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Toyota Europe's Freight Activity Outlook - 2030

The Effect of a Post White Paper Environment on European Freight Activities

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THE EFFECT OF A POST WHITEPAPER ENVIRONMENT ON EUROPEAN FREIGHT ACTIVITIES

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Preface

The document before you is the thesis report prepared as a culmination of work and knowledge that I obtained during my Master's Studies in Management of Technology at the faculty of Technology, Policy and Management of TU Delft. During this time I specialized in the field of integrated operations and supply chain management which was closely linked to the topic of the study.

The study commenced in May 2011 and was conducted within the Energy Research Group (ERG) of Toyota Motor Europe (TME) with the aim of analyzing the effects of the EU White Paper on transport on Toyota's freight activities. By the end of the study, a model had been developed which could forecast the year by year modal split and CO2 emissions of Toyota freight operations between 2011 and 2030.

I had the privilege to pursue this project within an environment where I received continuous encouragement, respect, and support. A number of individuals deserve special acknowledgement. Without them, I would not have been able to accomplish this study:

First, I would like to extend my sincere gratitude to Prof.dr.ir. Lóránt Tavasszy, my thesis chair professor, who continuously supported my progress with ideas and inspiration. In addition, I would like to thank Ir. Marcel Ludema, my first supervisor, who not only instructed me through the different stages of the project, but also provided me with numerous useful and practical tips on scientific communication and how to implement a research project. Also, I would like to thank Dr. Daniel Scholten, my second supervisor, for the insightful suggestions and support he gave me throughout this project. The members of my committee taught me how to think independently while providing me with guidance on all aspects of the research.

Furthermore, I would like to thank my supervisors at TME, Dr. Muriel Desaeger and Ir. Timothy Waltniel, General Manager and Manager at ERG. They trusted my judgment and offered me flexibility throughout the project. Dr. Desaeger, offered me guidance through the difficult stages of the project and Mr. Waltniel, provided me with valuable hands-on solutions to existing problems. Indeed, without them, I would not have been able to deal with such a challenging project. In addition, through their mentoring, I was able to experience the internal dynamics of one of the largest multi-national corporations in the World.

Moreover, I am grateful for the continuous support of Dr. Ali Mohammadi, who was pivotal to the realization of this project. Likewise, thanks to Tanke-san, Stephan, Didier, Dorothee, Julien, Myelene, Danny, Jake, Francesco and all other members I had the pleasure to work with who contributed to a positive and pleasant work environment.

I would also like to extend my special thanks to Ghazaleh, Amir, Pouyan, Farshad, Hooman, Ario and many others who without them, my years in Delft would not have been as enjoyable. Also special thanks to Viktor, Tamas, Tommy, Petr, and Philipp who made my life in Brussels an experience I will never forget.

Last but not least, I would like to thank my amazing and lovely parents, Marita and Bijan, and my wonderful brothers Iman and Arman, who have always stood by my side with their unconditional love and endless support. I owe them much more than I would ever be able to express.

Salman Farhanieh
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Summary

Since 1990, this energy consumption in transport has been increasing at an average annual growth rate of approximately 1.6%. Freight transport activity, as one of the main contributors to this growth, is forecasted to increase by 50% by 2020. As a result, a number of policy issues have been raised, which can be summarized as follows:

- Congestion in the European transport system is having a negative impact on cost and time of transport and is increasing fuel consumption.
- Freight transport needs to be in line with EU's climate change targets.
- Freight transport is highly dependent on fossil fuel which is not in line with EU's oil independence policies.

Following these concerns, the White Paper on Transport: Roadmap to a Single European Transport Area was published on 28 March 2011 by the European Commission. In this document, it was evident that the EU, for the first time, directly targeted the European freight industry and expected a reduction of CO_2 emissions and a shift away from road freight to alternative modes.

After noticing the shift of EUs attention towards freight, Toyota Motor Europe, raised the question concerning the effect this shift will have on its European supply chain operations. This concern initiated a study which calumniated in the formation of this Master thesis document. The study focuses on the possible effects the EU initiatives will have on European freight and subsequently Toyota's freight activities. The research resulted in the construction of a model which was used to forecast the future modal split and CO_2 emissions of Toyota's freight activities.

In order to support the initiated study, a research objective was developed and its scope was defined. The main objective was to study the effects of EU policies on the EU freight industry[1] with regards to developments in "freight costs" and "CO_2 emissions factors" and to further on, analyze the subsequent influence on the business of Toyota Motor Europe concerning its "modal split" and "total CO_2 emissions".

Based on the defined research objective and the scope, the main research question was defined as:

"How will the targets, outlined in the EU White Paper, change European freight and to what extent and effect will Toyota Motor Europe's freight activities, with regards to modal split and total CO_2 emissions, be affected by the changes?"

In order to answer the research question, the research methodology was designed and the methods which were to be used were selected. The methods were the following:

- Literature Review
- Direct Observations
- Stakeholder Analysis
- Qualitative interviews and Stated Preference Surveys
- Spread Sheet Modeling

[1] The European Transport System: The free movement of individuals and of goods, by means of different modes of transport, within the European internal market with the goal to ensure sustainable development, maximize use of space, enhance safety and promote international cooperation (DG Move, 2011).

The modeling technique which was decided to be used for the study was spreadsheet modeling. In order to outline the steps to be followed for the development of the spreadsheet model, a theoretical framework was developed which can be seen bellow.

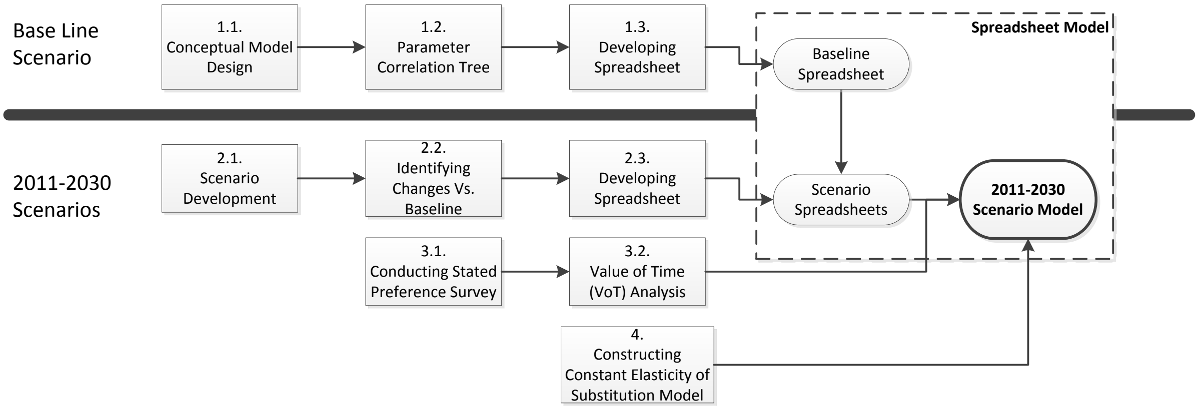


Figure 1 - Spreadsheet Model Development Steps

The tools which were to be utilized during the development of the model were subsequently identified as follows:

1. Scenario Development;
2. Value of Time Analysis (VoT);
3. Constant Elasticity of Substitution Analysis (CES).

Before utilizing these tools to develop the model, the main parameters influencing freight had to be identified. This was done by first analyzing the EU initiative to gain an accurate overview of their content and views. By doing so, it was discovered that their main discussion points where the following:

- Truck technology and efficiency
- Promotion of intermodal transport
- Optimize the performance of multimodal logistic chains
- Internalization of GHG cost (Fuel taxation, Road pricing)

After having analyzed the initiatives, a stakeholder analysis was performed in order to gain a proper insight into the position of the stakeholders towards European freight policies and the influential parameters. The main stakeholders identified where, EU institutions, the vehicle manufacturing industry, 3PLs, and NGOs. Through analyzing their stand point of the white paper it was possible to map their interest and power position.

Through utilizing the gathered information from the previous steps, it was now possible to identify the parameters:

1. New Technology Development and Promotion
2. Modal Split
3. Internalization of Externalities
4. Fuel Cost

After having identified the parameters, it was possible to develop the model for the study. According to the theoretical framework, this was done in two steps: 1. baseline spreadsheet development and, 2. 2011-2030 scenario model construction.

For constructing the baseline spreadsheet, at first, a conceptual model was designed in order to understand the inputs, outputs, and boundary conditions of the model. Using the information from the conceptual model, at the next step, a parameter correlation tree was developed for the purpose of defining the internal dynamics of the model. Through utilizing the knowledge gained from the previous two steps, the baseline spreadsheet was constructed.

In order to construct the 2011-2030 scenario model the following three steps had to be taken.

1. Development of the Scenario Spreadsheet
2. Constructing the Value of Time Analysis
3. Construction of Constant Elasticity of Substitution Analysis Tool

The scenario spreadsheet was to be constructed using the baseline spreadsheet as a platform. Before doing so, the scenarios, which were going to be used, had to be defined. For the purpose of this study, the following 5 scenarios were defined:

1. Business as Usual
2. Forced Modal Shift
3. New Fuel and Technology Promotion
4. Taxation
5. Maximum Impact

After having identified the differences between the scenarios and the baseline, the scenario spreadsheets were constructed.

The next step was to construct the Value of Time analysis which was done by designing a stated preference survey. This survey was to be used to gather data from Toyota's logistics groups. The data was, subsequently, going to be used for discrete choice modeling in order to estimate Value of Time. The BIOGEME software was furthermore, selected for performing the discrete choice simulation.

The final step was to construct the constant elasticity of substitution (CES) analysis tool. For the purpose of this study, a flat nested utility tree was used as can be seen bellow:

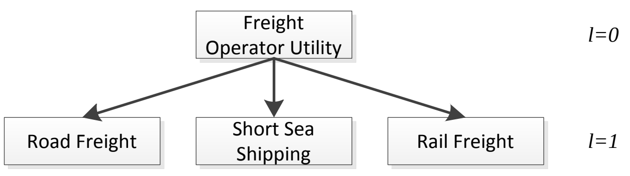


Figure 2 - The Nested Utility Tree Used for the Modeling

By using the utility tree and the constant elasticity of substitution functions, the CES tool was constructed.

After having performed each of the required steps, the 2011-2030 Scenario Model was constructed. The internal flow of the model can be seen bellow:

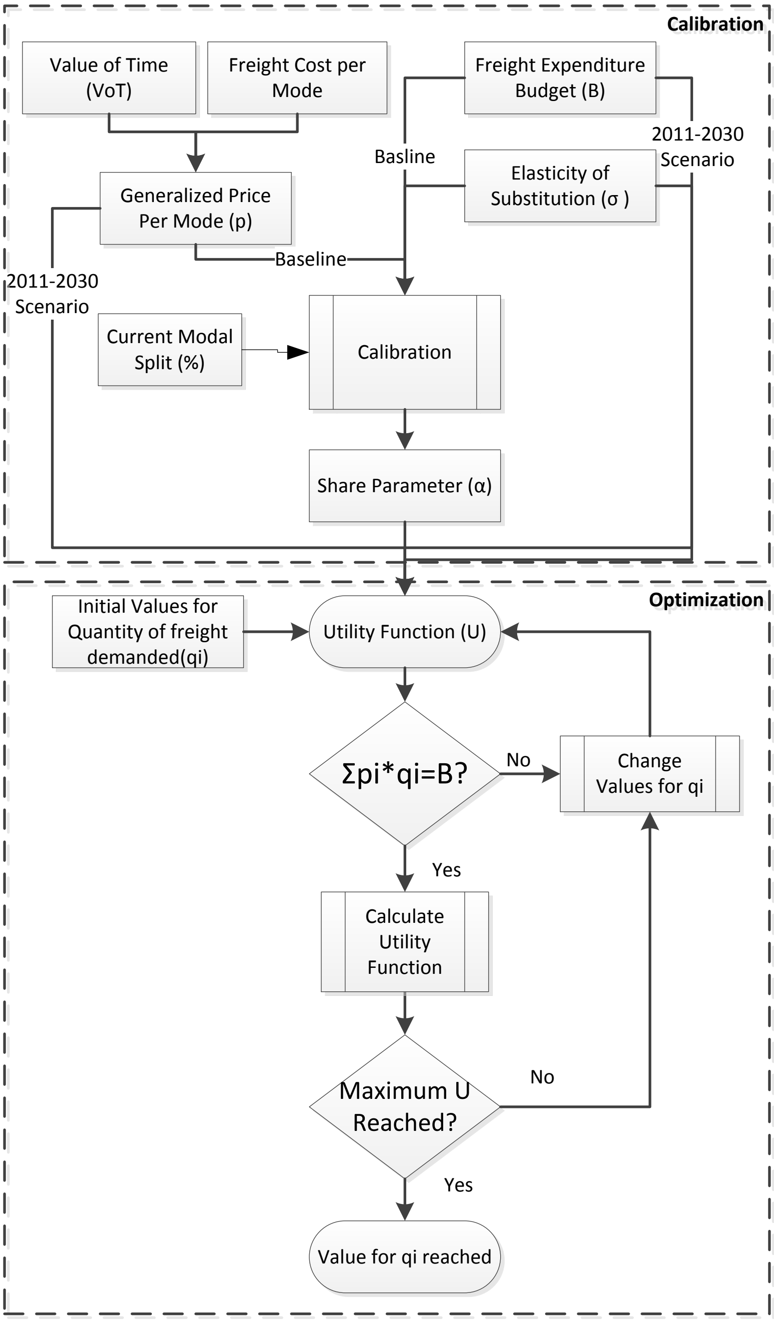


Figure 3 - 2011- 2030 Scenario Model Process Flow

In order to implement the optimization part of the model flow, excel solver was chosen and all the required links presented in the process flow were established.

As the model had now been developed, the next step was to evaluate it through a series of analyses. The evaluation started with the verification and validation. For this purpose, two series of tests were conducted: 1. Verification of intermediate simulation output and, 2. Historical data validation. The result of the former was used for the verification of the model and the results of the latter were compared with the actual data from Toyota for validation. As a result of these analyses, the tool was verified

Afterwards, the sensitivity of the tool was analyzed through conducting different “what-if scenarios”. In this analysis, (a combination of) the key variables influencing the value of the model’s parameters and inputs were first identified and their maximum potential variation during a year was estimated. Subsequently, each defined scenario was tested and the results were compared to the base case and the sensitivity of the variables was identified.

Another analysis was also conducted checking whether the tool provides consistent results as it is run with the different sets of input data. This analysis was performed since the model starts optimization regarding the initial values of the changing cells. Hence, for this analysis, the tool was operated several times with random initial values set for its changing cells. For each tested case, the difference between the solutions was small enough to be neglected. Hence, the tool was concluded to be robust.

After having evaluated the model, the next step was to execute the model. For this purpose, first, the baseline spreadsheet was executed using obtained data as input. For the baseline scenario, the following results were generated:

Baseline Freight Cost per Mode

In the generated results, it was shown that the cost of road freight had been increasing by approximately 24% since 2005. The cost for rail freight had been increasing by 24% under the same timeline. Short sea shipping cost had increase by an average of 27%.

Baseline Total Freight Expenditure

It was reported that between 2005 and 2011 only a 4% increase had been recorded in between 2005 and 2010. This could be tracked back to the financial crisis of 2007. Furthermore, road freight, has a 85% of total freight expenditure while rail freight and short sea shipping has a 6% and 9% share.

Baseline Freight CO_2 Emissions

CO_2 emissions were shown to have reduced by 6% since 2005. This was explained to be because of the reduction of freight activity as a result of the financial crisis. Furthermore, road freight has a 62% share of emissions while rail freight and short sea shipping have a 6% and 32% share.

After having executed the baseline spreadsheet, the next step was to determine the value of time. Through performing the stated preference survey with the representatives of each Toyota logistics group, the input data for the Biogeme software was attained. By running the software, the necessary data for estimating VoT resulted. The following results for VoT were estimated:

Table 1 - VoT per Logistics Group

Item	Value
β1	2.72E-05
β2	0.00301
VoT (€/hr)	110.66
VoT (€/hr/tonne)	0.135

Following this, the scenario spreadsheet was executed and the results were extracted. In order to execute the scenario spreadsheet, the first phase was to identify the input data for the scenario spreadsheet. According to the legislative tools defined to be present in each scenario, the input data were acquired based on the content of the tool. This was complemented by the rest of data which was acquired through adjusting to macro-economic trends (Inflation). The identified input data was then incorporated into the spreadsheet.

After having completed the execution of the scenario spreadsheet and the VoT analysis it was possible to combine the resulting information and executing the 2011-2030 scenario model. By doing this, the modal split and CO_2 emission for each logistics group and for each scenario could be estimated. The resulting values can be seen in Table 51.

Table 2 - Road Freight Share and CO_2 Emission Change

	Modal Split (Change in Road freight Share)			CO_2 Emissions (Reduction Compared to 2008)		
Logistics Group	**TPCE**	**PPLG**	**VLG**	**TPCE**	**PPLG**	**VLG**
Business as usual	-13%	-11%	-9%	-7%	-9%	+2.5%
Forced Modal Split	-30%	-30%	-30%	-13.5%	-22%	-12.5%
New Fuel and Tech Promotion	-18%	-19%	-18%	-23%	-31%	-2.5%
Taxation	-18%	-20%	-13%	-8%	-9%	+2.5%
Max Impact	-30%	-30%	-30%	-13.5%	-21%	-1%

The results presented in the table indicated that Toyota's logistics groups, in all cases, less the two marked ones, would not be reach the targets set by the EU in the white paper under normal conditions. This shows that reconsideration is needed in their current freight activities and that a long term strategy needs to be developed in order to enable a smooth transition towards aligning their activities with the targets set by the EU.

Keywords: White Paper on Transport, EU Freight, Freight Modal Split, Freight CO_2 Emissions, Freight Cost, Spreadsheet Modeling, Value of Time, Stated Preference Survey, Constant Elasticity of Substitution,

Table of Contents

List of Tables

List of Figures

I. Introduction

The transport of freight, ranging from raw material to finished products and goods, is vital for the economy and society. It enables the division of labour and economic growth. The future prosperity of the European continent depends on the ability of all of its regions to remain fully and competitively integrated in the world economy. Efficient transport is vital in making this happen (European Commission, 2007a).

The European Transport System[2] has provided a high degree of mobility with an ever increasing performance in terms of speed, comfort, safety and convenience. However, an in-depth evaluation undertaken by the European Commission has shown that, while several features of the transport system have improved in the last decade - notably its efficiency, safety and security - there has been no structural change in the way the system operates. The inability of past policies to modify the current transport pattern is one of the main causes of unsustainable trends: growing CO2 emissions, persistent oil dependency and mounting congestion (European Commission, 2011c).

As a result of said problems, the European Commission carried out an analysis of possible future developments of these problems of unchanged policies and based on the results defined a long-term strategy that would transform the EU transport system into a sustainable system by 2050 (European Commission, 2011b).

This Master thesis was formulated in order to conduct a research into the possible effects of future European regulations on the freight activities and will be combined with a case study on Toyota Motor Europe's supply chain. Hence, the study was conducted on site within the Toyota Energy Research Group (ERG). As a result of the proposed research, a model was developed which provided supply chain managers with a tool for studying and anticipating the effects of the European regulations on supply chains.

In the following section, first a background to the problem will be presented. This will then be followed by the definition of the problem at hand. Furthermore, the research scope and objective will be presented. Subsequently, the main research question will be introduced. Finally the structure of the report will be explained.

1. Background

In this section, initially, the problem sketch will be presented in order to explain what has initiated the study. This will then be followed by a brief description of Toyota Motor Europe and its motivation for conducting this research. Afterwards the problem definition and the research objective will be presented. Thereafter, the research scope, research question, and research type will be defined. Finally, the outline of the report will be presented

[2] The European Transport System: The free movement of individuals and of goods, by means of different modes of transport, within the European internal market with the goal to ensure sustainable development, maximize use of space, enhance safety and promote international cooperation (DG Move, 2011).

1.1 Problem Sketch

Enlargement, market liberalization and economic growth during the 90s contributed to the continuous increase of EU's energy consumption. During the same period the phase out of old power plants, improvements on energy efficiency and the uptake of renewable energy sources contributed to the decrease of CO_2 emissions in the region (Blesl et al., 2010). An illustration of the mentioned trends can be seen in Figure 4.

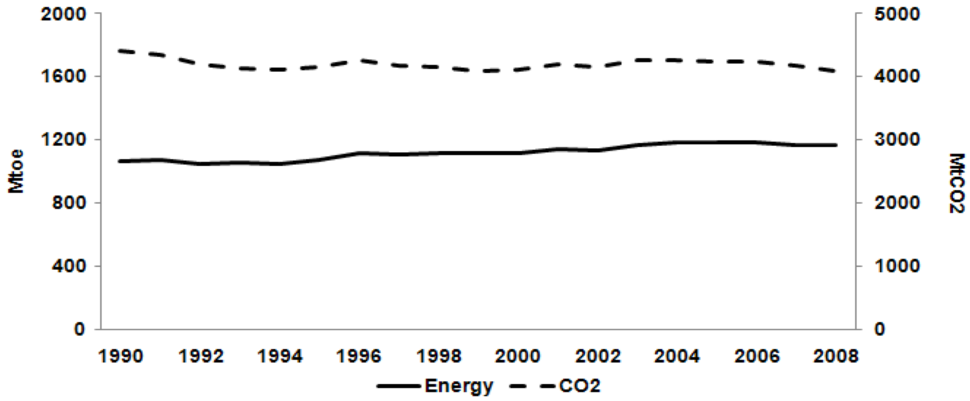


Figure 4- EU's energy and CO_2 Evolution (Blesl, et al., 2010)

Recent crisis in oil rich regions (i.e. Middle East & Northern Africa) have raised concerns about EU's energy security which in turns has created uncertainties within the energy market.

From an economic point of view The European Transport System, as previously defined, is a crucial sector within the EU economy. It ensures territorial cohesion, increases the EU's competitiveness, brings together people and cities, and allows the transport of goods through all member states. The European Transport System as can be seen in Figure 5 accounts for about 30% of EU's final energy consumption with a high dependence on imported oil (European Commission, 2010a). In addition the logistic industry generates a significant 15% of EU GDP (Harbour, 2011).

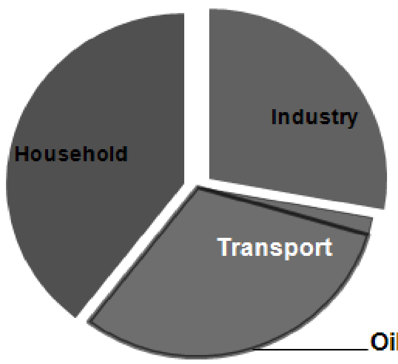


Figure 5 - EU's Final Energy Distribution (European Commission, 2010a)

However, since 1990, this energy consumption in transport has been increasing at an average annual growth rate of 1.6%. This rate is significantly higher that the increase of energy consumption in other sectors which during the same period increased by an annual rate of 0.5% (Lorne & Tchung-Ming, 2011). In addition, the European Commission has predicted a 50% increase of freight transport between 2000 and 2020 (European Commission, 2001).

The European Union now has the task of reducing the energy consumption in order to limit CO_2 emissions and to preserve Europe's energy independence while simultaneously maintaining economic stability. Thus far, the focus has been on passenger cars and light duty vehicles but the focus is turning towards heavy duty vehicles.

As a result of the mentioned issues, freight transport has raised a number of policy issues which will have to be addressed if its sustainability and efficiency are to be guaranteed. The issues can be summarized as the following:

- Congestion in the European transport system is having a negative impact on cost and time of transport and is increasing fuel consumption.
- Freight transport needs to be in line with EU's climate change targets.
- Freight transport is highly dependent on fossil fuel which is not in line with EU's oil independence policies.

These events have led to a shift of EU policies which has been reflected in the initiatives developed by the EU. One of the main initiatives developed by the EU was the White Paper on Transport: Roadmap to a Single European Transport Area which will furthermore be introduced:

1.1.1 The EU White Paper

The White Paper on Transport: Roadmap to a Single European Transport Area, which will further on be identified as the White Paper, was published on 28 March 2011 by the European Commission. Within this report, the Commission visualizes the path on which it expects to achieve a competitive and sustainable transport system for the future. The path is sketched upon the concept of "freedom of mobility" which is believed to be vital for the European internal market and the quality of life of its citizens. Hence, the Commission argues that in order to achieve these targets, ensured transport growth and continuous support for mobility is essential, however, with accompanying environmental conditions (European Commission, 2011b).

Following the notion that oil will become scarcer in the future and a recent statement by the International Energy Agency (IEA) that the less successful the world is in decarbonizing, the more problems will arise in the energy sector due to increasing oil prices (energy technology perspectives 2010, iea), the EU has called for a reduction of worldwide greenhouse gas (GHG) emissions by 80-95% below 1990 levels by 2050. Within the White Paper the Commission has determined that a reduction of at least 60% of GHGs by 2050 with respects to 1990 for the transport sector is required. Accordingly the White Paper argues that a reduction of circa 20% by 2030 with respects to 2010 levels will be needed to reach the desired long term targets (European Commission, 2011b).

In order to reach this goal a series of key subjects within the report have been touched upon that will directly and/or indirectly influence the future of freight.

1.2 Motivation for the Study

The cause for concern, which led to development of this research, was raised by the Energy Research Group (ERG) within Toyota Motor Europe and consequently, the ensuing study was undertaken on site and was supported internally by the different divisions within the company.

As previously mentioned, for the past decades, European regulation has been targeting passenger transport and light duty vehicles regarding CO_2 emission limits and energy consumption. The developments in this sector have closely been monitored by responsible divisions within Toyota in order to remain competitive within the industry in sustain the business. However, lately it had been observed that the attention of regulatory bodies was shifting towards monitoring and regulating freight.

Toyota utilizes freight to accommodate its vast European supply chain in order to support its manufacturing activities within the continent. As has been explained in Appendix A, Toyota Motor Europe follows its parent company's (Toyota Motor Corporation) manufacturing philosophy in relaying on lean manufacturing and just in time (JIT) delivery called the Toyota Production System (TPS). Hence, the company relies on the flexibility of its supply chain in order to be able to operate within the structures dictated by TPS. Thus, it can be concluded that the supply chain is an integral part of Toyota's business model and any influencing factor on its operation is closely monitored (Iyer et al., 2009).

Therefore, after the shift of EUs attention towards freight, the question was raised within Toyota concerning whether or not these recent developments would alter freight activities across Europe and subsequently affect Toyota's supply chain. Following this concern, investigation into this topic ensued which led to the development of this research.

The expectation of Toyota from the outcome of this study is to utilize it in their long term strategy and planning activities. In specific, the results will be integrated into their long term budget planning in order to anticipate radical changes in the cost of their supply chain operations. Furthermore, it will be used to develop long term strategies to enable a smooth transition towards aligning their activities with the targets set by the EU.

Further on, a brief introduction to Toyota Motor Europe and its European Supply chain operation will be presented.

1.2.1 Brief Introduction to Toyota Motor Europe

Based in Brussels, Belgium, Toyota Motor Europe NV/SA handles the wholesale marketing of Toyota and Lexus vehicles, parts & accessories, and manages Toyota's European manufacturing and engineering operations. Toyota first began selling cars in Europe under an official distributor agreement in 1963. Since then, the company has matured into the leading Japanese car manufacturer in this highly competitive market. Toyota has invested over €7 billion throughout Europe since 1990, and currently employs approximately 80,000 people, both directly and through retailer channels. Toyota's operations in Europe are supported by a network of 29 National Marketing and Sales Companies in 48 countries, a total of more than 3,000 sales outlets, and nine manufacturing plants. As an important player in Europe, Toyota continues to grow, both geographically and in terms of market (TME, 2011; TME Corporate Affairs, 2010). A detailed introduction to Toyota Motor Corporation and the Energy Research Group can be found in Appendix A.

1.2.2 Toyota Motor Europe's Supply Chain

TME's supply chain operations are based on the Toyota Production System philosophy. The operations are divided into three separate divisions (TME Corporate Affairs, 2010):

- Production and Logistics Control
- Vehicle Logistics Group
- Parts Supply Chain Group

Further on, a short description of each division will be presented.

1.2.2.1 Production Parts Logistics Group (PPLG)

This division distributes components from suppliers to Toyota's manufacturing sites for vehicle assembly. The components needed for production are sourced from suppliers within Europe and outside of Europe. The components are then distributed to the related manufacturing plants through extensive supply chain networks.

1.2.2.2 Vehicle Logistic Group (VLG)

The vehicle logistic group manages the import and export of new vehicles and customizes individual orders. The manufactured cars rolling out of the manufacturing plants, or entering the continent from plants outside of Europe, are transported to national marketing and sales companies (NMSC's) which are later distributed to local dealerships.

A schematic overview of the supply chain operation of the Production and Logistics control group and the Vehicle Logistic Group can be seen in Figure 6. The red arrows indicate Toyota's freight activities in across Europe and the world.

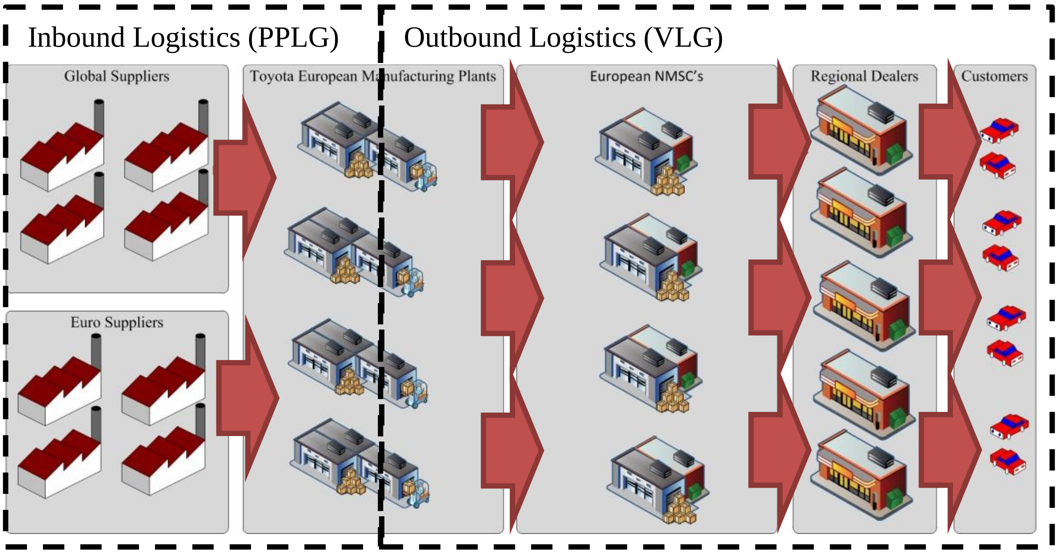


Figure 6 - Schematic of Production & Logistics Control group and Vehicle Logistics group Supply Chain

1.2.2.3 Toyota Parts Center Europe (TPCE)

This group manages the procurement, storage and distribution of accessories and spare parts for Europe. It holds the responsibility of ensuring the availability of parts for every vehicle that is on the road in Europe, regardless of age or origin. In order to achieve this, the group maintains relationships with all current and previous suppliers in Europe and co-ordinate the exchange of parts across Toyota's global after sales network. The parts are sourced from the suppliers and consolidated at the Toyota Parts Center Europe, located in Diest – Belgium. The parts are then shipped to the NMSC's across Europe and from there on to local dealerships. A schematic overview of the supply chain operation of the Part Logistics Group can be seen in Figure 7.

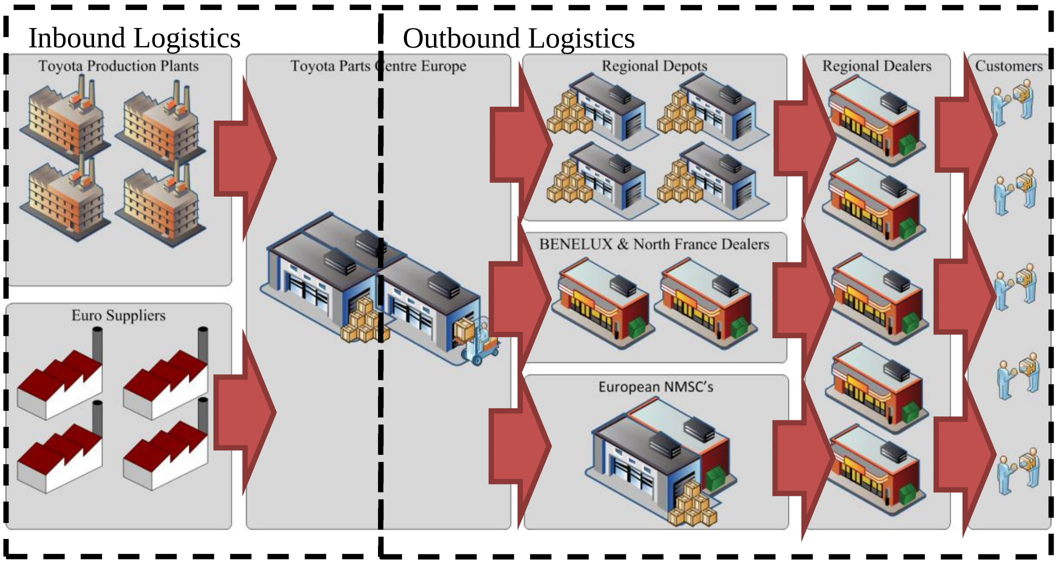


Figure 7 - Part Logistics Group Supply Chain Schematics

A summary of the operations of each one of the divisions can be viewed in Figure 8.

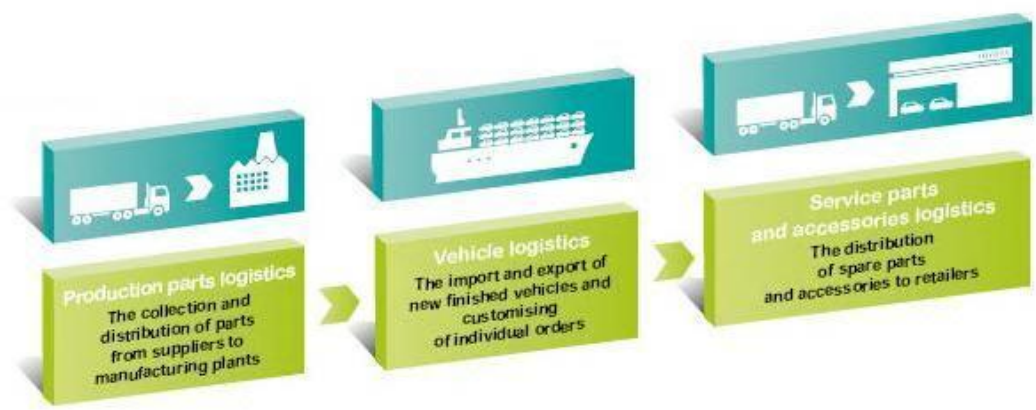


Figure 8 - TME Logistics Operations (TME Corporate Affairs, 2010)

2. Problem Definition

Based on the previously presented initiative and through the summary which can be seen in Figure 9 which is a summary of the legislative means implemented by the EU since 1998, it can be predicted that future regulations on emission performance will be focused on the freight industry. According to the evidence seen thus far, this new direction will demand changes in the industry. Studies have shown that logistics activities account for between 4% and 30% of companies' budget. Hence, any change induced by regulations imposed by the European Union will be of importance industries. As previously mentioned, the importance of these events is also evident for Toyota Motor Europe. Hence, any changes in the transport sector are of interest for Toyota.

Thus, the problem at hand can be defined as follows:

The effect of European regulations may influence the EU freight industry and create a changing environment. The effect of the changing environment may have the potential to cascade down and affect Toyota Motor Europe's business.

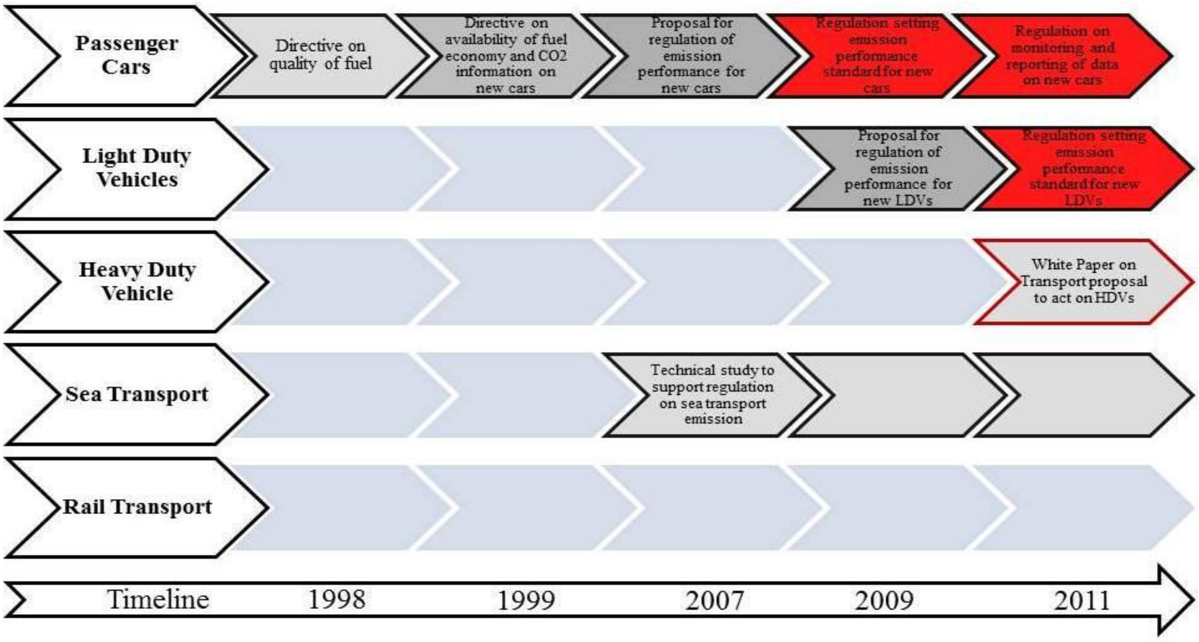


Figure 9 - Timeline of EU Regulation Development for Emission Performance

3. Research Objective

The main objective of this research is to study the effects of EU policies on the EU freight industry[3] with regards to developments in "freight costs" and "CO_2 emissions factors" and to further on, analyze the subsequent influence on the business of Toyota Motor Europe concerning its "modal split" and "total CO_2 emissions". More specifically, the policies proposed by the EU will be analyzed and the implications of these policies and their effect on different parameters effecting freight will be investigated on an EU level. Furthermore, based on this information a model explaining the relationship between freight and the parameters will be developed which will be followed by the development of a set of scenarios for the future of freight. Finally, through using the developed model, the future of freight activities in each of the scenarios for Toyota's supply chain will be explored.

4. Research Scope

The scope of the research will be limited to the following boundaries:

- The study will be done with an outlook towards the year 2030 (following ERGs year 2030 energy/fuel outlook (Desaeger, 2011)).
- The research will be isolated to the future changes in the EU freight industry. No study will be performed on the global freight industry.

[3] The European Transport System: The free movement of individuals and of goods, by means of different modes of transport, within the European internal market with the goal to ensure sustainable development, maximize use of space, enhance safety and promote international cooperation (DG Move, 2011).

- The changes in the freight industry that will be analyzed will be limited to changes influenced by new EU regulations effecting energy and emissions. Other influencing factors will not be analyzed providing they are not directly or indirectly related to the regulations.
- The case study will be limited to the supply chain of Toyota Motor Europe and no study will be performed on Toyota Motor Corporation's supply chain providing it is not directly connected to TME's supply chain.
- The study of TME's supply chain will be limited to inbound, outbound and service parts logistics. No study will be performed on the remainder of the supply chain (e.g. reverse logistics)

5. Research Question

Based on the research objective and the scope of the research, the main question which the outcome of the research intends to answer is:

"How will the targets, outlined in the EU White Paper, change European freight and to what extent and effect will Toyota Motor Europe's freight activities, with regards to modal split and total CO_2 emissions, be affected by the changes?"

6. Research Type

The study which has been performed can be described as a combination of an initial qualitative research performed gain sufficient insight into the problem, and a quantitative research performed to quantify the outcome of the qualitative research.

7. Structure of the Report

In the forthcoming report, it is intended to answer the posed research question. This will be performed throughout five main chapters

In chapter I, the background of the problem was explained in section 1. The underlying motivation for conducting the study was also presented in this section. In section 2 the problem was defined which was followed by the explanation of the research objective in section 3. In section 4 and 5 the research scope and question was introduced. Finally, the research type was defined in section 6.

In chapter II, the research sub-questions will be defined in section 1. The research framework and methods used for the study will then be explained in section 2. The theoretical frameworks for the study and the tools utilized for the study will then be introduced in section3.

In chapter III, a detailed analysis of the EU initiatives will be presented. Further on, the stakeholder analysis performed for the purpose of the study will be explained. In section 3, the main parameters identified will be introduced. Finally, the analysis of why each parameter was selected will be presented.

Chapter IV will focus on the development of the model utilized for answering the research question. In section 1, the baseline spreadsheet development steps will be explained. This will be followed by the detailing of the steps followed to construct the 2011-2030 scenario model. Finally, an overview of the developed model will be presented in section 3.

Chapter V will detail the evaluation process of the developed model. In section 1, the verification and validation process of the model will be explained. This will be followed by explaining the sensitivity analysis performed on the model. In section 3, the robustness analysis of the model will be presented.

In Chapter VI, the execution of the model will be presented. Frist, in sector 1, the execution of the baseline spreadsheet will be detailed. Further on, in section 2, the estimation of Value of Time for Toyota's logistics groups will be presented. Finally, in section 3, the 2011-2030 scenario model execution steps will be explained.

At this stage of the report, all the research sub-questions will have been addressed and hence, the main research question of the study will have been answered. Thus, the report will conclude with Chapter VII which will present the conclusion and recommendations of the study.

II. Research Methodology

In order to effectively conduct the study at hand, initially, the methodology intended to be used for the purpose of the study had to be defined. This chapter will focus on detailing this process. At first the research sub-questions accompanying the main research question will be explained. This will be followed by a detailed overview of the research framework used for the study. Finally, the theoretical framework of the study will be presented and explained.

1. Research Sub questions

In order to answer the mentioned question and gain a more in depth view into the future of European freight a series of sub question will need to be answered. These support questions will provide the research with means necessary to answer the main question:

1. What are the main factors and parameters influencing EU freight and how are they affecting it?

In order to understand how and to what extent the freight industry is influenced by external stimuli (i.e. the white paper) an overview of parameters (e.g. fuel price) which directly determines the direction of the industry is needed.

2. What is the current status of EU freight industry concerning the main factors and parameters?

As Toyota's supply chain is part of the European supply chain network, any change in the network would effectively influence the underlying chains. As the main goal of this research is to investigate the future of Toyota's supply chain, the current status and structure of the freight industry needs to be analyzed in order to create a reference.

3. How does Toyota Motor Europe currently operate within the freight industry?

In order to forecast the future of Toyota's freight activities, it is imperative to first gain an understanding of the current way the company is conducting freight activities.

4. How will the future of the European freight industry affect Toyota Motor Europe's freight activities?

In order to answer the defined sub-questions, a research framework had to be developed which would act as a guideline in the research activities. This framework will be presented in the following section.

2. Research Framework

The first step of developing the research framework was to define the conceptual framework for the research which has been illustrated in Figure 10. The conceptual framework, basically visualizes the research question within the context of the study. As can be seen, the current status of freight affects governmental (EU level and national level) policies. The governmental policies will influence the parameters effecting freight with the possibility of changing their appearance (e.g. taxation as a parameter will increase due to policies). The influence of policies on the parameters is mediated by the current status of these parameters. For instance, if the current status of parameter dictates that it cannot be further changed, it will not be influenced by the policies. Changes in the parameters effecting freight will directly sway the future status of freight. At the final step, the future status of freight will affect the future of Toyota future freight activities under the mediation role of the current status of the activities.

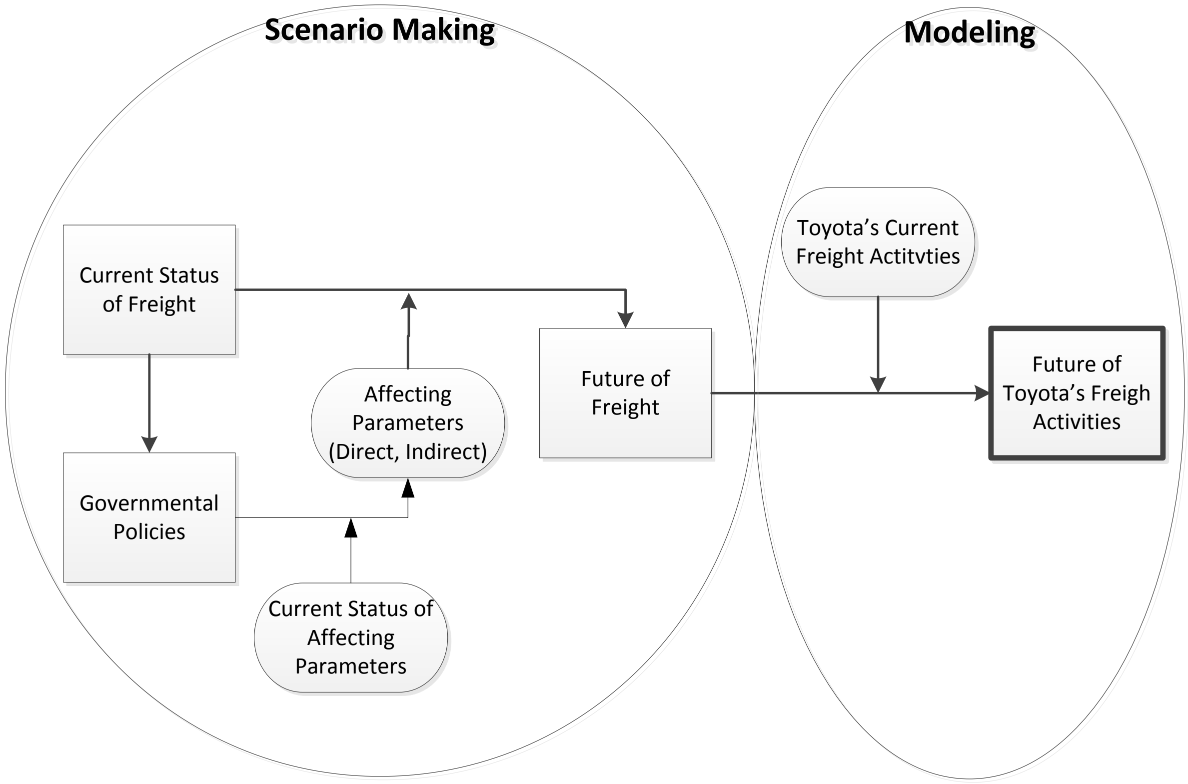


Figure 10 - Conceptual Framework

2.1 Research Methods

To facilitate answering the questions addressed previously, it is necessary to utilize proper research methods. The research methods which were used for this research were the following:

- Literature Review
- Direct Observations
- Stakeholder Analysis
- Qualitative interviews and Stated Preference Surveys
- Spread Sheet Modeling

A summary of the research methods which will be used for different parts of the research can be found in Table 3.

Table 3 - Summery of Research Methods

Methodology / Research Question	Literature Review	Direct Observation	Stakeholder Analysis	Qualitative Interviews and Survey	Modeling
What are the main factors and parameters influencing EU freight and how are they affecting it?	✓		✓	✓	
What is the current status of EU freight industry concerning the main factors and parameters?	✓✓	✓	✓	✓✓	✓
How does Toyota Motor Europe currently operate within the freight industry?	✓✓			✓✓	✓
How will the future of the European freight industry affect Toyota Motor Europe's freight activities?	✓			✓	✓✓

✓✓Primary research method
✓Secondary research method

Further on, each of these choices will be explained in detail:

2.1.1 Literature Review

In order to study all of the research sub questions, at first, an extensive literature review was conducted. For question 1 and 3 the literature review was focused on existing document provided by the European Commission and official governmental bodies with the addition of studies conducted on the EU freight industry. This provided the necessary insight and the sufficient data needed to understand the current status of EU freight and its influencing parameters. For the 3rd question, the available data for Toyota's freight activities was examined which provided a preliminary insight into the current status of their operation. Further on, in order to develop the model which was used to answer question 4 and 5, a review of literature on different modeling and simulation methods was required.

In the interest of this study and in order to understand the dynamics influencing the development process of the White Paper, the various actors with a vested interest in the issue and their level of involvement needed to be analyzed. In order to perform this analysis, a powerful tool namely stakeholder analysis was chosen. Following, a brief introduction to stakeholder analysis will be presented and the results of the analysis will be discussed.

2.1.2 Stakeholder Analysis

When studying the 1st and 2nd sub question, it was deemed essential to understand what attitude the stakeholders of the study had taken towards the parameters influencing freight. Such and insight would enable a more accurate identification of the main parameters which would fit the context of the study. In addition, it would also provide us with an overview of the current status of the parameters from the stakeholder's perspective. Hence, It was decided to conduct a stakeholder analysis which will further on, be explained.

2.1.2.1 Stakeholder Analysis Concept

In every project, program or policy development process various actors are involved who are committed to change the course of the development process towards their preferential outcome. Hence, it is of great importance to identify the actors which have the power to change the course of the process (Bourne & Walker, 2005).

During a stakeholder analysis, qualitative information are obtained and analyzed to determine the interest of which actors are to be taken into account. These actors have a vested interest in the policy being promoted. They may be internal or external to the process and their level of involvement may vary. According to Schmeer (1999) these actors can be grouped into the following categories:

- International/donors;
- National political;
- Public officials (i.e. Ministry of Finance);
- Labor (i.e. Unions);
- Commercial and private for-profit;
- Nonprofit (NGOs);
- Civil society
- Consumers.

2.1.2.2 Stakeholder Mapping

Stakeholder mapping is a powerful tool that can be used to help policy makers, managers and researchers to better understand priorities within the environment they are studying and can furtheron lead to more effective strategy making (Johnson & Scholes, 2001).

Various stakeholder mapping techniques have been developped within the context of policy making and project management. One of these techniques was devloped by Mendelow (1981) where he presented a model of environmental scanning where environmental dynamism and stakeholder power was included. The technique explores the power which the stakeholders posses relative to a policy, organization, or strategy. However, it also considers the fact that the stakeholders power is liable to change depending on how the environment influences the basis of the power. As can be predicted, the relevant factors of this model are power and dynamism where power ranges from low to high and dynamism from static to dynamic. These factors construct a grid where each of the stakeholder, depending on their carachteristics, can be positioned.

The model presented by Mendelow was later simplified by Johnson and Scholes (2001) where dynamism was exchanged with interest and as such a power/interest matrix was presented which can be seen in Figure 11. This table analyses how interested each stakeholder is to influence the outcome of the issue and whether or not they posses the power to do so.

Power		Level of Interest: Low	Level of Interest: High
	Low	A Minimal Effort	B Keep Informed
	High	C Keep Satisfied	D Key Players

Figure 11 - Stakeholder mapping, the power/interest matrix (Johnson, et al., 2001)

According to Scholes (1998) each of the stakeholders position and behavior can be described through their positioning within this table and can be generalized as follows:

A Stakeholders: Because of the lack of power and interest of this group of actors, they tend to be flexible and more likely to accept the direction and outcome of the situation. These stakeholders are classified as small stakeholders and are usually not asked to participate in the process.

B Stakeholders: The actors in this category tend to rally other actors to support the process. In addition, if the process tends to be unfacorable to their cause, they may stop joing forces with more powerfull actors. As a result of their influence, these group of stakeholders are kept in the loop of the process and recent developments.

C Stakeholders: This group of stakeholders have the potential to gain interest and shift towards D stakeholders if they are not kept satisfied. Hence, in order to prevent this shift, they are usually reasurred of the outcomes of the process well in advance.

D Stakeholders: These stakeholders have the ability to either act as major opponents or to be a major driver of the process. During the first steps of the process these actors should be assured of the necessity of change and further on asked for input regarding the implementation process.

Using this categorization and the Power/Interest matrix, and through analyzing the gathered information about the stakeholders, it was possible to accurately position each of the identified stakeholders within the matrix.

2.1.3 Direct Observations, Qualitative, non-Directive Interviews & Stated Preference Survey

When studying the 1st, 2nd, and the 3rd sub questions qualitative interviews were used and direct observations was specifically used when examining sub question 2. As observation is one of the most fundamental methods in research (Adler, 1994) the information gathered from this method was the backbone of understanding Toyota’s freight activities. These two research methods were executed in parallel and were complementary to each other. More specifically, the results obtained from each of the methods provided information which was used while conducting the other one. For instance, a specific observation within Toyota’s supply chain would raise questions which were asked during the interview with the specialist in the field and vice versa. For the qualitative interviews, experts in the respective field from Toyota were consulted. For the direct observations, key locations within

Toyota's supply chain was observed and studied. One of these locations, for instance, was Toyota Parts Center Europe in Diest, Belgium.

Both interviews and observations have some specific drawbacks. For instance, employees may not answer the questions truthfully, or some issues needed for the research may not be observed. But the combination of these two methodologies prevents these drawbacks to materialize as they complement each other.

The reasons why qualitative interview is chosen for this research is fourfold. First, all people to be interviewed are professionals in their own field and hence, they are able and willing to devote a certain amount of time for this research. Second, the needed information is from a new field both for the researcher and the application of the information is new for the company. Third, in a qualitative interview, answers to questions might need clarification or might lead into new questions. And finally, the interviewees are subjects and will have the chance to provide their point of view (Yeung, 1995).

The type of interview that was used for the study was unstructured interviews. The motivation for using this type is that it is more flexible. As the interviews will not be identical and will be done in the form of a discussion regarding the study, there will be no need to follow a detailed interview guide. This will encourage the interviewees to speak openly and give as much detail as possible. The interviews will be conducted with specialists from the relevant Toyota stakeholders of the study (Zhang. & Wildemuth., 2009).These stakeholders include:

- Toyota Parts Center Europe (TPCE)
- Toyota Motor Europe vehicle logistics group (VLG)
- Toyota Motor Europe parts logistics group (PPLG)

In addition, a State Preference survey was performed with the different groups for the purpose of the 3rd and 4th sub-question. This procedure will be explained in detail when the theoretical framework is introduced.

2.1.4 Modeling

Models are tools which are widely employed in decision making (Davis & McCuen, 2005). A model is a similar representation of a system but at the same time simpler than the original which is used to gain more insight into the behaviors of business processe (Ciochetto et al., 2005). Among the purposes of developing models is to enable the researched to predict the results of chnages in the original system. A model should be include the the salient future of the system to the highest degree without compromising the simplisity of it. The model should hence be devised in souch a way that it is a tradeoff between realism and simplicity (Maria, 1997). The type of model selected for conducting this study was a spreadsheet modeling. This will furtheron be explained in detail.

2.1.4.1 Spreadsheet Modeling

Various modeling techniques have been defined in scientific literature. However, according to Smith (2003) Spreadsheet models are effective tools that can be used to analyze transport activities. These tools have the ability to reflect the different perspectives of the involved actors and can be modified to display different situations. This type of model is generally used to analyze the impact of internal and external factors on different parameters such as cost, productivity and investment. The use of these tools has increased substantially in the last two decade driven by the need to better understand the dynamics of transport. Following this logic, it was determined to utilize a "spreadsheet model" for the purpose of this study.

In developing a spreadsheet model a baseline model is developed as a first step to reflect the current status which is followed by the development of scenarios which are later compared with the baseline. In general, in order to develop the spreadsheet model, a series of predefined steps are to be taken. According to Monahan (2000) five stages can be defined in the development of a model-based decision making project:

1. **Problem Formulation:** The problem at hand has to be carefully defined and the different stakeholders and their level of involvement need to be determined. Based on the problem definition a clear objective needs to be identified. This step was previously explained in Chapter I.
2. **Model Development:** In this step the actual model needs to be detailed. This specification will consist of the mathematical relationships between the relevant variables. It may also include steps that need to be done in order to complete activities related to the model development and rules related to the sequencing of the activities. This step will be explained in Chapter III.
3. **Determining the Results:** Depending on the type of model developed, this can be performed through finding an optimal solution using the developed model. This step should present the best solution, or at least not worst, among other available solutions. The solution can also be qualitatively defined based on the outcome of the developed model.
4. **Evaluating and Testing the Solution:** The final solution offered by the model needs to be evaluated as it is of great importance to understand why a particular solution is better than other solutions. It can be argued that final objective is not to solve the problem but also to gain insight into the problem and understand the solution. This step along with step 3 will be presented in Chapter IV
5. **Implement the Solution:** The final output of the model needs to be implemented in the environment where the problem was initially defined. This step of the modeling process cannot be generalized as it depends on the properties of the problem environment. This step will be introduced in Chapter V.

The interrelationship between each of the presented steps has been illustrated in Figure 12.

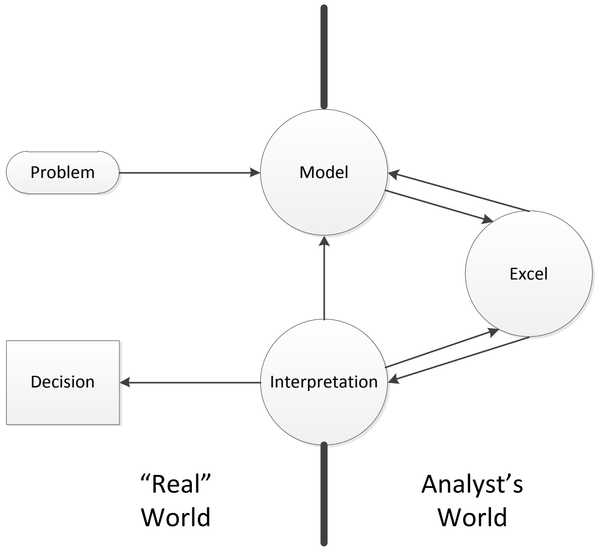


Figure 12 - Model Development Steps (Monahan, 2000)

3. Theoretical Framework

In order to develop the spreadsheet model which would be utilized in this study a series of steps was outlined. These steps were followed in a sequential order which resulted in the final spreadsheet model. The development process has been illustrated in Figure 13. As can be seen, the total process has been broken down to two separated sections: 1. the baseline Scenario Spreadsheet Construction, and 2. the 2011-2030 Scenarios Spreadsheet Construction. In the final step the result of these two sections are consolidated into the final spreadsheet model. For each of the mentioned sections the following steps needs to be accomplished:

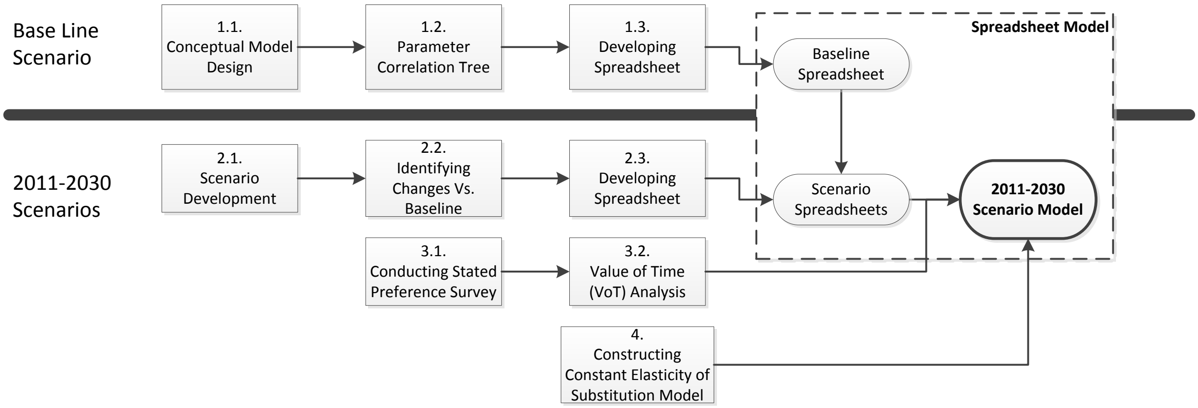


Figure 13 - Spreadsheet Model Development Steps

Baseline Scenario

For constructing the baseline scenario spreadsheet, the first step was to design the conceptual (mathematical) model using the information gathered from studying the European freight industry. The second step was to use the conceptual model in order to develop “Parameter Correlation Tree (PCT)”. In the third step, by using the information provided from the PCT, it was possible to develop the relationships within the spreadsheet which finally enabled the development of the baseline spreadsheet.

2011-2030 Scenarios

For the scenario spreadsheet, the first step was to develop the relevant scenarios. In the second step, by using the scenarios, it was possible to determine the changes in the parameters compared to the baseline. Using this information and utilizing the baseline spreadsheet interrelations, it was possible to develop the scenario spreadsheet.

Next, a stated preference survey was conducted at Toyota Motor Europe which was used to estimate Value of Time (to be explained later).

Finally, a constant elasticity of substitution (to be explained later) was developed. Through combining the output of the scenario spreadsheet, the Value of Time analysis, and the constant elasticity of substitution model, the final scenario spreadsheet was constructed.

In the following sections, the tools utilized in order to accommodate these steps will be presented.

3.1 Utilized Tools

In order to construct the model through following the steps introduced in the theoretical framework, a set of tools were needed. The tools utilized were the following:

1. Scenario Development;
2. Value of Time Analysis (VoT);
3. Constant Elasticity of Substitution Analysis (CES).

In this section, these tools will be introduced and their scientific concept will be explained.

3.1.1 Scenario Development

One of the tools that are available in business and politics for strategic long term planning is scenario development. This tool has the ability to capture future developments in rich detail and can be used to compensate for decision making inaccuracies. According to Schoemaker (1995), the main motivation for developing scenarios is to compensate two common errors, namely, under and over prediction of change. Most policy makers and corporations tend to under predict future changes which can cause inaccurate long term strategic planning. Hence, scenario development offers a solution in between under and over prediction which effectively helps to expand the range of accessible possibilities. Scenario development accomplishes this by dividing our knowledge into two areas:

1. Things we believe we have knowledge about and
2. Elements of our knowledge we consider uncertain or unknowable.

There are various scenario development techniques available which can be used for the purpose of studies similar to the one at hand. However, considering the context of this study, the technique which will be utilized is a scenario development process used by General Electric to perform environmental analysis. Georgantzas and Acar (1995) offer a detailed analysis of the necessary steps of this process. The different steps can be seen in Figure 14.

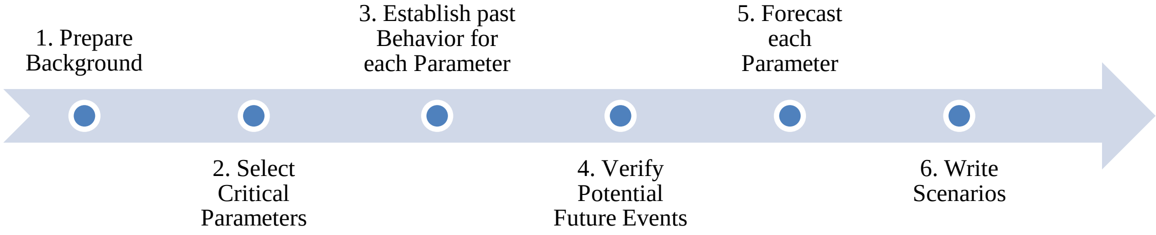


Figure 14 - General Electric's Scenario Development Process for Environmental Analysis

Through following the mentioned steps, the scenarios for freight in 2011-2030 were developed. These scenarios will be presented and discussed in the Chapter IV.

3.1.2 Value of Time Analysis

The next tool utilized for constructing the model was Value of Time (VoT) Analysis. Studying and analyzing VoT is of great importance for freight policy and planning application. The reason for this importance can in short be explained in that it is a tool which enables the study of the attractiveness of transport modes (Tavasszy & Meijeren, 2011). VoT can be used as a tool for justifying investment in infrastructure for the freight industry through the quantification of the benefits to society, including reduction of greenhouse gas emissions. The quantification process, as can be seen from this study, is a complex procedure. To develop a single quantifiable overall figure, all freight components need to be decoded into a single unit which in the case of this study is a monetary currency. When analyzing the freight industry, travel time and the effect it has on decision behavior is of great importance. Because of the qualitative nature of the effect of travel time, VoT concepts can be used to quantify the effect and convert it to a monetary currency (Antoniou et al., 2007).

As described, VoT is an important aspect of freight planning and infrastructure management. However, it is a very unpredictable measure that depends on numerous parameters and varies between regions and industries. In addition, because of its latent theoretical construct it is not easy to quantify or measure VoT (Antoniou, et al., 2007).

At least four different approaches have been used in the past to determine VoT for freight (Kawamura, 1999). They are:

1. The cost savings method, which is centered around the cost savings to freight operators per unit of time
2. The revenue method, which estimates the net increase in profit due to reduced travel times
3. The Cost-of-Time savings method which estimates the cost of providing time savings for a specific project
4. The willingness to pay method, which measures the perceived value of time from observed or stated choices under trade-off situations involving time and money.

However, recently it can be observed that the willingness to pay method has become the prevailing method of choice for researches when estimating VoT. In the past decades several studies in Europe has been conducted using this method. Some of these studies include VoT study for the Netherlands (Gunn H. & Rohr, 1996), Sweden (Alger et al., 1996) and Switzerland (Axhausen et al., 2004).

Through a more detailed analysis of these studies it can be established that discrete choice modeling is mostly used when applying the willingness to pay method. Due to practical reasons, most studies use logit models. In terms of input data, the studies use stated-preference data which is due to the difficulty of obtaining revealed preference data. Hence, for the purpose of this study, it was decided to utilize these techniques which will further on be explained in detail.

3.1.2.1 Discrete Choice Model

Discrete choice modeling is a useful tool for analyzing and forecasting the outcome of any given decision making process. This technique can be used in numerous different situations as behavioral responses have a discrete and qualitative nature. Similar to most econometric modeling tools, the importance of discrete choice modeling is in its ability to predict the decision making behavior of a group of individuals (Ben-Akiva & Lerman, 1985).

Discrete Choice Modeling Theory

In the context of freight travel time, the methodological tool mainly used for analyzing freight operator’s behavior is discrete choice modeling (Ben-Akiva, et al., 1985). The models used in practice are based on the random utility theory (RUT) which assumes that individual preference of freight operators can be explained by a deterministic part of utility, V_{ij}, and a stochastic component, ε_{ij} (Koppelman & Bhat, 2006), the random utility specification in the case of respondent i choosing among j alternatives is expressed in Equation 1:

Equation 1 $$U_{ij}(choice\ j\ for\ individual\ i) = V_{ij} + \varepsilon_{ij}$$ *j=1,....,J*

The systematic component is assumed to be the part of utility contributed by attributes that can be observed by researchers, while the random component is the part of utility contributed by attributes unobserved by researchers. The observed part of systematic utility V_{ij} is a function of "attributes in the alternative" and "characteristics of the decision maker". The attributes in the alternative is represented by X and the characteristics of the decision maker is denoted by a vector β (Ben-Akiva, et al., 1985):

Equation 2 $$V_{ij} = \sum_{k=1}^{K} \beta_i X_{ik}$$

Utility maximization theory assumes that a freight operator chooses the alternative that yields the highest utility level. This leads to the following random utility model:

Equation 3 $$\Pr[U_{ij} > U_{il}] = \Pr[(\varepsilon_{il} > \varepsilon_{ij}) < (V_{ij} > V_{il})]$$ **For all j≠i**

The empirical specification of V_{ij} is crucial to modeling freight operator's choice behavior due to the fact that the utility function not only reflects individual's decision making process but also determines the predictive capability of the choice model. The most extensively used model in transportation studies is the Multinomial Logit (MNL) model, which assumes that the random terms are autonomously and identically distributed. Under these assumptions, the choice probability for respondent i to choose alternative j become:

Equation 4 $$\Pr[Y_i = j] = \frac{\exp(V_{ij})}{\sum_{l=1}^{J} \exp(V_{ij})}$$ **where** $V_{ij} = \sum_{k=1}^{K} \beta_i X_{ik}$

This model can be solved by using maximum likelihood estimation method. The log likelihood function is given as:

Equation 5 $$\log L = \sum_{i=1}^{n} \sum_{j=1}^{J} d_{ij} \log \Pr[Y_i = j]$$

d_{ij} is defined as the choice proportion distributed by the respondent i to alternative j in each choice profile, and we have $\sum_j d_{ij} = 1$ under each choice profile (Greene, 2003).

3.1.2.2 Value of Time Estimation Process

In order to be able to estimate VoT, the following steps needs to be followed:

1. Developing Stated Preference Survey
2. Value of Time Estimation

Furthermore, these steps will be presented.

1. Developing the Stated Preference Survey

In order to obtain the necessary data for estimating the Value of Time, it was imperative to conduct a survey with the employees of Toyota Motor Europe's logistics departments. Hence, the first step of the Value of Time Estimation process was to develop a suitable survey which would enable the acquisition of the necessary data. In order to find a suitable survey technique for this purpose, initially a review of the concept was needed. Further on, a description of the survey design concept will be presented

Survey Design and Administration

The input data for the discrete choice model may either be revealed-preference (RP) or stated-preference (SP) data. Revealed-preference data represent the actual behavior of decision makers and can be acquired through field studies and existing data. Stated-preference data represent the behavior of decision makers in hypothetical situations which can be acquired using stated-preference surveys. Apart from practical reasons, the motivation for using stated preference is the ability to gain insight into nonexistent alternatives or alternatives where revealed-preference data is limited (Antoniou, et al., 2007; Louviere et al., 2000)

In order to obtain the data an acquisition technique is needed. Hence, a description of data acquisition techniques will follow.

Data acquisition Techniques

Numerous techniques for obtaining data based on the preference of decision makers exist. All of these techniques in principle assume that a service can be described in terms of the attributes of said service and the level of the attribute. Hence, the focus will be on the value that decision makers place on the attributes. For this purpose the respondents are given a set of mutually exclusive and multi-attribute alternatives and are asked to evaluate and choose one alternative they prefer (Accent & RAND Europe, 2010).

These data acquisition techniques can be categorized into four groups, which reflect differences in theoretical assumptions, analysis techniques and experimental design procedures (Adamowicz & Boxall, 2001; Bateman et al., 2002; Kjær, 2005)

- Discrete choice or stated-preference survey
- Contingent ranking
- Contingent rating
- Paired comparisons

By utilizing the information presented in this section, it was possible to design the required survey for the study.

2. Value of Time Estimation

In order to analyze the obtained data from the surveys and estimate the Value of Time, the theoretical knowledge previously presented had to be fine-tuned to the context of the study which will now be explained.

In the context of freight Value of Time estimation, transport time and transport cost elements are of importance to the freight operators' decision behavior. Accordingly, the utility function supporting this characteristic will be as follows (Yen et al., 2005):

Equation 6 $$U = \beta_T . T + \beta_C . C + \beta_0$$

Where T denotes the travel time and C gives the travel cost and β_T and β_C are the coefficients of time and costs which needs to be estimated in order to evaluate Value of Time. These coefficients will be estimated through the multinomial logit model previously introduced.

These coefficients capture the sensitivity of the decision makers' utility towards changes in transport time and cost. Consequently the ratio of these coefficients can capture the trade-off between travel time and travel cost. We can hence define the Value of Time for freight as:

Equation 7
$$VoT = \frac{\beta_T}{\beta_C}$$

In order to estimate the value of β_T and β_C, it was decided to use a commercially available software package. The software package which was chosen for the task was Biogem.

3.1.3 Constant Elasticity of Substitution (CES) Analysis

The next tool which was utilized for the purpose of developing the final scenario model was Constant Elasticity of Substitution Analysis (CES). Before explaining the underlying concept of CES a brief background on why it was selected will be presented.

3.1.3.1. Background

One of the main goals of this study was to estimate the future modal split for each of the Toyota Motor Europe's logistics groups. Up until this step, the cost data for the different modes could be obtained through the scenario spread sheet. Furthermore, the Value of Time for the logistics groups was established through the VoT analysis. However, the availability of this information would not enable the prediction of future modal split. Hence, an additional tool was needed which could accomplish this task.

At first, in order to provide consistency, it was decided to utilize multinomial logit (MNL) which had previously been used for estimating VoT. By using the MNL concepts previously introduced, the tool was constructed. Through using the data obtain during the VoT analysis (based on stated preference data), the preference and future tendencies of Toyota's logistics groups were integrated into the tool. In addition, in order to integrate their historical tendencies, it was decided to acquire revealed preference (RP) data. However, when trying to obtain this information from the logistics group, it was discovered that because of internal policy reasons, they were not able to provide the requested data. Therefore, when testing the validity of the tool with actual data, it was discovered that it did not reach the required level of validity and hence was not validated.

Following this setback, it was decided to use Constant Elasticity of Substitution (CES) analysis for developing the tool. This concept has previously been utilized in various studies and has proved to be effective in the development of transport-environment models. Some of the studies utilizing CES which can be named are the following:

- Assessing policies towards sustainable transport in Europe: an integrated model (Zachariadis, 2006);
- COMPASS: The COMPetitiveness of EuropeAn Short-sea freight Shipping compared with road and rail transport (Eef Delhaye et al., 2010);
- The PLANET Model Methodological Report: Modeling of Short Sea Shipping and Bus-Tram-Metro (Gusbin et al., 2010)

- TREMOVE – A Policy Assessment Model to Study the Effects of Different Transport and Environment Policies on the Transport Sector for all European Countries (Ceuster et al., 2007).

Through using CES, it was possible to integrate future tendencies of Toyota logistics group through using generalized price, which consists of the sum of price and VoT, as an input to the tool. In addition, through using historic modal splits, which was available, historic tendencies could also be integrated.

In the following section, initially an introduction to the constant elasticity of substitution analysis will be presented which would be followed by a description of how the constant elasticity of substitution model was constructed.

3.1.3.2 Constant Elasticity of Substitution Theory

The Constant Elasticity of Substitution function was developed by the Stanford group around Arrow, Chenery, Minhas, and Solow (1961) and has in recent years gained in importance in econometric analyses where it has replaced the so-called Cobb-Douglas function (Douglas & Charles W. Cobb, 1928). Where the Cobb-Douglas function restricted the elasticity of substitutions used in the model, CES allows any non-negative constant elasticity of substitution. Hence, CES can be described as a generalization of the Cobb-Douglas function (Henningsen & Henningsen, 2002)

For the purpose of freight modeling, the use of Constant Elasticity of Substitution Function has several advantages (Eef Delhaye, et al., 2010):

- Assuming a constant value for the elasticity of substitution is realistic for moderate changes in demand levels relative to the baseline value
- The CES function can be easily calibrated using a minimum amount of available data.
- They are a consistent aggregate of discrete choice behavior when the number of decision makers is sufficiently large. As previously mentioned, discrete choice behavior is a method utilized when choices between mutually exclusive alternatives are modeled, as is the case with freight.

The CES utility function has the following form:

Equation 8 $$U = [\sum_{i=1}^{n} \alpha_i^{\frac{1}{\sigma}} q_i^{1-\frac{1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$$

Where U represents utility, q shows the quantity of different services provided, α is a share parameter and σ denotes the elasticity of substitution. i stands for the different services or products that affects utility. In the context of freight, the different services represent different modes of transport.

The quantity is estimated through the maximization of Equation 8, subject to the budget constrains presented in Equation 9 and with the availability of the share parameter and elasticity of substitution.

Equation 9 $$B = \sum_{i=1}^{n} (p_i q_i)$$

Where P_i represents the generalized price of each mode of transport, and B represents the total annual budget spent on freight. The generalized price consists of the sum of the actual price of the specified mode and the Value of Time (VoT).

3.1.3.3 CES Calibration

Assuming a nested utility tree with *l* levels as shown in Figure 15, the solution of the optimization problem presented in the previous section will be of the following form:

Equation 10

$$q_{i,l} = \frac{B}{p_{i,0}}\left[\alpha_{i,l}\left(\frac{p_{i,l-1}}{p_{i,l}}\right)^{\sigma_{l-1}}\right] \times \left[\alpha_{i,l-1}\left(\frac{p_{i,l-2}}{p_{i,l-1}}\right)^{\sigma_{l-2}}\right] \ldots \left[\alpha_{i,1}\left(\frac{p_{i,0}}{p_{i,1}}\right)^{\sigma_{0}}\right]$$

By using existing data on current modal split and generalized price in Equation 10 the function parameter $\alpha_{i,l}$ can be calculated to exactly reproduce the baseline conditions. Through this process the CES functions will be calibrated and can be further used in simulations for various scenarios.

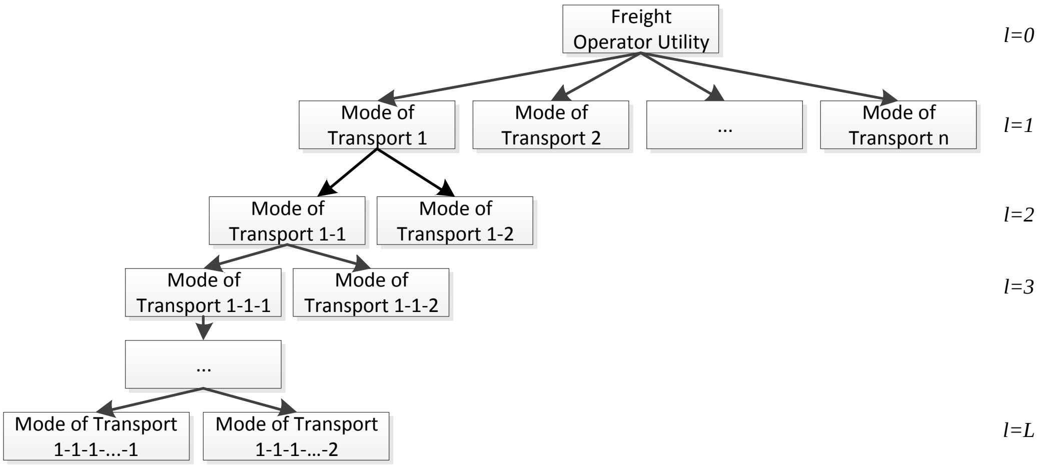


Figure 15 - Nested Utility Tree with *l* Levels

After having introduced the research methodology in detail, in order to develop the model it was first essential to analyze the environment resulted from the publishing of the White Paper. This would enable the identification of the main parameters influencing freight. In the next chapter this process will be explained.

III. Analysis of the Environment

In order to develop the model which would be utilized for the study, at first, the main parameters influencing freight had to be identified. In order to do so, a complete understanding of the white paper, the accompanying initiatives, and subsequently the environment created by the publishing of them was needed.

In this chapter, an overview of the mentioned analysis and the identification of the parameters will be presented. At first, a detailed analysis of the EU initiatives will be introduced. This will be followed by the explanation of the stakeholder analysis performed for the purpose of creating an understanding of the environment of the study. Finally, the parameters will be introduced and analyzed.

Thus, the chapter will answer the first sub-question of the study which is:

What are the main factors and parameters influencing EU freight and how are they affecting it?

1. Analysis of the EU Initiatives

Before determining the most influential parameters it was of importance to analyze the content of the main initiatives proposed by the EU. Gaining an accurate overview of the content of the initiatives will enable the identification of the influencing parameters. In the following section, this overview will be presented.

1.1 The White Paper

A initial analysis of the White Paper shows that 40 concrete initiatives for the next decade has been suggested for building a competitive transport system that will increase mobility, remove major barriers in key areas and fuel growth and employment. Simultaneously, the proposals intends to dramatically reduce Europe's dependence on imported oil and cut carbon emissions in the transport sector (European Commission, 2011b).

Deviating from previous editions of the White Paper, where the transport industry is addressed as a whole this edition specifically discusses the European freight industry.

Analyzing the White Paper further in detail shows that the major points which the white paper focus on and which would directly/indirectly influence the freight industry are the following (European Commission, 2011b):

Truck technology and efficiency

- Halve the use of "conventionally-fuelled" cars in urban transport by 2030; phase them out in cities by 2050
- Low carbon sustainable fuels in freight in order to reduce CO2 from freight by 2050

Promotion of intermodal transport

- 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050.
- Better modal choices through the integration of modal networks

Optimize the performance of multimodal logistic chains

- Development of appropriate infrastructure in order to increase efficiency of the chains
- Deployment of a fully functional and EU-wide multimodal trans-European transport network (TEN-T) core network by 2030

Internalization of GHG cost (Fuel taxation, Road pricing)

- Move towards full application of “user pays” and ”polluter pays” principle and private sector engagement to eliminate distortions

1.2 The Accompanying Initiatives

Apart from the White paper on transport which directly tackled the European Transport System, other initiatives to reduce emissions have also been introduced that have also included the Transport System in their targets. In the following section these initiatives will be briefly presented.

1.2.1 Europe 2020 Strategy

In the past decades the European Union has faced a series of structural problems, namely lack of growth and productivity, inadequate participation of the population in the labor market, rather incomplete accommodation of the constraints linked to ageing. Whilst these problems have yet to be solved, new complications are arising for the continent. Competition from emerging economies and climate change dilemmas are among the new challenges which the EU will have to face. In addition, the financial crisis of 2008, which distressed the financial institutions across the continent, impaired past attempts of addressing these challenges and further propagated the effect of the mentioned challenges (Heuse & Zimmer, 2011). Within this context and with an emphasis on strengthening the EU, the Europe 2020 strategy was devised and endorsed by the European Council in June 2010.

Through analyzing the content of the strategy it can be established that the main focus is to turn the EU into a “smart, Sustainable and inclusive” economy. In detail the three mutually reinforcing pillars of this strategy are:

- **Smart growth:** developing an economy based on knowledge and innovation.
- **Sustainable growth:** promoting a more resource efficient, greener and more competitive economy.
- **Inclusive growth:** fostering a high-employment economy delivering social and territorial cohesion

These strategies in turn are broken down into seven flagship initiatives which each formed a subject of a communication from the commission (Heuse, et al., 2011).

One of the flagship initiatives is the "Resource efficient Europe" Initiative which partly addresses transport. According to the Commission this initiative intends *“to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernize our transport sector and promote energy efficiency” (European Commission, 2010b).*

The purpose of this initiative is partly to present a vision to modernize and decarbonize the transport sector thereby contributing to increased competitiveness. Some of the measures considered are early deployment of electrical mobility, better logistics and pursuing the reduction of CO_2 emissions for the transport sector through the development and promotion of new technologies (European Commission, 2011a).

Within the initiative, a set of key components have been outlined in the form of a series of coordinated roadmaps. For the purpose of transport the following components are mentioned (European Commission, 2011a) :

1. Present a vision for a low-carbon, resource-efficient, secure and competitive transport system by 2050 that removes all obstacles to the internal market for transport, promotes clean technologies and modernizes transport networks
2. Proposals to reform the energy infrastructure and trans-European networks for transport in the context of the next EU budget to align these areas with the requirements of a resource-efficient, low-carbon economy;

1.2.2 The European Climate Action and Renewable Energy Package

In March 2007, the European Union stepped up its energy and climate change ambitions to a new level and endorsed an integrated approach aiming to reduce GHG emissions and increase the penetration level of renewable energy sources. The main motivation for this package was the transformation of EU into a highly energy-efficient and low-carbon economy. To initiate this process, EU heads of states and government officials set a series of climate and energy targets to be met by 2020 (European Commission, 2008b). In January 2008 the commission published these targets in the form of the "European Climate Action and Renewable Energy Package". The targets can be summarized as follows (European Commission, 2008a):

- 20% reduction of GHG emissions below 1990 levels;
- 20% share of renewable energy sources on final energy consumption, with a mandatory objective of 10% biofuel for the transport sector
- 20% reduction in primary energy consumption compared with projected levels, to be achieved by energy efficiency.

According to the impact assessment prepared by the Commission, In order to achieve the 10% biofuel share on final energy consumption, significant investments would be crucial. However it is argued that this investment would result in substantial reduction in oil imports and reduction of greenhouse gas emissions (European Commission, 2008a).

So far the biofuel target for transport has shown to be the most controversial part of the European Climate Action and Renewable Energy Package. An internal report by the Commission warns that the targets would cost European taxpayers €33 – €65bn between now and 2020 (O'Brien & Robinson, 2008). In addition, a report from the Commission states that using biofuel produced by European manufacturers is not a cost-efficient solution for reducing greenhouse gas emissions (European Commission, 2006b).

Through an in depth analysis of the content of the EU initiatives, specifically the EU White Paper on Transport, it can be established that the initiatives are seeking to achieve improvements with regards to the Modal split and Greenhouse gas emissions.

2. Stakeholder Analysis

As was explained in previous chapters, in order to gain a proper insight into the position of the stakeholders towards European freight policies and the influential parameters, it was essential to perform a stakeholder analysis. This analysis would provide us with a perception of which parameters would be of greater importance and which to a lesser extent within the current environment. In the following section, the stakeholder analysis which was performed using the concepts previously explained will be presented.

2.1 Identifying the Stakeholders

The identification process of the stakeholders of this study was performed through an initial analysis of the problem and by brainstorming with ERG members. The results of these two processes where later consolidated through mind-mapping the available information. The outcome of this procedure can be seen in Figure 16. As can be seen in the figure, the stakeholders have been grouped into two categories. Tier one stakeholders and tier two stakeholders. Tier one stakeholders can be defined as actors which have a direct vested interest in the content of the White Paper. Likewise, tier two stakeholders are also actors with a stake in the outcome of the developments. However, these actors are indirectly involved in the process and can influence it to a lesser extent.

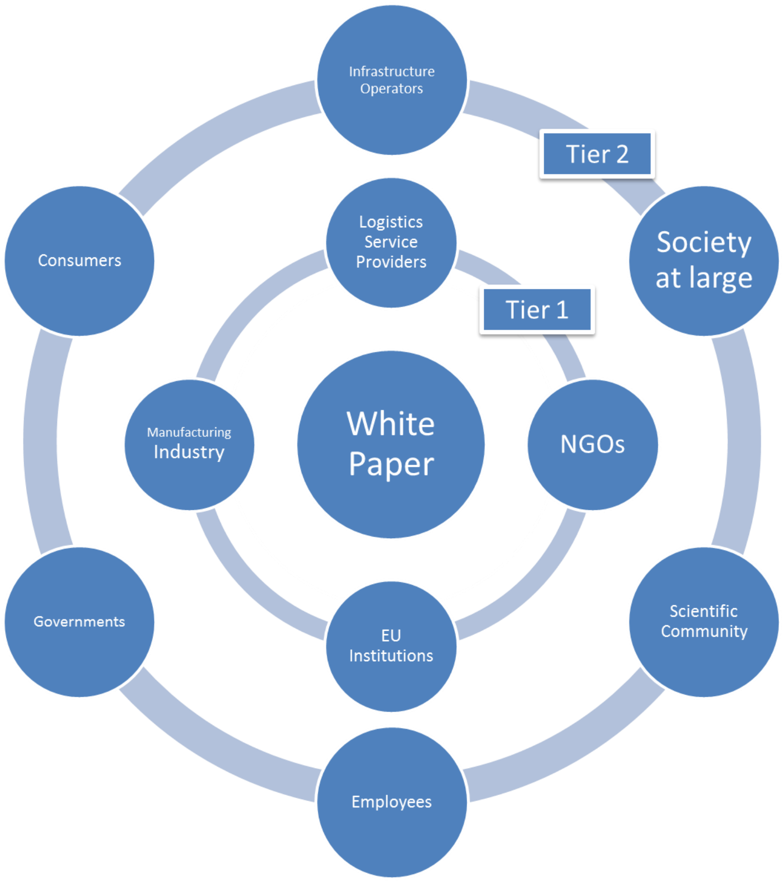


Figure 16 - The White Paper on Transport Stakeholders

Within the context and scope of this study, the interest and influencing power of the tier one stakeholders are of most importance and hence, the stakeholder analysis will focused on this group of stakeholders. In the next section, a brief introduction to these stakeholders will be presented and their views on the topic at hand will be discussed.

2.1.1 EU Institutions

EU institutions are the main responsible parties for developing legislative initiatives such as the White Paper. These institutions are responsible for the directions which the region will embark on and hence have high stakes in the development of legislative initiatives. As the White Paper is the brain child of one of these institutions, namely the European Commission, it is evident that it has the highest interest in the outcome of the endeavor. In addition, because of the legislative power of the EU institutions, they will have the ability to also exercise this power during the process.

2.1.2 European Automotive Industry

The components used in the manufacturing of road vehicles in Europe are transported from suppliers to manufacturing plants across the continent. The manufactured vehicles are subsequently transported to distribution centers and further on to dealerships and final customers. It can be argued that the income stream of these manufacturers depends on the integrity and the performance of the supply chain connecting the supplier to the final customer. Following this logic, it can be established that any changes in the supply chain will affect the livelihood and income stream of these manufacturers which subsequently position them as a stakeholder in the discussions surrounding the White Paper and the accompanying initiatives.

In order to achieve a more accurate analysis of the European Automotive Industry's involvement as a stakeholder, the association representing the cumulative interests and views of the industry in Europe will be examined. The association which represents the European automotive industry is ACEA. Further on, this association will be introduced and its power and influence in the discussions surrounding the white paper will be analyzed.

2.1.2.1 European Automobile Manufacturers Association (ACEA)

The European Automobile Manufacturers Association (ACEA), founded in 1991, represents the vision and interest of the major vehicle manufacturers based in Europe. According to ACEA's mission statement (ACEA, 2012), the goal of this association is to:

"Work together in an active association to ensure effective communication and negotiation with legislative, commercial, technical, consumer, environmental and other interests."

The association formed due to the increasing need of the member companies for representation in their technological, industrial and commercial contributions and interests. In short ACEA act as a lobbying group for the European Automotive Industry (ACEA, 2012).

As have been described, the White Paper will potentially influence freight activities across Europe. These issues put the vehicle manufacturing industry as a stakeholder of the White Paper because of its reliance on freight and efficient logistics. ACEA as the industry's representative will as such gather the views of the industry and act as the direct stakeholder in the related discussions.

ACEAs Views on the White Paper

According to ACEA, European vehicle manufacturers are committed to the development of efficient and sustainable logistic chains. The importance of efficient logistics stems from the industries need to get components to plants on a just-in-time basis and the need to deliver the finished product to the customers while respecting the ever increasing stringent order times demanded by the customers (ACEA, 2006) .

However, with regards to the White Paper and the accompanying initiatives, ACEA has taken a more aggressive stance. ACEA's view on the White Paper was published in their impact assessment on this report, where ACEA argues that some of the claims made in the White Paper are incorrect and that subsequently the roadmap and the targets suggested are not achievable (ACEA, 2011). The comments from ACEA were made on the entirety of the topics discussed in the White Paper. However, some comments where specific aimed at freight. ACEA's main comments were focused on the following items:

- **Truck technology and efficiency**

In order to effectively reduce current CO_2, vehicle technology should not be the only focal point of discussion. Infrastructure, driver behavior, consumer awareness are among numerous issues which should also be brought into the discussion if effective gains are to be achieved. An Integrated Approach is the solution to this dilemma which includes elements such as, improved logistics, freight consolidation, optimized packaging, longer vehicles and improved aerodynamics

- **Promotion of intermodal transport**

With regards to promotion of intermodal transport, the target of shifting road freight over 300 km to alternative modes of transport is not confirmed by scientific research and is not economically or environmentally beneficial. Furthermore, transport modes should not be in competition with each other, but need to act as complementary solutions if the goal is to achieve the most optimal solution with regards to freight. The effect of this approach can be seen in Figure 17

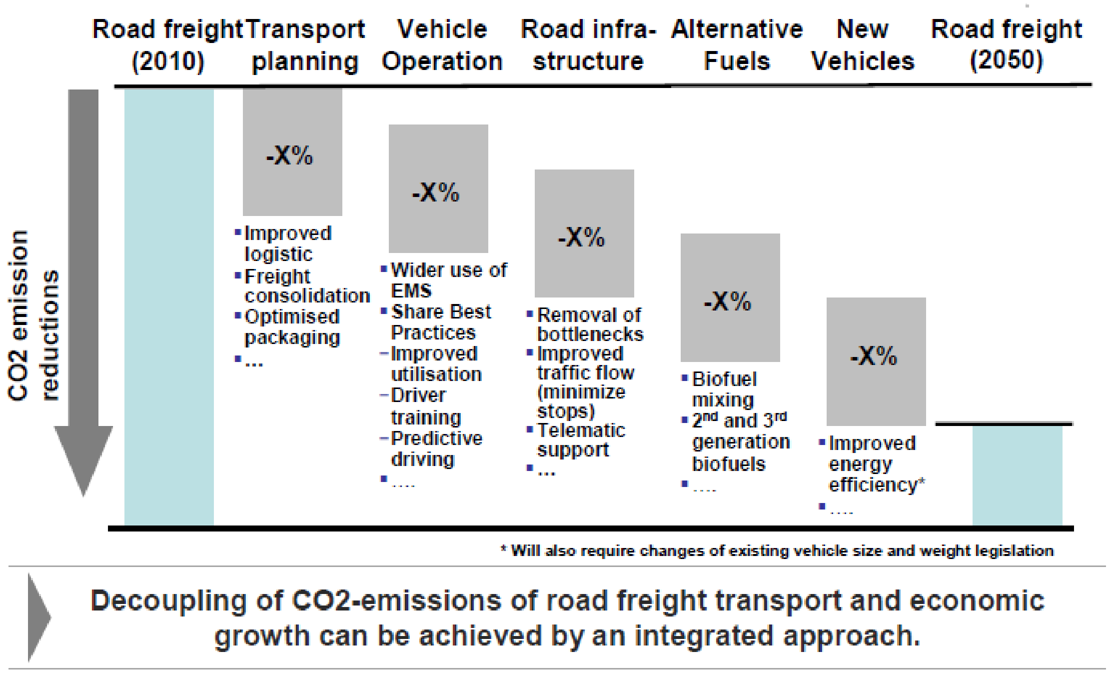


Figure 17 - Integrated Approach to Reduce CO2 Levels (ACEA, 2011)

- **Optimize the performance of multimodal logistic chains**

In order to increase the efficiency of logistics chains, the development of infrastructure is key as have been suggested within the White Paper. However, other solutions should not be ignored. The ability to utilize maximum capacity, reducing empty runs and supply chain integration is among alternative solutions to this problem.

- **Internalization of GHG cost**

While ACEA agrees that the most efficient solution to the improvement of environmental performance of freight transport is charging for the internalization of the external costs, it argues that charging needs to comply with a set of predefined criteria's. The set of criteria's introduced by ACEA are the following:

- Avoiding double taxation;
- The collected revenue should be allocated to initiatives focused on reducing external cost, e.g. investment in infrastructure solutions;
- The charges should apply to all modes of transport;
- The level of charges need to be fair and scientifically measurable;
- The charging system should be simple and transparent.

2.1.3 Logistic Service Providers

The trend of outsourcing logistic activities by companies has constantly increased in the recent decades. These activities were previously undertaken in-house and because of concerns such as, risk control, cost control and service quality where replaced by third party logistics (3PL) (K. Rao & R.R. Young, 1994). In contrast to their customers, 3PLs have the ability to optimize their service through the control of the whole transportation chain and by using their accumulated specialized knowledge and available technology (C. Facanha & A. Horvath, 2005).

As a result of the increasing demand for outsourcing logistics activities, large companies offering a wide range of logistic solutions have emerged. These logistic solutions range from only transport or warehousing function to total logistic solutions. However, among the services offered, transportation is more widespread than others (K. Selviaridis & M. Spring, 2007).

Up until recently, environmental factors have not been the major concern while selecting 3PL partners and performance objectives such as cost, flexibility, service quality and reliability have been considered the major criterion (C. Wolf & S. Seuring, 2010). However, as transportation is the main service offered by the 3PLs and considering the fact that freight is the target of the White Paper and its accompanying initiatives, it can be assumed that environmental factors will play a more predominant role in 3PL partner selection. As a result, the Logistic Service Providers will act as a direct stakeholder of the White Paper.

3PL service providers' interests and views in Europe are represented by various associations and organizations. Some of them that can be mentioned are the European Freight Forwarders Association (EFFA), European Logistics Association (ELA), European Transport Workers Association (ETF), and the Alliance of European Logistics. Up until now, apart from the ETF, no major organization has yet expressed its views on the White Paper in a detailed impact assessment. However, these associations have through press releases and other media voiced their initial opinions on the matter.

For instance, The Alliance of European Logistics has praised the Commissions initiative to move towards intermodal logistics. However, they have also asked the Commission to reflect on how the goals of the White Paper are to be realized. Furthermore, they have listed the following set of requests (AEL, 2011):

- The EU should remove infrastructure bottlenecks;
- The use of higher capacity vehicles should be enlarged;
- It has to be ensured that vehicle regulations should be balanced;
- Carbon accounting and reporting should be standardized;

- Innovative logistics should be invested in;
- Maximum vehicle mass and dimension should be reviewed to favor intermodality.

In addition, the ETF as a representative of the workers within the transport industry has expressed its views on the White Paper in their impact assessment. While some of the initiatives presented by the White Paper have been praised in this report, criticism to some issues has also been expressed. For instance, criticism has been focused on the timeline of achieving the outlined targets. According to the ETF, some of the targets are not achievable in the current framework. Lack of fair competition among the transport modes have also been mentioned as a cause for concern. A major discrepancy which, according to the ETF, can be found is the incompatibility of some of the targets. For instance, maritime transport emissions are expected to be reduced by 40% by 2050 compared to 2005 while at the same time the Commission is promoting an increase of maritime transport (ETF, 2011).

2.1.4 NGOs

Over the past decades, Non-Governmental Organizations have increase in number and influence and have come to be a decisive factor in resolving issues related to businesses and governments. Although, it has been argued that the involvement of these organizations in business and governmental affair may lead to “institutional sclerosis”, their influence and power cannot be denied. These organizations may include consumer, labor, environmental, industry association and many other organizations (Doh & Teegen, 2003). However, because of the specific focus of this study and its initiator (the White Paper) on CO_2 reduction issues, the primary focus will be directed towards NGOs promoting environmental causes in Europe. Various NGOs are active in the environmental protection scene in Europe. Transport & Environment, Friends of the Earth Europe, Environment Forum, and Green European Foundation are among NGOs active in Europe.

These organizations have voiced their opinion about the White Paper in various forms since it was published. Furthermore, as an example of the views of the NGOs, the views of the Environment Forum and Green Europe Foundation will be presented:

2.1.4.1 The Environment Forum

According to its mission statement, The Environment Forum which is a coalition between the Institute for European Environmental Policy (IEEP) and Pescares Italia aims to support environmental NGOs in their dynamic and constructive role in the EU enlargement process. (Environment Forum, 2012b). The Environment Forum recently published a position paper on transport where the White Paper was addressed. In this report, while supporting the initiatives proposed, they argue that in order to achieve the targets outlined in the White Paper, early deployment of technologies under development is required. Also, sustainable behavior through better information dispersion and pricing schemes is requested. In addition, development of acceptable infrastructure through EU funding is requested (Environment Forum, 2012a).

2.1.4.2 The Green European Foundation (GEF)

The Green European Foundation is an actor involved in the European scene and is linked to various European Green actors while still acting as an independent entity. The European Green Party and the Green Group in the European Parliament are among the actors which GEF is linked to. According to their mission statement, GEF aims at bridging the gap between the national and the European levels of Green politics (Green European Foundation, 2012).

In their position paper towards European Transport Policy, with regards to the White Paper, GEF praises the European Union’s commitment for the past two decades in their active commitment to reform the European transport sector. In addition, while appreciating the intent of the White Paper, they claim that the proposed investments in large-scale projects are a cause for concern. According to GEF, these investments are not consistent with EU's sustainability, climate change and environmental goals as funds are generally directed towards large scale projects which are potentially damaging to the environment. It is further on suggested that smaller projects with higher importance should be prioritized. Furthermore, they call for the internalization of external costs for all transport modes by as soon as 2014 in order to boost the competitiveness of rail transport. It is likewise proposed that sustainability criteria should also be taken into consideration by the EU while developing alternative fuel strategies.

2.2 WhitePaper of Transport Stakeholder Mapping

By utilizing the information gathered on each of the stakeholders, which was previoulsy introduced, each of the tier 1 and tier 2 stakeholders have been placed accordingly in the power/interest matrix which has been illustrated in

Figure 18 Furthermore, the underlying justification of the placements within the matrix will be explained and the implication of each placement will be discussed. Our attention will be focused on the Tier 1 stakeholders because of their importance in our study.

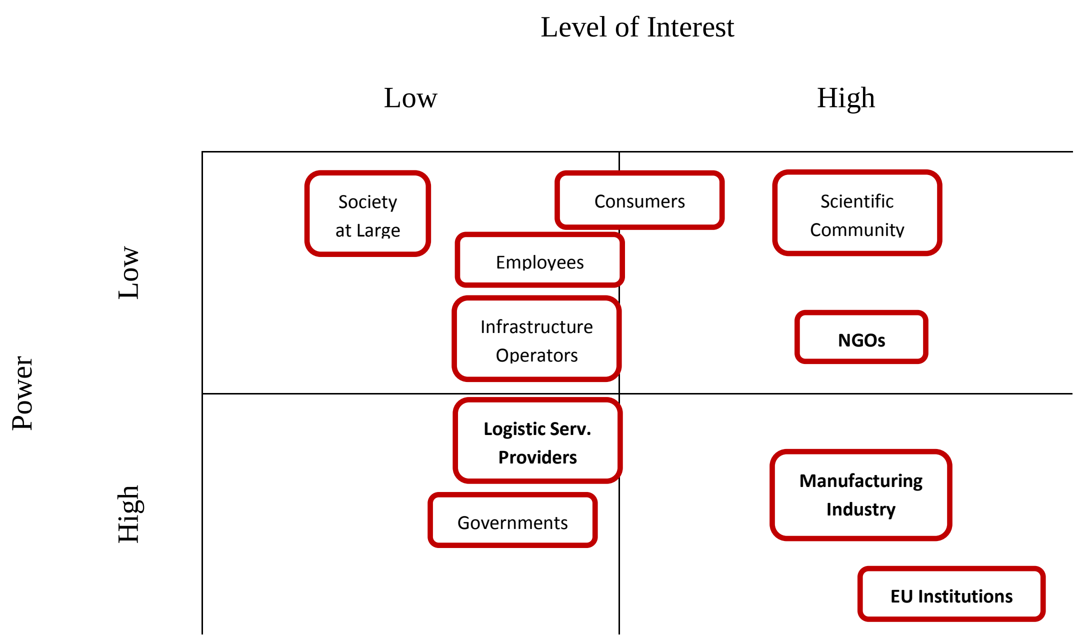


Figure 18 - Stakeholder Power/Interest Matrix

- **EU Institutions:**
  - **Interest:** Reducing CO_2 Emissions is currently considered one of the major targets of EU institutions. Transport as a significant contributor to EU emissions is currently in within the sight of the EU and reduction in this industry would be considered as a substantial achievement. Hence, the issue of transport carries great interest on behalf of EU institutions, which can also be corroborated by the increasing amount of recent regulations, amendements and studies on the topic published by the EU.
  - **Power:** As the legilative body that they have the highest power and can decide on how the process should or should not proceed.

- **Manufacturing Industry**
    - **Interest:** The transport budget of manufacturing corporations as previously mentioned ranges between 4% and 30%, depending on their activity, of their total expenditure. This amount is significant for these corporations and any external factors which would have the potential to significantly influencing their expenditure and profit is of the highest interest to them.
    - **Power:** As this group of stakeholders are represented by lobbying groups and have access to significant capital, they may used these assets in order to influence the process if deemed necessary.

- **Logistic Service Providers (3PLs)**
    - **Interest:** Although the topic at hand is focused on changing the transport industry in Europe, 3PLs do not have a significant interest in the process as they will be able to shift their increased costs to their customers. However, this is true as long as they are constantly informed about the developments from relevant actors. If the confidence of receiving updates are breached which may cause confusion, their interest may increase.
    - **Power:** Similar to the manufacturing industry, the interest of these actors are represented by lobbying groups which have the support of significant capital muscle and can be used to influence the process.

- **Non Governmental Organiations (NGOs):**
    - **Interest:** As previously explained, the NGOs in question are the organizations focused on enviornmental afairs. As transport in Europe accounts to the significant amount of approximately 30% of energy destribution and CO_2 amissions (European Commission, 2010a), a reduction in these figures would be consistent with their goals and hence desirable.
    - **Power:** Environmental NGOs usually consist of private individuals with a common goal of improving the state of the environment. These groups usually do not enjoy being backed by industries and hence do not have access to capital support which significantly reduces their power in a political environment.

3. The Identified Parameters

After having analyzed the major initiatives brought forth by the EU and investigated the current stakeholder environment a set of parameters were detected. These parameters have been addressed directly or indirectly within the initiatives and have evoked reaction from the stakeholders. The European Commission in order to promote the initiatives and reach the proposed targets will need to prepare appropriate legislative proposals which will most likely target these parameters. These parameters, if affected may prompt changes in the European transport sector. The following parameters have been targeted in the initiatives and are considered to be influential in the transport sector:

1. New Technology Development and Promotion
2. Modal Split
3. Internalization of Externalities
4. Fuel Cost

Furthermore, an analysis of why these parameters were identified will be presented.

4. Analysis of the Parameters

The reason why the mentioned parameters were identified others were not can be traced back to the context of the study and the attention directed towards them on behalf of the White Paper and the other initiatives. In the following section, the underlying rational for the selection of each parameter will be presented.

4.1 New Technology Development and Promotion

New technological options that could help to control CO_2 emissions will be key to lower transport emissions in the EU. According to the White Paper any delayed action and timid introduction of new technologies would lead to a sharp decline in EU transport. The importance of technological improvements has been pointed out in the Initiatives which will further be analyzed.

Technology Development in the White Paper

In the White Paper, one of the main suggested strategies to reach the designated Greenhouse Gas reduction targets is a strategy called “Innovating for the Future - Technology and Behavior”.

It is argued that through technological innovation, a shift towards a more efficient and sustainable European transport system will be achieved with less investment and in a shorter time frame. Furthermore, it is stressed that the technological improvement needs to be supported by regulatory framework conditions standardization and interoperability throughout the content (European Commission, 2011b).

Europe 2020 Strategy

Within the Europe 2020 Strategy it is suggested that a reform in the research and innovation funds is needed to reinforce Europe’s technology strength with the goal of promoting clean technologies and modernizing transport (European Commission, 2008a).

Furthermore in the "Resource efficient Europe" flagship initiative, the Commission suggests strategies to improve resource efficiency in various policy areas and suggests that concrete proposals should be prepared in the near future to tackle these issues.

The “Strategic Transport Technology Plan” is one of the strategies which specifically targets transport. It intends to present a medium-term strategic agenda for research, innovation and deployment, and describe how advanced technologies can contribute to EU objectives (European Commission, 2011a).

The European Climate Action and Renewable Energy Package (ECAREP)

Over the past decade, renewable energy technologies and energy efficiency have become established in Europe through rapid technology development. However, according to the European Climate Action and Renewable Energy Package, in order for Europe to meet its climate and energy goals, this process needs to substantially accelerate. Furthermore, it is argued that to accelerate the process, technological development in Europe needs to be stimulated and tools should be made available to promote innovation and create a competitive edge in clean energy technologies. Moreover, the Commission claims that platforms are needed to ensure maximum utilization of the new technologies when they arrive to the market.

Furthermore, the initiative presents The "EU Strategic Energy Technology Plan" as a tool which will use the EU's levers to help uphold Europe's leadership in sustainable technologies. In this plan one of the key challenges for the next 10 years is explained to be bringing more efficient energy conversion and end-use devices and systems to the transport mass market, for instance the full scale introduction of fuel cells (European Commission, 2007b).

However, more importantly the plan explains that in order to achieve a sustainable European energy system, fundamental changes in the infrastructure is required which will transform the energy industry and its existing infrastructure. This process will affect diverse sectors, including the transport sector.

4.2 Modal Split

Modal split is a topic which has not been addressed in detail in the Europe 2020 Strategy and the ECAREP and only minor references to the issue can be found in these initiatives. For instance, in the 2020 strategy it is suggested that the implementation of inter-modal nodes should be accelerated (European Commission, 2008a). However, one of the major challenges raised by the White Paper is modality. According to the Commission, the goal is to shift 30% of freight transport over 300 km from road to rail or waterborne transport by 2030 and 50% by 2050.

Within this context, the White Paper suggests that legislative measures should be taken which would facilitate intermodal transport. Also investments should be directed towards developing infrastructures to support a multimodal freight corridor across Europe (European Commission, 2011b).

4.3 Internalization of Externalities

Similar to Co-Modality, Internalization of Externalities has only been discussed in detail in the White Paper. According to the Commission, within the context of transport, Internalization of Externalities refers to the elimination of tax distortions and unjustified subsidies in order to align market choices with sustainability needs. These measures are essential for establishing equal opportunities between modes which are in direct competition.

The recent proposal by the Commission to amend the "Eurovignette Directive" for heavy duty vehicles is perceived as a first step towards realizing this objective (European Parliament and of the Council, 2011a).

However, the matter is not only limited to road freight as the Commission is committed to proceed with the internalization of external costs for all modes of transport (European Commission, 2011b). As a testament to its commitment, in its Communication of Strategy for the Internalization of External Costs, the Commission has presented a common methodology for the whole transport sector (European Commission, 2008d).

4.4 Fuel Cost

One of the main targets of the described initiatives is the reduction of greenhouse gasses and increasing the use of renewable energy. Apart from environmental motivation, it is argued that following this strategy will reduce EU's dependency on oil and gas imports which will subsequently decrease the EU economy's exposure to raising and volatile energy prices and geopolitical risks (European Commission, 2007b, 2008a, 2011b).

Within both the White Paper and the EU Strategic Energy Technology Plan two main market-based instruments are being suggested for the reduction of greenhouse gas emissions: Energy Taxation and

Emission Trading System (European Commission, 2007b, 2011b). Apart from aviation, no plans for applying an emission trading system for the transport sector have been announced. However, energy taxation is currently applied on a small scale on fuels. The White Paper argues that a revision of the Energy Taxation Directive would act as an opportunity for reducing greenhouse gasses (European Commission, 2011b).

In addition, in the "Resource Efficient Europe" initiative of the Europe 2020 strategy, it is stated that a framework for the use of market-based instruments (i.e. energy taxation) should be prepared. Furthermore, the initiative calls for a revision of the Energy Taxation Directive with the motivation that it will modernize the framework for energy taxation so that it will better support the high-priority objective of sustainable growth and promote a more resource efficient, competitive economy (European Commission, 2011a).

By the end of this chapter the first research sub-question was answered and it was possible to initiate the construction of the model which will be presented in the next chapter.

IV. Development of the Model

Using the knowledge gained from studying the EU initiatives and analyzing the stakeholders, it was possible to identify the main parameters influencing freight. By utilizing this information and following the theoretical framework outlined in Figure 13 of Chapter II, it was possible to construct the model. Further on, this process will be presented in this chapter.

In this chapter, at first, the development of the baseline spreadsheet will be detailed. Subsequently, the steps taken to construct the 2011-2030 scenario spreadsheet will be explained. Finally, an overview of the developed model will be presented.

1. Baseline Spreadsheet

The first section of the model which had to be developed was the Baseline Scenario spreadsheet. In this section by analyzing the current structure in the freight industry and using existing data, the basic spreadsheet was developed which was later on be used as a stepping stone for the 2011-2030 Scenario spreadsheet development. The different steps of this process will further on be explained.

1.1 Conceptual Model Design

The first step for developing the baseline spreadsheet was to design the initial conceptual model which the model would be based on. During this step, the model itself was assumed to be a black box with no indication on how internal structure of the model should present themselves and only the inputs, outputs and boundary conditions of the model where established. These elements where identified based on the problem definition, the research questions and the objectives. An illustration of the conceptual model developed can be seen in Figure 19.

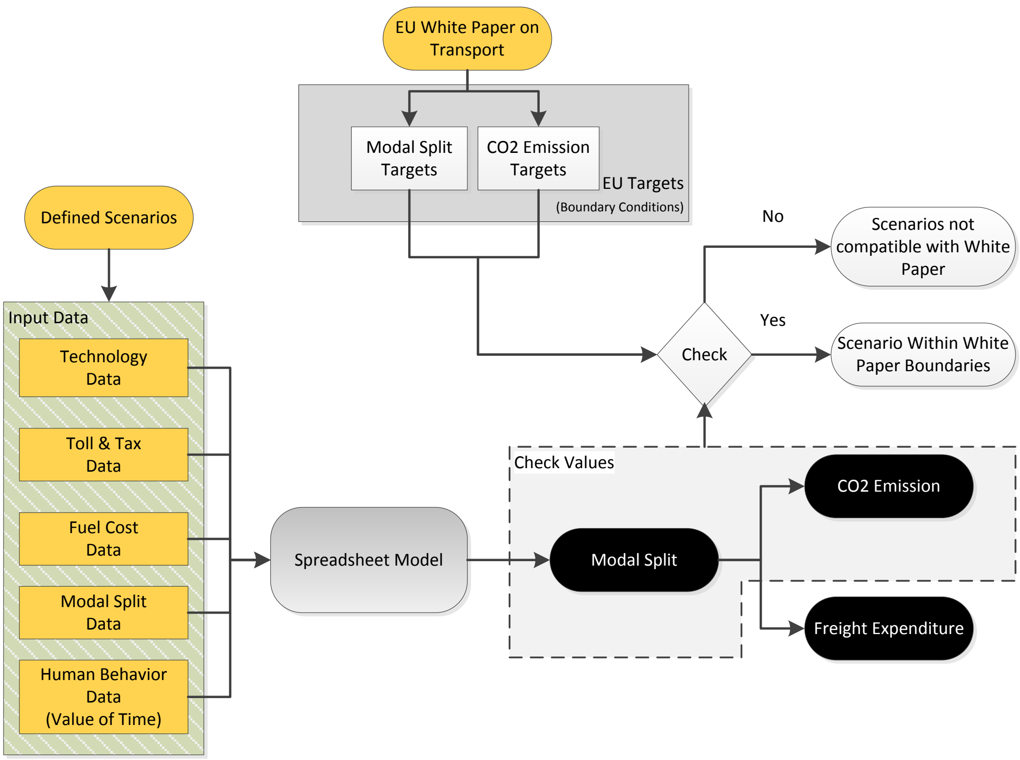


Figure 19 - The Conceptual Model

As can be seen in the figure, the starting point of the process is the *defined scenarios*. These scenarios include the current baseline scenario and the future scenarios which will be developed based on the content of the white paper.

Based on the scenario in question, data was extracted and used as *input data* for the model. Using the available information from previous chapters, the input data was established to consist of the following:

1. Technology Data
2. Toll and Tax Data
3. Fuel Cost Data
4. Modal Split Data
5. Human Behavior Data (Value of Time)

As can be inferred from the presented list, the first four items correspond to issues which were referred to by the White Paper numerous times and where among the targeted areas with high potential of improvement. However, the fifth item was not among the areas targeted by the White Paper. The underlying motivation for including this item to the list is the influence of human behavior in decision processes. This aspect of the model will be explained in more detail in future sections.

The obtained data will in the next step be inserted into the *spreadsheet model* where our desired output will be produced. The desired output defined for this model is a combination of goals outlined in the White Paper and a target which is of great value for Toyota Motor Europe as one of the stakeholders of the White Paper. In the case of the former, the targets in question are *CO_2 emission levels* and *modal split* and for the latter the target refers to *final freight expenditure*. Furthermore, as can be seen, modal split precedes CO_2 emission levels and modal split. This can be justified by the fact that CO_2 emissions and freight cost defers between different modes of transport. This issue will furthermore be discussed in detail in following sections.

Following this step, the outputs categorized as *check values*, are to be compared to their corresponding predefined targets set out by the White Paper which was previously introduced. If the outputs would place within the boundaries of the targets of the White Paper, the scenario resulting in the output would be labeled to be *within the boundaries of the White Paper targets*. If not, they will be labeled as *not compatible with the White Paper*.

1.2 Parameter Correlation Tree (PCT) Development

The second step of developing the spreadsheet model is the development of the PCT. The purpose of this step is to expand the understanding of the model, which up until this step has been presented as a black box through the conceptual model. While, in the conceptual model, the internal structure of the model was not presented, the goal of the PCT is to illustrate this structure and to reflect the existing interconnections between the input data and the outputs. To put it simply, the purpose of the PCT is to define the internal dynamics of the model and to enable the development of the final spreadsheet model. The PCT developed for the purpose of this study can be seen in Figure 20.

In developing the PCT, the *first phase* was to place the input parameters at the base of the tree and the output parameters at the top. The *second phase* consisted of breaking down the input parameters to their most basic quantifiable sub-parameters. This phase was vital for the development of the internal structure of model because it was not possible to quantify the standalone input parameters directly as they were a result of the cumulative values of their sub-parameters. In the *third and final phase*, the goal was to discover the logical relationships between the input parameters and the output parameters. After identifying these relationships, the goal of the PCT of showing the internal dynamics of the model was achieved. Furthermore, each of the PCT development phases will be explained in more detail:

First Phase: This phase was rather straight forward and as mentioned consisted of positioning the input parameters at the bottom and the output parameters at the top of the PCT. However, because of the characteristics of the parameters involved, a series of considerations needed to be taken which are the following:

- As the output of the model consists of both CO_2 Emissions and Freight Expenditure, *Technology* could not be represented as a standalone parameter. Technology, in the context of our study, consists of two elements, namely the financial element (the cost of technology) and the technological effect on CO_2 emissions. Hence, as can be seen in the figure, Technology was divided into these two elements.
- In the conceptual model, *Modal Split* was represented both in as an input parameter and as an output parameter. To clarify, in the baseline scenario, Modal split act as an input parameter and in the 2011-2030 scenarios, it is a product of the model. Hence, in the PCT, it was decided to merge these two aspects of Modal Split and place it on the top of the Tree mainly due to aesthetic reasons.
- As will be explained in future sections, in order to quantify *Value of Time*, inputs from the other parameters are needed. Hence, it was placed in between the output parameters and the other input parameters. It is also imperative to point out that the concept of Value of Time was only used in the 2011-2030 scenarios.

Second Phase: The second phase of the process consisted of breaking down the input parameters to their most basic quantifiable sub-parameters. The result of this process can be seen in the PCT. This process was conducted through analyzing each of the parameters in great detail. By doing this, it was possible to understand the building blocks of each parameter. The analysis was performed through reviewing studies and documents available on each parameter. The documents used for this purpose will further on be listed:

- **Fuel Cost:** In order to define the sub-parameters of fuel cost a recent study conducted internally within the ERG group titled Fuel Road Map 2030 (Energy Research Group, 2011) was used.
- **Toll and Tax:** For the purpose of Toll and Tax the following studies and documents where utilized:
  - COMPASS: The Competitiveness of European Short-Sea Freight Shipping Compared with Road and Rail Transport (Eef Delhaye, et al., 2010)
  - Railway Reform & Charges for the Use of Infrastructure (OECD, 2005)
  - Amendment of Directive 1999/62/EC on the charging of heavy goods vehicles for the use of certain infrastructures (European Parliament and of the Council, 2011a)
- **Technology:** The following literature was used to obtain the sub-parameters for technology:
  - Reduction and Testing of Greenhouse Gas Emissions (GHG) from Heavy Duty Vehicles - Lot 1:Strategy (Hill et al., 2011)

Third Phase: The purpose of the third phase was to visualize the internal structure of the model through finding logical connecting between the input parameters and the output parameters. The outcome can be seen in the PCT and the flow of data can be determined through the direction of the arrows connecting the parameters.

Within the final PCT, a series of imperative relationships can be spotted which will be used in the development of the spreadsheet model. These relationships and the justification of them are as follows:

- **Fuel cost, Tool & Tax, and Technology Depreciation → the Cost of Ownership**

  As mentioned, Freight Expenditure is one of the output parameters of the model. Toll & tax, Fuel Cost, and Technology Depreciation represent cost parameters and hence, had to be connected to freight expenditure. In order to ease the process, these parameters were consolidated in an intermediate parameter, named *Cost of Ownership*. This value, when summed up with the service provider margin, resulted in *Cost per Mode* which could now be directly connected to Freight Expenditure.

- **Cost of Ownership and Freight Service Provider Margin → Cost per mode**

  This study was initiated to analyzing freight expenditure from the perspective of the vehicle manufacturing industry. *Cost of ownership* corresponds to the cost that the logistics service providers will face. Hence, in order to utilize this value within the context of this study, *the profit margin of the service provide*r was added which resulted in *cost per mode* of transport.

- **Cost per Mode and Value of Time (VOT) → Modal Split**
  When analyzing *modal split, cost per mode* will only tell one side of the story as Modal split also depends on human behavior which here is represented by VoT. This parameter will be discussed in detail in future sections. Suffice to say at this point, by using the cost per mode and value of time, modal split can be analyzed.

- **Average CO_2 Emission Factors and Modal Split → CO_2 Emissions**
  The rationale behind this relationships stems from the fact that through obtaining the *average CO_2 emission factor* per mode of transport and multiplying this value by the volume of each mode of transport (*modal split*), total *CO_2 emissio*n will result.

- **Cost per Mode and Modal Split→ Freight Expenditure**

  This relationship follows the same rationale as CO_2 emissions. Namely, in order to calculate total *freight expenditure*, *modal split* needs to be multiplied by the *cost per mode*.

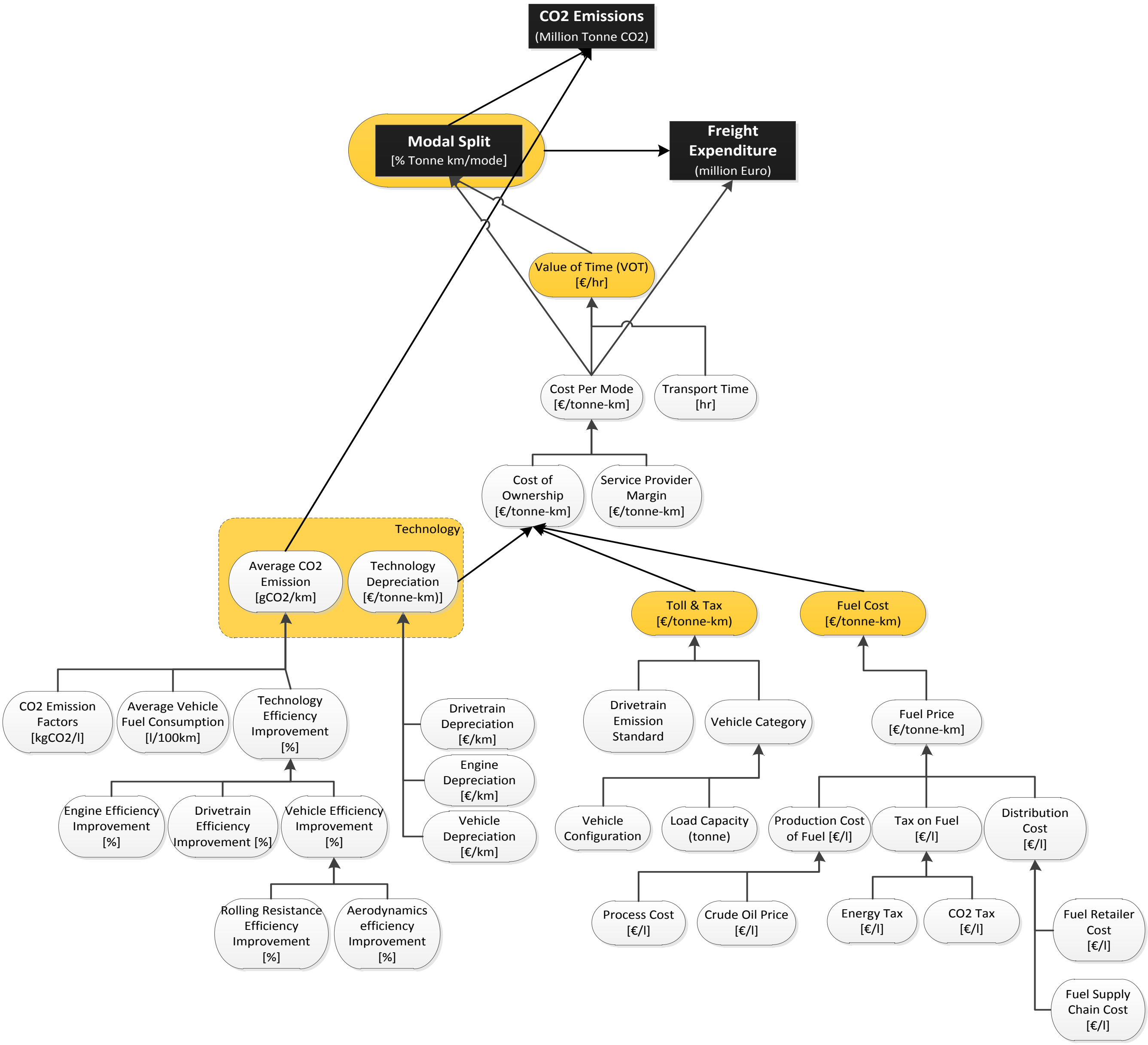


Figure 20 - Freight Parameter Correlation Tree

1.3 Developing the Baseline Spreadsheet

The next step in developing the baseline spreadsheet model was to construct the spreadsheet. This was accomplished through utilizing the knowledge created during the PCT development step. The PCT clearly illustrates the internal structure of the model which enables the clarification of the input data needed for the spreadsheet. The development of the spreadsheet consisted of the following four phases:

1. Defining the modes of transport;
2. Developing the cost breakdown structure;
3. Determining the connections in the spreadsheet.
4. Building the Spreadsheet

In the following section these phases will be explained in detail.

1.3.1 Defining the Modes of Transport

The first phase of developing the spreadsheet was to identify the modes of transport which should be included within the study and to define their properties. While analyzing the modes of transport currently utilized within Europe the following modes where identified (European Commission, 2012; McKinnon, 2010):

- Road freight
- Rail freight
- Short sea shipping[4]
- Inland waterways
- Airfreight
- Pipelines

The Modes of Transport

When developing the model it was noticed that some of the mentioned modes were either not within the scope of our study or were not relevant to the context of the study. Hence, as will be further explained, in order to achieve concrete results, some of the modes of transport were phased out from the study and the desired modes where selected.

- **Pipelines**

When introducing the content of the White Paper and the accompanying initiatives, the main focus was on road, rail, sea and air transport and no specific focus was directed towards pipelines. Furthermore, pipeline transport is considered to be a specialized mode of transport which is generally used for the transportation of petroleum products. Hence, pipeline transport was excluded from the list of modes as it was not considered to be within the context of our study.

- **Air Freight & Inland Water Ways**

Both of these modes of transport are utilized for general transportation of goods. However, as can be seen in Table 4 between 2006 and 2010 the portion of freight activities carried out by air freight and inland water ways within Europe is respectively 0.1% and 3.5%. In order to simplify the study a share of at least 10% of total freight was considered as a threshold for a mode to be relevant to our study. Furthermore, according to Toyota Motor Europe's logistics departments, these modes of transport are generally not utilized by them. Hence, air freight and inland water ways were excluded from the study.

Table 4- European Freight Modal Split (% tonne-km) (European Commission, 2012)

Year	Road	Rail	Inland Water Ways	Pipelines	Sea Shipping	Air Freight
2006	45.5	10.7	3.4	3.3	37	0.1
2007	45.9	10.7	3.5	3.1	36.7	0.1
2008	45.9	10.8	3.6	3	36.6	0.1
2009	46.5	9.9	3.6	3.3	36.7	0.1
2010	45.8	10.2	3.8	3.1	36.9	0.1

[4] Short Sea Shipping (SSS) is a complex maritime transport service, offered by logistics service providers and performed by different ranges of ships that are capable of carrying unitized and non-unitized cargo within body of water surrounding the European continent (Paixao & Marlow, 2001).

Following the exclusion of the mentioned modes of transport, the following three modes were selected as the modes which the focus of the study would be directed towards:

- Road freight
- Rail freight
- Short Sea Shipping

1.3.1.1 Means of Transport

The modes of transport which would be included in the study were previously identified. However, within each of the listed modes a wide range of different vessels and vehicles carrying different properties and characteristics are utilized. Therefore, using average properties across each mode would result in inaccurate results. In order to prevent this inaccuracy, the main vehicles and vessels generally used for each mode within Europe had to be identified.

Through analyzing the available studies on the different modes of transport previously identified, the vehicles and vessels currently in used in Europe were identified. The list of these means of transport can be seen in Table 5.

Table 5 - Means of Transport by Mode (Eef Delhaye, et al., 2010; Hill, et al., 2011; OECD, 2005; Paixao, et al., 2001)

Mode	Road	Short Sea Shipping	Rail (Electric/Diesel)
Means of Transport	HDT -7.5t	Large RoPax	Container
	HDT 7.5-16t	Small RoPax	General Cargo
	HDT 16-32t	LoLo Container Ship	Wet Bulk
	HDT +32t	RoRo Ship	Dry Bulk

1.3.2 Developing the Cost Breakdown Structure

The second phase of the process of constructing the spreadsheet model was to develop the cost breakdown structure for each of the modes of transport. Through analyzing available studies on the cost of freight, the following breakdowns where developed for each mode. The information used for constructing the cost breakdown structure for each mode was extracted from the TREMOVE project (TML, 2010), the COMPASS study (Eef Delhaye, et al., 2010), and the Modal Comparison Framework report (NEA, 2003).

1.3.2.1 Road Freight Cost Breakdown Structure

The breakdown structure developed for road freight can be seen in Table 6. As can be seen, distinction between *direct costs* and *tax costs* were made to clarify the nature of each cost. In addition, in the cost break down, some factors will have no or limited impact from the White Paper and will mostly be influenced by micro-economic trends. However, as the goal of the study is to calculate total freight expenditure and not only to detect changes in the value, all factors have been included in the breakdown.

Table 6 - Road Freight Cost Break Down Structure (Eef Delhaye, et al., 2010; NEA, 2003; TML, 2010)

Cost Category	Cost Item	Impact by WP
Direct Costs	Maintenance	No
	Depreciation	Yes
	Labor	No
	Insurance	No
	Fuel	Yes
Tax Costs	Registration	No
	Ownership	No
	Infrastructure fee	Yes
	Insurance	No
	Labor Tax	No

1.3.2.2 Rail Freight Cost Breakdown Structure

In general, the publicly available information for the cost structure of rail freight is scarce. In order to gain sufficient overview of the internal cost structure used in the rail freight industry, information form the Cost Benefit Analysis Study of the Railway Line Iron Rhine Between Belgium and the Netherlands (E. Delhaye et al., 2009) was used as a primary source along with the pervious sources mentioned. The obtained information from these sources enabled the development of the breakdown structure which can be seen in Table 7.

As can be seen in the breakdown, like road freight, each cost item has been categorized in order to clarify the nature of them. The categories are the following:

- **Average fixed costs** that represent cost which on average is constant over time and logistics service providers will have to endure independent of the service they will provide.
- **Average variable costs** which are not constant but variable over time and depend on the properties of service the logistics service provider will offer.
- **Average energy costs** are also costs that vary over time due to the volume of service offered or the constant fluctuation of energy prices.

Similar to road freight, some parameters will likewise have no or limited impact from the future regulations and will mostly be influenced by micro-economic trends.

Table 7 - Rail Freight Cost Breakdown Structure

Cost Category	Cost Item	Impact by WP
Average Fixed Costs	Depreciation	Yes
	Maintenance	No
	Insurance	No
	Rest Value	No
	Rental price of wagons	No
	Labor	No
	Overhead	No
Average Variable Costs	Infrastructure fee	Yes
	Shunting	No
Average Energy Cost	Fuel	Yes

1.3.2.3 Short Sea Shipping Cost Breakdown Structure

By using the information available in the previously mentioned sources the cost breakdown structure for short sea shipping was developed which can be seen in Table 8. As with the breakdown of the former modes, the impact of the White Paper on the items has likewise been indicated.

It is also imperative to mention that the gross margin of short sea shipping is mentioned as a standalone item, unlike the aforementioned modes where the gross margin is distributed along the other items.

Table 8 - Short Sea Shipping Freight Cost Breakdown Structure

Cost Item	Impact by WP
Fuel	Yes
Depreciation	Yes
Interest	No
Labor	No
Gross Margin	No
Infrastructure Fee	Yes
Maintenance	Yes
Administration Fee	No
Lube Oil	No
Insurance	No

1.3.3 Determining the Connections in the Spreadsheet

For the purpose of determining the necessary connections within the spreadsheet, the sub-parameters identified in the PCT provided the necessary insight. It showed the building blocks of the sub-parameters which would potentially be affected by the White Paper. By combining this information with the cost breakdown structures from the previous section, it was possible to mathematically link the elements needed to develop the spreadsheet.

The two outputs for the baseline scenario which are of importance are the Total Freight Expenditure and Total CO_2 Emissions. Hence, in this section, the flow of data within the spreadsheet will be explained in two phases linked to these two outputs. For the purpose of showing the data flow a bottom-up approach has been utilized.

1.3.3.1 Total Freight Expenditure Data Flow:

The flow of data for the calculation of total freight expenditure can be seen in Figure 21. As can be seen, the expenditure is the sum of the expenditure calculated for each mode of transport which in turn is the product of their respective costs and their modal share.

For the next step, in order to define the data flows for each mode of transport, because of the different properties of modes, they had to each be analyzed separately. Furthermore, the data flow developed for the modes will be presented.

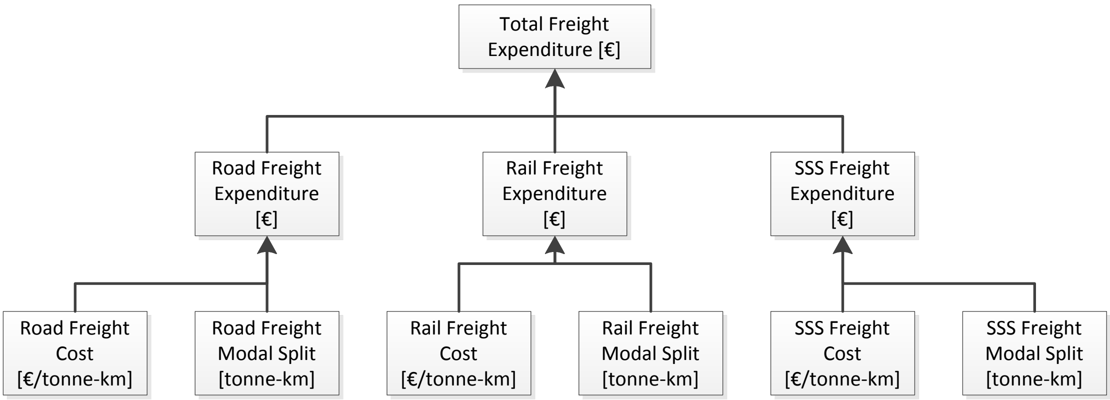


Figure 21 - Total Freight Expenditure Data Flow

Road Freight Cost:

The cost data flow for road freight can be seen in Figure 22. The chart is applicable to each of the four means of transport previously identified for road freight.

Within the chart, the following relationships are imperative to the model as they are susceptible to be influenced by the White Paper (and they relate to the PCT):

- **Depreciation** which is the sum of the purchasing price of the tractor and, if available, the accompanying trailer. Deprecation cost directly relates to technology depreciation which was introduced in the PCT.
- **Fuel Cost** is the product of fuel price and the fuel consumption rate of the vehicle in question. Subsequently, fuel price is the sum of energy taxation and the tax free fuel price. It is also worth mentioning that fuel cost was one of the input parameters of the PCT.
- **Network** in the case of road freight represents the Eurovignette tax on road freight. Depending on the Euro standard of the vehicle and the load capacity, a tax rate is assigned to the vehicle in question. It will later be presented that the distribution of Euro standards among vehicles across Europe was used to obtain an average rate for all vehicles within a load category.

It is important to mention that all the costs were to be calculated over the total lifecycle of the vehicle. In other words, the resulting unit from the flow would have been €/vehicle over its lifecycle. As the desired unit of measurement in freight is tonne-kilometer, it was vital to convert the cost to the desirable unit. This was achieved by multiplying road freight cost by the load factor of the vehicle and its total activity over its lifecycle.

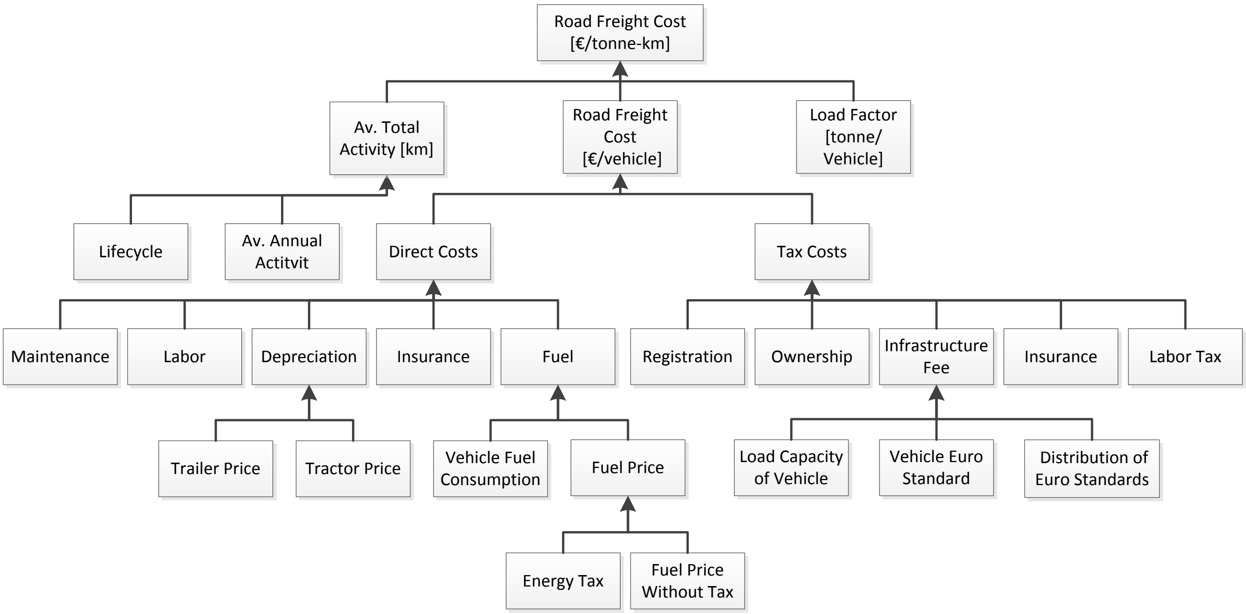


Figure 22 - Road Freight Cost Data Flow

Rail Freight Cost:

The cost data flow for rail freight can be seen in Figure 23. Similar to road freight the chart is applicable to each of the four means of transport identified for rail freight.

While developing the chart it was discovered that currently, within Europe, the locomotives used for rail freight are either utilizing an electric drivetrain or a diesel engine which was reflected in the figure. In order to address this problem in the case of fuel, depreciation, and shunting, the cost for each type of engine was separately calculated and an average value was obtained through averaging this value over the share of each type used across Europe.

Furthermore, depending on the train category and the engine used, the number of locomotives used per train varies which had to be taken into account while calculating depreciation cost. Hence, the purchasing price of each locomotive type was multiplied by the number of locomotives.

Also, similar to road freight, all the costs are calculated over the lifecycle of the locomotive with the resulting unit being €/vehicle over its lifecycle. The desired unit of tonne-kilometer was obtained for rail freight through multiplying rail freight cost by the train load factor, maximum payload and the locomotives total activity over its lifecycle.

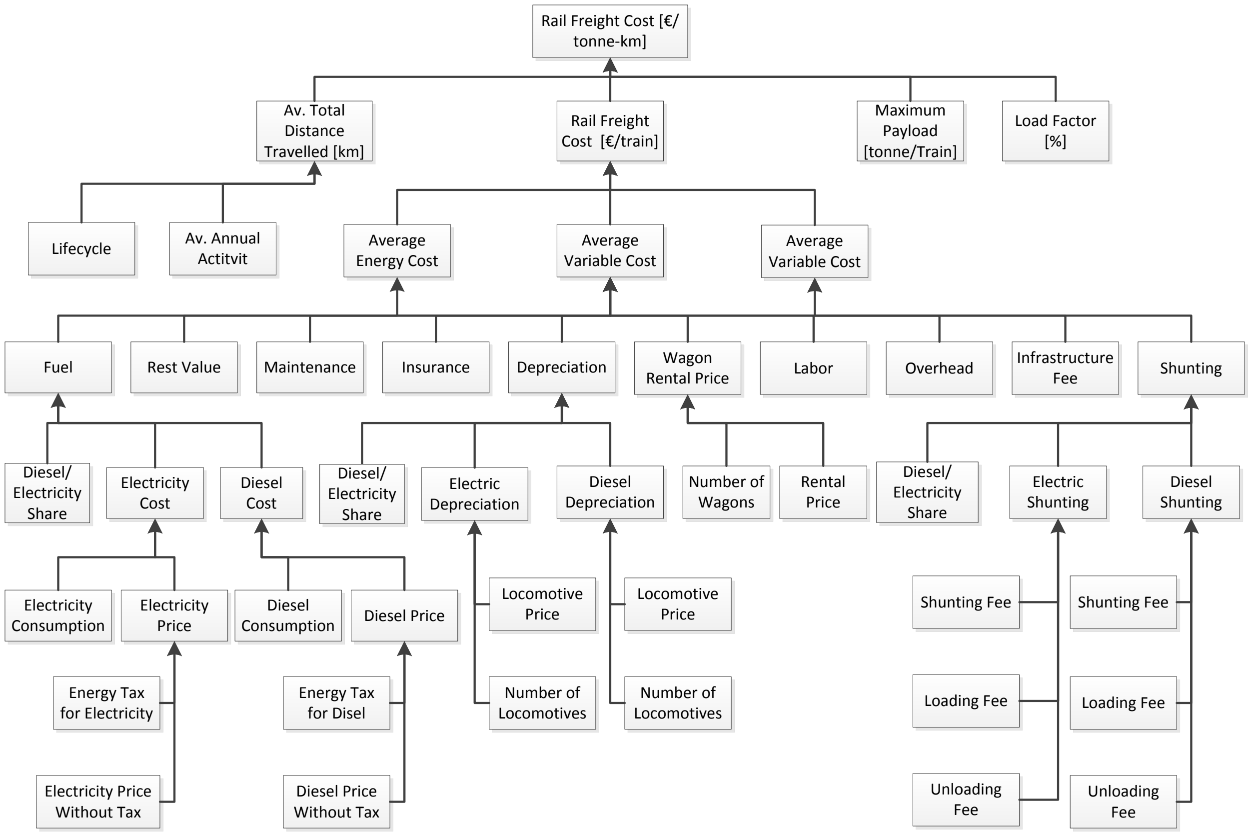


Figure 23 - Rail Freight Cost Data Flow

Short Sea Shipping (SSS) Freight Cost:

As with Road and Rail freight, the data flow of short sea shipping was also developed in accordance with the available means of transport. The resulting structure has been illustrated in Figure 24.

Similar to the previous freight modes, in order to achieve a desired unit of calculation, the SSS freight cost had to be multiplied by the full cargo weight of the ship and the total distance travelled over its lifecycle. Furthermore, Full cargo weight, is a product of the TEU[5] capacity of the ship and the load factor per TEU.

[5] TEU: Twenty-Foot Equivalent Unit

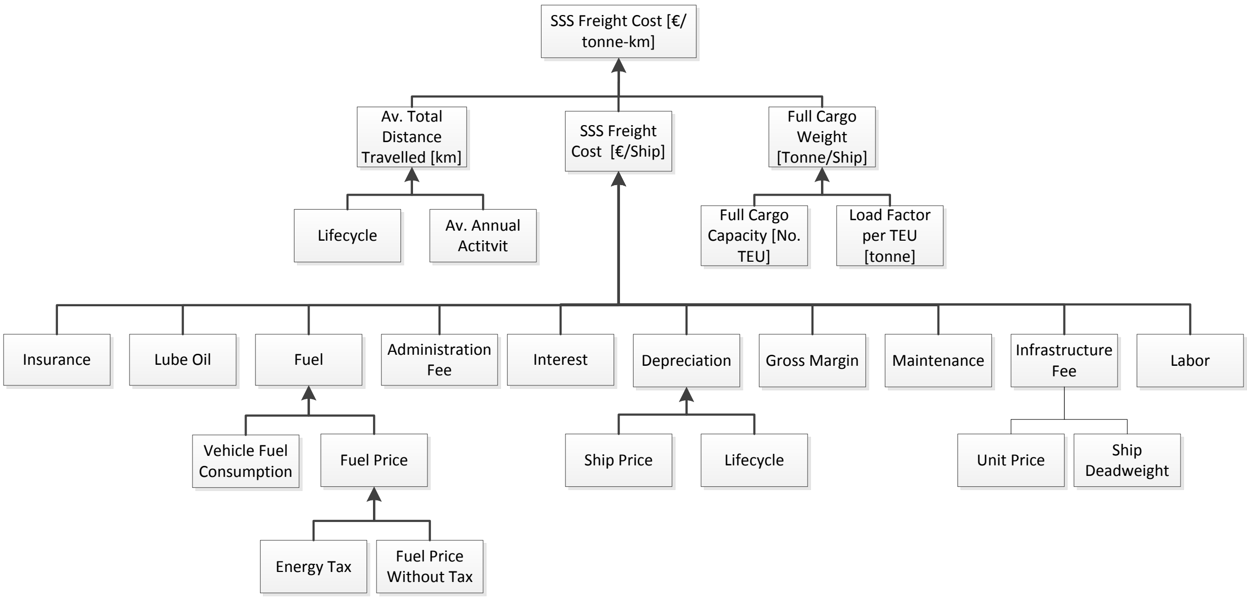


Figure 24 - Short Sea Shipping Freight Cost Data Flow

1.3.3.2 CO_2 Emission Data Flow:

The total CO_2 emission is the sum of the CO_2 emissions of each mode of transport. CO_2 emission for short sea shipping and road freight is a product of the fuel consumption and the fuel emission factor corresponding to each of the modes. Subsequently, fuel consumption is the product of their respective modal share and their fuel consumption factor. For rail freight, the CO_2 emission is the product of rail CO_2 emission factor and its modal share. The data flow obtained from this logic has been illustrated in Figure 25.

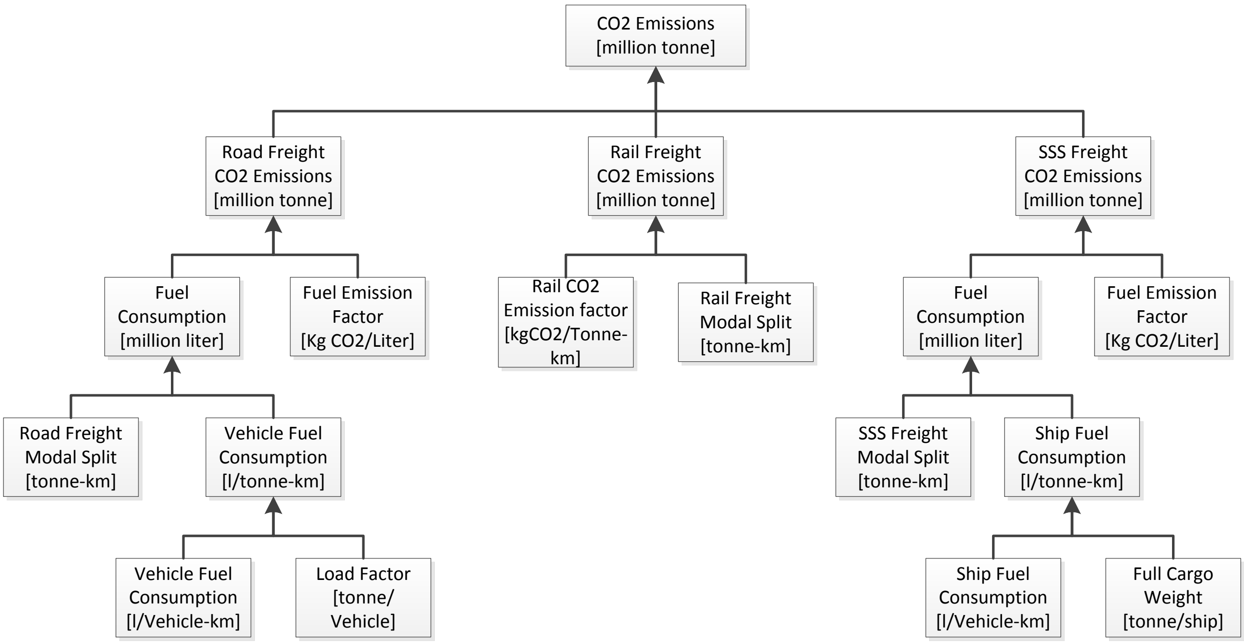


Figure 25 - CO_2 Emission Cost Data Flow

1.3.4 Building the Spreadsheet

The charts depicting the data flows developed in this section were subsequently used to develop the baseline spreadsheet. The existing elements within each chart was assigned a cell within the excel sheet and by following the data flow depicted in the charts, the cells where linked to each other.

2. 2011-2030 Scenario Model

The second step in developing the model was to develop the 2011-2030 scenario model. In order to do so, as was presented in the theoretical framework presented in Chapter II, three steps had to be taken which are the following:

4. Development of the Scenario Spreadsheet
5. Constructing the Value of Time Analysis
6. Construction of Constant Elasticity of Substitution Analysis Tool

Furthermore, these steps will be explained in detail over the course of this section.

2.1 Development of the Scenario Spreadsheet

The next step in developing the 2011-2030 scenario model was to develop the scenario spreadsheet. In this step through developing scenarios and comparing their conditions with that of the baseline scenario, the modified spreadsheet was developed based on the baseline spreadsheet. The different steps of the process will further on be explained.

2.1.1 Scenario Development Process

The different steps of the scenario development process previously presented in Chapter II, up until the last two steps were all accomplished in previous sections of the study, which will now be discussed.

Step 1 - As per definition, establishing *the background of the scenarios* involves the overall assessment of the environmental factors of the industry under investigation. This step was accomplished in detail when the research problem was defined.

Step 2 - *Selecting the critical parameters*, which involves identifying the industry's influential parameters, was performed when the parameters influenced by the White Paper and the accompanying initiatives where introduced in Chapter III. To recap, these parameters include: Fuel cost, Technology, Tax and toll, Modal split.

Step 3 – *Establishing the past behavior for each parameter* was a task which was undertaken during the development of the baseline spreadsheet. One of the goals of the baseline spreadsheet was to illustrate the trend of change within each parameter. Hence, their behavior between 2005 and 2011 on a European level was time lined in detail which will be presented in later chapters.

Step 4 – *The verification of potential future events* was a process which was undertaken when the content of the White Paper and the accompanying Initiatives where analyzed.

Step 5 and Step 6 - In the context of this study, it was decided that the sequence of step 5 and step 6 should be altered. At first, using the knowledge gathered from the first four steps, the scenarios were first developed. Using these scenarios and the structure developed for the baseline spreadsheet, the future of each of the parameters were forecasted.

Furthermore, the developed scenarios will be presented and explained:

2.1.2 Scenarios for 2011-2030

For the purpose of this study, through following the steps introduced in the previous section, five scenarios were developed. In this section, the underlying arguments for the development of each of the scenarios will be presented. Furthermore, the properties of the scenarios will be introduced in later sections. The scenarios in question are the following:

6. Business as Usual
7. Forced Modal Shift
8. New Fuel and Technology Promotion
9. Taxation
10. Maximum Impact

2.1.2.1 Business as usual

As indicated in the title of this scenario, this scenario assumes that no legislation will be institutionalized as a result of the guideline presented in the White Paper. To be more specific, this entails that the parameters would not be subject to changes over the period suggested by this study. However, it is important to indicate that these parameters will not remain constant during this period but, will follow the macro-economic and technological trend in general.

2.1.2.2 Forced Modal Shift

As was discussed in detail one of the main targets of the White Paper is to shift 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050 (European Commission, 2011b). This topic has been a source of great controversy within the freight community in Europe. The lash back on this suggestion of the White Paper was highly visible in two prominent European transport events, namely the European Transport Forum (ETF) seminar and the International Road Transport Union-EU conference.

Based on this knowledge, this scenario was developed with the premise that within the 2011-2030 time line, legislation would be in place which would follow the White Paper guideline of shifting freight by 30% from road to alternative modes.

2.1.2.3 New Fuel and Technology Promotion

Similar to the previous scenario, the principle of this scenario is based on one of the focal points of the white paper, that is, the development of new innovative technologies and the shift away from traditional fossil fuel sources to new sustainable sources.

According to the White Paper and the accompanying initiatives, the promotion of new fuels could be achieved through the implementation of new energy taxation schemes. Also, the promotion of new technologies could similar to passenger vehicles be achieved through implementing requirements on performance on vehicles and their performance (European Commission, 2011b).

Based on this information, this scenario was developed with the premise that within the time frame of the study, new taxation schemes and performance requirements would be institutionalized by the EU.

The following items are currently under consideration by the EU for legislative purpose and have the properties to be used by the EU to promote new fuels and technologies:

- **Energy Taxation:** Currently, energy taxation is only based on the energy content of fuels. However, the proposal under investigation is aimed to introduce an additional taxation based on the carbon content of the fuel (European Parliament and of the Council, 2011b).

- **MARPOL:** The International Maritime Organization (IMO) recently adopted an amendment to the MARPOL Annex VI which is aimed at reducing air pollution from ships. This amendment has been implemented by the EU, although the content of this amendment is yet to be proposed as an official directive by the European Commission. An impact assessment on the future requirements of this amendment has been prepared and the feasibility of a legislative proposal is under investigation (SKEMA, 2010).

- **Non Road Mobile Machinery (NRMM) Directive:** The amendments of the NRMM directive foresees review clauses for certain elements of the directive. One of these review clauses is the introduction of emission standards stage IIIB and stage IV to the directive which would require after treatment equipment for diesel trains (Zeebroeck et al., 2009).

- **Performance Requirements for Heavy Duty Vehicles:** Currently, performance requirements for vehicles and their components exist for passenger vehicles. However, these requirements do not apply to heavy duty vehicles which could change in the near future.

2.1.2.4 Taxation

In the White Paper, it is specifically mentioned that one of the solutions of the transport CO_2 emission dilemma is to implement taxation schemes, whether these schemes would be aimed at energy content, CO_2 emission or the usage of infrastructure (European Commission, 2011b).

Considering this information, this scenario focuses on a situation where the EU decides to battle the CO2 emissions from freight by solely focusing on the enactment of various taxation schemes.

The following items are to be considered as possible legislative options for the EU to impose the desires taxation schemes:

- **eMaritime:** The initiative is aimed to promote the utilization of advanced technologies in the maritime sector. If the initiative would be implemented as legislation in Europe, it is expected that a reduction in network costs would result (DG Move, 2010).

- **Emission Trading Scheme:** Currently the maritime sector in Europe is exempt from the carbon trading scheme. However, it is expected that this scheme along with an emission tax will eventually be introduced for the maritime sector (CE Delft, 2009).

- **Eurovigenette:** An amendment on the Eurovignette has recently been adopted by the EU which assigns proposed new maximum limits for charging heavy duty vehicles and also a new charging methodology. The member states will furthermore have the option to implement the maximum limit of charging within their borders.

- **Railway Network Access Levy:** Currently, with accordance to EU legislation, each member state is required to have a regulator to control railway charges and conditions (European Parliament and of the Council, 2001). However, legislation for regulating the railway networks charges was proposed in 2008 which is still under consideration and could effectively increase rail network charges (European Commission, 2008c).

- **Energy Taxation:** This directive was introduced in the previous section.

2.1.2.5 Maximum Impact

As can be deduced from the tile of this scenario, the premise is that the EU would enact all of the tools at its disposition. That is a combination of taxation schemes, restrictions and requirements and forced modal shift, which has all been mentioned in the White Paper as means to achieve the desired targets.

The potential legislative tools in reach of the EU for enabling the conditions advocated by this scenario is the sum of all the tools introduced for the previous scenarios.

2.1.3 Developing the Spreadsheets

The next step in developing the scenario spreadsheet was to construct the actual spreadsheet**.** The spreadsheet was developed based on the baseline spreadsheet model as most of the parameters would remain constant. However, due to the premise offered by each scenario, some additional elements had to be added to the baseline spreadsheet which was accomplished in this step. The development of the spreadsheet consisted of the following two phases:

1. Identifying changes in the 2011-2030 scenarios vs. the baseline
2. Building the Spreadsheets

In the following section these phases will be explained in detail.

2.1.3.1 Identifying changes in the 2011-2030 scenarios vs. the baseline

In this section, the changes that had to be implemented into the baseline spreadsheet will be explained. As the changes vary between the scenarios, each scenario will be explained separately.

1. Business as Usual Scenario

It was previously explained that the premise of this scenario is that no change will occur based on the guidelines of the White Paper. Hence, it is expected that no change compared to the baseline is to be detected.

2. Forced Modal Split Scenario

According to this scenario, similar to business as usual, no change is expected to occur in the structure of the data flow and subsequently the spreadsheet. As was previously explained while explaining the development process of the PCI, modal split only act as an input parameter for the baseline spreadsheet, whereas for the 2011-2030 spreadsheet it will act as an output parameter. However, the implication of this scenario will act as a boundary condition for the level of modal split allowed during the 2011-2030 timeframe. Subsequently, this boundary will alter the value of total freight expenditure and CO_2 emissions.

3. New Fuel and Technology Promotion Scenario

The premise of this scenario was the addition of new taxation schemes and performance requirements. Therefore, changes were expected to occur in the structure of the data flows of the baseline spreadsheet. In addition, the changes would be directed towards the main input parameters (excluding modal split) of the spreadsheet.

Using the content of the potential future legislative opportunities, the changes were projected for each mode which will furthermore be presented.

Changes to the Road Freight Expenditure Data flow:

The projected changes in the road freight expenditure data flow has been illustrated in Figure 26. In this figure, only the altering elements of the total structure are being presented.

As can be seen, fuel taxation, under the assumptions of this scenario, does not consist of a single element but has been split into carbon and energy taxation. This is an effect of the Energy Taxation directive.

In addition, because of the expected future performance requirement for road freight vehicles, the price of upgrading to comply with these requirements has been added to the depreciation cost.

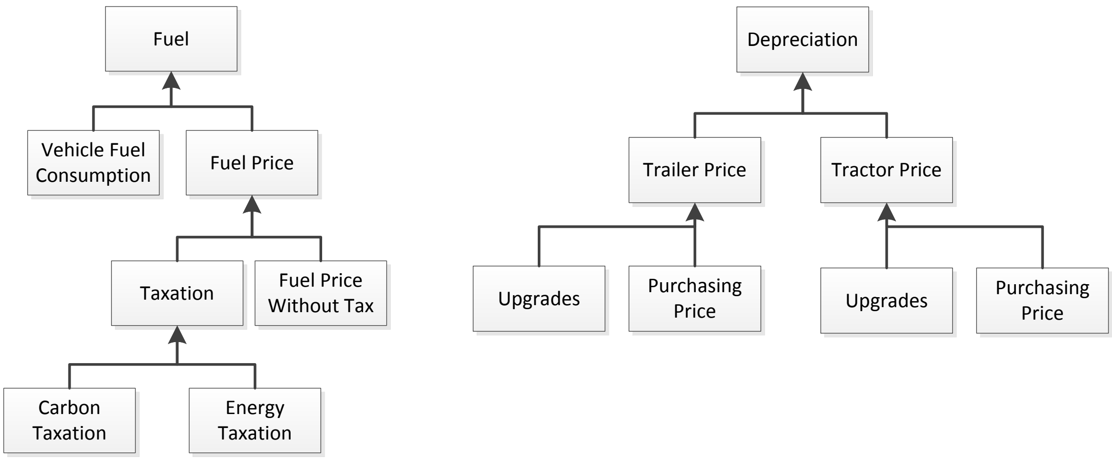


Figure 26 - Structural Changes of Road Freight Expenditure Data Flow for Scenario 3

Changes to the Rail Freight Expenditure Data flow:

The predicted changes for the rail freight expenditure data flow can be seen in Figure 27. Again similar to road freight, in this figure, only the altering elements of the total structure is being presented.

As can be seen, the taxation on electricity and diesel has been split into carbon and energy taxation which is due to the Energy Taxation Directive.

Also because of the effects of the NRMM directive, the price of treatment equipment has been added to the depreciation cost. However, it is important to note that the treatment equipment, under the NRMM, is only required for diesel driven trains.

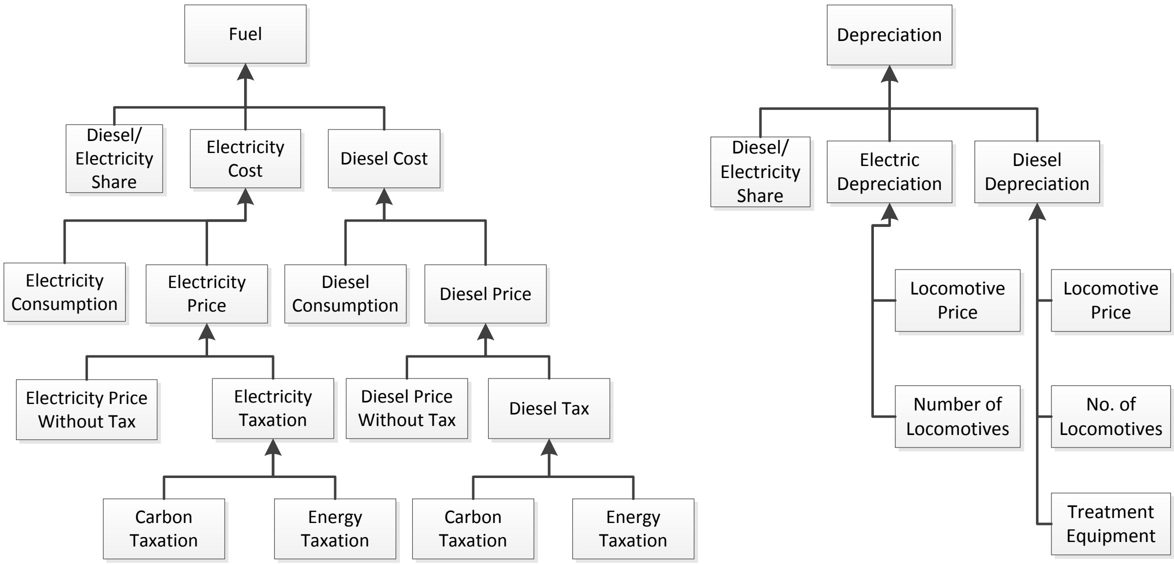


Figure 27 - Structural Changes of Road Freight Expenditure Data Flow for Scenario 3

Changes to the Short Sea Shipping Freight Expenditure Data flow:

The changes that can be expected to occur in the short sea shipping freight expenditure data flow structure can be seen in Figure 28. As with the previous modes, only the changing elements will be presented.

Following the logic presented for road and rail freight, fuel taxation will be a sum of energy and carbon taxation for short sea shopping. In addition, due to the MARPOL Annex VI amendment, the fuel for shipping will require lower sulphur content compared to the current fuel standards used (Eef Delhaye, et al., 2010). This will effectively result in higher fuel prices. However, this change is not of a structural nature but of a quantitative nature which cannot be detected in the figure.

In addition, because of the effects of the MARPOL Annex VI amendment, equipment upgrades will have to be added to the existing technologies used in ships which will be included in the depreciation cost.

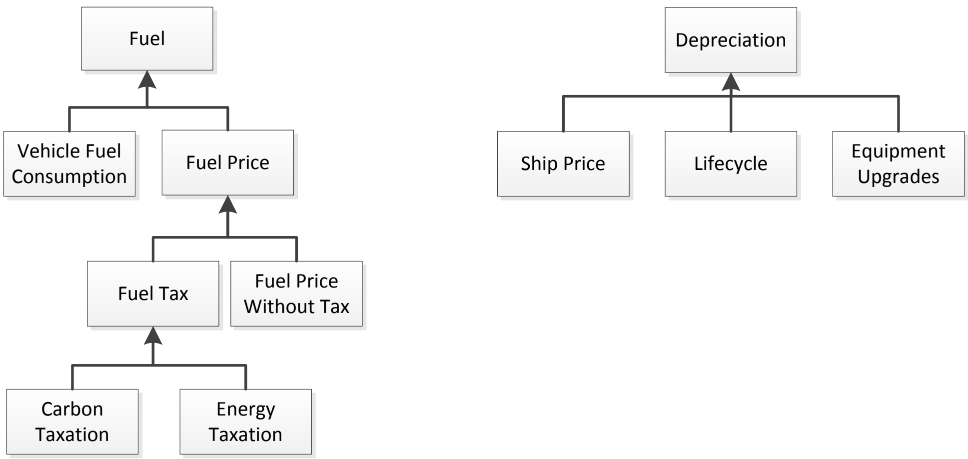


Figure 28 - Structural Changes of Road Freight Expenditure Data Flow for Scenario 3

Changes to the CO_2 Emission Data Flow:

The changes that can be expected to occur in in the CO_2 emission data flow structure has been illustrated in Figure 29. Again, only the changing elements will be presented.

As can be seen, the only change compared to the original structure that can be expected is the inclusion of a technology improvement impact element for road freight. This is because, the guidelines advocated by the White Paper mainly promotes reduced CO_2 emissions through shifting freight from roads to alternative modes of transport. In addition, the technology improvements proposed for rail and short sea shipping through the MARPOL amendment for the former and NRMM directive for the later do not focus on CO2 emissions. It should also be noted that the current alternative fuels are not applicable to rail and sea freight.

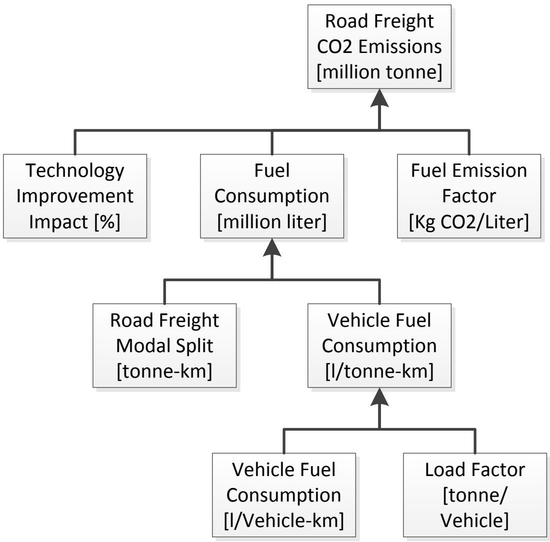


Figure 29 - Structural Changes the CO_2 Emission Data Flow for Scenario 3

4. Taxation Scenario

The outline of this scenario was the implementation of various new taxation schemes. Hence, changes are expected to transpire in the original data flow structure. Similar to the previous scenario, the changes are to be directed towards the main input parameters, namely technology (depreciation fee), fuel cost, and tolls and taxation (fuel cost and network fee).

Using the content of the potential future legislative opportunities, the changes were projected for each mode which will furthermore be presented.

Changes to the Road Freight Expenditure Data flow:

The changes that can be expected to occur to the road freight expenditure data flow structure for this scenario can be seen in Figure 30.

Due to the assumption that the Energy Taxation Directive will also be implemented in this scenario, fuel cost will follow the same logic as for the previous scenario.

As for network costs, because of the amendment to the Eurovignette Directive, an element to the structure has been added, which is the distance travelled for the vehicles. In addition, the rates have also changed which will not alter the structure.

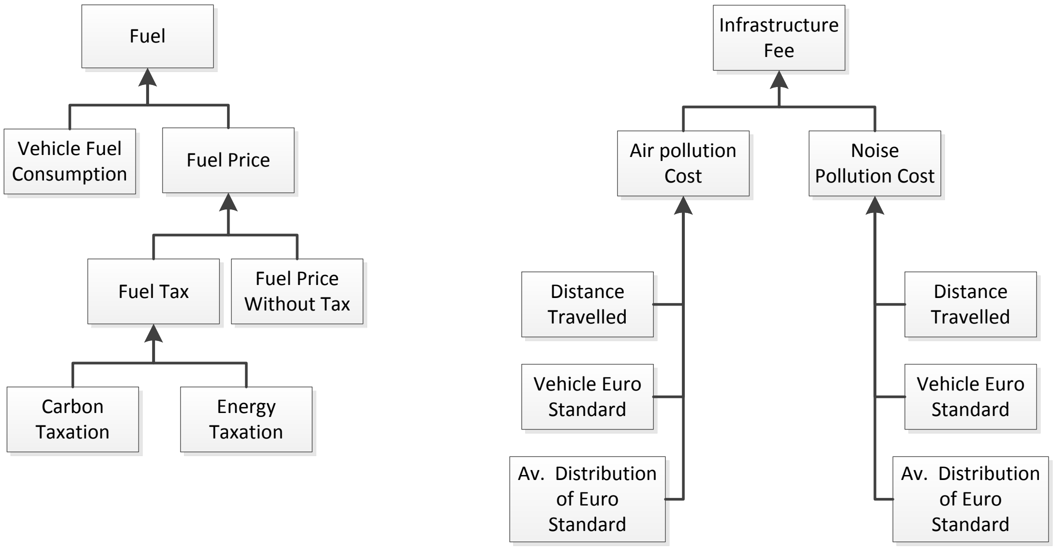


Figure 30 - Structural Changes of Road Freight Expenditure Data Flow for Scenario 4

Changes to the Rail Freight Expenditure Data flow:

The expected changes to the rail freight expenditure data flow for this scenario has been illustrated in Figure 31.

As can be seen only the fuel structure will change in a similar fashion to the previous scenario. The rate of infrastructure fee will also change due to the Railway Network Access Levy proposal. However, no change to the data flow structure is expected according to the proposal.

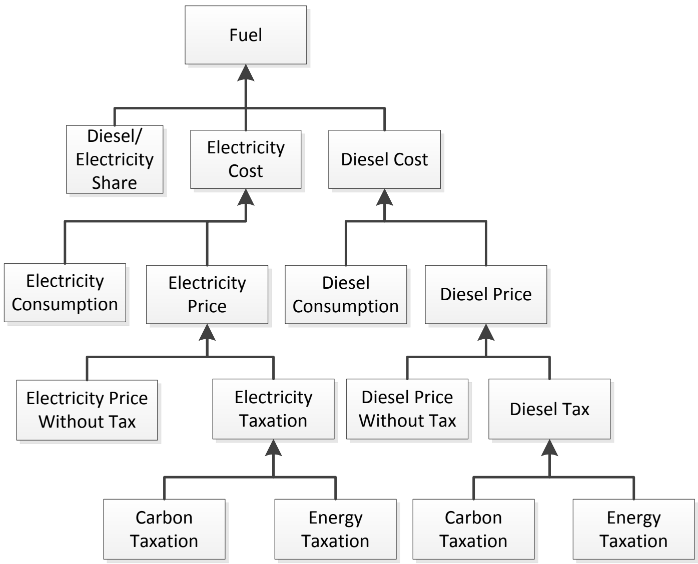


Figure 31 - Structural Changes of Rail Freight Expenditure Data Flow for Scenario 4

Changes to the Short Sea Shipping Freight Expenditure Data flow:

The changes that can be expected to occur to the short sea shipping freight expenditure data flow structure for this scenario has been presented in Figure 32.

Similar to the previous scenario, fuel structure will change because of the Energy Taxation Directive. In addition, the structure for infrastructure fee will change compared to the original structure. Due to the anticipated addition of the maritime sector into the European Carbon Trading Scheme, this element has been added to the structure. Also, the rate of port fee will change because of the eMaritime initiative which, however, will not add any additional elements or change the structure of the data flow.

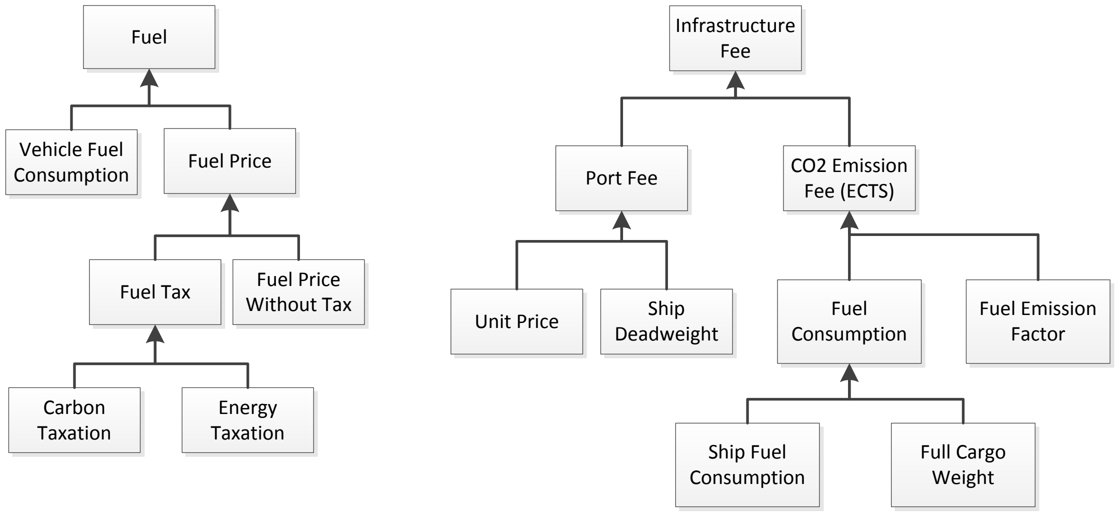


Figure 32 - Structural Changes of Short Sea Shipping Freight Expenditure Data Flow for Scenario 4

5. Maximum Impact

For the maximum impact scenario, the changes in the structure of the freight expenditure data flow consisted of a consolidation of all the changes introduced for scenario 3, 4, and 5. In addition, the modal split boundary condition explained for scenario 2 will also be included in the final calculation.

2.1.4 Building the Spreadsheet

The changes in the data flows developed in this section were subsequently implemented in the baseline data flow structure which resulted in the 2011-2030 data flow structure. Further on, based on the baseline spreadsheet, the additional elements introduced in this section were assigned a cell within the excel sheet and by following the data flow depicted in the charts, the cells where linked to each other.

2.2 Constructing the Value of Time Analysis

The next step in developing the 2011-2030 scenario model was to construct the Value of Time Analysis. The Value of Time as was previously explained, correspond to the effect of human behavior in freight modal split analysis. As one of the objectives of this study was to analyze the effect of changes in freight on Toyota Motor Europe’s logistics activities, the Value of Time analysis was specifically focused on Toyota. To be more specific, the aim was to analyze the effect of human behavior within the company on logistics activities.

For this step, initially a stated preference survey was developed and next a platform was selected and configured in order to enable the analysis of the data obtained from the survey.

In this section, first, construction of the stated preference survey will be explained which will be followed by the details regarding the platform selected to perform the analysis.

2.2.1 Constructing the Stated Preference Survey

For conducting the stated preference survey, it was decided to conduct the survey utilize an online survey service in order to increase the accuracy of the obtained data and ease the data consolidation process. The service selected for this purpose was Qualtrics.com where the survey was constructed.

For the purpose of this study, Discrete Choice Modeling was decided to be used to estimate the Value of Time for freight. Hence, the data acquisition technique which was to be utilized was a discrete choice or stated choice survey.

While designing the survey it was important to consider the variety of logistics activities conducted at Toyota. Toyota Motor Europe's logistic activities as have been explained Consist of three separate groups: Service Parts Logistics, Vehicle Logistics Group, and Production Parts Logistics. Due to the different areas of responsibility of each of the mentioned groups, their approach to conducting logistics differs from each other. These differences include:

- **Time restrictions:** Some of the groups need to follow tight schedules whereas some have a more relaxed approach to time.
- **Budget Restriction:** The level of budget and expenditure ability is not equal between the groups.
- **Vehicles or Vessels they utilize:** According to the category of product they are responsible to ship, the means of transport differs.

Hence, in order to avoid generalization, it was decided to conduct the stated preference survey separately for each group. This would make the results of the study more relevant to the groups and provide them with information which would enable a more accurate decision making process.

In addition, because of the different means of transport used by each group, the data used for each individual survey would defer. The data used was based on the characteristics of the means of transport which was used more prominently by the group.

While designing the survey, it was imperative to design the questions in such a way that the respondents had to choose one alternative out of two or more alternatives which was given to them. The survey had to be designed so that the respondent were forced to make trade-offs between changes in the value of the attributes.

The data which was to be used in the survey questions were developed through generating a series of random distances which a specific volume of goods were to be transported across. The expected total travel time would then be a product of these distances and the speed of the mode in question. Similarly, the cost would be the product of the weight of the goods, the distance and the price of the mode which in turn would be extracted from the baseline spreadsheet. This process can be seen in Figure 33.

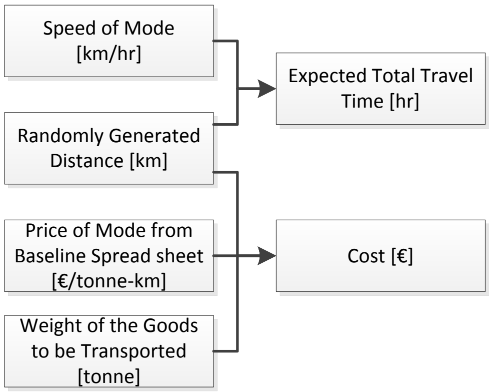
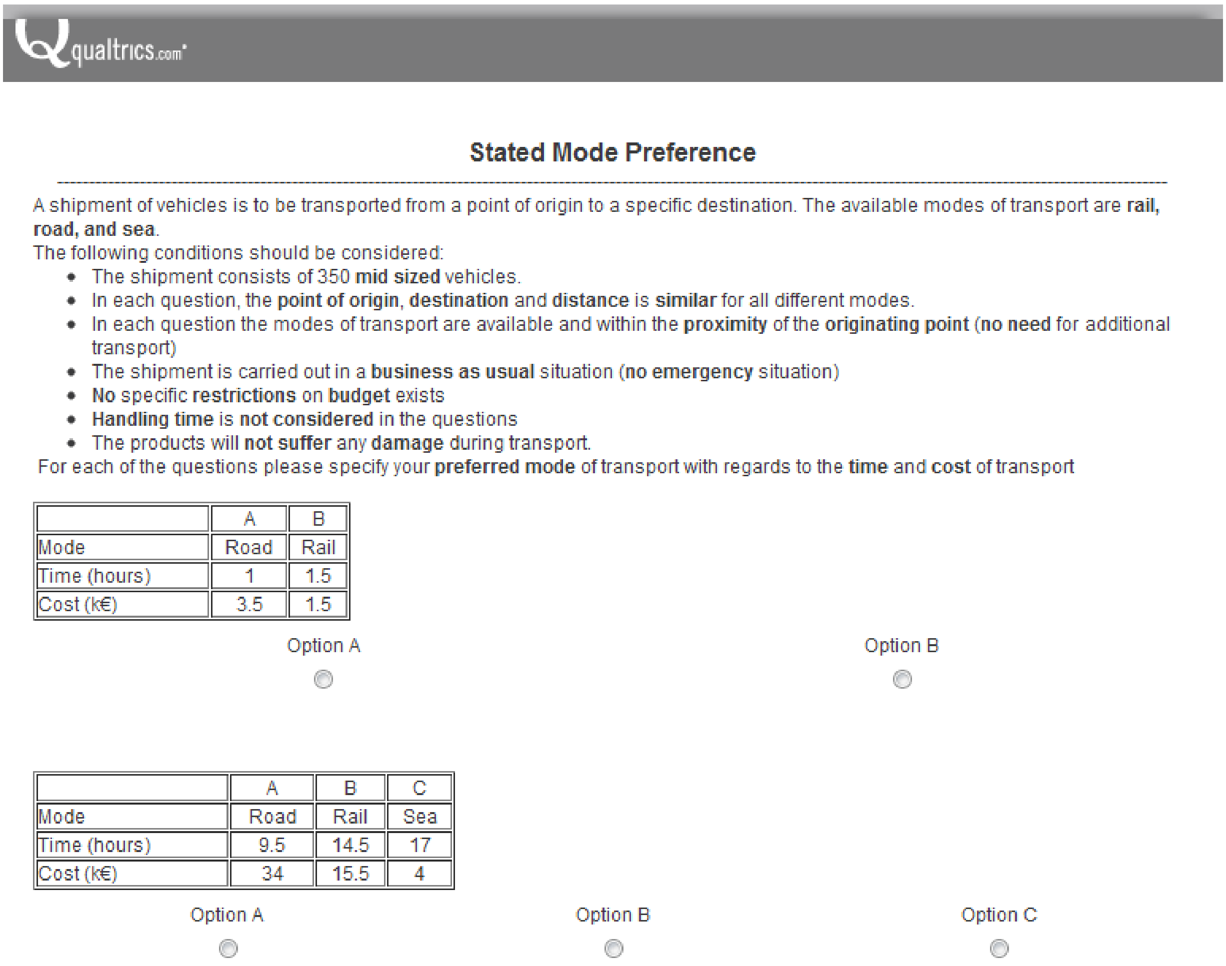


Figure 33 - Survey Data Development Process

An example of a survey question which was developed based on this guideline can be seen in Figure 34. Furthermore, the stated preference surveys developed for each one of the groups can be seen in Appendix B.


qualtrics.com

Stated Mode Preference

A shipment of vehicles is to be transported from a point of origin to a specific destination. The available modes of transport are **rail, road, and sea**.

The following conditions should be considered:

- The shipment consists of 350 **mid sized** vehicles.
- In each question, the **point of origin, destination** and **distance** is **similar** for all different modes.
- In each question the modes of transport are available and within the **proximity** of the **originating point** (**no need** for additional transport)
- The shipment is carried out in a **business as usual** situation (**no emergency** situation)
- **No** specific **restrictions** on **budget** exists
- **Handling time** is **not considered** in the questions
- The products will **not suffer** any **damage** during transport.

For each of the questions please specify your **preferred mode** of transport with regards to the **time** and **cost** of transport

	A	B
Mode	Road	Rail
Time (hours)	1	1.5
Cost (k€)	3.5	1.5

Option A ◯ Option B ◯

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	9.5	14.5	17
Cost (k€)	34	15.5	4

Option A ◯ Option B ◯ Option C ◯

Figure 34 - Sample of Questions used in the Stated Preference Survey

The management for each of the groups where contacted and the underlying rational for conducting the survey where presented to them. It was further on, requested that each group should nominate a number of employees with sufficient knowledge about how logistic activities is conducted in their respective groups.

The following number of participants was introduced by each group:

- Toyota Parts Centre Europe (service parts logistics): 12
- Vehicle Logistics Group: 12
- Production Parts Logistics: 12

The low number of participants from vehicle logistics can be traced back to the small size of the groups.

Further on, the surveys were sent out to the participants by E-mail with clear instructions on how to complete the questions. The surveys were completed online and the results were returned.

The next step of constructing the Value of Time analysis was selecting a platform to analyze the obtained data. This step will henceforth be explained.

2.2.2 Selection of Data Analysis Platform

BIerlaire Optimization toolbox for GEv Model Estimation (BIOGEME) is a software package which is designed with the purpose to be used in the context of discrete choice model research. The software was developed by the Transport and Mobility Laboratory of the EPFL University in Switzerland. It allows the estimation of parameters for a various range of models. The multinomial logit model which would be used as the underlying basis for the Value of Time analysis is among the model which the software is able to process (Bierlaire, 2003).

For the purpose of the study, the latest stable release of the software was chosen (BIOGEME 2.0). A screenshot of the interface of this version of the software can be seen in Figure 35.

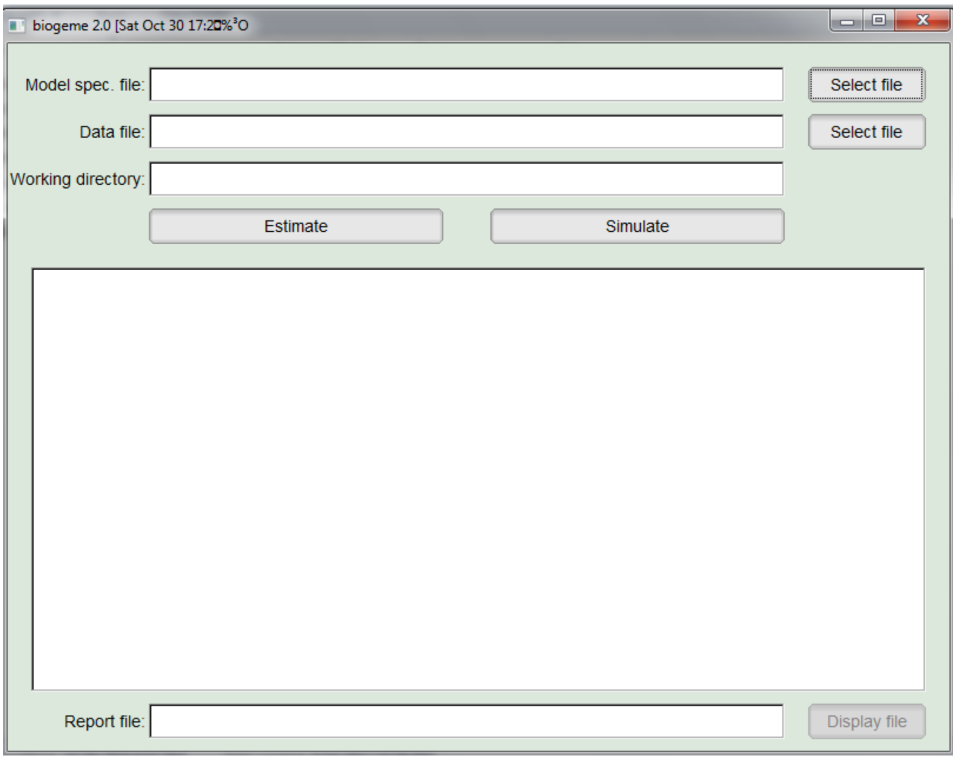


Figure 35 - Screenshot of BIOGEME Interface

As can be seen, the software will initially require two input files. In addition, the software will also read a parameter file from the software folder. These file are the following:

- Parameter file containing the parameters controlling the behavior of Biogeme;
- Model spec. file which contains the specification of the model in question;
- Data file that contains the data acquired from the stated preference survey.

In addition, the output files from the software are the following:

- A file reporting the results of the estimation
- The same file in HTML format
- A file containing the specification of the estimated model
- A file containing statistics on the data

2.2.2.1 Biogeme Input Files

The information which had to be provided as input was the model spec. file and the data file. Defining the parameter file was not mandatory as it is predefined to the default behavior of Biogeme which is what was needed for this study.

The data file was compiled through following the format suggested by the software handbook (Bierlaire, 2009) and arranging the data acquired from the stated preference survey. A sample of the arrangement of the data can be seen in Figure 36.

Id	RP Weight	Choice	x11	x21	x31	x12	x22	x32	av1	av2	av3	
1	1	2	15500	1000	1000	1	1.5	2	1	1	0	1
1	0	2	43500	3500	3000	3	2.75	6	1	1	0	1
1	0	2	21500	2000	1500	1.25	1.5	3.5	1	1	0	1
1	0	2	70000	5000	4000	4.5	5	10	1	1	0	1
1	0	2	115000	11000	7500	9.5	10	17	1	1	1	1
1	0	2	230000	21000	12500	19	20	34.5	1	1	1	1
1	0	3	340000	42000	22500	38	40	69	1	1	1	1
1	0	3	590000	75000	38000	66	71	120	1	1	1	1
1	0	2	850000	105000	53000	95	102	172	1	1	1	1
1	0	2	150000	14000	22000	12	13	22	1	1	1	1
1	0	3	288000	25500	43000	23.5	25.5	43	1	1	1	1
1	0	3	425000	53000	28000	47	53	28	1	1	1	1

Figure 36 - Sample of Data Arrangement for the Data File

The spec. file was also developed through following the suggested format of the handbook. Hence, Equation 6 and the theoretical base developed were implemented into the file. The content of the spec. file developed can be seen in bellow:

```
// Freight Value of Time Analysis logit model
// Author: Salman Farhanieh, TUDelft-Toyota Motor Europe
// April 2012

[ModelDescription]
"Example of a logit model"
"3 alternatives and 5 parameters"
"2 parameters are estimated"

[Choice]
Choice

[Beta]
// Name Value  LowerBound UpperBound  status (0=variable, 1=fixed)
ASC1      0.0      -10       10          1
ASC2      0.0      -10       10          0
ASC3      0.0      -10       10          0
BETA1     0.0      -10       10          0
BETA2     0.0      -10       10          0

[LaTeX]
ASC1   "Constant for alt. 1"
ASC2   "Constant for alt. 2"
ASC3   "Constant for alt. 3"
BETA1  "$\beta_1$"
BETA2  "$\beta_2$"

[Utilities]
// Id Name  Avail  linear-in-parameter expression (beta1*x1 + beta2*x2 + ... )
  1  Alt1  av1  ASC1 * one + BETA1 * x11 + BETA2 * x12
  2  Alt2  av2  ASC2 * one + BETA1 * x21 + BETA2 * x22
  3  Alt3  av3  ASC3 * one + BETA1 * x31 + BETA2 * x32

[Expressions]
// Arithmetic expressions for name that are not directly
// available from the data
one = 1

[Model]
// $MNL stands for MultiNomial Logit
$MNL
```

These two files were to be used as input for the software which the model would use to run the simulation to estimate and report the β values introduced in Chapter II. Through using the β values in Equation 7 It would be possible to estimate the value of time.

2.3 Construction of the Constant Elasticity of Substitution Analysis Tool

The next step in developing the 2011-2030 scenario model was to construct the Constant Elasticity of Substitution Analysis Tool.

By utilizing the theoretical knowledge presented in Chapter II, the constant elasticity of substitution analysis tool was constructed. The different steps for developing the tool were the following:

1. Defining the nested utility tree
2. Creating the governing CES function
3. Calibration of the mode
4. Designing the CES Model

In this section the different steps of the process will be presented.

2.3.1 Defining the Nested Utility Tree

The first step of the process was to define the nested utility tree. For the purpose of this study, only the most generalized categorization of modal split was considered which meant that no sub categories in modal split (e.g. size, speed, and ...) would be considered. Hence, the nested utility tree which the model would be based on took the form of a flat CES-tree in which on the same level, a choice is to be made between the different modes. The nested utility tree defined for this study can be seen in Figure 37:

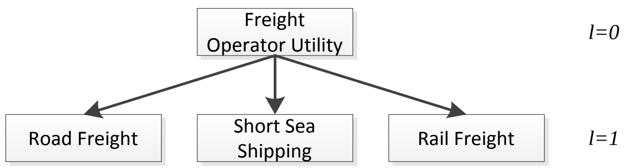


Figure 37 - The Nested Utility Tree Used for the Modeling

2.3.2 Creating the Governing CES Function

By using the nested utility tree it was possible to create the governing CES utility function. By using the generalized CES utility function presented in Equation 8 of Chapter II and modifying it to correspond to the nested utility function the CES utility function for the purpose of this study was created which took the following form:

Equation 11

$$U = \left[\left(\alpha_{Road}^{\frac{1}{\sigma}} \times q_{Road}^{1-\frac{1}{\sigma}}\right) + \left(\alpha_{Rail}^{\frac{1}{\sigma}} \times q_{Rail}^{1-\frac{1}{\sigma}}\right) + \left(\alpha_{SSS}^{\frac{1}{\sigma}} \times q_{SSS}^{1-\frac{1}{\sigma}}\right)\right]^{\frac{\sigma}{\sigma-1}}$$

Where U represents freight operator utility, q shows the quantity of freight demanded (modal split), α is a share parameter and σ denotes the elasticity of substitution.

The freight quantity is to be estimated through the maximization of Equation 11, subject to the following budget constrains:

Equation 12

$$B = (p_{Road} \times q_{Road}) + (p_{Rail} \times q_{Rail}) + (p_{SSS} \times q_{SSS})$$

Where, B is the budget available to spend on freight activities and p is the generalized price equal to the sum of Value of Time and freight cost.

2.3.3 Calibrating the Model

After having created the CES utility functions, the model needed to be calibrated in order to calculate the values of α for road, rail and SSS. Through considering the nested utility tree and by using the generalized equation (Equation 10), the calibration equation for the model took the following form:

Equation 13 $$q_{Road} = \frac{\left(\frac{\alpha_i}{p_i}\right)^{\sigma} \times B}{(\alpha_{Road}^{\sigma} \times p_{Road}^{1-\sigma}) + (\alpha_{Rail}^{\sigma} \times p_{Rail}^{1-\sigma}) + (\alpha_{SSS}^{\sigma} \times p_{SSS}^{1-\sigma})}$$

As i can represent road, rail or short sea shipping (sss), the equations represented three separate equations. In other words, a system of simultaneous equations had developed which needed to be solved. In the equations, the values of p, q, and B could be extracted from the baseline spreadsheet and σ was a constant value extracted from literature.

2.4 Designing the 2011- 2030 Scenario Model

After having performed each of the required steps the final step of the construction of the 2011-2030 Scenario Model was to design the actual model which was conducted through utilizing the information developed during the previous steps. This was accomplished through first developing the process flow for the Model. The process flow can be seen in Figure 38.

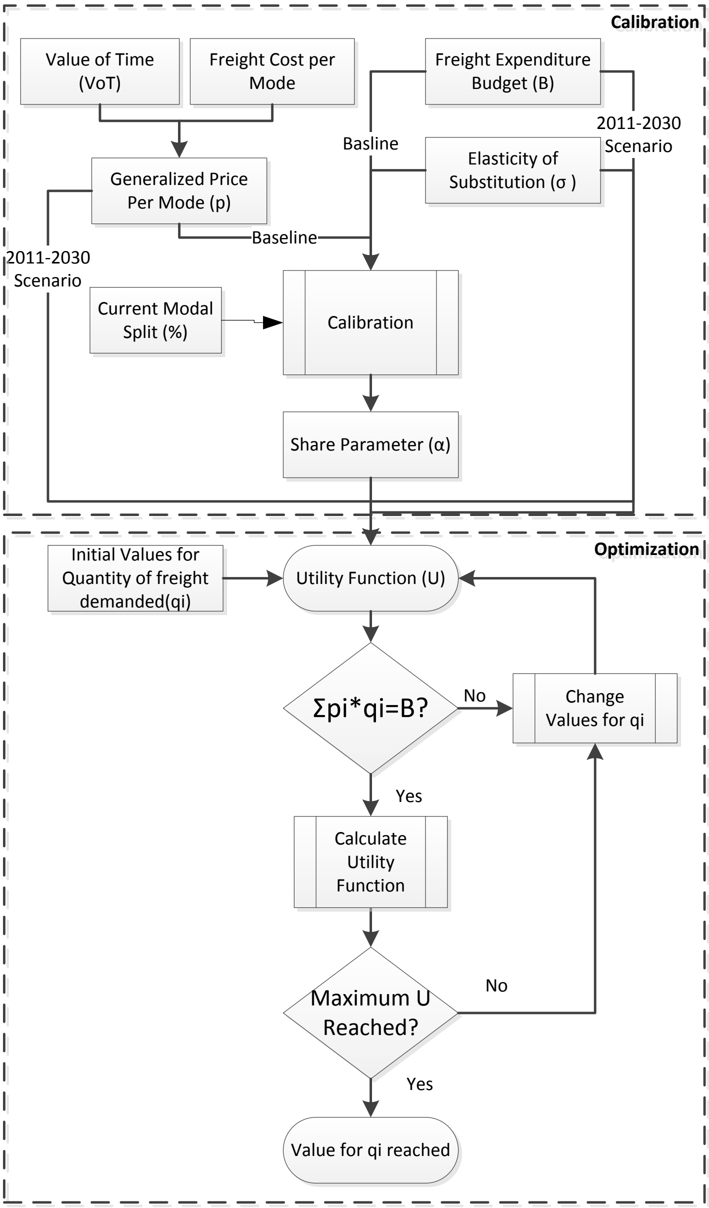


Figure 38 – 2011- 2030 Scenario Model Process Flow

As can be seen from the figure, the baseline generalized price, freight expenditure budget, and elasticity of substitution is used to calibrate the model. The output of the of (α) along with the 2011-2030 scenarios generalized prices, freight expenditure budget, elasticity of substitution, and an initial value for quantity of freight are fed into the utility equation. The $B = \sum p_i \times q_i$ proposition is then tested. If the proposition does not hold, new values for q_i are selected. If the proposition is true, the utility function is calculated. If the maximum of U is not achieved, again new values for q_i are selected. If maximum is reached, the values selected for q_i is the desired values which represent modal split.

In order to implement the optimization part of the model flow, excel solver was chosen. In the excel sheet, all the required links presented in the process flow were established. As the condition for each scenario were to be different, a separate excel sheet was developed which corresponded to each scenario. The input parameters for each sheet were subsequently linked to the scenario spreadsheet matching the scenario in question. Furthermore, as the modal split was to be estimated for each logistics group separately, a set of excel sheets were developed for each logistics group

3. Model Overview

To recap this Chapter, the two major steps to develop the spreadsheet model were the development of the baseline spreadsheet, and the 2011-2030 scenario model. Through completing these two major steps, the totality of the spreadsheet model was developed. A summary of the functionality of the model can be seen in Figure 39.

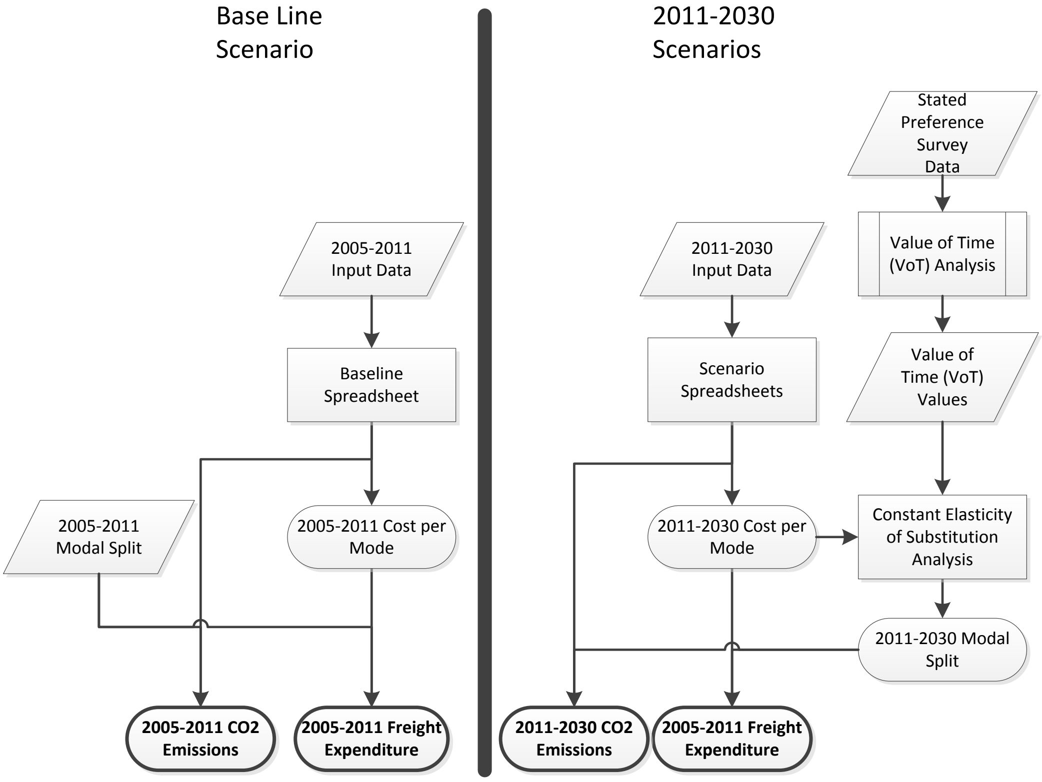


Figure 39 - Summary of the Spreadsheet Model Functionality

Before utilizing the model, it was imperative to evaluate it in order to determine its credibility. The next chapter will explain the evaluation process.

V. Evaluation of the Model

The purpose of the model evaluation process is to assure the credibility of the model since results collected would otherwise not be rendered reliable and the answers provided for the research questions would not be deemed trustworthy.

In this chapter, at first the verification and validation of the model will be presented. This will be followed by the sensitivity analysis description. The chapter will end with the analysis of the robustness of the model.

1. Verification and Validation

In order to be able to utilize the output of the model the model needs to first be validated and verified. In this section, the validation and verification process will be explained and the results will be analyzed.
As mentioned, in order to assure that the output of the model is reliable and can be used for forecasting future freight conditions, it first needs to be verified and validated. In Figure 40 a schematic overview of the verification and validation process can be seen.

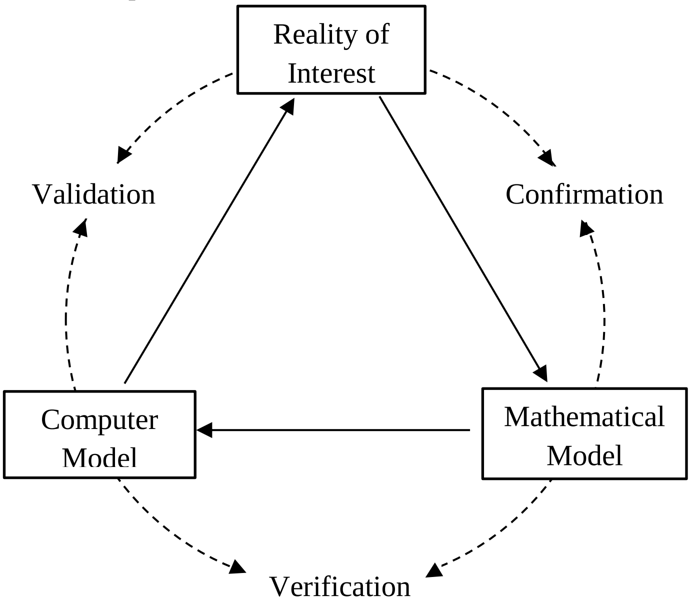


Figure 40- Schematic Overview of the Model Verification and Validation Process (Schlesinger, 1979)

The modeling process can be identified in the figure through the solid lines and the model assessment process can be seen as the dashed lines. As has been previously explained, the reality, in our case the European freight industry, is first analyzed and its desired properties are translated into mathematical equations. These equations are furthermore converted into a computer model which will be able to describe predefined aspects of the reality of interest. The process of converting the mathematical model into a computer model needs to be verified in order to guarantee that the implementation of the model has properly been performed and that the model does not contain any bugs (Kleijnen, 1995).

To summarize, the output of the computer model shown in Figure 40 can only be utilized for explaining the reality of interest after having been validated. The validation procedure is hence undertaken in order to provide the user with confidence that the outcome of the model is what was originally intended.

There are two basic techniques for validating a model which are Static or Dynamic testing (Fairley, 1976). According to Sargent (2007) in static testing the correctness of the computer model is determined through examining the structure, statements and codes of the model. In dynamic testing however, the computer model is executed under different conditions and the output is analyzed in order to determine whether or not the model and its implementations are correct.

The testing procedure of the computer model is performed by the designer of the model which will thereby conclude if the model is verified and valid. The model can also be verified and validated by an independent party in order to eliminate biased conclusions and increase credibility (Sargent, 2007).

In order to verify and validate the developed model for this study, it was decided to use dynamic testing in favor of static testing techniques. As mentioned before, meant that the model would be evaluated through executing it and analyzing the output. The two techniques which was utilized for this purpose were: 1. Verification of intermediate simulation output and, 2. Historical data validation.

For the first technique, rare events and situations with a higher simplicity degree than the reality was considered. Under these conditions, the results was calculated manually and furthermore, compared with outputs from the model (Kleijnen, 1995).

For the second technique, historical data of the reality of interest was used as input for the model. The resulting output was then compared with actual data in order to determine whether or not the model projected an accurate depiction of the reality of interest (Sargent, 2007).

After comparing the description of each of the techniques with Figure 40 it can be seen that the first technique was to be used to verify the model whereas the second technique was to be used to validate the model.

Furthermore, the analysis of the conducted test performed in order to determine whether or not the model is valid will be presented.

1.1 Verification

In this section, the verification procedure of the model will be described and the results will be analyzed in order to determine whether the model was verified or not.

As previously described, the verification activity was undertaken in order to make sure that the mathematical model had been properly translated into a computer model. In order to do so, as mentioned the Verification of intermediate simulation output technique was used. As such, the output of the model needed to be compared with the results calculated manually. For this purpose, 5 simple and rare events was developed and solved both through the model and manually. The details of the assumptions used for each of the events used for the tests can be seen in Table 9.

Table 9- Assumptions used for the Verification Tests

Test No.	Budget (M€)	Demand (Million tkm)	2011 Initial Conditions						2020 Freight Cost		
			q_{Road} (%)	q_{Rail} (%)	q_{Sss} (%)	P_{road} (€/tkm)	P_{rail} (€/tkm)	P_{SSS} (€/tkm)	P_{road} (€/tkm)	P_{rail} (€/tkm)	P_{SSS} (€/tkm)
1	6	100	0	50	50	0.0928	0.0453	0.072	0.0996	0.0508	0.0802
2	8	100	50	0	50	0.0928	0.0453	0.072	0.0996	0.0508	0.0802
3	7	100	50	50	0	0.0928	0.0453	0.072	0.0996	0.0508	0.0802
4	7	100	33.3	33.3	33.3	0.0928	0.0453	0.072	0.0996	0.0508	0.0802
5	7	100	40	20	40	0.1229	0.0802	0.022	0.128	0.0923	0.0211

As can be seen in the table, for tests 1 to 4, a fictional condition was considered where the means of transport used by Toyota consisted of HDV+32t for road, Dry Bulk train for rail, and Small Ropax for Short Sea Shipping freight.

For tests 1 to 3, it was assumed that Toyota was only using two of the modes of transport at current conditions and for test 4, it was presumed that the freight activities was split equal across all modes of transport.

Test No. 5 however, was entirely based on actual conditions existing for Toyota VLG group with regards to means of transport and initial modal split.

For all of the tests, it was decided to allocate a freight demand of 100 million tonne-km. In addition, the budget assigned for each test was based on the freight cost corresponding to the demand with regards to the initial conditions (modal split & Price)

The modal split and CO_2 emissions at the year 2020 for each of the mentioned tests were once calculated through the model and once manually. The results of these calculations can be seen in Table 10.

Table 10 - Summary of the Verification Process Outcome

Test No.	Mode	Calibration		Output				Verified
		α		q (tkm)		CO_2 (Million kg)		
		Manual Calculation	model	Manual Calculation	model	Manual Calculation	model	
1	Road	0	0	0.00	0.00	0	0	Yes
	Rail	0.388	0.362	68.70	68.16	2.35	2.33	
	SSS	0.612	0.638	31.30	31.84	8.72	8.87	
					Total	**11.07**	**11.20**	
2	Road	0.551	0.530	40.03	38.41	4.12	3.95	Yes
	Rail	0.000	0.000	17.25	16.92	0.59	0.58	
	SSS	0.449	0.470	42.72	44.67	11.91	12.45	
					Total	**16.61**	**16.98**	
3	Road	0.631	0.656	37.50	36.95	3.86	3.80	Yes
	Rail	0.369	0.344	62.50	63.05	2.14	2.16	
	SSS	0	0	0.00	0.00	0.00	0.00	
					Total	**5.99**	**5.96**	
4	Road	0.409	0.415	25.1	24.67	2.60	2.54	Yes
	Rail	0.233	0.217	48.7	49.27	1.64	1.68	
	SSS	0.358	0.368	26.2	26.06	7.31	7.26	
					Total	**11.55**	**11.48**	
5	Road	0.622	0.624	37.36	36.39	4.02	3.91	Yes
	Rail	0.236	0.236	19.77	19.42	0.68	0.66	
	SSS	0.142	0.139	42.88	44.19	4.56	4.70	
					Total	**9.26**	**9.28**	

As can be seen in the table, comparing the results, in all cases the model allocates modal split and calculates CO_2 emissions in the same way as manually calculated. The limited differences which can be detected between the results can be attributed to rounding of values during manual calculation. Hence, it can be determined that the model is verified.

1.2 Validation

In this section, the validation procedure of the model will be explained and it will be determined whether or not the model was validated or not through analyzing the results of the process.

It is always of importance for the user of models that the results extracted from the model correctly corresponds to reality. In the previous test, simple and rare events were considered for the model verification process. Obviously, these rare events do not resemble the actual situations which a company such as Toyota would face. Hence, as mentioned before, the Historical data validation technique was used to ensure whether or not the model corresponds to reality.

For this purpose, modal split from the past 5 years (2007-2011) was obtained from Toyota's logistic groups databases. Unfortunately, it was not possible to obtain any CO_2 emission data from previous years as they had not been recorded in such a way which would suit the study. However, comparing the modal splits provides an accurate view of the validity of the model as the CO_2 emission levels are directly linked to the modal splits. Subsequently the modal split for this time frame was calculated using freight cost, freight demand and budget for each specific period.

After comparing the outcome of each period with the actual modal split, it can be observed that approximately the same level of modal split is suggested. However, one exception can be detected for years 2007 and 2008 in VLGs modal split. In both these years VLG is using 40% road freight whereas the model determines that the optimal solution under the corresponding conditions is to allocate 33.3% and 32.4% respectively to road freight. After consulting VLG members, it was revealed that because of infrastructure restrictions, it is not possible to allocate a lower than 40% modal share for road freight even if it would be the more desirable option.

Taking these items into considerations, it can be argued that the results of the tests were satisfying and that the model is valid. These results of the test can be seen in Table 11

Table 11 - Summary of the Validation Process Outcome

Logistcs Group	Actual (tkm)				Model (tkm)		
	Year	q_{Road}	q_{Rail}	q_{SSS}	q_{Road}	q_{Rail}	q_{SSS}
PPLG	2007	1004.64	43.68	43.68	1010.20	43.16	38.64
	2008	941.85	52.33	52.33	925.82	53.24	67.44
	2009	930.93	35.04	35.04	920.92	56.65	23.43
	2010	898.17	28.67	28.67	879.06	54.08	22.36
	2011	873.60	18.20	18.20	873.11	23.20	13.69
TPCE	2007	819.72	204.93	341.55	841.12	200.42	324.65
	2008	798.34	199.58	332.64	775.86	212.02	342.66
	2009	889.81	127.12	254.23	891.64	141.51	237.99
	2010	848.23	121.18	242.35	849.23	135.16	227.35
	2011	772.20	148.50	267.30	772.41	155.94	259.64
VLG	2007	731.50	385.00	770.00	659.88	380.23	884.89
	2008	702.24	369.60	739.20	598.14	362.44	887.42
	2009	677.60	338.80	677.60	704.25	367.16	622.59
	2010	614.46	355.74	614.46	655.00	357.57	604.43
	2011	616.00	308.00	616.00	594.37	345.18	600.44

1.3 Validity/Verifiability of the Model

In the previous sections it was argued that in order to verify and validate the model two tests had to be performed, that is the "verification of intermediate simulation output" test for verification and the "historical data validation" test. Based on the results achieved from these tests, it can be concluded that the model has been both verified and validated.

However, it should be noted that, the verification and the validation of a model is not absolute and is a subjective process. A model is believed to be verified and validated if the results are successful enough concerning the degree which satisfies the users' purpose (Carson, 2002). During the verification and validation of the model in this case study, in addition to the designer of them model, the client found it verified and valid in order to serve the purpose of the study.

2. Sensitivity Analysis

The definition of Sensitivity analysis according to Saltelli et al. (2004) can be summarized as "the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input".

For the purpose of this study, a sensitivity analysis was conducted in order to enable the recognition of key variables which influences the modal split and CO_2 emission levels. In addition, through sensitivity analysis, the effect of changing the variables can also be examined (Pannell, 1997).

In order to carry out a proper sensitivity analysis, firstly, the key variables had to be identified. Afterwards, the effect of possible changes in these variables was required to be calculated. Finally, the direction and scale of possible changes regarding the key variables were to be analyzed (Belli et al., 2001).

In the following section, the different steps of the sensitivity analysis will be explained.

2.1 Identifying the Key Variables

Before identifying the key variables it was important to define what a key variable within the context of the study is. For the purpose of this study, any input parameter which potentially may vary from year to year has been considered. Hence, it is important to point out that the variables which will henceforth be discussed are different from internal variables within the model which change during the course of the optimization process.

As previously mentioned while introducing the development process of the model the input parameters which influences modal split re the price of the different freight modes and VoT. In addition, budget and freight demand are also influential as they act as boundary conditions for the model. The input parameters which influence CO_2 emissions are Fuel consumption and CO_2 emission factors.

Among the mentioned parameters and inputs, all except Fuel consumption and CO_2 emission factors were identified as key variables for the sensitivity analysis. The reason why Fuel consumption and CO_2 emission factors were excluded is that CO_2 emissions is directly calculated through multiplying the output from the model (freight demand per mode) with the corresponding fuel consumption and emission factor. Hence, the internal dynamics of the model will not affect the influence of these parameters which effectively means that the proportion of change in their values will directly be reflected in the final value of CO_2 emissions.

Moreover, the cost parameter used as an input for the model is generalized price which is the sum of actual price and VoT. Hence, for the purpose of this analysis, the cost parameter subjected to change was generalized price.

Furthermore, the identified key variables will be explained:

2.1.1 Generalized Price

Generalized price was one of the key variables which were necessary to be included in the sensitivity analysis. The underlying reason for this necessity is the fact that the majority of the initiatives proposed by the EU will potentially influence the cost of freight. As such, the cost of freight is expected to fluctuate throughout the timeframe of the study.

It is important to note that although it was mentioned that VoT is a key variable for the model, within the context of this study, as no change in Toyota's business model is to be expected in the near future, it is assumed that VoT will not be changing.

2.1.2 Demand

Total freight demand was the next key variable, necessary to be included in the sensitivity analysis. The importance of this variable can be traced back to the fact that demand may fluctuate in the future and will directly impact modal splits and CO_2 emissions.

It is important to mention that for this study it was assumed that Toyota's freight demand will not change within the 2011-2030 time frame as net fluctuations of the demand was expected to be zero. However, in reality it may vary from year to year because of factors external to the scope of this study.

2.1.3 Budget

Freight budget was also a variable which is of importance for the sensitivity analysis. Any change in budget will potentially influence modal splits and CO_2 emissions.

Similar to freight demand, Toyota's budget was assumed to be constant within the timeframe of the study. However, depending on factors not within the scope of the study, the budget level may change from year to year.

2.2 Change Estimation for Key Variables

After having identified the key variables, the effects fluctuations in their values would have on the output of the model was calculated.

The first step for this investigation was to define an event which was to be used as the baseline case. For this purpose, the initial conditions of VLG were used to calculate the modal split and CO_2 emissions for the year 2011. The initial conditions were a budget of M€116, and freight demand of 1540 million tonne-km, and a 40, 20, 40 percent modal split for road, rail, and short sea shipping respectively.

Once the base case problem was solved, different scenarios were defined by changing the key variables. In these scenarios, it was required to set the maximum and the minimum values which within them the key variables or combination of key variable could fluctuate. Hence, a good estimation was needed for the probable changes of these variables.

The fluctuation limits for the variable in each of the scenarios are rough estimations which may potentially occur between each year. Furthermore, In order to be vigilant, for each of the scenarios, extreme situations were considered which effectively meant that the rate of change for each variable is larger than estimated.

2.2.1 Sensitivity Analysis Scenarios

In the following section, the scenarios considered for the sensitivity analysis will be presented and explained.

Based on the cost figures extracted from the baseline spreadsheet (maximum impact scenario), it was observed that the most extreme increase in cost between two consecutive years for a mode of transport is estimated at 5%. Hence the following scenarios were developed for freight cost:

- **Scenario 1a:** Cost of road freight increase by 10%
- **Scenario 1b:** Cost of road freight reduction by 10%
- **Scenario 2a:** Cost of rail freight increase by 10%
- **Scenario 2b**: Cost of rail freight reduction by 10%
- **Scenario 3a:** Cost of short sea shipping freight increase by 10%
- **Scenario 3b:** Cost of short sea shipping freight reduction by 10%

Between 2007 and 2011 Toyota Motor Europe experienced an approximate sales drop of 25% as a result of the financial crisis. Although this drop was not distributed equally during the timeline, it can be assumed that on average a drop of 6.25% was experience per year. As sales figures are directly linked with production volume and subsequently freight demand, the following scenarios were considered for freight demand:

- **Scenario 4a:** Freight demand reduction of 8%
- **Scenario 4b:** Freight demand increase of 8%

Also between 2007 and 2011, all of the Toyota logistics groups were forced to decrease their budget because of decrease in demand. However, as freight cost was increasing in this time frame, the reduction was limited to 1% per year. Hence the scenarios developed for budget are the following:

- **Scenario 5a:** Budget reduction of 2%
- **Scenario 5b:** Budget increase of 2%

In addition, scenarios were also defined concerning extreme changes in most probable combinations of the key variables:

- **Scenario 6:** Cost of freight increase of 10% and Increase in demand of 8%
- **Scenario 7:** Cost of freight increase of 10% and Budget reduction of 2%
- **Scenario 8:** Increase in demand of 8% and Budget reduction of 2%
- **Scenario 9:** Cost of freight increase of 10%, Increase in demand of 8% and Budget reduction of 2%

After the scenarios had been defined, the model was used to calculate the outcome of each scenario. The results of calculations compared to the results of the base case, illustrated the sensitivity of the tool to each key variable or combination of key variables.

2.2.2 Sensitivity of the Model

For the purpose of studying the sensitivity of a model, a Sensitivity Index had to be defined and calculated. Various sensitivity indices with different properties have been defined within scientific literature and depending on the context of the study and the analysis at hand these indices can be utilized. Among these indices, an index introduced by Hoffman and Gardner (1983) delivers the most compelling results while being the least complex (Hamby, 1995). Hence, this index was adopted for the sensitivity analysis of this study. The index is defined as follows:

Equation 14 $$SI = \frac{(D_s - D_b)}{D_b}$$

Where D_b corresponds to the output of the model in the baseline case, and D_s refers to the output in the tested scenario. As the modal split and CO_2 emissions are considered to be the main outputs of this model, the sensitivity index was only calculated for these specific outputs. As such, the sensitivity index for Modal Split and CO_2 Emissions was defined as follows:

Equation 15 $$SI_{q,Road} = \frac{(q_{Road,s} - q_{Road,b})}{D_{Road,b}} \text{ , } SI_{q,Rail} = \frac{(q_{Rail,s} - q_{Rail,b})}{D_{Rail,b}} \text{ , } SI_{q,SSS} = \frac{(q_{SSS,s} - q_{SSS,b})}{D_{SSS,b}}$$

Equation 16 $$SI_{CO2} = \frac{(CO2_{s,} - CO2_b)}{CO2_b}$$

Where qi is the quantity of demand for mode i and the CO_2 represents the total CO_2 emissions.

The sensitivity indices calculated for all scenarios can be seen in Table 12. As can be seen in the table regarding the road freight quantity index ($SI_{q,Road}$), among the key variables identified, the model shows the highest sensitivity to freight demand (scenario 4a and 4b). The change in this variable in combination with the change in cost and budget (scenario 9), will present even greater change in road freight demand. However, this scenario occurs with less probability compared to the rest of the scenarios. The underlying reason for this can be traced back to the higher cost of road freight. As demand for freight increases, the model tends to allocate freight quantities to other modes in order to stay within the budget.

For rail freight quantity index ($SI_{q,Rail}$), the model shows the highest sensitivity towards the change in road and rail freight cost (scenario 1 and 2). The reason for this is the integration of VoT into the model which means that the model tends to gravitate towards faster modes of transport. Hence, when cost of road increases, the fastest mode of transport the model prefers to allocate demand is rail freight. Similarly, when rail freight cost increases, the fastest mode at hand is road freight. This explanation can also be made for the reverse situations.

In the case of short sea shipping freight quantity index ($SI_{q,SSS}$), the model demonstrates the most sensitivity towards freight demand (scenario 4a and 4b). Also the sensitivity increases when freight demand changes in combination with cost and budget (scenario 9). The explanation for this occurrence follows the same logic as was explained for road freight. As freight demand increases, the model decides to allocate freight quantity to the less costly freight mode in order to remain within the budget.

Table 12 - Sensitivity Index Values for Modal Split and CO2 Emissions

Scenario	Scenario Description	Modal Split						CO_2 emissions	
		$q_{Road,s}$- $q_{Road,b}$	$SI_{q,Road}$	$q_{Rail,s}$- $q_{Rail,b}$	$SI_{q,Rail}$	$q_{SSS,s}$- $q_{SSS,b}$	$SI_{q,SSS}$	$CO2_s$- $CO2_b$	SI_{CO2}
0	Baseline for 2011	-	-	-	-	-	-	-	-
1.a	Road price +10%	-9.52	-2%	23.08	7%	-13.56	-2%	-1.72	-1%
1.b	Road price -10%	13.67	2%	-25.22	-7%	11.55	2%	1.89	1%
2.a	Rail price +10%	13.41	2%	-24.80	-7%	11.39	2%	1.86	1%
2.b	Rail price -10%	-11.80	2%	29.69	9%	-17.89	-3%	-2.21	-2%
3.a	SSS price +10%	-1.48	0	3.22	1%	-1.73	0	-0.24	0
3.b	SSS Price -10%	1.44	0	-3.01	-1%	1.57	0	0.23	0
4.a	Demand - 8%	-32.87	-6%	-4.11	-1%	160.18	27%	13.24	9%
4.b	Demand +8%	37.13	6%	-3.21	-1%	-157.12	26%	-12.69	-9%
5.a	Budget -2%	-20.40	-3%	-7.42	-2%	27.82	5%	0.43	0
5.b	Budget + 2%	20.66	3%	6.98	2%	-27.64	-5%	-0.40	0
6	Demand +8%, Budget - 2%	-52.51	-9%	-12.84	-4%	188.55	31%	13.77	1%
7	Budget - 2%, Cost + 10%	-20.31	-3%	-7.21	-2%	27.52	5%	0.42	0
8	Demand - 8%, Cost + 10%	-32.32	-5%	-3.68	-1%	159.20	27%	13.21	9%
9	Demand + 8%, Cost + 10%, Budget - 2%	-51.82	-9%	-12.33	-4%	187.34	31%	13.74	10%

For the CO_2 emission index (SI_{CO2}), it can be seen that it follows the same pattern as road and short sea shipping freight. That is, the highest sensitivity is towards freight demand (scenario 4a, 4b, and 9). The reason for this result is twofold: 1. any change of the amount of freight activity will directly impact CO_2 emission levels and, 2. short sea shipping freight has a higher CO_2 emission rate compared to road and rail. Hence, any changes in short sea shipping will have a more significant impact on CO_2 emissions compared to changes in road and rail.

If, freight demand and budget is to be ignored in the analysis, then it can be seen that all of the indices show approximately the same sensitivity towards road and rail freight cost (scenario 1a, 1b, 2a, and 2b). The underlying reason for this event was previously explained as the models gravitation towards faster modes of transport.

After having performed the sensitivity analysis presented in this section, the next step is to determine whether or not the model is robust. The robustness of the model which is evaluated through considering the initial values of the changing cells set by the user will be evaluated in the following section.

3. Robustness Analysis

In this section, the robustness of the model will be evaluated considering the initial values the user sets for the changing cells before the initiation of the optimization process. As mentioned before, excel solver was used as a platform to develop the model. According to the developers of excel solver, the software utilizes GRG algorithms in its source code (Fylstra et al., 1998). As GRG algorithms tent to start the optimization using initial values for its changing cells (Ladson et al., 1978), it was imperative to perform this test.

Thus, the aim of this analysis was to confirm whether or not the output of the model remains the same for cases where the input values are manipulated compared to where they are not. In other words, will the provided output of the model be influenced by the initial values or not.

In this section, the design of the robustness test will first be explained which will be followed by the results extracted from the test and the analysis of the results.

3.1 Design of the Robustness Test

In order to perform a robustness test, various techniques have been developed and utilized. The technique selected for the purpose of this study, is the "Random value" technique where the model is first tested using random initial values for the changing cells and then the results of the tests are compared (Micskei et al., 2006).

For the purpose of performing the robustness test by using the random value technique, a case had to be initially selected. The case selected for this study was the actual forecasting of modal split and CO_2 emissions during the year 2012 for TPCE. The reason why this case was selected was that the event was based on actual conditions and hence big enough to provide higher probability of variations in the output. In addition, the consistency of the model results was then more likely to be accepted by Toyota's Logistics groups.

For the analysis, the first test was performed using no initial value for the changing cells. The second test was used using the actual 2011 data extracted from TPCE database. The test was then repeated 8 times using random initial values for the changing cells.

3.2 Robustness of the Model

The results of the conducted robustness test can be seen in Table 13. In this table, the modal split and CO_2 emission for each of the test has been illustrated.

Table 13 - Modal Split and CO_2 Emission Values from the Robustness Test

Initial Values	No Value	2011 Data	Random 1	Random 2	Random 3
q_{Road} (tkm)	743,065,573	743,065,574	743,065,595	743,065,584	743,065,550
q_{Rail} (tkm)	168,216,620	168,216,619	168,217,124	168,216,921	168,216,621
q_{SSS} (tkm)	276,717,808	276,717,807	276,717,286	276,717,495	276,717,807
CO_2 (Ktonne)	117,797,207	117,797,207	117,797,170	117,797,185	117,797,207
Initial Values	**Random 4**	**Random 5**	**Random 6**	**Random 7**	**Random 8**
q_{Road} (tkm)	743,065,572	743,065,575	743,065,589	743,065,592	743,065,573
q_{Rail} (tkm)	168,216,629	168,216,618	168,217,139	168,217,104	168,216,648
q_{SSS} (tkm)	276,717,799	276,717,807	276,717,272	276,717,307	276,717,780
CO_2 (Ktonne)	117,797,206	117,797,207	117,797,169	117,797,172	117,797,205

In order to determine whether or not the model is robust, an index had to be developed and utilized. The index used for this purpose is the "Coefficient of Variance"(Will & Butcher, 2007). The equations used for calculating the coefficient of variance are the following:

Equation 17 $\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$ (Mean)

Equation 18 $s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})}$ (Standard Deviation)

Equation 19 $c_y = \frac{s}{\bar{x}}$ (Coefficient of Variance)

Where x_i represents the output for each test and n denotes the number of tests performed.

In Table 14, the mean, standard deviation and coefficient of variance calculated for each tests have been illustrated. As can be seen, all the robustness indices have insignificant values. Hence, it can be concluded that the results of the model is not influenced by using different initial values. As such, it can be said that the model is highly robust.

Table 14 - Robustness Index Values for Road and CO_2 Emissions

Data	Mean	Standard Deviation	Coefficient of Variance (robustness index)
q_{Road}	743,065,578	12.40	0.0000017%
q_{Rail}	168,216,804	225.75	0.0001342%
q_{SSS}	276,717,617	233.28	0.0000843%
CO_2	117,797,193	16.29	0.0000138%

After having evaluated the model it was now possible to execute the model and extract the relevant information for the study. The execution of the model is the topic of the next chapter.

VI. Execution of the Model

In the previous chapters, the model which was to be utilized for the purpose of this study was developed and evaluated. In this chapter, the execution of the model and the achieved results will be presented.

In the following chapter, at first the execution of the baseline spreadsheet will be explained which will be followed by the estimation of Value of Time for Toyota Motor Europe's logistics groups. The results from these two steps provided the required input data for the 2011-2030 scenario model which was then executed. Subsequently, the detailing of this final step will end this chapter.

The results obtained from execution of the baseline spreadsheet will answer the second sub-question of the research which is:

What is the current status of EU freight industry concerning the main factors and parameters?

Furthermore, the results attained from estimating the Value of Time will provide a response to the third research question, namely:

How does Toyota Motor Europe currently operate within the freight industry?

Finally, the results acquired from the 2011-2030 scenario model will enable the answering of the fourth sub-question of the research which asks:

How will the future of the European freight industry affect Toyota Motor Europe's freight activities?

1. Baseline Spreadsheet Execution

The first step of executing the model was to implement the Baseline Spreadsheet. In this section, the execution process and the results of the baseline spreadsheet will be presented and discussed.

The baseline spreadsheet was designed to projects the freight cost and CO_2 emission trend of European freight between 2005 and 2010. Furthermore, it had the purpose of introducing the internal dynamics of cost and emissions and act as a stepping stone for forecasting the 2011-2030 scenarios.

In order to explain the execution, the input data which was used in the spreadsheet will be presented. Furthermore, the results from using the data in the spreadsheet will be discussed.

1.2 Input Data for the Baseline Spreadsheet

In order to ease the process of presenting the input data, the spreadsheet had to be broken down into its main components. These components are:

1. Modal Split
2. Total Freight Expenditure
3. CO_2 Emission

It is imperative to note that all input data which will be introduce in this section, directly correspond to the input elements depicted in the model structures. Furthermore, the input data for each of these three components will be explained.

1.2.1 Modal Split Spread Sheet

As the cost of each mode of transport is different, in order to calculate the total freight expenditure, the modal split for freight was needed. The data of modal split history within the EU is available and could be obtained.

1.2.1.1 Historical Trends in Modality

The road and rail freight activity's historical data could be obtained from the Eurostat data base. For short sea shipping the data was obtained from the EU Energy and Transport Statistical Pocketbook. The modal split data between 1995 and 2010 can be seen in Table 15.

Table 15 - European Modal Split per Year(European Commission, 2010a; Eurostat, 2011)

Year	million tonne-km per Mode		
	Road Transport	Rail Transport	Short Sea Shipping
1995	1289000	386000	1146000
1996	1303000	392000	1160000
1997	1352000	410000	1193000
1998	1414000	393000	1232000
1999	1470000	384000	1268000
2000	1519000	404000	1314000
2001	1556000	386000	1334000
2002	1606000	384000	1355000
2003	1625000	392000	1378000
2004	1747000	416000	1427000
2005	1800000	414000	1461000
2006	1854000	440000	1505000
2007	1915000	453000	1532000
2008	1878000	443000	1498000
2009	1731391	387539	1472000
2010	1612450	417443	1480000

As the baseline spreadsheet is categorized based on the means of transport, we used the share of each transport means within its own mode in order to obtain the share of each in the total picture. The share of each transport means can be seen in Table 16.

Table 16 - Share of each Means of Transport (Eef Delhaye, et al., 2010; European Commission, 2012; Eurostat, 2012; Hill, et al., 2011)

Mode of Transport	Road Freight				Rail Freight		Short Sea Shipping Freight			
Vehicle or Vessel	**HDT +32t**	**HDT 16-32t**	**HDT 7.5-16t**	**HDT -7.5t**	**Diesel**	**Electric**	**LoLo**	**RoRo**	**Ropax Small**	**Ropax Large**
Share	9%	32%	24%	36%	32%	68%	32%	33%	11%	24%

By using this data, the share of each mode within EU freight could be obtained which can be viewed in Table 17.

Table 17 - Modal Split per Means of Transport

Year	Road Transport				Rail Transport		Short Sea Shipping			
	HDT +32t	HDT 16-32t	HDT 7.5-16t	HDT -7.5t	Diesel	Electric	LoLo	RoRo	Ropax Small	Ropax Large
1995	4%	15%	11%	16%	4%	9%	13%	13%	4%	10%
1996	4%	15%	11%	16%	4%	9%	13%	13%	4%	10%
1997	4%	15%	11%	16%	4%	9%	13%	13%	4%	10%
1998	4%	15%	11%	17%	4%	9%	13%	13%	4%	10%
1999	4%	15%	11%	17%	4%	8%	13%	13%	4%	10%
2000	4%	15%	11%	17%	4%	8%	13%	13%	4%	10%
2001	4%	15%	11%	17%	4%	8%	13%	13%	4%	10%
2002	4%	15%	11%	17%	4%	8%	13%	13%	4%	10%
2003	4%	15%	11%	17%	4%	8%	13%	13%	4%	10%
2004	4%	15%	12%	17%	4%	8%	13%	13%	4%	9%
2005	4%	16%	12%	18%	4%	8%	13%	13%	4%	9%
2006	4%	16%	12%	17%	4%	8%	13%	13%	4%	9%
2007	4%	16%	12%	18%	4%	8%	13%	13%	4%	9%
2008	4%	16%	12%	18%	4%	8%	12%	13%	4%	9%
2009	4%	15%	12%	17%	3%	7%	13%	13%	4%	10%
2010	4%	15%	11%	16%	4%	8%	13%	14%	5%	10%

Through using the modal split data, the calculation of total freight expenditure and CO_2 emission was possible. However, before calculating these values, the unit values for cost and CO_2 emission had to be computed.

1.2.1.2 Total Freight Expenditure Spreadsheet

In order to calculate Total Freight Expenditure, the unit cost for each of the modes had to be established. In the following section, the data used for the calculating process of total freight expenditure will be presented. In order to ease the process, the inputs will be introduced mode by mode.

1. Road Freight Unit Cost

The goal here was to establish the value for each parameter of the road freight breakdown structure shown in Table 18 which would be utilized in calculating road freight unit cost. The input values needed for this task will furthermore be explained.

It can be seen in Figure 22 - Road Freight Cost Data Flow , apart from deprecation cost, fuel cost, and infrastructure fee, the rest of the main elements where not broken down to sub-elements. It was assumed that these parameters would not be influenced by the White Paper and hence it was not necessary to examine their internal structure. The input values for these parameters can be seen in Table 18.

Table 18 - Cost Assumptions for non-influenced Parameters for year 2010 (Eef Delhaye, et al., 2010)

Cost Category	Item	Cost per Day			
		HDT -7.5t	HDT 7.5-16t	HDT 16-32	HDT +32
Direct Costs	Repair	5	15	40	60
	Labor	35	40	75	100
	Insurance	3	10	25	40
Taxation Costs	Registration	0.1	0.2	0.5	0.6
	Ownership	1	3	7	10
	Insurance	1	2	5	7
	Labour Tax	40	45	80	110

In order to calculate the values for depreciation cost, Fuel cost and infrastructure fee, a different set of input data was needed which will hereby be explained:

- **Depreciation Cost:**

The input parameters for calculating the depreciation cost for road freight can be seen in Table 19. The values indicated in this table are based on a research performed by Toyota's production planning department and indicate an average price over a 5 year period (PPMD, 2010).

Table 19 - Depreciation Cost Input Values (PPMD, 2010)

Vahicle Type	Purchase price (€)	Trailer Purchase Price (€)
HDT -7.5 Ton	25000	NA
HDT 7.5-16 Ton	70000	NA
HDT 16-32 Ton	75,000	25000
HDT +32 Ton	100,000	25000

- **Fuel Cost:**

Fuel cost was defined as the product of fuel price and fuel consumption. The fuel used by road freight vehicles is mainly diesel fuel. Hence, the input data for fuel price was based on diesel fuel. In addition, as the historical data for fuel is available, only the price with taxes was used. The diesel prices can be seen in Table 20.

Table 20 – Average Diesel Price across Europe (The Market Observatory for Energy, 2011)

Diesel Price Including Tax							
Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Price (€/liter)	1.0318	1.0942	1.1085	1.2828	1.0077	1.1697	1.3693

Average diesel consumption for heavy duty vehicles can be seen in Table 21.

Table 21 - Average Diesel Consumption of Heavy Duty Vehicle (Hill, et al., 2011)

Vehicle Type	Liter/100km, Diesel						
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
HDT -7.5 Ton	16.5	16.4	16.3	16.1	16	16	16
HDT 7.5-16 Ton	21.4	21.4	21.2	21.2	21.1	21	21
HDT 16-32 Ton	24.8	24.7	24.7	24.6	24.6	24.6	24.5
HDT +32 Ton	31.5	31.3	31.2	31	31	30.9	30.8

- **Infrastructure Fee:**

In order to calculate infrastructure fee for road freight, information retrieved from the Eurovignette directive and its amendments were used. Within this directive, annual, monthly and daily rates for different load and axle configuration have been stated. However, as the goal of this study was to analyze extreme condition in order to be able to proactively engage future situations, the maximum rates suggested by the EU to the member states were used. It is important to note that the initial directive was in effect between 1999 and 2006 which was followed by an amendment that was in effect between 2006 and 2011. Both of these values were used in the spreadsheet and can be seen in Table 22. In addition, the vehicle category proposed in the directive is "minimum four axle vehicles" and "maximum three axle vehicles". In order to ease the calculation process it was assumed that "minimum four axle vehicles" correspond to above 16 tonne vehicles and "maximum three axle vehicles" to below 16 tonne vehicles.

Table 22 - Eurovignette Charges in Effect Between 1999 and 2011 per Month (European Commission, 1999, 2006a)

Vehicle Category	Eurovignette Charges (€/month)									
	EURO 0		EURO I		EURO II		EURO III		EURO IV and less polluting	
	99-06	**06-11**	**99-06**	**06-11**	**99-06**	**06-11**	**99-06**	**06-11**	**99-06**	**06-11**
<16 tonne	1550	2233	1400	1933	1250	1681	1250	1461	1250	1329
>16 tonne	960	1332	850	1158	750	1008	750	876	750	797

As was mentioned before, in order to ease the calculation of infrastructure fee, a single weighted average of Eurovignette rates for the different vehicle category (load capacity) was used. This was achieved through using the European heavy duty vehicle fleets. The average distribution share between 2005 and 2011 can be seen in Table 23:

Table 23 - European Average Euro Standard Distribution Share 2005-2011(Hill, et al., 2011)

Euro Standard	Conventional	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
Distribution Share	19%	10%	24%	26%	15%	6%	0%

Unit Conversion:

As could be seen in the data presented, the unit ranged from €/day (i.e. repair cost) to €/lifecycle (i.e. depreciation cost). In order to enable adding the values together, a standard unit over the lifecycle of the vehicle (€/vehicle) was needed. In the next step, €/vehicle had to be converted into our desired value (€/tonne-km). The available units were converted to €/tonne-km through using the data available in Table 24 and Table 25

Table 24 – Average Road Freight Activity Data for 2010 (ACEA, 2009)

Vahicle Type	ACEA Annual Estimates (km)	Lifecycle (Years)	Working Days	Working hours/day
HDT 16-32 Ton	60,000	10	300	8
HDT +32 Ton	135,000	10	300	8

Table 25 - Load Factors (TML, 2010)

Size Class	ton/vehicle
HDT -7.5 Ton	1.1
HDT 7.5-16 Ton	3.6
HDT 16-32 Ton	6.4
HDT +32 Ton	13.2

2. Rail Freight Unit Cost

The target here was to define the value for each parameter of the rail freight breakdown structure. These values would be utilized in calculating rail freight unit cost. The input values needed for this task will furthermore be explained.

The cost breakdown structure of rail freight was introduced in Chapter IV. It can be seen in Figure 23 that deprecation cost, fuel cost, and infrastructure fee, shunting and wagon price where broken down to sub-elements. Among these elements it was assumed that Shunting and wagon price along with the rest of the parameters would not be influenced by the White Paper and hence it was not necessary to examine their internal structure.

Furthermore, the cost for rail freight was the sum of average fixed costs, average variable costs, and average variable operator costs for energy. The input parameters used for each will further on be presented:

- **Average fixed cost:**

The input data used to calculate average fixed cost can be seen in

Table 26.

Table 26 – Input Data for Average Fixed Cost (NEA, 2003)

Category	Container		General Cargo		Wet Bulk		Dry Bulk	
Drive Train	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**
Locomotive prise (€)	2400000	3200000	2400000	3200000	2400000	3200000	2400000	3200000
No. of locomotives	2	1	2	1	2	1	3	2
Wagon rental (€/jourmey)	22	22	18	18	25	25	16	16
No. of wagons	29	29	25	25	18	18	30	30
Labor (€/jourmey)	325	325	325	325	325	325	325	325
Maintenance costs (€/jourmey)	28	19	28	19	28	19	42	37
Insurance costs (€/jourmey)	7	4.5	7	4.5	7	4.5	10	9
Rest Value (€/jourmey)	45	30	45	30	45	30	67	60
Overhead (€/jourmey)	27	18	27	28	27	18	40	36

The locomotive depreciation cost is the product of the locomotive price and the number of locomotives. Similarly, the wagon rental cost is the product of wagon daily rental price and the number of wagons rented.

- **Average Variable Cost**

In order to calculate average variable cost, shunting cost and infrastructure cost had to be calculated. The data used to calculate shunting cost can be seen in Table 27.

Table 27 - Input Data for Shunting Cost (NEA, 2003)

Category	Container		General Cargo		Wet Bulk		Dry Bulk	
Drive Train	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**
Shunting cost (€/jourmey)	400	600	400	600	400	600	400	600
Loading cost (€/jourmey)	550	550	6400	6400	3900	3900	4200	4200
Unloading cost (€/jourmey)	550	550	6400	6400	3900	3900	4200	4200

The Infrastructure fee currently varies considerably between different European countries and it is not possible to make a comparison. Even within one country, the infrastructure fee may vary from region to region. However, for the purpose of this study an EU zone average of 4005 €/jourmey was used (OECD, 2005).

- **Average Energy Cost**

For the energy cost we applied the cost model developed internally within Energy Research Group which will give the expected Diesel and Electricity price for rail traction. The diesel price can be seen in Table 20 which was previously presented and the electricity prices can be seen in Table 28

Fuel cost was defined as the product of fuel price and fuel consumption. The fuel used by rail freight consists of either diesel fuel or electricity. Hence, the input data for fuel price was based on diesel and electricity. In addition, as the historical data for both diesel and electricity is available, only the price with taxes was used. The diesel prices can be seen in Table 20 and the electricity prices can be seen in Table 28.

Table 28 - Historical Electricity Prices (The Market Observatory for Energy, 2011)

	Electricity Price Including Tax						
Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Price (€/Kwh)	0.09	0.1	0.12	0.14	0.16	0.17	0.183

For the amount of energy used by the locomotives the following input was used:

Table 29 - Energy Usage of Locomotives (NEA, 2003)

Category	**Container**		**General Cargo**		**Wet bulk**		**Dry bulk**	
Drive Train	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**
Electric kWh or Diesel liter per km	7.11	27.43	4.81	19.29	5.38	22.86	8.66	44.54

Unit Conversion:

Similar to road freight, the units of the input data ranged from €/day (i.e. wagon rental cost) to €/lifecycle (i.e. purchasing price). In order to enable adding the values together, again a standard unit over the lifecycle of the vehicle (€/train) was needed. In the next step, €/train had to be converted into our desired value (€/tonne-km). In order to achieve this, the following data was used:

The available units were converted to the unit in question through using the data available in Table 30 and Table 31

Table 30 - Average Rail Freight Activity Data for 2010 (NEA, 2003)

Average journeys per year	Lifecycle (years)	Average international trip (km)
210	20	1000

Table 31 - Average Rail Load Capacity(NEA, 2003)

Category	Container		General Cargo		Wet Bulk		Dry Bulk	
Drive Train	Diesel	Electric	Diesel	Electric	Diesel	Electric	Diesel	Electric
Maximum payload (tonne)	2030	2030	710	710	1950	1950	1200	1200
Loadfactor (%)	90	90	75	75	100	100	100	100

3. Short Sea Shipping Freight Input Data

The target here was to define the value for each parameter of the short sea shipping freight for this table in order to be able to calculate short sea shipping freight unit cost. The input values needed for this task will furthermore be explained.

Table 32 - Cost Breakdown Input Data for Short Sea Shipping (Eef Delhaye, et al., 2010)

Cost Item	Large RoPax	Small RoPax	LoLo Container	RoRo Ship
Depreciation (€/day)	15000	3500	2000	8000
Interest (€/day)	12000	3000	2000	6500
Labor (€/day)	7500	3500	1500	2000
Gross Margin (€/day)	8000	2500	1500	3500
Infrastructure Unit price (€/tonne)	0.5	0.33	0.11	0.3
Maintenance (€/day)	3300	1000	1000	1400
Administration fee (€/day)	2700	1000	500	1000
Lube Oil (€/day)	6000	4000	400	400
Insurance (€/day)	1500	300	300	500
Guide Deadweight (tonne)	12000	3000	11000	10000
Fuel consumption (tonne/Day)	53.3	7	28	37.9
Cargo Weight (Ton)	7250	1000	7200	2800

In order to calculate infrastructure fee, the unit price was multiplied by the guide deadweight of the ship. Furthermore, fuel cost was defined as the product of fuel consumption and the price of fuel.

The fuel used by short sea shipping freight consists of diesel oil. Hence, the input data for fuel price was based on diesel oil. The historical data for diesel oil is available, hence, only the price with taxes was used. The diesel oil prices can be seen in Table 33.

Table 33 - Historical Diesel Oil Prices (The Market Observatory for Energy, 2011)

Diesel Oil Price Including Tax							
Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Price (€/liter)	0.2408	0.28	0.2738	0.3496	0.2738	0.3599	0.4583

Unit Conversion:

The units of the input data for short sea shipping were entirely €/day. In order to enable adding the values together, again, a standard unit over the lifecycle of the vehicle (€/ship) was needed. In the next step, €/train had to be converted into our desired value (€/tonne-km). In order to achieve this, the following data was used:

Table 34 -Average Short Sea Shipping Freight Activity Data for 2010

	Large RoPax ship	Small RoPax Ship	LoLo Container Ship	RoRo Ship
Full Cargo Capacity (TUE)	290	40	600	200
Load Factor of TUE (tonne)	25	25	12	14
Lifecycle	40	40	40	40
Working Days	300	300	300	300

Macro-Economic Input

It is of importance to note that all the input data introduced are influenced by macro-economic trends. In order to compensate these effects during the analysis, the data was adjusted using the yearly inflation rate of the EU which has been reported by the World Bank. The data for inflation rates across Europe can be found in Table 35.

Table 35 - European Inflation Rates Since 2005 (World Bank, 2011)

Year	2005	2006	2007	2008	2009	2010	2011
Inflation Rate	2%	2%	2%	3%	1%	1%	2%

1.2.1.3 CO_2 Emission Spreadsheet

In order to calculate the total CO_2 emissions, the share of each means of transport within total freight (tonne-km) needed to be multiplied by the average fuel consumption and subsequently by the average CO_2 emission factor for that transport means. The calculated values can be seen in the next two tables for road freight and short sea shipping. For rail freight, within different sources, average emission factors for rail freight varies between 0.0073 to 0.023 kg CO_2/tonne-km. The value which will be used in our study will be based on the value recommended by TREMOVE, which is 0.0263 kg CO_2/tonne-km.

Furthermore, it is important to note that the CO_2 emission factors are based on Well to Wheel data.

Table 36 - Average Fuel Consumption and CO_2 Emission Factors for Road Freight (Hill, et al., 2011; Mckinnon & Piecyk)

Vehicle Type	Average Vehicle Fuel Consumption (l/tonne-km, Diesel)						
	2005	2006	2007	2008	2009	2010	2011
HDV 7.5t	0.044	0.044	0.043	0.043	0.043	0.043	0.043
HDV 7.5-16t	0.057	0.057	0.057	0.057	0.056	0.056	0.056
HDV 16-32t	0.066	0.066	0.066	0.066	0.066	0.066	0.065
HDV +32t	0.084	0.083	0.083	0.083	0.083	0.082	0.082
Vehicle Type	**Average CO2 Emission factor (kg CO2/tonne-km, Diesel)**						
	2005	2006	2007	2008	2009	2010	2011
HDV 7.5t	0.128	0.127	0.126	0.125	0.124	0.124	0.124
HDV 7.5-16t	0.165	0.165	0.164	0.164	0.163	0.162	0.162
HDV 16-32t	0.192	0.191	0.191	0.190	0.190	0.190	0.189
HDV +32t	0.244	0.242	0.241	0.240	0.240	0.239	0.238

Table 37 - Average Fuel Consumption and CO2 Emission Factors for Short Sea Shipping 2005-2010 (Mckinnon, et al.)

Ship Type	Average Ship Fuel Consumption (l/Tonne-km)	Average Ship CO2 Emission factor (kg CO2/tonne-km, Diesel)
Large RoPax	0.0075	0.0248
Small RoPax	0.0197	0.0650
LoLo Container	0.0062	0.0206
RoRo	0.0174	0.0574

1.3 Baseline Spreadsheet Execution Results

In the following section, the output resulting from executing the baseline spreadsheet using the previously explained input data will be presented. First the cost of each mode of transport will be shown. The results for freight expenditure will follow this and finally, the CO_2 emissions of freight will be illustrated.

1.3.1 Freight Cost per Mode

The changes of the cost for road freight between 2005 and 2011 can be seen in Figure 41. The illustrated data has been broken down based on the available vehicle categories defined for the study. It can be seen that the average cost of road freight has increase by approximately 24% since 2005.

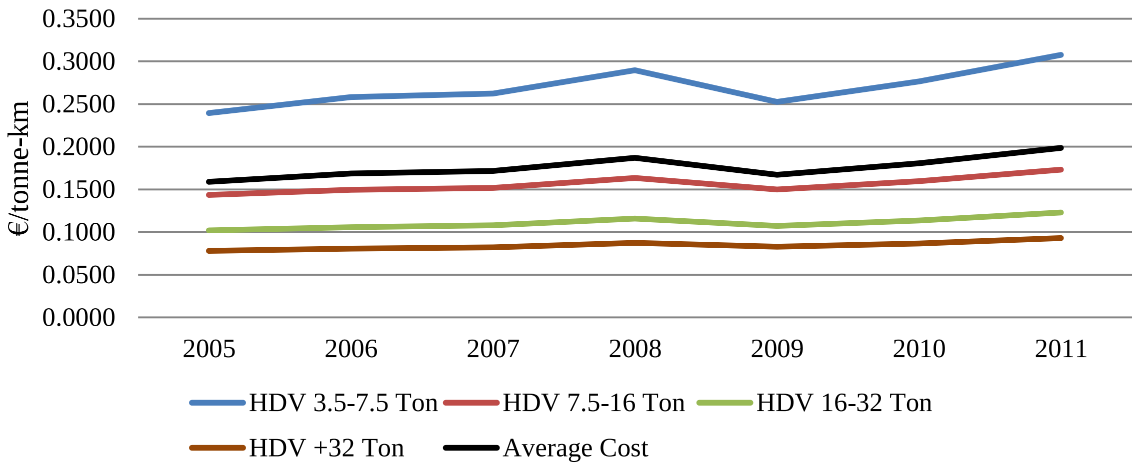


Figure 41 -Road Freight Cost Evolution per Year

In Figure 42 the variation in rail freight cost since 2005 can be seen. The data is classified according to the rail freight categorization performed for the study. It can be seen that the cost of freight has been increasing by a rate of roughly 17% since 2005.

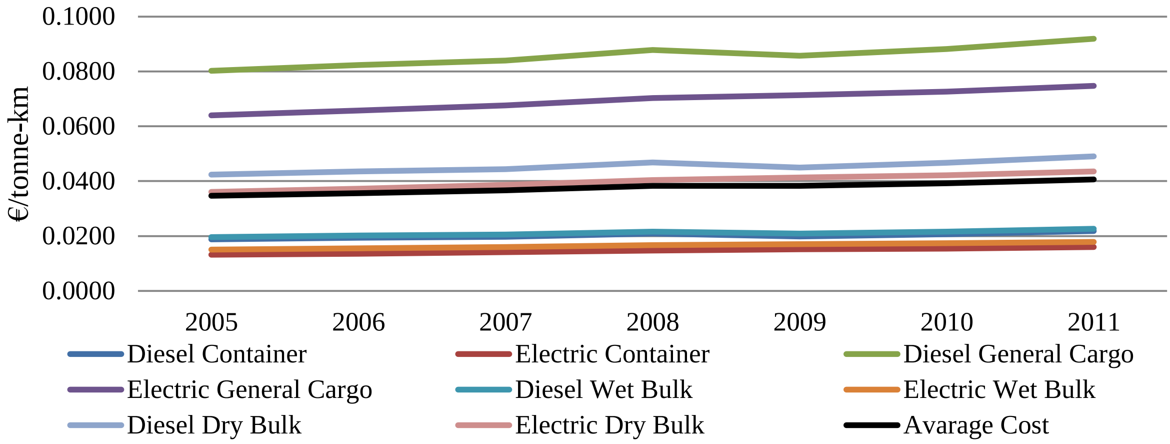


Figure 42 - Rail Freight Cost Evolution per Year

In Figure 43 the evolution of short sea shipping freight cost has been illustrated. The chart has been broken down to the ship types which were categorized for the study. The average cost for short sea shipping has increase by an average of approximately 27% between 2005 and 2011.

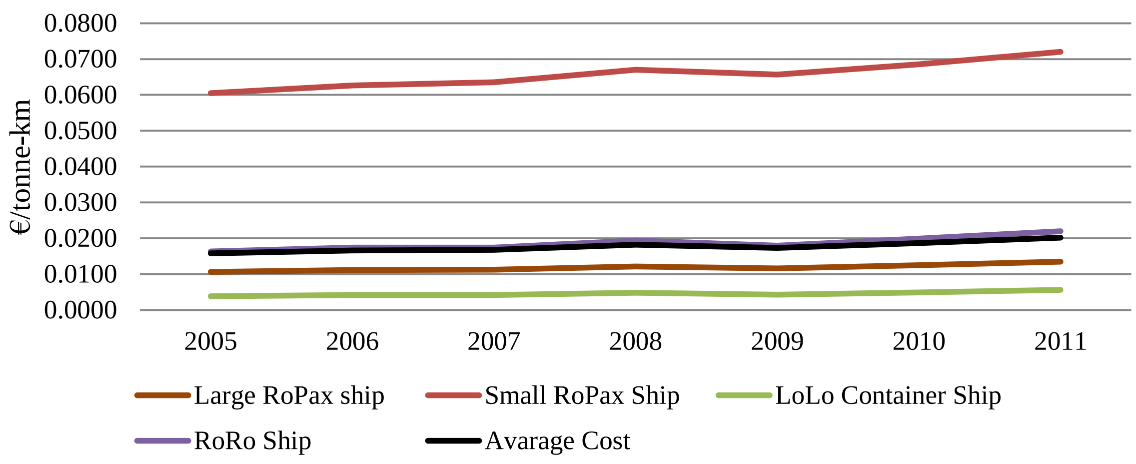


Figure 43 – Short Sea Shipping Freight Cost Evolution per Year

1.3.1.1 Comparison of Costs:

Comparison between costs is not straightforward as costs were derived from different sources and as costs for each mode vary largely between vessel and vehicle type. From the cost values obtained from the spreadsheet it can be estimated that in general rail freight and short sea shipping are cheaper modes compared to road freight. However, the highest cost for RoPax ships of 0.072 €/tonne-km and diesel general cargo trains of 0.091 €/tonne-km is comparable to the cost of HDV+32t vehicles of 0.093 €/tonne-km.

Furthermore, when considering the modal split of 46% for road, 12% for rail and 42% for short sea shipping freight, it can be established that, besides from cost, other factor also play a role in modal split. This implication, shows the importance of Value of Time (VoT) and Constant Elasticity of Substitution analysis which will be performed for the 2011-2030 scenarios.

In addition, the relatively high importance of fuel cost in the final price of freight can be established:

- For road freight, the share of fuel cost varies between 30% for HDT +32t and 60% for HDT-7.5t vehicles;
- For rail freight, the share differs between 8% for electric general cargo and 21% for diesel container train;
- For short sea shipping, the share is between 27% for large Ropax and 54% for small RoPax.

1.3.2 Total Freight Expenditure

Through using the cost for each mode previously presented and multiplying it by the share of each transport category of total freight activity, the expenditure for that category was calculated. By summing up all the values, the total freight expenditure was calculated. The evolution of the freight expenditure between 2005 and 2010 can be seen in Figure 44. It is important to note that, as European freight modal split for 2011 is yet to be published, it was only possible to calculate the expenditure for 2011.

Figure 44 - Total Freight Expenditure per Year

It can be seen that in between 2005 and 2008, the total amount of freight expenditure increased by 22%. However, with the outbreak of the 2007 financial crisis and the slowdown of economies, freight expenditure decreased by 17%. Hence, the total evolution of freight expenditure since 2005 has been 4%.

Furthermore, it can be seen in Figure 45 that in 2010 road freight cost expenditure accounts for approximately 85% of total expenditure, whereas Short sea shipping and rail freight account for 9% and 6% of the total. The significant difference can be traced back to the amount of road freight activity which is performed as short distance delivery by HDV -7.5t which accounts for approximately 48% of road freight expenditure.

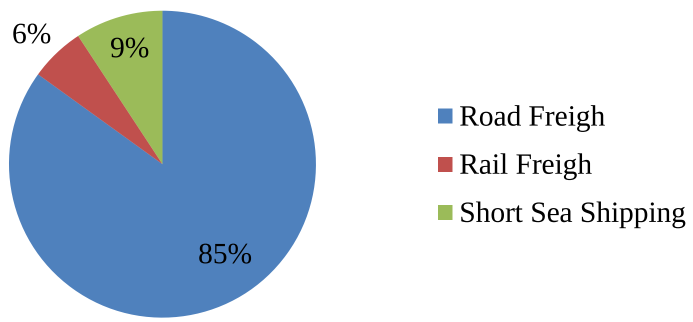


Figure 45 - 2010 Freight Expenditure per Mode of Transport

1.3.3 Freight CO_2 Emissions

Through utilizing the CO_2 emission factors previously presented and multiplying them by the share of each transport category of total freight activity, the freight CO_2 emission can be calculated. The CO_2 emission trend between 2005 and 2010 can be seen in Figure 46.

Figure 46 - Freight Total CO_2 Emissions per Year

It can be seen that between 2005 and 2007 a surge of 6% in CO_2 emission occurred. Similar to freight expenditure, following the 2007 financial crisis, as freight activities decrease, the CO_2 emissions decreased by approximately 12%.

Furthermore, it can be seen that in 2010, road freight accounted for approximately 62% of CO_2 emissions within Europe whereas, rail freight and short sea shipping accounted for 6% and 32% respectively.

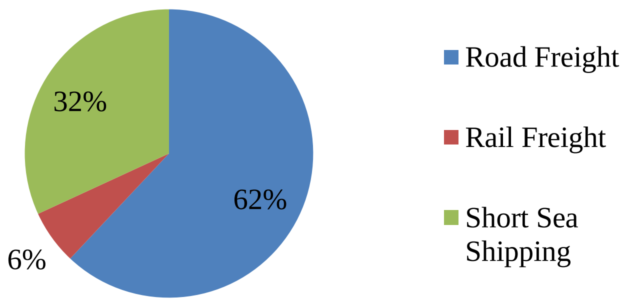


Figure 47 - Freight CO_2 Emission per Mode of Transport

2. Value of Time Estimation

The second step of executing the model was to perform the value of time (VoT) analysis in order to obtain a quantitative estimation of VoT for Toyota's logistics groups. This will provide an insight into how Toyota operates within the European freight industry. In order to estimate VoT, at first, the data obtained from the stated preference survey was analyzed. The output from this analysis was further on used to compute VoT.

2.1 Stated Preference Data Analysis

For the purpose of this study, as was explained in Chapter IV, a survey was tailored for each Toyota logistics group. The data obtained from the completion of the survey was then at first arranged into individual input data files for each logistics group which along with the model specification file were used as input for Biogem. Subsequently, the data analysis was performed by the software for each group and report files were generated were the values for β_C and β_T were estimated. However, according to the generated reports, the t-test and p-values were not within the threshold of the model which meant that the estimations had not achieved appropriate levels of robustness. After analyzing the output it was the determined that the underlying reason for this the insufficient number of observations recorded for each logistics group which did not enable the model to converge on a credible value.

In order to accommodate the lack of observations, the data sets obtained from all the groups were merged a singular input data file and the analysis was performed again. This time, appropriate values for the t-test and p-value was reported which meant that the estimation were robust.

The report generated by the software for the combination of the three logistics group can be seen bellow:

```
   Toyota VoT Analysis
   3 alternatives and 5 parameters
   2 parameters are estimated

                           Model: Multinomial Logit
Number of estimated parameters: 4
        Number of observations: 293
         Number of individuals: 293
           Null log-likelihood: -281.347
           Init log-likelihood: -281.347
          Final log-likelihood: -185.864
         Likelihood ratio test: 190.966
                    Rho-square: 0.339
           Adjusted rho-square: 0.325
           Final gradient norm: +3.552e-002
                    Diagnostic: Convergence reached...
                    Iterations: 136
                      Run time: 00:01
           Variance-covariance: from analytical hessian
                   Sample file: Survey_TOYOTA.DAT

Utility parameters
******************
Name  Value      Std err   t-test p-val    Rob. std err Rob. t-test Rob. p-val
----  -----      -------   ------ -----    ------------ ----------- ----------
ASC1  0.00       --fixed--
ASC2  1.04       0.228     4.57   0.00     0.222        4.68        0.00
ASC3  0.854      0.357     2.39   0.01     0.357        2.39        0.01
BETA1 -2.72e-005 6.02e-006 -4.52  0.00     7.03e-006    -3.87       0.00
BETA2 -0.00301   0.00792   -0.38  0.02     0.00833      -0.36       0.03

Utility functions
*****************
1       Alt1    av1     ASC1 * one + BETA1 * x11 + BETA2 * x12
2       Alt2    av2     ASC2 * one + BETA1 * x21 + BETA2 * x22
3       Alt3    av3     ASC3 * one + BETA1 * x31 + BETA2 * x32


Correlation of coefficients
***************************
Coeff1 Coeff2 Covariance Correlation t-test   Rob. covar. Rob. correl. Rob. t-test
------ ------ ---------- ----------- ------   ----------- ------------ -----------
BETA1  BETA2  1.22e-008  0.255       2.38     1.39e-008   0.238        1.56
ASC2   ASC3   0.0596     0.732       2.76     0.0572      0.721        1.35
ASC3   BETA2  -0.00117   -0.414      3.38     -0.00146    -0.492       1.37
ASC3   BETA1  9.71e-007  0.452       3.39     1.10e-006   0.440        2.12
ASC2   BETA1  4.16e-007  0.303       5.57     3.10e-007   0.198        4.51
ASC2   BETA2  -9.04e-005 -0.0501     5.58     -0.000377   -0.203       5.02

Smallest singular value of the hessian: 0.622821
```

By utilizing the reported values, the Value of Time was calculated for each logistics group. Furthermore, VoT estimated for Toyota Motor Europe will be presented.

2.2 Value of Time for Toyota Logistics Groups

Through utilizing the data obtained from the report file it was possible to estimate the value of time. By inserting the values of β_T and β_C into Equation 7 the VoT was calculated. The results of the calculations can be seen in Table 38.

Table 38 - Value of Time Estimation for Toyota Motor Europe

Item	Value
Survey Transport Load (tonne)	820
β1	2.72E-05
β2	0.00301
VoT (€/hr)	110.66
VoT (€/hr/tonne)	0.135

As can be seen in the table, the unit VoT is initially expressed as €/hr which is not the desired unit of €/tonne-km. At first, the unit needs to be converted to €/hr/tonne. This was achieved through dividing the initial value of time by the average survey transport load. The survey transport load is the weight of the load which was supposed to be transported in accordance to the description of the survey which deferred between the groups. In the next step, in order to convert €/hr/tonne to €/tonne, the obtained value had to be divided by the speed of the means of transport used by the each group. The results of this calculation can be seen in Table 39

Table 39 - Value of Time per Logistics Group per means of Transport

Logistics Group	TPCE			VLG			PPLG		
Means of Transport	HDT 16-32t	LoLo Container Ship	General Cargo	HDT 16-32t	RoRo Ship	Container	HDT 16-32t	LoLo Container Ship	Container
Speed (km/hr)	60	26.0	40	60	26.0	40	60	26.0	40
VoT (€/hr/ton)	0.135			0.135			0.135		
VoT (€/tonne-km)	0.0023	0.005	0.003	0.0023	0.0042	0.0034	0.0023	0.0051	0.0034

2.3 Validation of the VoT Estimation

In order to validate the estimated VoT, it was decided to compare the values obtained for the study with values existing in literature. The source used for this purpose was a study performed by Zamparini and Reggiani (2007) on empirical freight VoT observations related to several European and North American countries. The data obtained from this study can be seen in

Table 40 - Minimum, Maximum, and Average VoT across Europe

	Minimum	Maximum	Avarage
Region	Sweden	Belgium	EU
Value (€/hr)	35	180	105

As can be seen, the VoT for Toyota's logistics groups is places in between the minimum and maximum values observed in the EU region and is close to the EU average. Hence, it was determined that the estimated VoT was valid and could be used as an input for the model.

3. 2011-2030 Scenario Model Execution

The third and last step of executing the model to implement the 2011-2030 scenario model. In this section, this process and the results obtained will be presented and discussed.

In order to execute the scenario model, as was explained in the introduction to this chapter, first the freight cost per mode needed to be obtained for each scenario. Next these values had to be combined with the Value of Time for the logistics groups and inserted into the CES optimization model. The output of the CES model would be the modal split which would be used to calculate the freight expenditure and CO_2 emission for each Toyota logistics department.

Accordingly, in this section, the scenario model execution will be explained and the results obtained from it will be presented. The content of the section will be presented through the following steps:

1. Scenario Model input data
2. Constant Elasticity of Substitution Implementation
3. 2011-2030 Scenario Model Results

3.1 Scenario Model Input Data

The first step of executing the scenario model was to define the new input data for the spreadsheet. As the input data for the scenarios defers from each other, their input parameters will be explained separately.

It is important to note that only input data which will change in structure compared to the baseline spreadsheet will be presented. The reminder of the data is assumed to follow macro-economic trends and will be treated accordingly.

For all of the presented scenarios, the new cost figures per mode can be seen in Appendix C.

3.1.1 Business as Usual and Forced Modal Split Scenario

As was explained in the premise of these two scenarios, no legislations will be introduced during the timeline of the scenarios that will influence the values of the input data. Hence, it was assumed that the majority of the input data will follow macro-economic trends. Accordingly, the unaffected data was adjusted using projected inflation rates for the EU.

According to the European Central Bank (ECB), the projected inflation rate for Europe for the next five years is estimated to be approximately 2% annually (ECB, 2012). It was assumed that this value would extend up until 2030.

The input data which was assumed to not follow macro-economic trends were fuel price for all modes and fuel consumption for road freight. Fuel price was deemed to be susceptible to change because of its dependence on the volatility of oil price and fuel consumption due to the incremental improvements in technology. The updated values for fuel prices and fuel consumption for freight can be seen in Table 41 and Table 42.

Table 41 - Average Fuel Price across Europe (Energy Research Group, 2011; TRT, 2009)

Fuel Type	Year										
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
Diesel (€/liter)	1.42	1.48	1.52	1.44	1.35	1.28	1.22	1.2	1.16	1.2	1.24
Diesel Oil (€/liter)	0.52	0.55	0.6	0.54	0.5	0.41	0.36	0.34	0.35	0.35	0.39
Electricity (€/kwh)	0.191	0.198	0.21	0.189	0.179	0.17	0.165	0.15	0.13	1.16	1.17

Table 42 – Average Projected Fuel Consumption & CO2 Emission Factors (2011-2030) (Hill, et al., 2011; Mckinnon, et al.)

Vehicle Type	Average Vehicle Fuel Consumption (l/tonne-km, Diesel)		
	2010	2020	2030
HDV 7.5t	0.0427	0.0413	0.0397
HDV 7.5-16t	0.0179	0.0173	0.0167
HDV 16-32t	0.0103	0.0098	0.0093
HDV +32t	0.0097	0.0094	0.0087
Vehicle Type	**Average CO2 Emission factor (kg CO2/tonne-km, Diesel)**		
	2010	2020	2030
HDV 7.5t	0.1237	0.1199	0.1152
HDV 7.5-16t	0.0518	0.0501	0.0484
HDV 16-32t	0.0297	0.0285	0.0268
HDV +32t	0.0280	0.0273	0.0251

3.1.2 New Fuel and Technology Promotion

The basis for this scenario is that new taxation schemes and performance requirements would be institutionalized by the EU which would act as a promoter for new fuels and technologies. As it is assumed that new legislations would be put in place, it was expected that a change in input data will occur.

One of the major changes, which would influence all modes of transport, was identified as the introduction of CO_2 taxation in addition to the previous energy content taxation for fuels through the implementation of the amendment to the energy taxation directive (European Parliament and of the Council, 2011b). This piece of legislation would influence all the modes of transport. The new taxation values and their proposed date of implementation can be seen in Table 43:

Table 43 - New Energy Taxation Values (European Parliament and of the Council, 2011b)

	CO2-Related Taxation (€/t CO2)	General Energy Consumption Taxation (€/GJ)	General Energy Consumption Taxation (€/GJ)	General Energy Consumption Taxation (€/GJ)
Date	1-Jan-13	1-Jan-13	1-Jan-15	1-Jan-18
Gesoline	20	9.6	9.6	9.6
Diesel	20	8.2	8.8	9.6

The effect of the new energy taxation values on fuel prices can be seen in Table 44 where the new fuel prices have been introduced.

Fuel Type	Year										
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
Diesel (€/liter)	1.420	1.498	1.538	1.458	1.390	1.320	1.260	1.268	1.228	1.268	1.308
Diesel Oil (€/liter)	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241
Electricity (€/kwh)	0.191	0.198	0.21	0.189	0.179	0.17	0.165	0.15	0.13	1.16	1.17

The remainder of the forecasted new input parameters for each mode of transport will furthermore be presented.

3.1.2.1 Road Freight

One of the expected legislations was performance requirements for vehicles and their components. Performance requirements would create a need for equipment upgrades for the vehicles which would effectively result in increased depreciation cost. It is assumed that by 2030 an increase of 30% in fuel consumption is achievable for heavy duty vehicles through various sets of technology package improvements (Ernst, 2011). Hence, for this scenario it was forecasted that this improvement would be set as requirement by the EU. The cost increase and fuel consumption improvements as a result of these upgrades can be seen in Table 44.

Table 44 - Technology Improvement Cost and Effect on Fuel Consumption (Ernst, 2011; Hill, et al., 2011)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
Upgrade Cost (1000 Euro)	1.5	1.5	1.5	1.5	2	2	2	2	3	3	12	45
Fuel Consumption Improvement (%)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	7.5	7.5

In addition it is also anticipated that a reduction in the speed of heavy duty vehicles to 80kph will be required by 2013. It is estimated that this will result in a 5% reduction in fuel consumption. In addition, the EU is currently contemplating changing weight and dimension requirements for the vehicles. These changes will translate to an approximately 8% reduction of fuel consumptions because of improved aerodynamics. Finally, driver training may be introduced through a Driver Training Directive which will reduce fuel consumptions by 5%. Vehicle dimension change and driver training, if implemented, is expected to be implemented by 2015 (Ernst, 2011). The resulting values through the combination of the introduced changes can be seen in Table 45.

Table 45 - Average Projected Fuel Consumption and CO2 Emission Factors for Road Freight

Vehicle Type	Average Vehicle Fuel Consumption (l/tonne-km, Diesel)											
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
HDV 7.5t	0.042	0.041	0.039	0.035	0.033	0.032	0.032	0.031	0.031	0.030	0.028	0.026
HDV 7.5-16t	0.055	0.054	0.051	0.046	0.043	0.042	0.042	0.041	0.040	0.040	0.037	0.034
HDV 16-32t	0.065	0.064	0.060	0.054	0.050	0.050	0.049	0.048	0.047	0.047	0.043	0.040
HDV +32t	0.081	0.080	0.075	0.068	0.063	0.062	0.061	0.060	0.060	0.059	0.054	0.050

Vehicle Type	Average CO2 Emission factor (kg CO2/tonne-km, Diesel)											
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2030
HDV 7.5t	0.122	0.120	0.112	0.102	0.095	0.094	0.092	0.091	0.089	0.088	0.081	0.075
HDV 7.5-16t	0.160	0.158	0.147	0.133	0.125	0.123	0.121	0.119	0.117	0.116	0.107	0.099
HDV 16-32t	0.187	0.185	0.173	0.156	0.146	0.144	0.142	0.140	0.137	0.135	0.125	0.116
HDV +32t	0.235	0.232	0.217	0.196	0.183	0.181	0.178	0.175	0.173	0.170	0.157	0.146

3.1.2.2 Rail Freight

For rail freight, the introduction of the Stage IIIB and Stage IV of the NRMM directive was predicted. The introduction of these stages would indicate an increase in depreciation cost resulting from the need of upgrades because of after treatment requirements. The cost increase values can be seen in Table 46.

Table 46 - Rail Freight Depreciation Increase Following Stage IIIB and IV NRMM Directive (Zeebroeck, et al., 2009)

Stage	Period	Diesel Locomotives Depreciation Cost Increase (€/train-km)			
		Container	**General Cargo**	**Wet Bulk**	**Dry Bulk**
Stage IIIB	2011-2014	4980	4980	4980	4980
	2014-2030	9960	9960	9960	9960
Stage IV	2011-2014	5720	5720	5720	5720
	2014-2030	12141	12141	12141	12141

3.1.2.3 Short Sea Shipping Freight

For short sea shipping, the amendment to MARPOL Annex VI was predicted to come into effect across Europe. This amendment requires lower levels of Sulphur which is achieved through upgrading the scrubbers of the ships. This upgrade will increase depreciation cost and the fuel consumption and maintenance cost for the ships (SKEMA, 2010). The new input values for these parameters can be seen in Table 47.

Table 47 - Cost Increases for Short Sea Shipping Due to MARPOL Annex VI (SKEMA, 2010)

Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Depreciation (€/day)	819	836	852	869	887	904
Fuel Cost (€/day)	29901	30989	32891	34251	35610	36425
Meintenance (€/day)	55	56	57	58	59	60
Year	**2017**	**2018**	**2019**	**2020**	**2025**	**2030**
Depreciation (€/day)	923	941	960	979	999	1019
Fuel Cost (€/day)	37241	37784	38056	38328	41046	43765
Meintenance (€/day)	62	63	64	65	67	68

3.1.3 Taxation

The premise of this scenario is that new taxation schemes would implemented by the EU in order to reduce the level of CO_2 emissions in Europe. As it is assumed that new legislations are intended to be put in place, it was expected that the input data would change.

The amendment to the energy taxation directive presented for the previous scenario was also considered for this scenario. Hence, the input data introduced in Table 43 Will also apply to this scenario.

3.1.3.1 Road Freight

For road freight it was assumed that the amendment to the Eurovignette directive would be implemented to the maximum. As was previously explained, in 2006 an amendment to the original Eurovignette directive was voted for which was implemented up until 2011. In 2011 a second amendment was then voted for. This amendment will see significant changes in the rates and the calculation methodology compared to the previous versions. It is assumed for this scenario that the member states will adopt the maximum rates proposed by the EU. The rates can be seen in Table 48:

Table 48 - Eurovignette Charges in Effect as of 2011 and onwards (European Parliament and of the Council, 2011c)

Maximum Cost of Traffic-based air pollution		
Cent/Vehicle.kilometre	**Suburban roads (including motorways)**	**Interurban roads (including motorways)**
Euro 0	16	12
Euro I	11	8
Euro II	9	7
Euro II	7	6
Euro IV	4	3
Euro V	0	0
After 31 December 2013	3	2
Euro VI	0	0
After 31 December 2017	2	1
Less polluting than Euro VI	0	0
Maximum Cost of Traffic-based noise pollution		
Cent/Vehicle.kilometre	**Day**	**Night**
Suburban roads (including motorways)	1.1	2
Interurban roads (including motorways)	0.2	0.3

3.1.3.2 Rail Freight

For rail freight, the only changes which were predicted to occur were the increase in fuel price as an effect of the energy directive amendment. No further taxation schemes are forecasted to be implemented in this scenario.

3.1.3.3 Short Sea Shipping

For short sea shipping based on future GHG policies it was predicted that a carbon trading scheme along with an emission tax would be implemented. The implementation of these schemes would lead to a 33% increase of fuel cost by 2030 (CE Delft, 2009).

In addition, based on a survey carried out on eMaritime, it was estimated that a drop of approximately 20% in infrastructure fees could be expected for short sea shipping from technological and operational improvements within the ports.

3.1.4 Maximum Impact Scenario

The premise for this scenario is that all the legislative tools previously presented will be simultaneously implemented. Hence, it was predicted that a combination of all changes in the input data will occur. No additional legislative tools are expected to be implemented in this scenario.

3.2 Constant Elasticity of Substitution Implementation

The second step of executing the scenario model is to perform the constant elasticity of substitution analysis in order to obtain the modal split for each logistics group.

The constant elasticity of substitution functions was previously introduced. As was explained, the function defined for this study will need the data produced by the scenario spreadsheet and the Value of Time analysis in order to perform an optimization of each logistics group and estimate their future modal splits. These inputs were previously defined in the previous sections. In addition, a set of complementary data is also necessary to be able to calibrate the model. Furthermore, this set of data will be explained for each logistics group.

3.2.1 Calibration Input Data

The data input necessary to calibrate the model was obtained through interviews with the managers of each logistics group. The data can be observed in Table 49. It is important to note that according to Toyota's logisitcs Management, the freight activity and budget is not expected to fluctuate in the near future. However, according to the EU, it is expected that freight activity will increase by approximately 30% by 2030 with respect to 2005 values (EU, 2011).

Table 49 - Calibration Data Input per Logistics Group

	TPCE	VLG	PPLG
Annual Budget	100	114	109
2011 Total Freight Activity (tonne-km)	1,188,000,000	1,540,000,000	910,000,000
Modal Split (%)			
Road Freight	65	40	96
Rail Freight	12.5	20	2
Short Sea Shipping	22.5	40	2
Modal Split (tonne-km)			
Road Freight	772,200,000	616,000,000	873,600,000
Rail Freight	148,500,000	308,000,000	18,200,000
Short Sea Shipping	267,300,000	616,000,000	18,200,000

In addition to the mentioned data, the elasticity of substitution (σ) also had to be defined. This value had to be extracted from available literature as estimating it was out of the scope of this study. The data used for the purpose of this study was σ=2 with the assumption that it is equal across Europe (Gusbin, et al., 2010). Through utilizing the presented data, the model was calibrated and the share parameters (α_i) were estimated.

3.3 2011-2030 Scenario Model Results

As all the required data for the model had been acquired, it was possible to executed the model and obtain the results. For the optimization model, it was assumed that freight activity and budget for each of the logistics group would remain constant during the time period.

In this section, the modal split and the CO_2 emissions obtained will be presented and analyzed per logistics group.

3.3.1 Toyota Parts Center Europe (TPCE) Future Modal Split and CO_2 Emissions

The future modal split estimated for TPCE for the different scenarios can be seen in Figure 48 to Figure 52:

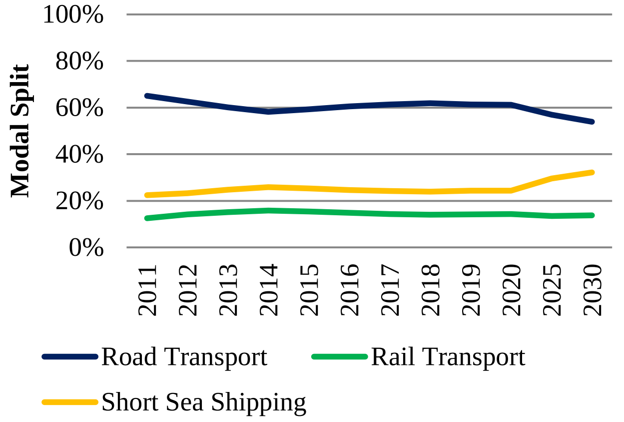


Figure 48 - TPCE Modal Split - Business as Usual

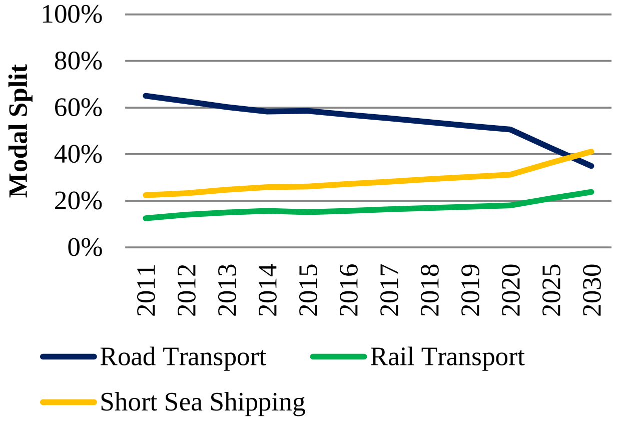


Figure 49 - TPCE Modal Split - Forced Modal Split

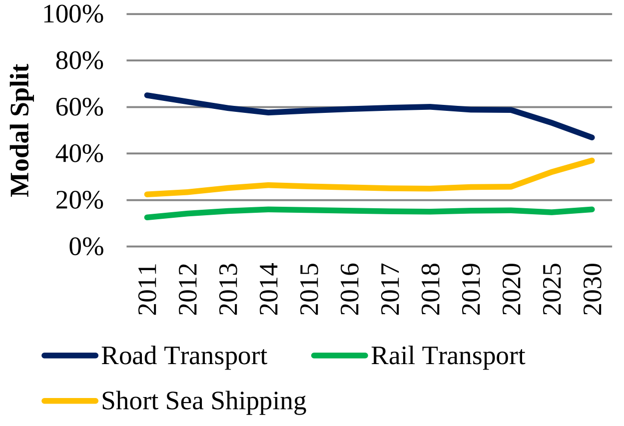


Figure 50 - TPCE Modal Split - New Fuel and Tech. Promotion

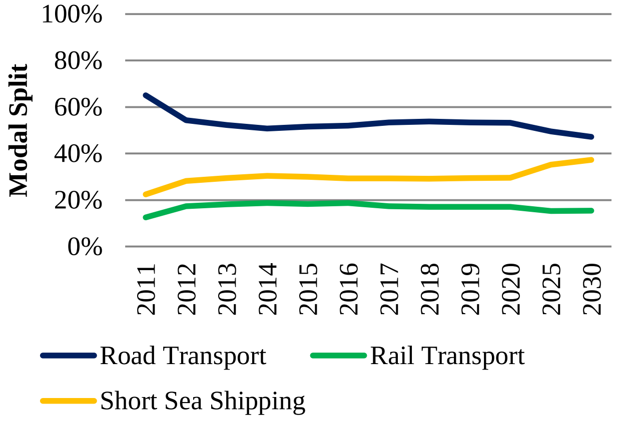


Figure 51 - TPCE Modal Split - Taxation

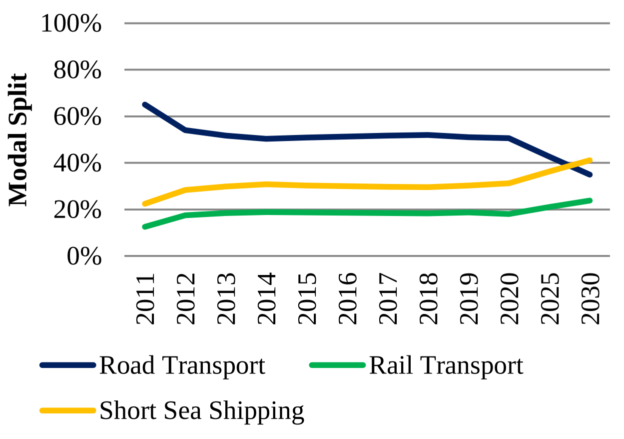


Figure 52 - TPCE Modal Split – Maximum Impact

As the White Paper specifically mentions a 30% shift from road freight to alternative modes of transport, the goal here is to investigate whether or not it has been achieved in the various scenarios. As can be seen in the figure, the following occurs for road freight during each scenario:

- Business as Usual: 11% decrease
- Forced Modal Split: 30% decrease
- New Fuel and Technology Promotion: 18% decrease
- Taxation: 18% decrease
- Maximum Impact: 30% decrease

As can be seen, only in forced modal split and maximum impact, the target of 30% is achieved.

The CO_2 emissions estimated for TPCE for the different scenarios can be seen in Figure 53 to Figure 57:

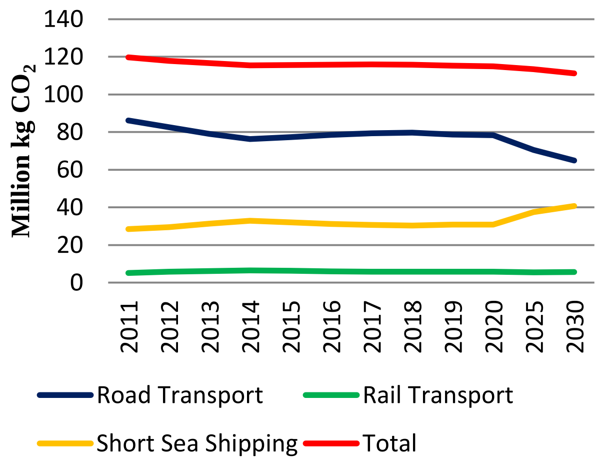


Figure 53 - TPCE CO_2 Emissions - Business as Usual

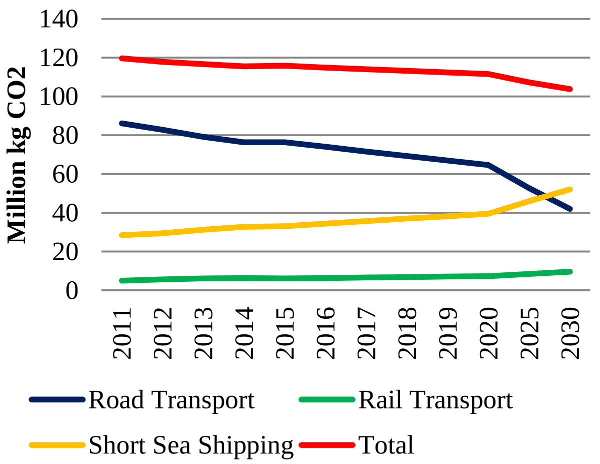


Figure 54 - TPCE CO_2 Emissions - Forced Modal Split

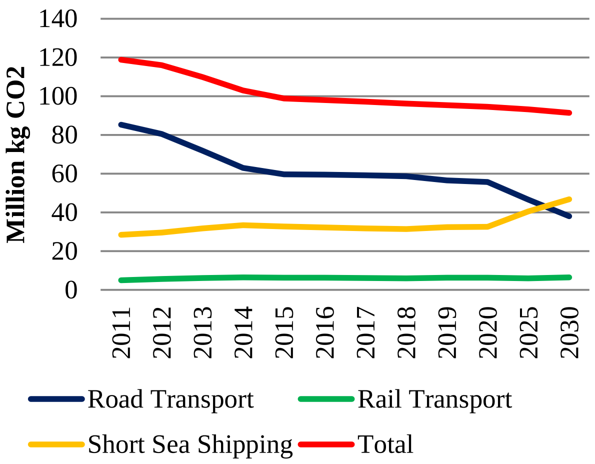


Figure 55 - TPCE CO_2 Emissions - New Fuel and Tech. Promotion

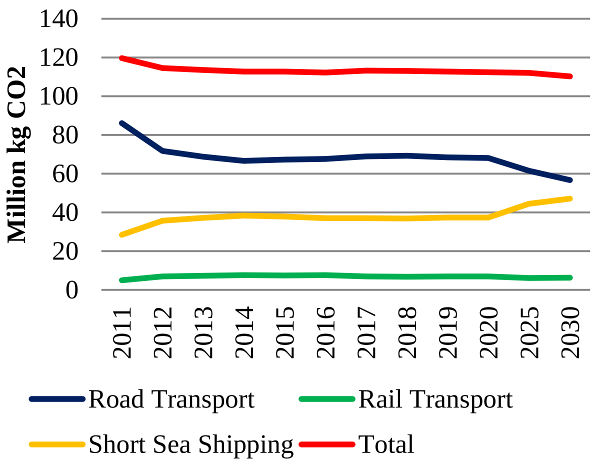


Figure 56 - TPCE CO_2 Emissions - Taxation

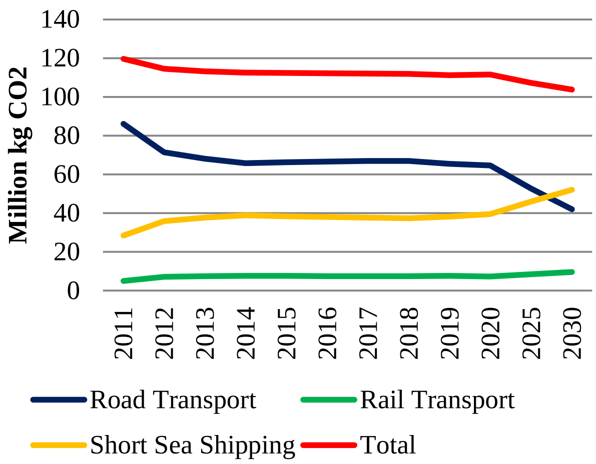


Figure 57 - TPCE CO_2 Emissions – Maximum Impact

The White Paper specifically mentions that a 20% reduction in CO_2 emission by 2030 with regards to 2008 values are desirable, the goal here is to investigate whether or not this target has been achieved in the various scenarios. As can be seen in the figure, the following occurs for CO_2 emissions during each scenario:

- Business as Usual: 7% decrease
- Forced Modal Split: 13.5% decrease
- New Fuel and Technology Promotion: 23% decrease
- Taxation: 8% decrease
- Maximum Impact: 13.5% decrease

As can be seen, only in the new fuel and technology promotion the target of 20% reduction is achieved. This can be traced back to the fact that when freight prices increases, following the groups historical behavior, a shift towards cheap short sea shipping occurs which currently is more polluting than road freight.

3.3.2 Vehicle Logistics Group (VLG) Future Modal Split and CO2 Emissions

The future modal split estimated for VLG for the different scenarios can be seen in Figure 58 to Figure 62:

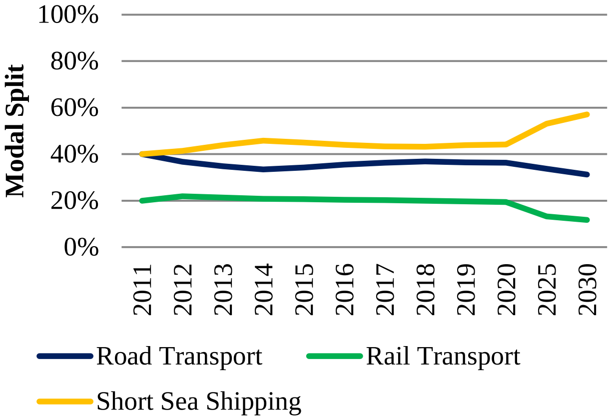


Figure 58 - VLG Modal Split - Business as Usual

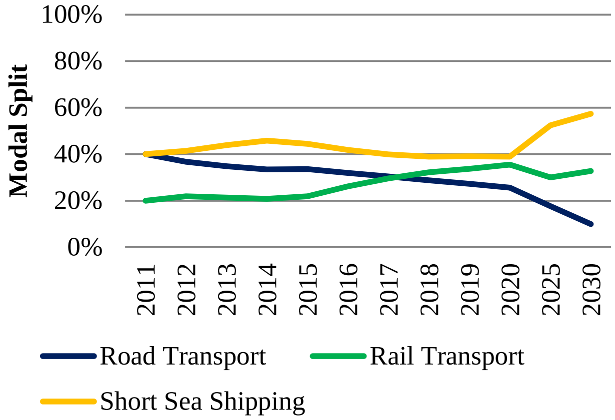


Figure 59 - VLG Modal Split - Forced Modal Split

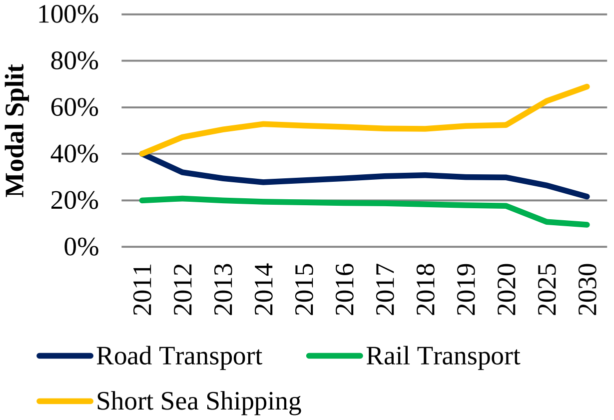


Figure 60 - VLG Modal Split - New Fuel and Tech. Promotion

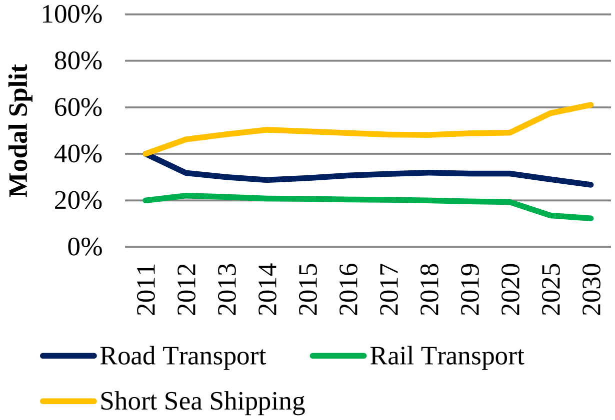


Figure 61 - VLG Modal Split - Taxation

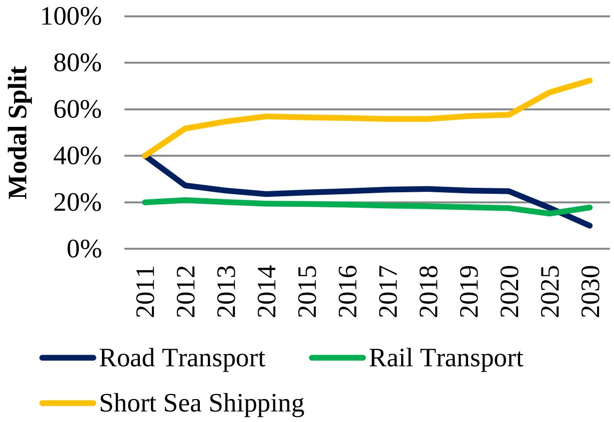


Figure 62 - VLG Modal Split – Maximum Impact

Similar to TPCE, the goal here is to investigate whether or not VLG has been achieved in the various scenarios. As can be seen in the figure, the following occurs for road freight during each scenario:

- Business as Usual: 9% decrease
- Forced Modal Split: 30% decrease
- New Fuel and Technology Promotion: 18% decrease
- Taxation: 13% decrease
- Maximum Impact: 30% decrease

It can again be observed that only in forced modal split and maximum impact, the target of 30% is achieved.

The CO_2 emissions estimated for VLG for the different scenarios can be seen in Figure 63 to Figure 67:

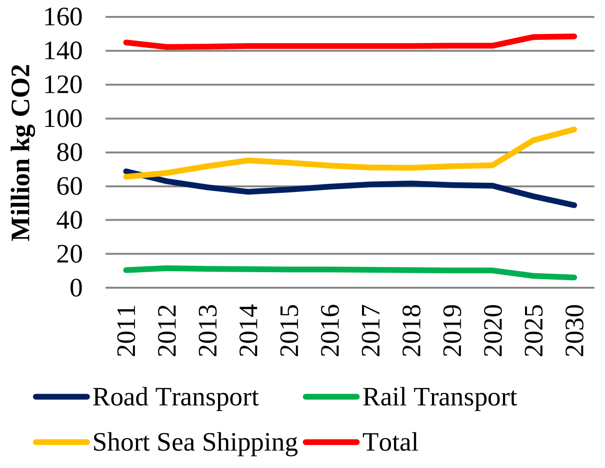


Figure 63 - VLG CO_2 Emissions - Business as Usual

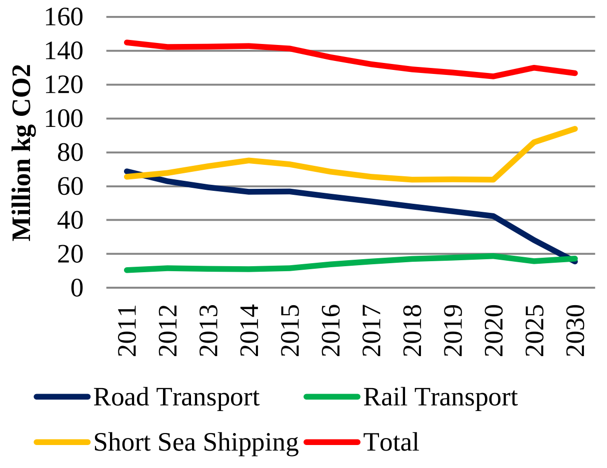


Figure 64 - VLG CO_2 Emissions - Forced Modal Split

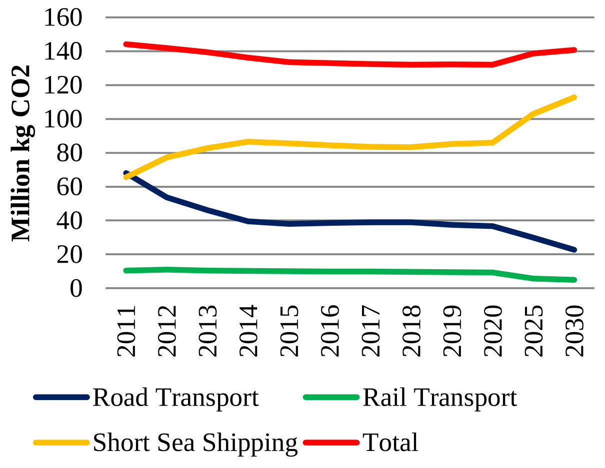


Figure 65 - VLG CO_2 Emissions - New Fuel and Tech. Promotion

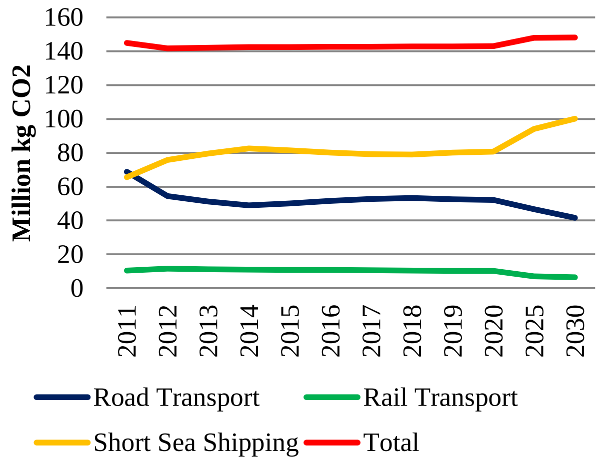


Figure 66 - VLG CO_2 Emissions - Taxation

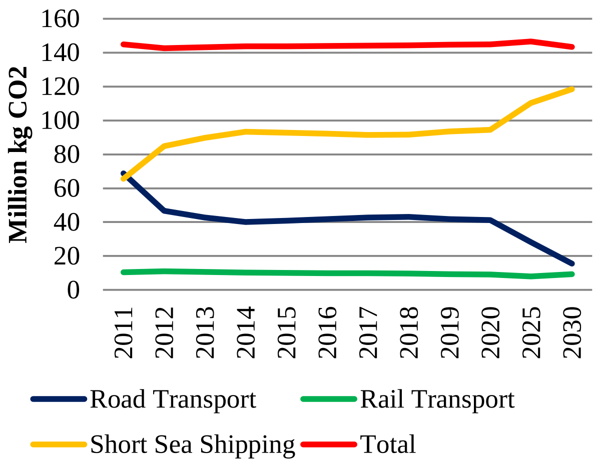


Figure 67 - VLG CO_2 Emissions – Maximum Impact

The goal here again is to investigate whether or not VLG has achieved the targets in the various scenarios. As can be seen in the figure, the following occurs for CO_2 emission levels during each scenario:

- Business as Usual: 2.5% increase
- Forced Modal Split: 12.5% decrease
- New Fuel and Technology Promotion: 2.5% decrease
- Taxation: 2.5% increase
- Maximum Impact: 1% decrease

As can be seen, in none of the scenarios the target is achieved. For forced modal split it can even be observed that the CO_2 emissions increase. This case is similar to TPCE and can be traced back to the fact that following the groups historical behavior, when freight prices increase, a shift towards cheap short sea shipping occurs.

3.3.3 Production Parts Logistics Group (PPLG) Future Modal Split and CO2 Emissions

The future modal split estimated for PPLG for the different scenarios can be seen in Figure 68 to Figure 72:

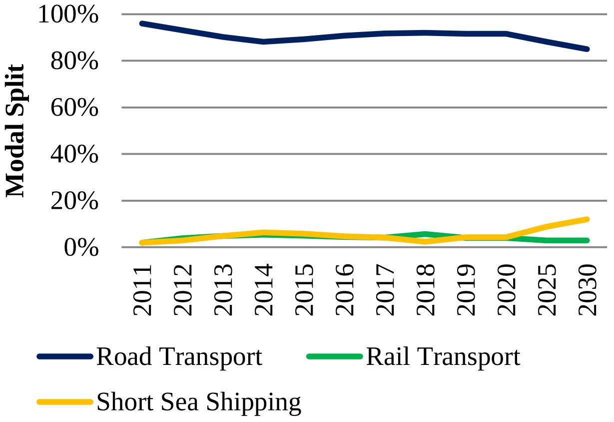


Figure 68 - PPLG Modal Split - Business as Usual

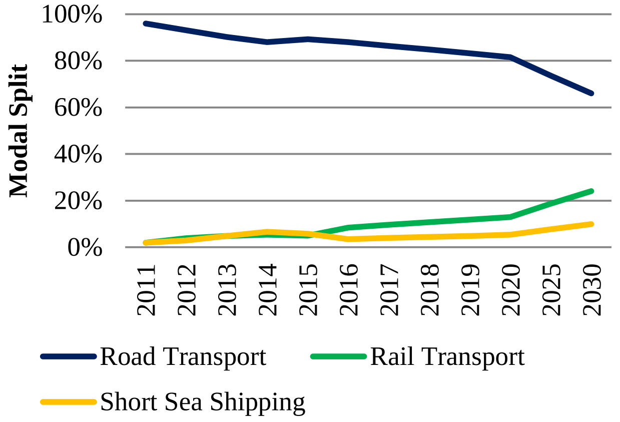


Figure 69 - PPLG Modal Split - Forced Modal Split

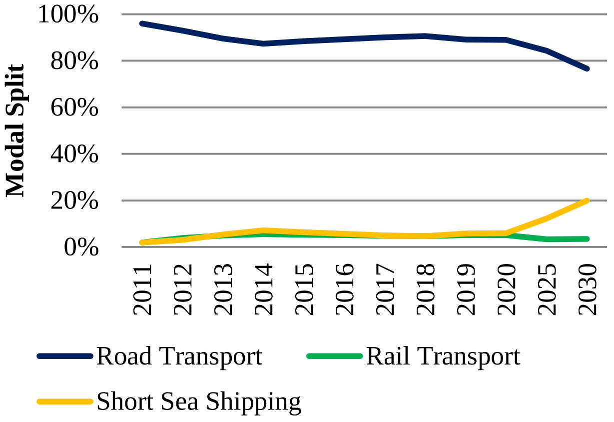


Figure 70 - PPLG Modal Split - New Fuel and Tech. Promotion

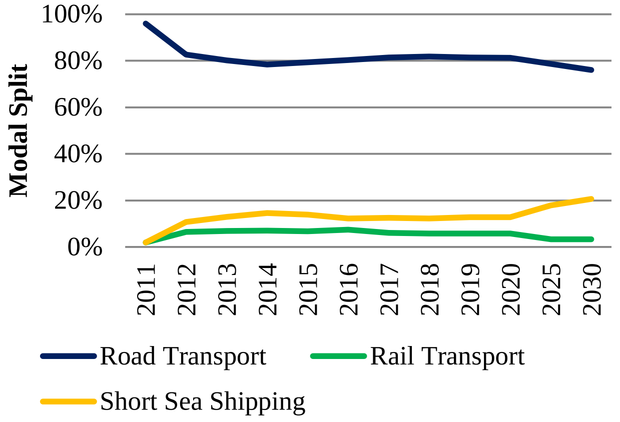


Figure 71 - PPLG Modal Split - Taxation

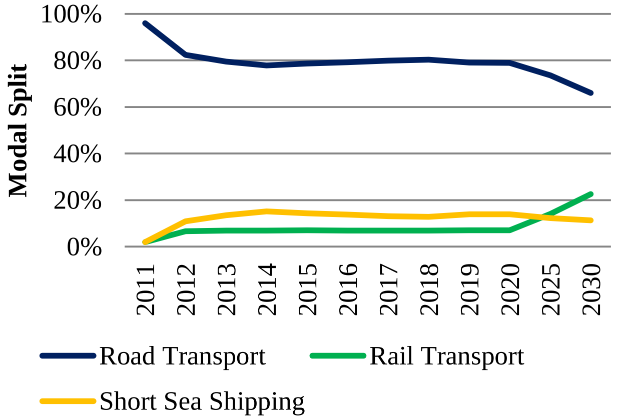


Figure 72 - PPLG Modal Split – Maximum Impact

Similar to previous groups, the goal is to investigate if the group has been able to achieve the emissions targets in the various scenarios. As can be seen in the figure, the following occurs for road freight modal split in each scenario:

- Business as Usual: 11% decrease
- Forced Modal Split: 30% decrease
- New Fuel and Technology Promotion: 19% decrease
- Taxation: 20% decrease
- Maximum Impact: 30% decrease

It can again be observed that only in forced modal split and maximum impact, the target of 30% is achieved. In addition, the tendency to switch to alternative modes are very low for PPLG, this can be traced back to the historical practice of the groups extensive use of road freight.

The CO_2 emissions estimated for PPLG for the different scenarios can be seen in Figure 73 to Figure 77.

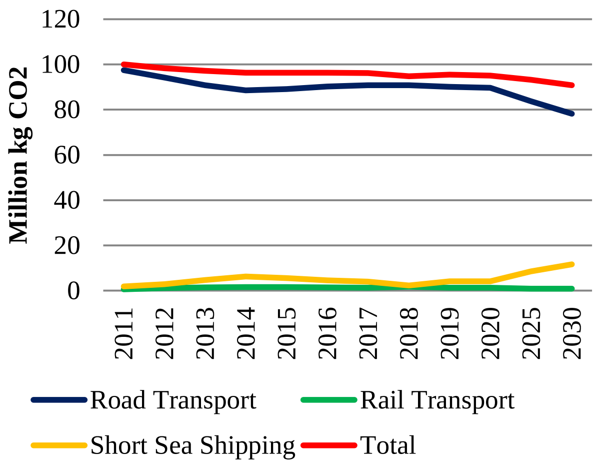


Figure 73 - PPLG CO_2 Emissions - Business as Usual

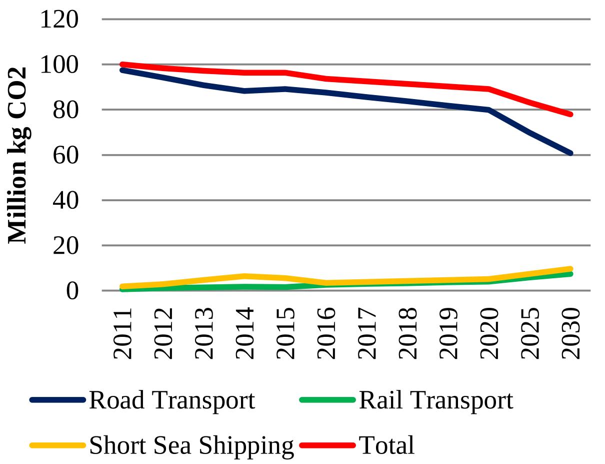


Figure 74 - PPLG CO_2 Emissions - Forced Modal Split

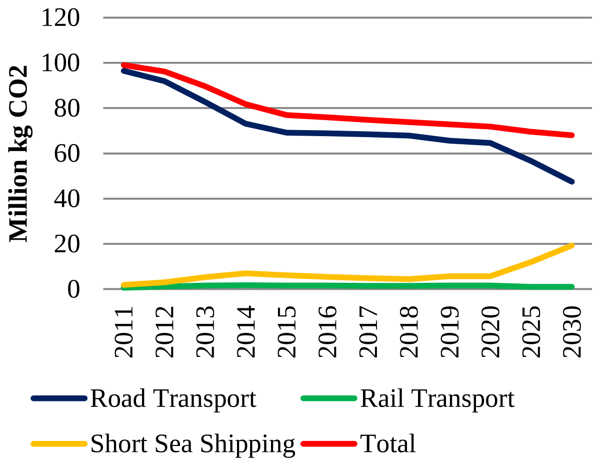


Figure 75 - PPLG CO_2 Emissions - New Fuel and Tech. Promotion

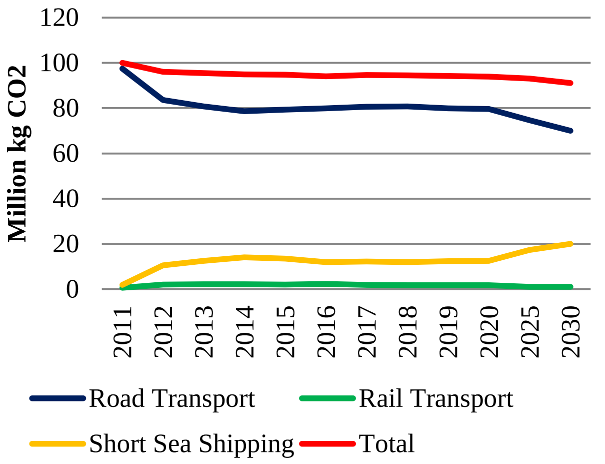


Figure 76 - PPLG CO_2 Emissions - Taxation

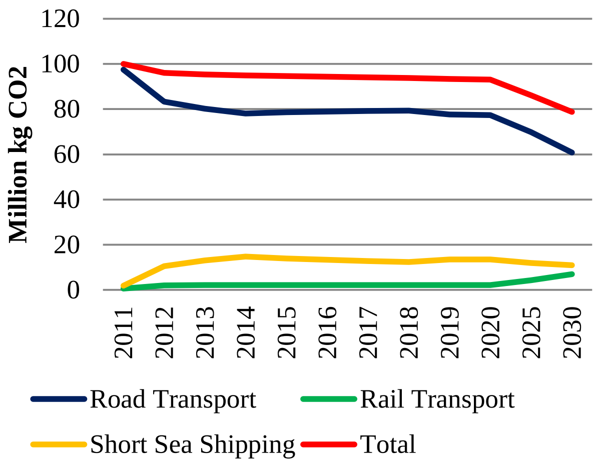


Figure 77 - PPLG CO_2 Emissions – Maximum Impact

As can be seen in the figure, through the investigation on whether the CO_2 emission targets will be achieved, the following change can be tracked in CO_2 emission levels:

- Business as Usual: 9% decrease
- Forced Modal Split: 22% decrease
- New Fuel and Technology Promotion: 31% decrease
- Taxation: 9% decrease
- Maximum Impact: 21% decrease

As can be seen, the situation for PPLG is significantly better that the other groups. The target is achieved in the forced modal split, new fuel and technology promotion, and maximum impact scenario. This occurrence can be traced back to the high historical usage of road freight by PPLG which has been reflected in the forecast. Because, it is expected that the highest fuel consumption improvements is going to materialize for road freight, the low shift to alternative modes will result in a significant improvement in CO_2 emissions.

By the end of this chapter, as mentioned in the introduction, the second, third, and fourth research sub-question had been answered. In the next Chapter the conclusion and recommendations of the report will be presented.

VII. Conclusion and Recommendation

In this chapter, the conclusions of the research project will be provided. This will be followed by a set of recommendations for Toyota Motor Europe as the company where the case study was performed, as well as recommendations for future research in this field.

1. Conclusions

In the Chapter I, the problem was defined through an analysis of the developing conditions which has led to the publishing of the white paper. It was explained that through the White Paper, the EU has for the first time directly targeted the European freight industry and is expecting a reduction of CO_2 emissions and a shift away from road freight to alternative modes.

Following the introduction of the problem, the research methodology was presented. The four sub-questions which would enable the answering of the main research questions were defined and the rational for each was explained.

Furthermore, the research framework was introduced. It was explained that for the purpose of the study, a spreadsheet model will be developed and that the research tools which would enable this process would be literature review, stakeholder analysis, direct observations, interviews, and conducting surveys.

In order to gain an insight into the environment created by the white paper, a detailed analysis of the report and the following initiatives were performed. To support the findings a stakeholder analysis was subsequently performed. The stakeholders identified were recognized as EU institutions, the vehicle manufacturing industry, environmental NGOs, and logistics service providers (3PLs). Through performing a stakeholder mapping, the power and influence of each of the stakeholders were determined. It was found that, EU institutions have the most interest and power followed by the vehicle manufacturing industry. NGOs were described as having a high interest but limited power while 3PLs were considered to have high power but low interest. Following these analyses, it was determined that the main influential parameters would be Fuel Cost, New Technology, Internalization of external cost, and Modal split. By obtaining this information, the first research sub-question was answered.

Next, the model development steps were introduced. It was explained that the spreadsheet model consisted of two main parts, the baseline spreadsheet and the 2011-2030 scenario model. The purpose of the baseline spreadsheet was to be used in order to analyze the historic trend of freight cost and CO_2 emissions. Furthermore, it was going to be used as a template for the scenario spreadsheet.

After having developed the baseline spreadsheet, the scenario model for 2011-2030 was developed. The first step of developing the scenario spreadsheet was to develop the appropriate scenarios. Five scenarios were developed based on the content of the White Paper. The scenarios were:

1. Business as Usual Scenario
2. Forced Modal Split Scenario
3. New Fuel and Technology Promotion Scenario
4. Taxation Scenario
5. Maximum Effect Scenario

Through analyzing the White Paper and the accompanying initiatives, it was predicted what future legislative tools would be potentially implemented in each one of the scenarios. This information was then used to develop the scenario spreadsheet.

The next step for developing the 2011-2030 scenario model was to develop a Value of Time (VoT) analysis for freight. For the purpose of this study the utility functions for estimating VoT were first developed. The next phase was to design the survey model which would gather the input data for the utility functions. The survey technique which was deemed appropriate for the study was a stated preference survey which was developed for each Toyota logistics group. It was furthermore, decided that the Biogeme software would be used to analyze the acquired data from the surveys.

The next step was to develop a constant elasticity of substitution (CES) analysis for estimating the future modal split. By developing a utility tree for the purpose of the study, the constant elasticity of substitution function was developed. Using this function, the calibration equation was also extracted.

After having developed the model, it was time to execute it and extract the results. At first, the baseline spreadsheet was executed and the following results were acquired.

Baseline Freight Cost per Mode

In the generated results, it was shown that the cost of road freight had been increasing by approximately 24% since 2005. The cost for rail freight had been increasing by 24% under the same timeline. Short sea shipping cost had increase by an average of 27%.

Baseline Total Freight Expenditure

It was reported that between 2005 and 2011 only a 4% increase had been recorded in between 2005 and 2010. This could be tracked back to the financial crisis of 2007. Furthermore, road freight, has a 85% of total freight expenditure while rail freight and short sea shipping has a 6% and 9% share.

Baseline Freight CO_2 Emissions

CO_2 emissions were shown to have reduced by 6% since 2005. This was explained to be because of the reduction of freight activity as a result of the financial crisis. Furthermore, road freight has a 62% share of emissions while rail freight and short sea shipping have a 6% and 32% share.

Through extracting the aforementioned data, the second research question had been answered.

After having executed the baseline spreadsheet, the next phase was to determine the value of time. Through performing the stated preference survey with the representatives of each Toyota logistics group, the input data for the Biogeme software was attained. By running the software, the necessary data for estimating VoT resulted. The following results for VoT were estimated:

Table 50 - VoT per Logistics Group

Item	Value
β1	2.72E-05
β2	0.00301
VoT (€/hr)	110.66
VoT (€/hr/tonne)	0.135

In the next step, the scenario model was executed and the results were extracted. In order to execute the scenario model, the first phase was to identify the input data for the scenario spreadsheet. According to the legislative tools defined to be present in each scenario, the input data were acquired based on the content of the tool. This was complemented by the rest of data which was acquired through adjusting to macro-economic trends (Inflation). The identified input data was then incorporated into the spreadsheet.

After having completed the execution of the scenario spreadsheet and the VoT analysis it was possible to combine the resulting information and performing the CES analysis. By performing the CES analysis, the modal split and CO_2 emission for each logistics group and for each scenario could be estimated. The resulting values can be seen in Table 51.

Table 51 - Road Freight Share and CO_2 Emission Change

	Modal Split (Change in Road freight Share)			CO_2 Emissions (Reduction Compared to 2008)		
Logistics Group	**TPCE**	**PPLG**	**VLG**	**TPCE**	**PPLG**	**VLG**
Business as usual	-13%	-11%	-9%	-7%	-9%	+2.5%
Forced Modal Split	-30%	-30%	-30%	-13.5%	-22%	-12.5%
New Fuel and Tech Promotion	-18%	-19%	-18%	-23%	-31%	-2.5%
Taxation	-18%	-20%	-13%	-8%	-9%	+2.5%
Max Impact	-30%	-30%	-30%	-13.5%	-21%	-1%

The results presented in the table indicated that Toyota's logistics groups, in all cases, less the two marked ones, would not be reach the targets set by the EU in the white paper under normal conditions. This shows that reconsideration is needed in their current freight activities and that a long term strategy needs to be developed in order to enable a smooth transition towards aligning their activities with the targets set by the EU.

2. Recommendations

After the conclusions of the project have been presented, some recommendations for the future are provided. These recommendations are grouped into recommendations for Toyota Motor Europe, and recommendations for future research.

2.1 Recommendations for Toyota Motor Europe

As could be seen in Table 51, the logistics groups within Toyota Motor Europe fail to achieve the targets set out in the white paper. In order to generate solutions for abating this shortcoming, the targets set out by the white paper was fixed in the model. Through back-tracking the procedure of the model, it was possible to estimate what changes has to be implemented by Toyota in order to achieve the targets. It is important to note that this procedure was performed on the most severe scenario, namely the maximum impact scenario, in order to observe the maximum implications for Toyota. This information will furthermore be presented for each of the logistics groups.

Toyota Parts Center Europe (TPCE)

For TPCE, by keeping the budget constant, through keeping the ratio of rail freight towards short sea shipping at approximately 65%, a reduction of 20% in CO_2 emissions and a 50% shift from road freight to alternative modes will be achieved.

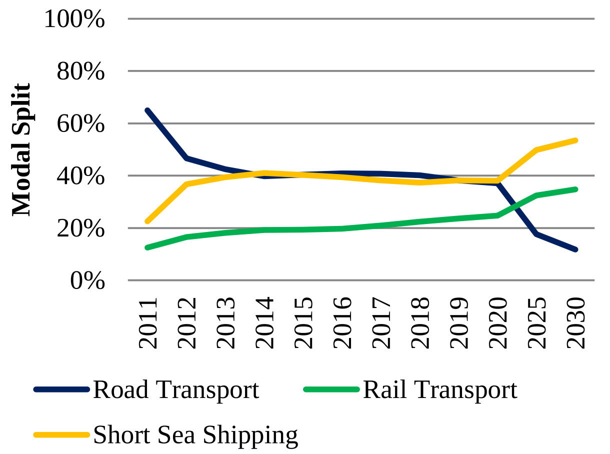


Figure 78 - TPCE Revised Modal Split

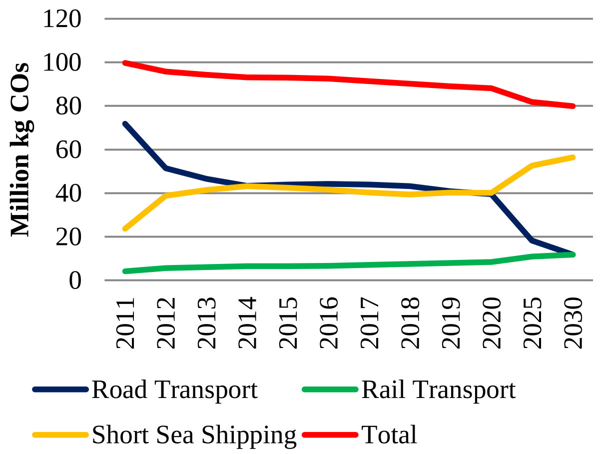


Figure 79 - TPCE Revised CO2 Emissions

Vehicle Logistics Group (VLG)

For VLG, by an increase on 24% in annual budget, through keeping the ratio of rail freight towards short sea shipping at around 85%, a reduction of 20% in CO_2 emissions and a 31% shift from road freight to alternative modes will be achieved.

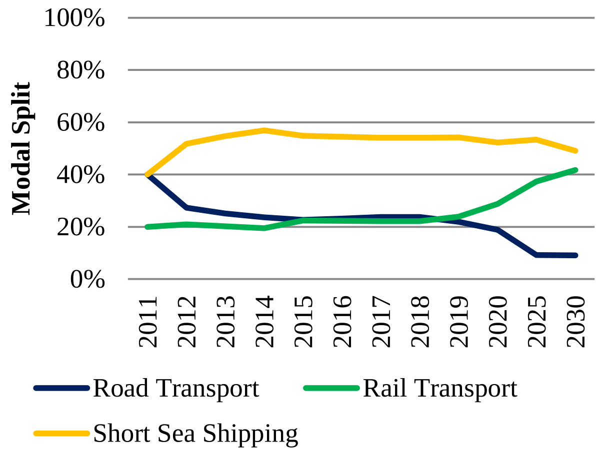


Figure 80 - VLG Revised Modal Split

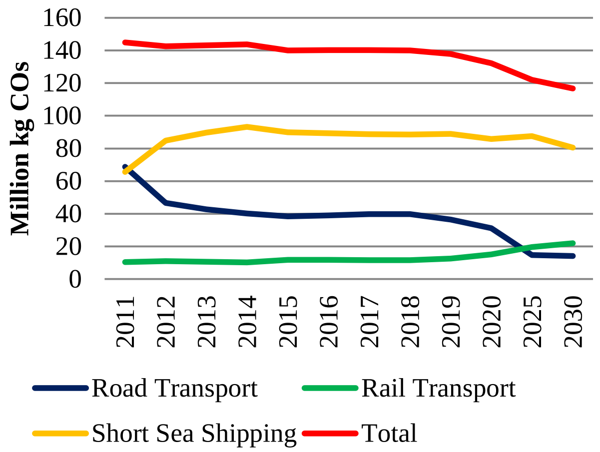


Figure 81 - VLG Revised CO2 Emissions

Production Parts Logistics Group (PPLG)

For PPLG, although the CO_2 target is achieved without intervention, it can also be obtained through keeping the budget constant, and keeping the ratio of short sea shipping freight towards rail freight at around 60%. This will result in a reduction of 20% in CO_2 emissions and a 30% shift from road freight to alternative modes. The benefit of using this combination is that a smaller shift towards rail freight is needed which is preferable for PPLG because of the limitations of rail freight infrastructure.

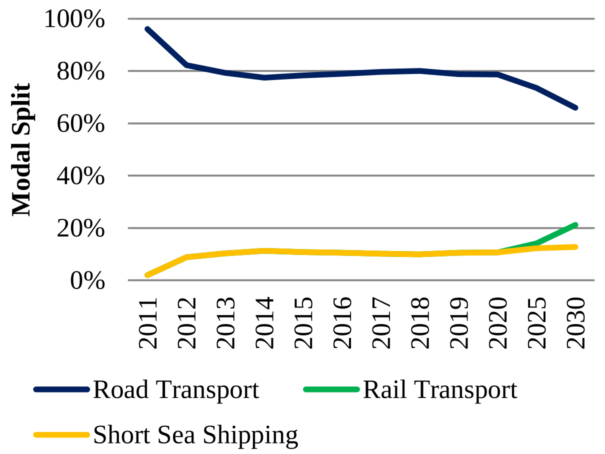


Figure 82 - PPLG Revised Modal Split

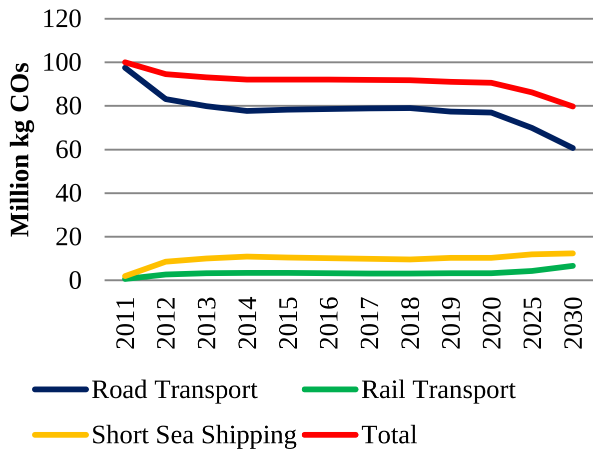


Figure 83 - PPLG Revised CO2 Emissions

The presented information can be used by Toyota to further analyze their supply chain and freight activities in order to determine whether or not it is applicable and what remedies needs to be taken with respect to re-engineering their supply chain.

Two of the assumptions of the model were that: 1. the budget for each of the individual groups remain constant over the years and 2. The freight activity of Toyota Motor Europe will remain constant. Accordingly, a future study for Toyota could include investigating if these assumptions would not be taken into account, how it would affect the outcome of the study.

In addition, a topic for future research could include investigating utilization of inland waterways as a means of transport and similarly, analyzing the potential of electrification of the supply chain.

2.2 Recommendations for Future Research

Because of time constraints, the scope of the study had to be limited to the effects of the White Paper. The model developed for the study could further be improved through including socio-economic factors such as tracking GDP, un-employment levels, and demographics. This would enable the inclusion of additional parameters which have the potential of influencing freight.

Furthermore, the model assumes averages over Europe which does not reflect an accurate image of the freight industry. Further developments of the model could be made in order to include regional differences.

In addition, the estimated Value of Time is based on the feedback received from a limited sample size from a limited population (Toyota Motor Europe's logistics groups). Hence, future research can be focused on acquiring data from a larges sample size, i.e. the European Vehicle Manufacturers which are active in a common industry.

3. Reflection on the Research

Considering the scope, the objective of this project was accomplished as scheduled and the questions were thoroughly answered. Furthermore, the sponsor of the project, who was the Energy Research Group of Toyota Motor Europe, was satisfied with the outcomes obtained from the study. Hence, it can be concluded that the project is performed successfully concerning the feedback from the sponsor.

In addition, the outcome of the study showed to be of significant value for the company. It demonstrated that, by following the current mindset towards freight activities, Toyota would not be able to achieve the targets defined by the EU and that a reconsideration of the current approach was required. This interpretation was further on strengthened by the decision of the logistics groups to utilize the results of the study in their long term planning activities.

Furthermore, the methods used for conducting the research properly accommodated the needs of the study and the, needed external data, if available was readily extracted and used.

Some of the problems encountered during the research are the following:

- Obtaining available data from Toyota logistics groups proved to be a time consuming task as they were not willing to provide internal information.
- Certain data needed for the study (e.g. revealed preference data) could not be obtained from the Toyota logistics groups due to policy restrictions.
- Because of the vast scope of the initial project idea, it was a difficult task to find a track to start the research. However, by the development of the Parameter Correlation Tree (PCT), it was possible to narrow down the scope and take further steps. Developing the PCT on an earlier stage may have enabled a more efficient process.

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IX. Appendices

In this supplementary section of the report, the appendices of the study will be provided. Appendix A will provide a brief introduction to Toyota Motor Corporation (TMC). In Appendix B, the surveys presented to Toyota's logistics groups will be shown. Finally, in Appendix C, the evolution of freight cost for each scenario will be illustrated.

A. Introduction to Toyota Motor Corporation

In this section a brief analysis of Toyota Motor Corporation and its European wing, Toyota Motor Europe will be presented. Furthermore, the supply chain of Toyota Motor Europe which will be one of the focal point of the study will be analyzed.

Toyota Motor Corporation (TMC)

Toyota Motor Corporation, established in 1937, is one of the world's leading automobile manufacturers, offering a full range of models from small passenger vehicles to trucks. Toyota ranks among the world's leading global corporations with global annual sales, combined with those of Hino and Daihatsu, totaled 9.3 million units in 2007, generating almost €159.6 billion in net revenues. Toyota has 52 manufacturing companies in 27 countries and regions excluding Japan, and markets vehicles in more than 170 countries, supported by a consolidated workforce of over 309,700 people (TMC Corporate Affairs, 2011; TME Corporate Affairs, 2008). The long term success of Toyota is the result of its innovative way of thinking and the subsequent developed corporate culture. Furthermore, an insight into this corporate culture will be provided.

The Toyota Way & the Toyota Production System

The power of Toyota is mainly attributed to the Toyota Way. In addition Toyota Production System (TPS) plays complementary role in Toyota's success (Iyer, et al., 2009).

The Toyota Way has created and enabled a culture of respect for individuals with the emphasis on promoting innovation and fostering cooperation. The main pillars of the Toyota way can be seen in Figure 84.

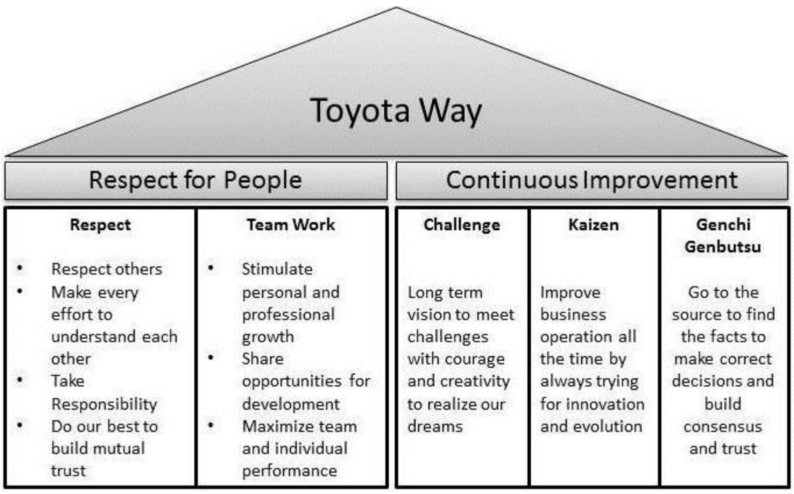

Figure 84 - Overview of the Toyota Way (TME Human Resources, 2010)

The consolidation of Toyota's values and principles in the Toyota Way allowed Toyota to reinforce the Toyota Way as cornerstone of its Global Management System (TME Human Resources, 2011):

- Toyota Way provides a globally consolidated self-sufficient system for all Toyota companies. Thanks to the consolidation of Toyota's values and principles in the 'Toyota Way 2001' all

Toyota companies, regardless where they are located, are able to learn and implement Toyota Way without having to rely on TMC (Toyota Motor Corporation) resources.

- Toyota Way ensures consistency throughout global Toyota. It provides a global standard on how to take decisions, how to solve problems, how to manage people, how to align direction, etc at Toyota. This facilitates cooperation, communication, best practice sharing among members, both within and between Toyota companies and ensures quality, efficiency and speed throughout the global organization.
- Toyota Way allows for acceptance and flexibility with the wide diversity of each regional operation. Within the framework of the TW, there is room for the cultural specifics inherent to regional operations.
- Toyota Way coordinates the large diversification of human resources in management. It brings people with many different professional and cultural backgrounds together behind a common vision, set of values and ways of working
- It ensures shared understanding of values and clarification of the business method. In other words, TW ensures that we all understand the company values and their daily application in the same way.

In addition, The Toyota Production System (TPS), with its emphasis on continuous improvement, the value of employee commitment and superior quality, has been recognized as a true benchmark in the eyes of the global automotive industry. Driven by the need to make more with less while ensuring the best possible quality and reliability, Toyota developed and fine-tuned the “just-in-time” philosophy, which allowed the company to reduce in-process inventory and efficiently produce only precise quantities of pre-ordered items with a minimum of waste. TPS became the driving force behind just-in-time, lean manufacturing, kanbans, quality systems, and continuous improvement practices (kaizen). This approach has become a key factor in the company’s development and success. (Iyer, et al., 2009). The main pillars of Toyota Production System can be seen in Figure 85.

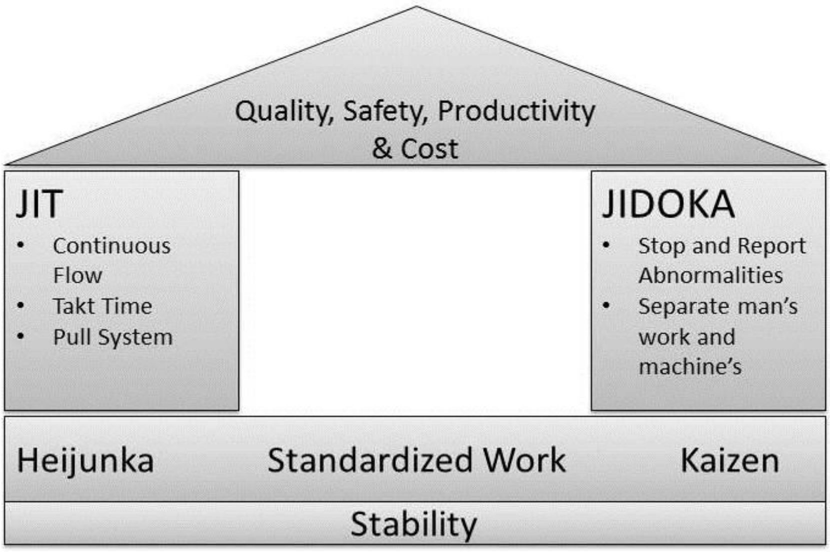

Figure 85 - Overview of Toyota Production System (TME Human Resources, 2010)

Essentials of TPS (TME Human Resources, 2011)

Further on, a description of the essentials of TPS will be explained:

JIDOKA - Highlighting/visualization of problems.

Quality must be built in during the manufacturing process. If a defective part or equipment malfunction is discovered, the machine concerned automatically stops, and operators stop work and correct the problem.

For the Just-in-Time system to function, all of the parts that are made and supplied must meet predetermined quality standards. This is achieved through JIDOKA. In addition:

1. JIDOKA means that a machine safely stops when the normal processing is completed. It also means that, should a quality or equipment problem arise, the machine detects the problem on its own and stop, preventing defective products from being produced. As a result, only products satisfying the quality standards will be passed on to the next processes on the production line.

2. Since a machine automatically stops when processing is completed or when a problem arises and is communicated via the "ANDON (problem display board)," operators can confidently continue performing work at another machine, as well as easily identify the problem cause and prevent its recurrence. This means that each operator can be in charge of many machines, resulting in higher productivity, while the continuous improvements lead to greater processing capacity.

Just-in-Time – Productivity improvement

Making only "what is needed, when it is needed, and in the amount needed. JIT enables the production of quality products efficiently through the complete elimination of waste, inconsistencies, and unreasonable requirements on the production line.

In order to deliver a vehicle ordered by a customer as quickly as possible, the vehicle is efficiently built within the shortest possible period by adhering to the following:

1. When a vehicle order is received, a production instruction must be issued to the beginning of the vehicle production line as soon as possible.
2. The assembly line must be stocked with small numbers of all types of parts so that any kind of vehicle ordered can be assembled.
3. The assembly line must replace the parts used by retrieving the same number of parts from the parts-producing process (the preceding process).
4. The preceding process must be stocked with small numbers of all types of parts and produce only the numbers of parts that were retrieved by an operator from the next process.

Outside of Japan, Toyota first started making inroads into foreign markets in the late 1950's. Now, half a century after they initiated their international endeavor, the company enjoys a word wide presence and has factories in most parts of the world, manufacturing or assembling vehicles for local markets (TME Corporate Affairs, 2008).

Energy Research Group (ERG)

Within TME, the energy research group was created in 2008 in order to support R&D, Sales, Manufacturing and Corporate Planning Divisions. The main missions of this group can be categorized as follows (Desaeger, 2011):

- To contribute to mid & long term energy strategy planning by gathering, analyzing and predicting major movements in the field of energy.

- Guide the company towards the most appropriate energy direction for mobility and propose innovative approaches in order to achieve success.

Currently the long term energy strategy of the group is focused on an outlook towards the year 2030.

B. Stated Preference Survey

1. Stated Preference Survey for Toyota Parts Center Europe

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Stated Mode Preference

A shipment of vehicles is to be transported from a point of origin to a specific destination. The available modes of transport are **rail, road, and sea**.
The following conditions should be considered:

- The shipment consists of **100 tonnes** of service parts.
- In each question, the **point of origin**, **destination** and **distance** is **similar** for all different modes.
- In each question the modes of transport are available and within the **proximity** of the **originating point** (**no need** for additional transport)
- The shipment is carried out in a **business as usual** situation (**no emergency** situation)
- **No** specific **restrictions** on **budget** exists
- **Handling time** is **not considered** in the questions

For each of the questions please specify your **preferred mode** of transport with regards to the **time** and **cost** of transport

	A	B
Mode	Road	Rail
Time (hours)	0.9	1.5
Cost (€)	1500	500

Option A ○ Option B ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	64	100	148
Cost (€)	64000	21000	14000

Option A ○ Option B ○ Option C ○

	A	B
Mode	Road	Rail
Time (hours)	4.5	7
Cost (€)	4000	1500

Option A ○ Option B ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	23	36	53
Cost (€)	20000	7500	5000

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	37	58	85
Cost (€)	25500	12000	8000

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	18	29	42
Cost (€)	16000	6000	4000

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	9.5	15	21
Cost (€)	8000	3000	2000

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	92	145	210
Cost (€)	64000	29000	20000

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	12	19	28
Cost (€)	10500	4000	2600

Option A Option B Option C

	A	B
Mode	Road	Rail
Time (hours)	1.5	2.5
Cost (€)	2200	550

Option A Option B

	A	B
Mode	Road	Rail
Time (hours)	3	4.5
Cost (€)	2500	1000

Option A ○ Option B ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	46	72	106
Cost (€)	32000	15000	10000

Option A ○ Option B ○ Option C ○

2. Stated Preference Survey for Production Parts Logistics Group

qualtrics.com

Stated Mode Preference

A shipment of vehicles is to be transported from a point of origin to a specific destination. The available modes of transport are **rail, road, and sea**.

The following conditions should be considered:

- The shipment consists of **1800 tonnes** of production parts.
- In each question, the **point of origin**, **destination** and **distance** is **similar** for all different modes.
- In each question the modes of transport are available and within the **proximity** of the **originating point** (**no need** for additional transport)
- The shipment is carried out in a **business as usual** situation (**no emergency** situation)
- **No** specific **restrictions** on **budget** exists
- **Handling time** is **not considered** in the questions

For each of the questions please specify your **preferred mode** of transport with regards to the **time** and **cost** of transport

	A	B
Mode	Road	Rail
Time (hours)	0.9	1
Cost (k€)	15.5	1.5

Option A ○ Option B ○

	A	B
Mode	Road	Rail
Time (hours)	4.5	5
Cost (k€)	70	5

Option A ○ Option B ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	9.5	10	17
Cost (k€)	115	11	7.5

Option A ○ Option B ○ Option C ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	12	13	22
Cost (k€)	150	14	10

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	95	102	172
Cost (k€)	850	105	53

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	23.5	25.5	43
Cost (k€)	288	27	16

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	66	71	120
Cost (k€)	590	75	38

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	47	51	86
Cost (k€)	425	53	28

Option A Option B Option C

	A	B
Mode	Road	Rail
Time (hours)	1.25	1.5
Cost (k€)	21.5	2

Option A Option B

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	19	20	34.5
Cost (k€)	230	21	12.5

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	38	40	69
Cost (k€)	340	42	22.5

Option A ○ Option B ○ Option C ○

	A	B
Mode	Road	Rail
Time (hours)	3	2.75
Cost (k€)	43.5	3.5

Option A ○ Option B ○

3. Stated Preference Survey for Vehicle Logistics Groups

qualtrics.com

Stated Mode Preference

A shipment of vehicles is to be transported from a point of origin to a specific destination. The available modes of transport are **rail, road, and sea**.

The following conditions should be considered:

- The shipment consists of 350 **mid sized** vehicles.
- In each question, the **point of origin**, **destination** and **distance** is **similar** for all different modes.
- In each question the modes of transport are available and within the **proximity** of the **originating point** (**no need** for additional transport)
- The shipment is carried out in a **business as usual** situation (**no emergency** situation)
- **No** specific **restrictions** on **budget** exists
- **Handling time** is **not considered** in the questions
- The products will **not suffer** any **damage** during transport.

For each of the questions please specify your **preferred mode** of transport with regards to the **time** and **cost** of transport

	A	B
Mode	Road	Rail
Time (hours)	1	1.5
Cost (k€)	3.5	1.5

Option A ○ Option B ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	9.5	14.5	17
Cost (k€)	34	15.5	4

Option A ○ Option B ○ Option C ○

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	95	145	170
Cost (k€)	340	155	32

Option A ○ Option B ○ Option C ○

	A	B
Mode	Road	Rail
Time (hours)	1.5	2.5
Cost (k€)	5.5	2.5

Option A Option B

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	24	36	42
Cost (k€)	85	40	9

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	19	29	34
Cost (k€)	68	31	7

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	12.5	19	22
Cost (k€)	45	20	5

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	48	72	85
Cost (k€)	170	78	16.5

Option A Option B Option C

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	67	100	120
Cost (k€)	240	110	22.5

Option A Option B Option C

	A	B
Mode	Road	Rail
Time (hours)	4.5	7
Cost (k€)	16.5	7.5

Option A Option B

	A	B	C
Mode	Road	Rail	Sea
Time (hours)	38	58	68
Cost (k€)	136	62	13.5

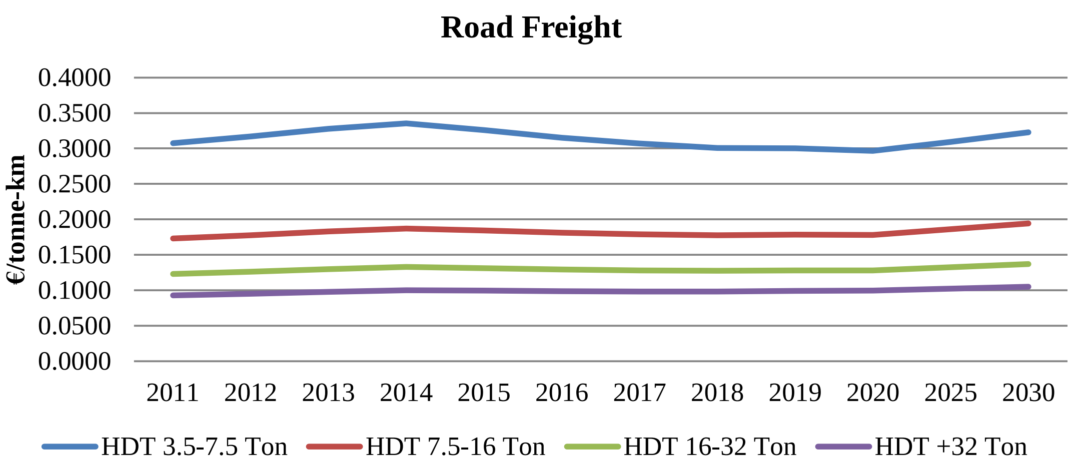
Option A Option B Option C

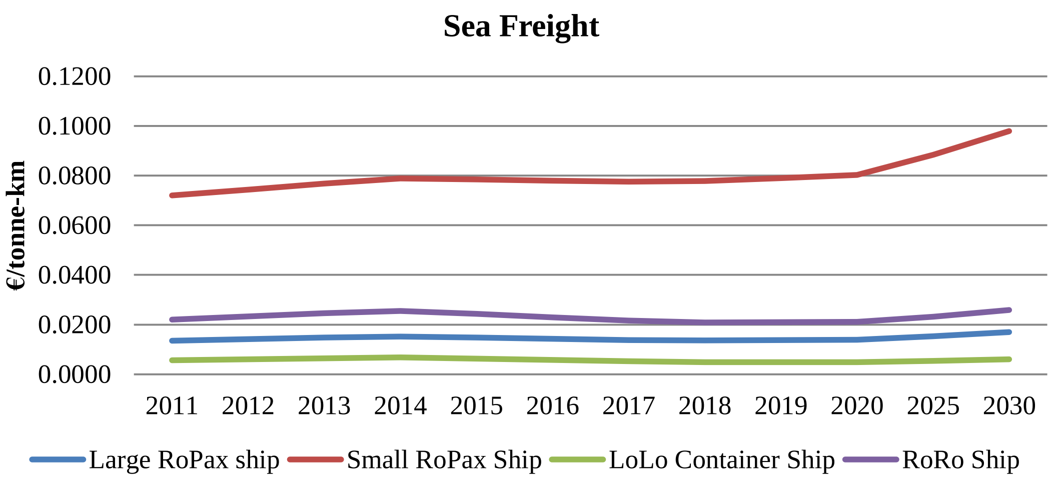
	A	B
Mode	Road	Rail
Time (hours)	3	4.5
Cost (k€)	10	4.5

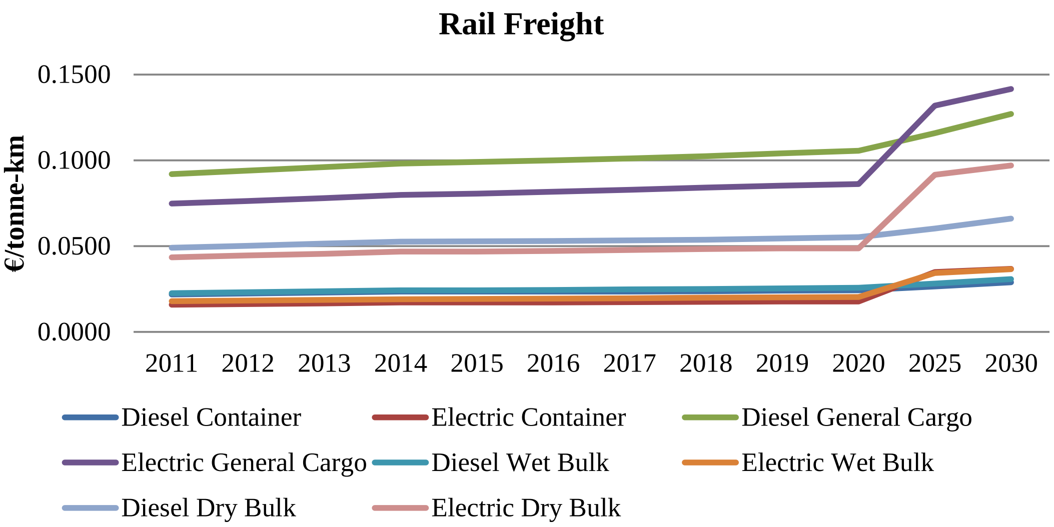
Option A Option B

C. Freight Cost Evolution for Scenarios

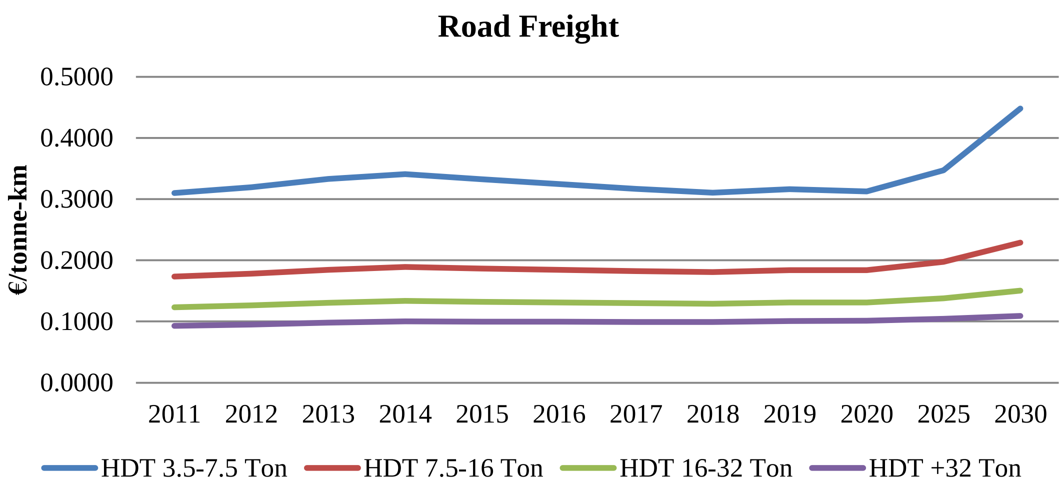
1. Business as Usual and Forced Modal Split Scenario

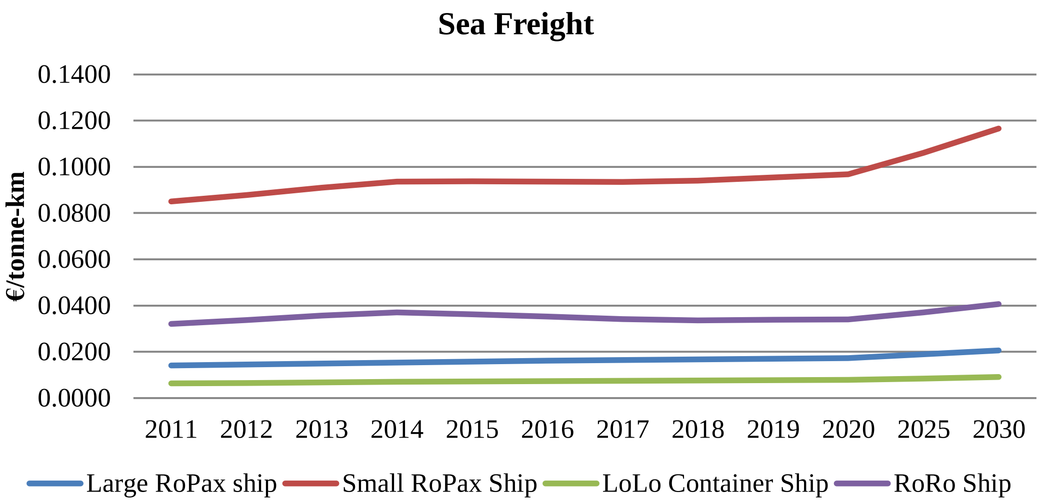


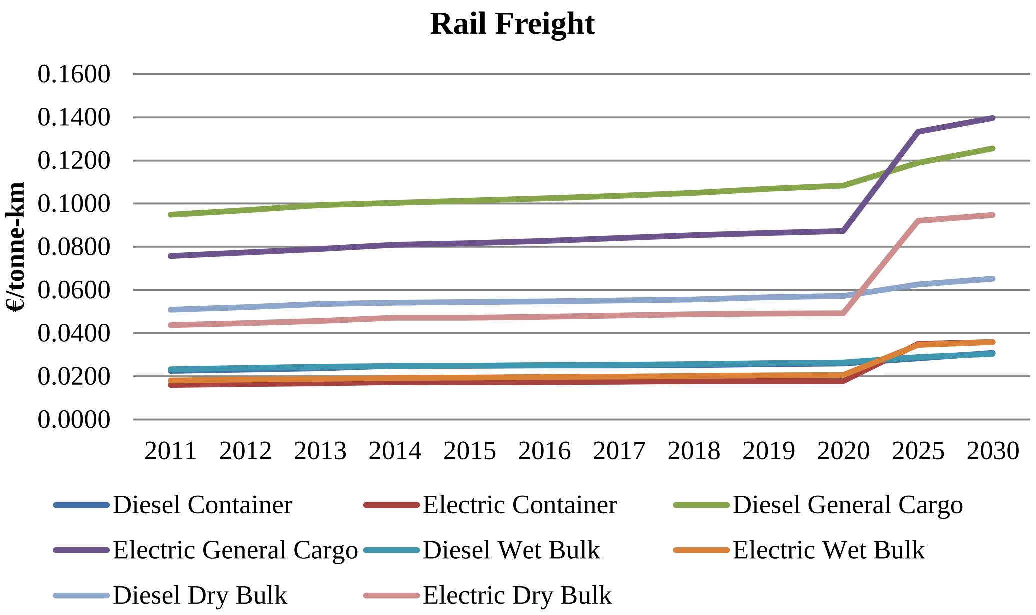




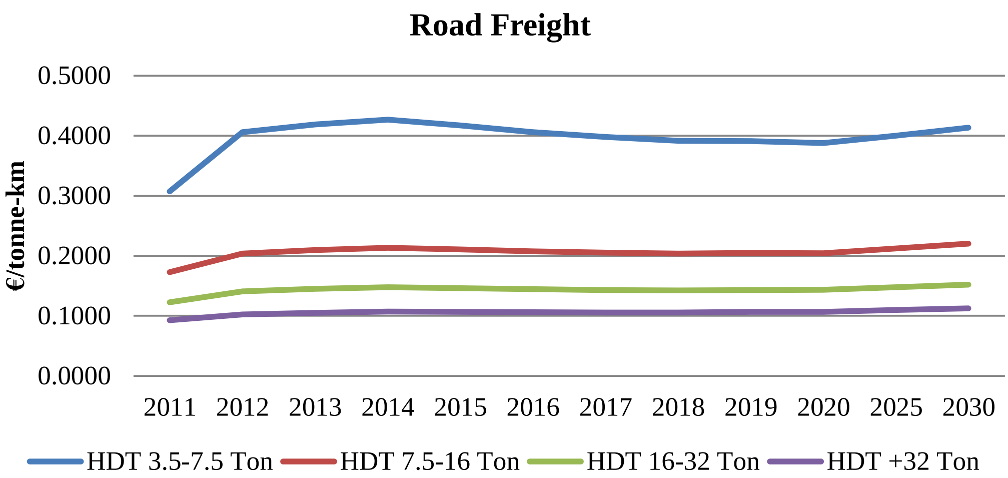
2. New Fuel and Technology Promotion Scenario

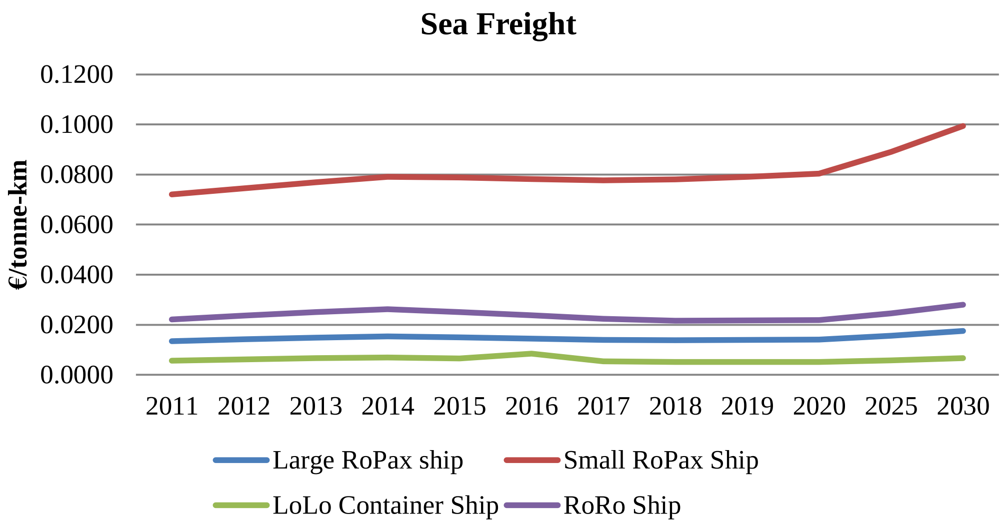


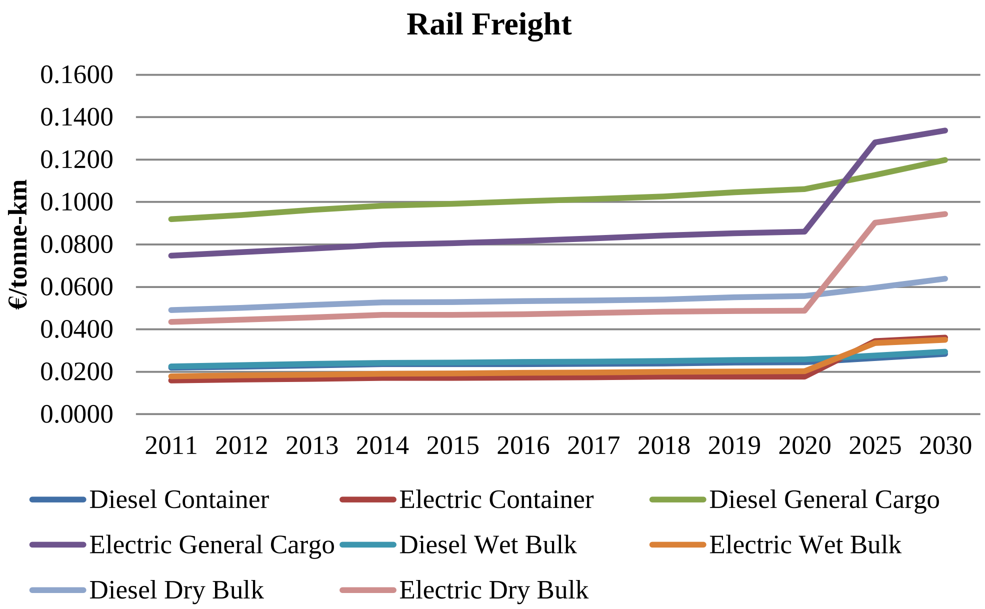




3. Taxation Scenario




Sea Freight
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
€/tonne-km
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2025 2030
Large RoPax ship
Small RoPax Ship
LoLo Container Ship
RoRo Ship


Rail Freight
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
€/tonne-km
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2025 2030
Diesel Container
Electric Container
Diesel General Cargo
Electric General Cargo
Diesel Wet Bulk
Electric Wet Bulk
Diesel Dry Bulk
Electric Dry Bulk

4. Maximum Impact Scenario