrastructure, such as roads and railways set movement patterns for freight transport with influence in industry and residence locations (Short and Kopp, 2005). For developed countries like the United Kingdom

the infrastructure is well connected and has high quality, the creation of new networks does not have such a large impact on economic development and emissions as in developing countries, (Banister and Berechman, 2001). The promotion of infrastructure like railways is related to pursue to gain the environmental benefits in its fuel efficiency.

Part of the government support for low carbon technologies takes the form of advice and guidance about how to report and reduce emissions. This is also the first step into setting targets for carbon reduction strategies. According to (McKinnon and Piecyk, 2009a), the scope of emissions is defined with consideration of the activity, industry sector and geography. In the United Kingdom are five important data sources: vehicle emission testing, survey of road freight operators, National Road Traffic Survey (NRTS), Records of Diesel Fuel purchases and the National Atmospheric Emissions Inventory (NAEI). The key variables of distance travelled in tonne-kilometres and fuel efficiency are estimated using data from the first three sources. It is necessary to be able to trust in the calculation of values to minimise variations between different emission calculations(McKinnon and Piecyk, 2009a).

In order to standardize the way of collecting statistical information the United Kingdom Defra has set guidelines for freight. There are international methodologies to calculate emissions but the Defra guidelines provide a common base for the calculation of emissions and their impacts in tonne-kilometres that currently represent the official set of the Britain's emission factors (Defra, 2011).

The range of policies to reduce carbon emissions in the UK indicates that there is a strong influence of scientific information in the Government and society because they are willing to adapt to changes in BAU based on research findings (Pearce, 2006). One private high-level initiative is the Logistics Carbon Reduction Scheme (LCRS) by the Freight Transport Association. The LCRS aims to gather information about CO_2 emissions and report improvements to achieve the reduction target of 8% by 2015. This target was also set as part of the initiative to address Climate Change and reduce the need for government reinforcement of legislation instruments. Following this strategy the FTA also carried a consultation to establish a realistic target to reduce the carbon emissions from the freight transport sector (FTA, 2011).

The scenarios simulating the implementation of options for reducing CO_2 emissions from the transport activities can be look as evidence of the potential for cutting off carbon emissions from the freight transport activities in UK companies. After the modelling of the 11 scenarios and the analysis of the results it was appreciated that Simulation 11 brought a reduction of 48% in carbon emissions. This scenario combines the modelling of reallocation of customers, expansion of vehicle capacity and use of biofuels. At looking to the modelling of each of these measures, the results for the reductions in the emissions are higher in the scenarios with the application of reallocation of customers. The results of the simulation of expansion of vehicle capacity in Simulation 3 give a negative percentage of 1.8%, and the following simulations including this measure give low percentage values that increase when the reduction of distance becomes bigger. The consolidation of loads by increasing vehicle capacity give positive results when combined with an important reduction of the distance travelled to provide customers. Even when the United Kingdom is a develop country with a vehicle fleet that is renew continuously, with governmental encouragement for fuel efficiency. The modelling of scenarios shows that there are other opportunities to reduce emissions and improve the operation.

5.2 Implementation of best practice recommendations and Government legislation, lessons from the UK to the Mexican situation

An important part of Britain's strategy to reduce emissions is to provide guidance. The Department for Transport has the Freight Best Practice Program (FBPP). The FBPP provides free information to companies about how to reduce fuel consumption, training to develop driver skills, equipment and information systems to manage the operation and help with performance management and multimodal options (DfT, 2011a). These kinds of recommendations improve energy efficiency and offer economic and environmental benefits. There are obstacles such as asymmetric data and need to give support to technological improvements that have to be conquered in order to achieve the sustainability goals for transport. Developing countries are also implementing environmental policies but their impact is limited because institutions need more capacity and infrastructure to implement them (Pearce, 2006).

In the case of Mexico, there is a need for the improvement of freight modes. Currently the biggest share of freight transport goes by road. The major problem for road freight

transport it is not the public infrastructure of roads but the need for more investment from the private sector in the modernization of HGV and LGV vehicles. Only 34% of the vehicles are 9 years or less old and 26% has between 10 and 19 years (SEMARNAT, 2011). There is also a situation of 'man-trucks' where single owners have one or two vehicles for the freight transport operations. The vehicles they possess are usually bought from the United States. Mexican laws allow buying vehicles from the US only when those are older to 10 years. As a result, the vehicles being use in Mexican roads are not as efficient as they could be if the fleet could have an age limit of around 4 years. There is an important need for finance programs and tax incentives to improve the fleet. The Clean Transport Program created by the Ministry of Environment and Natural Resources advises freight transport operators to implement drivers training, implement telematics systems, and vehicle improvements such as aerodynamics and truck weight reduction. The consultation is free but there is a need from the companies to invest their own resources to implement the best practice options (SEMARNAT, 2011).

The Mexican Ministry of Communications and Transport (SCT) in its development program for 2007-2012 identifies the major challenges to met in order to improve the freight transport operation that will also result in the decrease of the CO_2 emissions (SCT, 2007). For example Mexico has a weight limit for trucks with nine axles and 34 tyres of 66.5 (which is very high compared with the 44 tonnes weight limit in the UK) tonnes, with limits for height and width of 4.25 metres and 2.60 metres, respectively (DGN, 2008). The road freight transport statistics show that 6.1% of vehicles are overweight running on the roads which shows an increase of 1% compared to the previous year when the percentage was of 5.1% (Duque, 2011). This means that there is a need of the reinforcement of legislation to avoid the exceeding of weight limit of roads. The SCT also suggests the creation of a regulatory institution especially for freight transport as well as better statistics on GHG emissions. It also recognizes the European trend to stimulate the use of rail and waterborne freight transportation (SCT, 2007).

5.3 Summary

The United Kingdom is a developed country with policy and legislation resources to increase the participation of the private and public sector in the reduction of CO_2

emissions from freight transport operations. This happens through taxation such as the Fuel Duty, investments in technological improvements and its commercialization. Also giving incentives for the use of rail and waterborne to freight movement such as The Mode Shift Revenue Support Scheme.

In contrast, the Mexican economy is at an earlier stage in its economic development and oriented to exports. Most of the cargo is transported by road. Over the last 5 years the Government has built and upgraded road infrastructure of 16.5 thousand kilometres (Pérez-Jácome, 2011). Still there is a need of more funding to the modernization of fleet and promotion of sustainable transport policies. It is also important to gather more statistic information of the tonne-kilometres and fuel efficiency. This will allow setting accurate targets in the reduction of CO_2 emissions from the freight transport.

Chapter 6: Conclusions

This Chapter is divided four sections. The first one outlines the objectives and main findings. The second explains the project limitations, for the Macro and Micro Studies. The third gives recommendations and directions for future research for the two levels. The chapter ends with a brief summary of the overall conclusions.

6.1 Main findings

The first two objectives of the dissertation were to review macro and micro level initiatives in the UK and Mexico to reduce their CO_2 emissions from the freight transport sector. During the review it was found that the United Kingdom is well ahead in legislation initiatives and private sector participation to cut emissions. Several studies have been carried out in the UK to forecast the effects of Climate Change on a Business as Usual basis and modelled different scenarios allowing for the influence of changes in population behaviours and technological developments. Mexico has started the first steps in the creation of legal initiatives and Climate Change as an important topic in its development plans. For Mexico, the freight transport faces important challenges of infrastructure from private and public sectors. The challenges are in the creation of more road and rail infrastructure and renewal the fleet. There is also a need of gather statistical information in terms of the performance of vehicles and operational efficiency. Currently the statistical information available is focused on the amount and kind of goods moved and the economic value of the sector. There is a serious lack of data on energy efficiency and emissions in the freight transport sector.

Economic resources are an issue for both countries. Mexico and the United Kingdom are in different stages of their development, which makes the priorities different. This is a challenge but also an opportunity for Mexico because in developing its freight transport sit can learn from the experience from other countries like the UK and not to make the same mistakes as them during their development.

The biggest amount of CO_2 emissions produced globally comes from de energy use, which includes: electricity and heat generation, transport, industry and other fuel combustion activities (Figure 2). The implementation of carbon sequestration and

nuclear power still have economic and social debate ahead for they use to fully decarbonise de generation of energy. That is why reducing an amount of every contributing sector, such as transport is the option to achieve the nearest targets in cutting carbon emissions.

In the case of the UK recommendations from organisations such as Defra, IGD, Carbon Trust and the forecasting tools for 2050 Pathways are available online with guidelines provided for the public and private sector. These give direction about how to report their emissions and start setting targets to reduce them. So far, the biggest incentive to increase the fuel efficiency in the UK has been the high Fuel Tax. This is perceived by the industry as a sign that the Government will implement more policies and economic penalties to assure that the targets are achieved (FTA, 2010).

As the government is taking the Climate Change seriously, the private sector for freight transport represented in the Freight Transport Association has voluntarily started to measure the emissions from the sector and set targets to reduce them.

The review of the Food Industry Sustainability Strategy (FISS) published 6 important recommendations to the industry to reduce the external cost of the freight transport activities. The literature review looked at the various options and these with tested using real world company data provided from the ECR. This was modelled to evaluate the effects of the implementation of the best practice recommendations. Four options where modelled: relocating warehouses to centres of gravity, reallocation of customers, expansion of the vehicle capacity and the use of biofuels. The combination of options resulted in 11 different scenarios that were compared against the BAU operation.

The modelling suggested that, when compared to the BAU situation, combination of the best practice recommendations can bring savings up to 18% (for the Scenario number 11) in fuel consumption. Even in the cases where the reduction of the emissions is not great, there are still benefits in the operation like the ones coming from a logistics system resign, improving the location of distribution centres and the vehicle routing for distribution of products. This validates the potential of projects such as the ECR 'Starfish' project to show that substantial savings that can be made by following the Best Practice Recommendations published by FISS and IGD and tested by Defra.

One obstacle for the implementation of the recommendations may be the scale of investment needed to make changes. For example, in the case of the Centre of Gravity modelling for setting the Distribution Centre closer to customers the investment needed would be too high compared with the simulation of other scenarios.

The last objective of the dissertation was to consider what lessons the Mexican Government and business can learn from the UK efforts and plans to reduce emissions. This is discussed in the section 6.3 on recommendations and directions for future research.

6.1 Project Limitations

Macro Study

In the case of Mexico, there is not enough information available about the results of the implementation of programmes to reduce CO_2 emissions from the freight transport sector such as the Sectorial Development Program 2007-2012. Information was sought from sources like the Ministry of Environment and Natural Resources, the National Institute of Ecology, and the Mexican Transport Institute. The information needed was not found in these sources. This does not necessarily mean that the information is not being collected but that a better sharing of information is necessary. The statistical information from the freight transport sector gathered from the Mexican National Institute of Statistics and Geography (INEGI) does not have available information about the kilometres or tonne-kilometres moved in roads or by shipping. It does have information for rail probably because the rail operations are under the direct control of private companies.

Micro Study

The information provided by the ECR for the Micro study presented some limitations because it was not directly collected by the researcher. As the source of data has to remain anonymous the type of products transported are unknown. Nor was it possible to contact the company to discuss the data set or the nature of its operations. This could have shed light on anomalies, such as one relating to the reallocation of customers where from the total 485 customers, only 87 receiving goods from the closest depot to them. This might occur because there is a need of redesign the

distribution system but also could be because the products being distributed are not of the same kind.

The research did not aim to calculate economic values for the transportation. Having more information about the transport operation cost would make it possible to validate the savings in resources modelled in the different scenarios. Estimates could then have been made of the cost-effectiveness of the options in reducing CO_2 emissions.

In the beginning of the study, one of the objectives was to gather information from Mexican freight transport operators. Several companies were asked for information about their sustainable transport policies, but none of them gave information about it, even companies currently implementing recommendations from the Clean Transport programme. The results of the programme show savings in tonnes/year for 55 companies from passenger and freight transport. The results give no indications of energy or emission savings. It does not permit an assessment of the effects of the Clean Transport Program from the freight transport sector.

6.1 Recommendations and directions for future research

Macro Study

For the Mexican situation, it will be useful to have a better collection and sharing of the statistical information from the freight transport sector as well to use a wider variety of parameters to measure the performance of the activities. This will help to monitor the impact of the environmental policies implemented using metrics such as tonne-kilometres, empty running and kilometres travelled by type and age of vehicles. The Mexican Ministry of Communications and Transport is also aware of the importance of renewing the fleet and recommends the investment of more resources to achieve it. Cities in Mexico tend to grow by expanding their surface areas instead of concentrating. More urban concentration could signify a reduction in the distances travelled in the distribution of goods. Concentration and modal shift can have an important influence in reducing emissions in the Mexican business operations. Concentration reduces the average length of haul while rail and shipping are more fuel-efficient compared to road freight transport when moving goods over longer distances.

The Mexican freight transport system has the opportunity to change its operations and become more environmentally friendly. The United Kingdom and the European Union have online available information about their plans to improve the distribution of goods as well as much statistical information. Such organizations as the Carbon Trust in the UK and EPA in the USA have initiatives which could be used to reduce freight transport emissions in other countries. What is needed is a compilation of the information, translated so Mexico and other countries become aware of the options and access international consultancy and probably economic funds.

Until recently, the United Kingdom offered to the private sector a means of accessing consultancy and funding to invest in carbon reduction plans. This includes grants to stimulate the use of rail and waterborne freight ways. There is also an awareness and commitment from the members from the Freight Transport Association to improve fuel efficiency and operations to stimulate the reduction of the carbon emissions. It is clear that Mexican companies are seeking reductions in their fuel consumption to save resources and big companies are using private consultants to improve their logistics operations, but small companies or 'men-trucks' (i.e. owner-drivers) need more support to improve their situation. The Clean Transport Program is a free governmental initiative to help road freight operators to improve their performance but requires large investments from the companies and there are no mechanisms from the government to provide funds or grants.

Instead the Mexican government stimulates through taxation discounts and social responsibility programmes for companies when they contribute to the community. Freight transport is a "derived" activity and population generally perceives freight vehicles negatively. That is why there are not as many economic incentives from the government to stimulate improvements of the efficiency of freight operation compared to passenger transport programs. The implementation of taxes on fuel, promotes fuel efficiency and the involvement of the private sector into consider the importance of reduce its carbon emissions.

Technological developments are a key factor in meeting the Climate Change challenge. The Mexican government already has a system to promote the education on a Master and PhD level. There is a need of a stronger link between the industry and researchers and market incentives to integrate the use of research findings.

Micro Study

The results showed a relation between the consolidation of loads and the expansion of vehicle capacity in Simulation 11. A study simulating the same scenario using data more data could prove if there is a relation. Also an economical evaluation of the implementation will give other criteria for decision makers to evaluate when considering the implementation of these options.

In the case of future research at the Micro level it will be useful to have information about the type of products being transported. This will help the modelling to be more reliable. It will also be useful to have information about the scheduling of trips so that economic calculations can be made. The next step would be to simulate transport collaboration between businesses using data collected from other ECR companies.

A study like this could be carried out for Mexican freight transport operators though it would be difficult to achieve the same level of company participation and data collection. If it were possible it would be a major step towards improving the statistical collection from the freight transport sector.

6.2 Summary

The study shows that there are lessons to be learned by less developed countries from the experience of a country such as the UK which is actively trying to reduce carbon emissions in the freight transport sector. At the Macro level the government of a country such as Mexico need to collect much more freight data using parameters such as tonne-kilometres, distance travelled and fuel consumption by type of vehicle. They also need to establish legislation mechanisms and incentives to promote fuel efficiency in transport operators. There is also a need for more guidance and support from governmental departments for measurement and reporting of emissions, setting targets to reduce them and giving options such as the ones from FISS to reduce the external effects from food distribution. Promoting a stronger link between industry and research encourages the implementation of market incentives.

The simulation of the 11 scenarios using a real set of data identified the best options for the food manufacturer to cut CO_2 emissions relative to the BAU situation. A scenario comprising a combination of the reallocation of customers, expansion of vehicle capacity and use of biofuels offered reductions of up to 18% in CO_2

emissions, despite the fact that freight transport operations in the UK are already efficient. This suggests that the potential for cutting CO_2 emissions from freight transport in Mexico is likely to be high.

References

AHOUISSOUSSI, N. B. C. & WETZSTEIN, M. E. 1998. A comparative cost analysis of biodiesel, compressed natural gas, methanol, and diesel for transit bus systems. *Resource and Energy Economics,* 20, 1-15.

ALBRITTON, D. L. & BARKER, T. 2001. Climate Change 2001, Synthesis Report. Cambridge University Press.

ASTBURY, G. R. 2008. A review of the properties and hazards of some alternative fuels. *Process Safety and Environmental Protection,* 86, 397-414.

AYRES, R. U., TURTON, H. & CASTEN, T. 2007. Energy efficiency, sustainability and economic growth. *Energy,* 32, 634-648.

BANISTER, D. 2007. Reducing energy use in UK transport. *Working paper No. 1028.* Oxford: Oxford University Centre for the Environment, Transport Studies Unit.

BANISTER, D. & BERECHMAN, Y. 2001. Transport Investment and the promotion of economic growth. *Journal of Transport Geographhy*, 209-218.

BARKER, T., BERGAL, O. & BUDIN, S. 2009. EU Climate Change Group "EG Science".

BAUMGARTNER, M., LÉONARDI, J. & KRUSCH, O. 2008. Improving computerized routing and scheduling and vehicle telematics: A qualitative survey. *Transportation Research Part D: Transport and Environment,* 13, 377-382.

BELL, M. E. & FEITELSON, E. 1991. U.S. Economic Restructuring and Demand for Transportation Services. *Transportation Quarterly,* 45, 517-538.

BIROL, F. 2007. World Energy Prospects and Challenges. *Asia-Pacific Review,* 14.

BLAIR, T. 2005. Speech to Confederation of British Industry Annual Conference.

BONNAFOUS, A. & RAUX, C. 2003. Transport and Energy emissions: rail. *In:* HENSHER, D. A. & BUTTON, K. J. (eds.) *Handbooks in Transport 4: Handbook of Transport and Environment.* Elsevier.

BOWS, A., UPHAM, P. & ANDERSON, K. 2005. Growth Scenarios for EU and UK Aviation: contradictions with Climate Change Policy.

BRAND, C., TRAN, M. & ANABLE, J. 2010. The UK transport carbon model: An integrated life cycle approach to explore low carbon futures. *Energy Policy*.

BROWNE, M., ALLEN, J., ANDERSON, S. & WOODBURN, A. 2006. Night-Time Delivery Restrictions: A Review. *Recent Advances in City Logistics*, 245-258.

BROWNE, M., SWEET, M., WOODBURN, A. & ALLEN, J. 2005. Urban Freight Consolidation Centres.

BSI, B. S. I. 2011a. Methodology for calculation and declaration on energy consumption and GHG emissions in transport services (good and passenger transport).

BSI, B. S. I. 2011b. Specification for assesment of the Life Cycle Greenhouse Emissions of Goods and Services.

BURRELL, G. & MORGAN, G. 1979. Sociological Paradigms and Organizational Analysis. *Heinemann*, 1-37.

BURROUGHS, W. J. 2007. *Climate Change, a multidiciplynary approach*, Cambridge.

CHAPMAN, L. 2007. Transport and climate change: a review. *Journal of Transport and Geography*, 354-367.

CHOUDHARY, T. V., BANERJEE, S. & CHOUDHARY, V. R. 2002. Catalysts for combustion of methane and lower alkanes. *Applied Catalysis A: General,* 234, 1-23.

COLE, S. 1987. Applied Transport Economics.

DECC, D. F. E. A. C. C. 2011a. Energy Consumption in the UK 1970-2010 Table 1.7.

DECC, D. F. E. A. C. C. 2011b. *Policy and legislation, Climate Change Act 2008* [Online]. Available: http://www.decc.gov.uk/en/content/cms/legislation/cc_act_08/cc_act_08.aspx.

DECC, D. O. E. A. C. C. 2007. Energy white paper 2007: 'Meeting the energy challenge'.

DECC, D. O. E. A. C. C. 2010. 2050 Pathways Analysis.

DECC, D. O. E. A. C. C. 2011c. Energy Consumption in the UK, Table 1.5.

DEFRA, D. F. E. F. A. R. A. 2007. Report of the Food Industry Sustainability Strategy Champions' Group on Food Transport.

DEFRA, D. F. E. F. A. R. A. 2011. Guidelines to Defra/DECC's GHG Conversion Factors for company reporting.

DFT, D. F. T. 2007a. Low Carbon Innovation Strategy.

DFT, D. F. T. 2007b. Low Carbon Transport Innovation Strategy.

DFT, D. F. T. 2009. Guide to Mode Shift Revenue Support (MSRS) Scheme.

DFT, D. F. T. 2011a. Freight Best Practice Program.

DFT, D. F. T. 2011b. Grant funding to transport freight by rail and water.

DFT, D. F. T. 2011c. *Road freight statistics 2010* [Online]. Available: http://www.dft.gov.uk/statistics?post_type=release&series=road-freight [Accessed 05/12/2011 2011].

DGN, M. B. O. S. 2008. NOM-012-SCT-2-2008, on the weight and dimensions that trucks can move while traveling in general means of communication under federal jurisdiction.

DILANTHI AMARATUNGA & BALDRY, D. 2001. Case study methodology as a means of theory building: performance measurement in facilities management organisations. *Work Study,* 50, 95-105.

DTI, D. O. T. A. I. 2007. Meeting the Energy ChallengeA White Paper on Energy.

DUQUE, F. 2011. La densidad de la carga como instrumento para el diseño de vehiculos de los vehiculos que circulan con sobrepeso. *Revista Vinculando*.

ENKVIST, P.-A., NAUCLÉR, T. & ROSANDER, J. 2007. A cost curve for greenhouse gas reductionA. *The Mckinsey Quarterly*.

EU, C. O. T. E. C. 2006. Freight Transport Logistics in Europe – the key to sustainable mobility.

EU, E. C. 2011. Transport 2050: Commission outlines ambitious plan to increase mobility and reduce emissions.

EU, E. U. 2010. EU Energy and Transport in figures.

FISHER, D., MCKINNON, A. & PALMER, A. 2009. Reducing the external cost of food distribution in the UK. *Mena and Stevens - Delivering performance in food supply chains.*

FLEMMING, P. 2010. Value for enterprise marchitecture can generate value by appliying different approaches.

FREDERICK, K. D. & MAJOR, D. C. 1997. Climate Change and Water Resources. *Climatic Change, 37*, 7-23.

FTA, F. T. A. 2010. Logistics Carbon Reduction Scheme.

FTA, F. T. A. 2011.

GASPARATOS, A., EL-HARAM, M. & HORNER, M. 2008. A longitudinal analysis of the UK transport sector, 1970-2010. *Energy Policy,* 37, 623-632.

GOLDMAN, T. & GORHAM, R. 2006. Sustainable urban transport: Four innovative directions. *Technology Society*, 261-273.

GREENE, D. & WEGENER, M. 1997. Sustainable Transport. *Journal of Transport Geography,* 5, 177-190.

GUBA, E. G. & LINCOLN, Y. S. 1994. Competing paradigms in qualitative research. *Handbook of qualitative research.*

HARE, B. & MEINSHAUSEN, M. 2006. How Much Warming are We Committed to and How Much can be Avoided? *Climatic Change,* 75, 111-149.

HENSON, R. 2007. *The rough guide to Climate Change*, Rough Guides.

HM, G. 2008. Climate Change Bill.

HM, H. G. 2010. 2050 Pathways Analysis.

HMRC, H. R. A. C. 2011. Fuel Duty Rates.

HOUGHTON, J. 2001. The Science of Global Warming. *Interdiciplinary Science Reviews, 26*, 247-57.

IEA, I. E. A. 2009. Transport, Energy and CO2: Moving toward Sustainability - How the world can achieve deep CO2 reductions in transport by 2050.

IEA, I. E. A. 2011a. Clean Energy. Progress Report.

IEA, I. E. A. 2011b. Oil Market report.

IGD, I. O. G. D. 2008. Sustainable distribution - Best Practice - transport. Institute of Grocery Distribution.

IMP, M. P. I. 2009. GHG Emissions Scenarios in the medium and long terms, 2020, 2050 and 2070.

INEGI, N. I. O. S. A. G. 2009. Statistical Yearbook from the Mexican United States.

ISO, I. O. F. S. 2006. Specification Guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

JOHANSSON, B. 1999. The economy of alternative fuels when including the cost of air pollution. *Transportation Research Part D*, 91-108.

KVENVOLDEN, K. A. 1996. A review of the geochemistry of methane in natural gas hydrate. *Organic Geochemistry, 23*, 997-1008.

LEE, D. S., FAHEY, D. W., FORSTER, P. M., NEWTON, P. J., WIT, R. C. N., LIM, L. L., OWEN, B. & SAUSEN, R. 2009. Aviation and global climate change in the 21st century. *Atmospheric Environment, 43*, 3520-3537.

LEVIN, M. E. 1998.

MACHARIS, C. & BONTEKONING, Y. M. 2004. Opportunities for OR in intermodal freight transport research: A review. *European Journal of Operational Research, 153*, 400-416.

MCKINNON, A. 1996. The empty running and return loading of road goods vehicles

MCKINNON, A. 1999. A logistical perspective on the fuel efficiency on Road Freight Transport.

MCKINNON, A. 2005. The economic and environmental benefits of increasing maximum truck weight: The British Experience. *Transportation Research Part D*, 75-95.

MCKINNON, A. 2007. Decoupling of Road Freight Transport and Economic Growth Trends in the UK: An Exploratory Analysis. *Transport Reviews*.

MCKINNON, A. 2010. Green Logistics: The Carbon Agenda. *LogForum, 6*.

MCKINNON, A., CULLINANE, S. & WHITEING, A. 2010. *Green Logistics: Improving the Environmental Sustainability of Logistics*, Kogan Page.

MCKINNON, A. & EDWARDS, J. 2010. Opportunities for improving vehicle utilization. *In:* MCKINNON, A., CULLINANE, S., BROWNE, M. & WHITEING, A. (eds.) *Green Logistics, Improving the environmental sustainability of logistics.*

MCKINNON, A. & PIECYK, M. 2009a. Logistics 2050: Moving Freight by roadin a Very Low Carbon World.

MCKINNON, A. & PIECYK, M. 2009b. Measurement of CO2 emissions from road freight transport: A Review of UK experience. *Energy Policy*.

MELO, M. T., NICKEL, S. & SALDANHA-DA-GAMA, F. 2009. Facility location and supply chain management – A review. *European Journal of Operational Research, 196*, 401-412.

METZ, B., DAVIDSON, O., SWART, R. & PAN, J. 2001. *Climate Change 2001: Mitigation*, Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change , Cambridge University Press.

MORABITO, R., MORALES, S. R. & WIDMER, J. A. 2000. Loading optimization of palletized products on trucks. *Transportation Research Part E: Logistics and Transportation Review, 36*, 285-296.

MWEMEZI, J. J. & YOUFANG, H. 2011. Optimal Facility Location on Spherical Surfaces: Algorithm and Application. *New York Science Journal,* 4, 21-28.

NADER, J. 1991. Measurement of the impact of driving technique on fuel consumption: preliminary results. *Roads & Transportation*.

PALMER, A. & MCKINNON, A. 2011. ECR Project Starfish, An analysis of the opportunities for improving Transport Efficiency through Multi-lateral colaboration in FMCG Suppply Chains.

PARRY, M. L., CANZIANI, O. F., PALUTIKOF, J. P., VAN DER LINDEN, P. J. & HANSON, C. E. 2007. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*, Cambridge University Press.

PASTOWSKI, A. 1997. Decoupling Economic Development and Freight for reducing its negative impacts. *Wuppertal Papers*.

PATTERSON, M. 1998. Commensuration and theories of values in ecological economics. *Ecological Economics,* 25, 105-125.

PATTERSON, M. G. 1996. What is energy efficiency?: Concepts, indicators and methodological issues. *Energy Policy,* 24, 377-390.

PEARCE, D. 2006. The political economy of an energy tax: The United Kingdom's Climate Change Levy. *Energy Economics*, 149-158.

PEARSON, C. H. 2009. *Latitude, Longitude and Great Circles* [Online]. Available: http://www.cpearson.com/excel/LatLong.aspx [Accessed 12/01/2011.

PENNING, M. 2011. Semi-trailers, written statement. DfT, Depoartment for Transport.

PÉREZ-JÁCOME, D. 2011. Mexico protecs the more vulnerable: roads and highways.

RCEP, R. C. O. E. P. 1994. Transport and Environment.

RHA, R. H. A. 2008. http://www.rha.uk.net/.

RICCI, A. & BLACK, I. 2005. Measuring the marginal cost of transport. *Research in Transportation Economics,* 14, 245-285.

RUZZENENTI, F. & BASOSI, R. 2009. Evaluation of the energy efficiency evolution in the European road freight transport sector. *Energy Policy,* 37, 4079-4085.

SAP, S., APPLICATIONS AND PRODUCTS LOGIPLAN, LoadDesigner.

SARKAR, A. & MOHAPATRA, P. K. J. 2008. Maximum utilization of vehicle capacity: A case of MRO items. *Computers & Industrial Engineering,* 54, 185-201.

SATHAYE, N., HARLEY, R. & MADANAT, S. 2010. Unintended environmental impacts of nighttime freight logistics activities. *Transportation Research Part A: Policy and Practice,* 44, 642-659.

SAUNDERS, M., LEWIS, P. & THORNHILL, A. 2008. Research Methods for Business Students. Pearson Education.

SCHEELHAASE, J. D. & GRIMME, W. G. 2007. Emissions trading for international aviation—an estimation of the economic impact on selected European airlines. *Journal of Air Transport Management,* 13, 253-263.

SCHILLING, D., JAYAMARAN, V. & BARKHI, R. 1993. A Review of Covering Problem in Facility Location. *Location Science,* 1, 25-55.

SCHÄFER, A. & JACOBY, H. D. 2006. Vehicle Technology under Co2 constraint: a general equilibrium analysis. *Energy Policy*, 975-085.

SCT, M. M. O. C. A. T. 2007. Sectorial program for Communications and Transport 2007-2010.

SEMARNAT, M. O. E. A. N. R. 2009. Fourth National Communication to the United Nations Framework on Climate Change.

SEMARNAT, M. O. E. A. N. R. 2011. Clean Transport Program, Executive Summawy.

SENER, M. O. E. 2011. National Energy Strategy.

SENER, S. D. E. 2010b. National Energy Strategy.

SHORT, J. & KOPP, A. 2005. Transport Infrastructure: Investment and Planning. Policy and research aspects. *Transport Policy*, 360-367.

SPENS, K. M. & KOVÁCS, G. 2006. A content analysis of research approaches in logistics research. Vol. 36 374 - 390.

STERN, N. 2007. The Economics of Climate Change: The Stern Review. Cambridge University Press.

SULE, D. 2001. *Facility location and Allocation*, Deckker Inc, New York.

TAPIO, P., BANISTER, D. & LUUKKANEN, J. 2007. Energy and transport in comparison: Immaterialisation, dematerialisation, and decarbonisation in the EU15 between 1970 and 2000. *Energy Policy,* 32, 433-451.

TIGHT, M. R. & BRISTOW, A. L. 2005. What is sustainable levelof Co2 emissions from transport activity in the UK in 2050. *Transport Policy,* 12.

TOMAN, M. A. & SOHNGEN, B. 2001. *Climate Change*.

TSB, T. S. B. 2011. Ultra Low Carbon Vehicle Demonstrator Programme.

UNEP, U. N. E. P. 2001. The role of transport in environmental protection.

UNEP, U. N. E. P. 2009. Climate Change in Peril.

UNFCCC MEMBERS, U. N. F. C. O. C. C. 2010. Report of the Conference of the Parties on its sixteenth session.

UNFCCC, U. N. F. C. O. C. C. 1994. *Article 2, Full text of the convention.* [Online].

WALKO, ROBERT, L., BAND, LARRY, E., BARON, JILL, KITTEL, TIMOTHY, G. F., LAMMERS, RICHARD, LEE, TSENGDAR, J., OJIMA, DENNIS, PIELKE, ROGER, A., TAYLOR, CHRIS, TAGUE, CHRISTINA, TREMBACK, CRAIG, J., VIDALE & PIER, L. 2000. Coupled atmosphere–biophysics–hydrology models for environmental modeling. *J. Appl. Meteor.*, 931–944.

WATSON, J. & SCOTT, A. 2009. New nuclear power in the UK: A strategy for energy security? *Energy Policy,* 37, 5094-5104.

WB, W. B. 2011. World Development Indicators.

WBCSD, W. B. C. F. S. D. 2011. Green House Protocol: A corporate accounting and reporting standard.

WOODBURN, A. & WHITEING, A. 2010. Transferring freight to 'greener' transport modes. *In:* MCKINNON, A., CULLINANE, S., BROWNE, M. & WHITEING, A. (eds.) *Green Logistics, improving the environmental sustainability of logistics.*

WRI, W. R. I. 2012. Climate Analysis Indicators Tool (CAIT).

WÅHLBERG, A. E. 2007. Long-term effects of training in economical driving: Fuel consumption, accidents, driver acceleration behavior and technical feedback. *International Journal of Industrial Ergonomics,* 37, 333-343.

ZACHARIADIS, T. 2009. Exploring the relationships between energy use and economic growth with bivariate models: New evidence from G-7 countries. *Energy Economics*, 1233-1253.

ZHOU, G., HUI, Y. V. & LIANG, L. 2011. Strategic alliance in freight consolidation. *Transportation Research Part E: Logistics and Transportation Review,* 47, 18-29.