Sustainability and supplier involvement
a case study in the commercial automotive industry

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Award date:
2016

Link to publication
Sustainability and Supplier Involvement: A case study in the commercial automotive industry.

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in partial fulfillment of the requirements for the degree of

Master of Science
in Innovation Management

Executed at the Technical University of Eindhoven
Department of Industrial Engineering and Innovation Sciences
TU/e. School of Industrial Engineering and Innovation Sciences.
Series Master Theses Innovation Management

Subject headings: Corporate Social Responsibility, Sustainability, Supplier Involvement, $CO_2$ emissions, Automotive
Preface

I had the luck to execute this interesting research at one of the biggest automotive companies in the Netherlands, therefore, I would like to thank my mentor at DAF Trucks, Adriaan Knobbe. The reason why I call him my mentor is because he was not only of great help for my research, he also guided me in the company and coached me on several personal competencies. In my opinion this is of equal importance and are lessons that will be of big use for the rest of my career.

I would also like to thank both my mentors and supervisors Arjan van Weele and Alex Alblas for their very positive support and useful insights to take the report to the next level. Meetings with them were always very inspiring and motivating. They always inspired me with their enthousiasm during the project because both have a passion for what they do.

Last but definitely not least, I would like to take this opportunity to thank my parents. Without their great support I was not able to write this thesis. Because of them I had every opportunity I could wish for with respect to education. They always stood by me and supported me with every choice I made.

Niek van den Berge,
Eindhoven, 5 April 2016
Executive Summary

DAF Trucks is required to take into consideration regulations that are determined by governmental organizations. Strict regulations with respect to the emissions of the truck are currently a high focus for DAF. The truck produced needs to satisfy these regulations. The VECTO tool has been developed to align with these regulations. This simulation tool is able to calculate the CO₂ emissions of the truck. Every OEM in the European market is obligated to implement VECTO in the organization in order to make a CO₂ declaration for every truck produced. DAF needs to increase the competitive advantage of its end product and be more sustainable, the VECTO tool can help aid this. It is important for DAF Trucks to mobilize the knowledge and experience of the supplier market with respect to sustainable solutions. Furthermore, it is important to consider that more than 80% of the value of the truck is outsourced. Mobilizing knowledge and experience might contribute to the results of the VECTO tool.

First, a pre-study towards the sustainable mindset of DAF Trucks has been executed. Internal interviews have been performed and given an insight in the current activities of DAF Trucks and the mindset of employees. The initial impression from the interviews, from different employees from various departments, gave the feedback that currently there is no demand for a sustainable truck as long as there are no incentives or regulations. Furthermore, DAF is performing sustainable activities, however, is not currently communicating this with the market. This has the potential to affect competitive advantage and brand image.

This research project has attempted to find contributions that can reduce the CO₂ emissions of the truck. The scope of the CO₂ contributions is derived from the fuel use equation, which gives the following dimensions: aerodynamics, rolling resistance, drivetrain, engine, and driving resistances. The matrix in figure 0.0.1 is derived from interviews with experts in these dimensions.
The focus should not only be on a product level but also on a system and application level. This explains the absence of contributions in the left upper part of the matrix. This research project proposes a new focus for DAF, to concentrate on the proposed framework, with the three levels of contributions. The three suggested levels are given in the framework in figure 0.0.2.

The results of this research project with regards to the contributions have revealed a focus on the system level actions. These are contributions that are in sight for DAF Trucks. Although application level contributions might achieve the highest reduction they are very dependent on the incentives and regulations of governmental organizations. The learning curve of system level contributions is started and thus DAF is putting effort in this field of technologies. However, these contributions might contain new technologies not yet applied. It is therefore important to gather knowledge and experience from organizations outside of the company.

The purchasing department should take a facilitating role between suppliers and the engineering department in order to realize actions that can lead to a more sustainable truck.
First, in order to find sustainable solutions in an area where DAF is not yet competent, supplier involvement is a key ingredient. An initiative to introduce new topics is to invite organizations to the company. DAF Trucks has already implemented this incentive, however out of this research project derived that such tech-days should cast the net of focus to include well known suppliers but also new suppliers or even non-automotive to provide an alternative platform. The focus of these tech-days should also be on reducing the $CO_2$ emissions and thus the goal is to find green technology. Suppliers for green tech-days can be selected according to the green criteria that are proposed in this research project. In this selection the focus should be less on cost and quality since this might hinder creativity. Secondly, the green criteria should be used to select and assess a supplier that is going to supply the product or solution to DAF. The current Supplier Market Analysis and thus the purchasing dashboard of the buyer might need to be altered in order to achieve this. Finally, a dedicated team of a technical purchaser and engineer should be assigned in order to ensure that the activities will be realized.
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Chapter 1

Introduction

1.1 Background

According to van Weele and Vivanco in the book "The value chain shift", Corporate Social Responsibility (CSR) is about the relationship between the corporation and society. In this case a company is not only focusing on the shareholders, but also on benefits of other stakeholders [26]. DAF Trucks needs to deal with regulations that are determined by organizations which state the rules that the trucks have to satisfy. Currently, within the automotive industry strict legislation with respect to Green House Gases (GHG) is more active than ever.

A primary reason for this is that road transport alone is responsible for a quarter of the EU’s total emissions of CO$_2$ [40]. (N)GOs stress the need for greener transport [36] [37]. In Addition, the European Commission states that oil will become scarcer in future decades. Although transport has become more energy efficient, the EU transport is still for 96% of its energy need dependent on oil and oil products. Furthermore, they emphasize that if firms stick to the way the business is running, the oil dependence might still be just below 90% in 2020. The CO$_2$ emissions in the transport industry will still be one third higher in 2050 compared to the level in 1990. However, the goal is to reduce this by at least 60%.

The European commission recognizes that it is important to improve truck efficiency by development and the uptake of new engines and cleaner fuels [36]. The pictures 1.1.1 and 1.1.2 show the impact of road transport on the environment. The first picture illustrates the total emissions of CO$_2$ in the transport sector in the EU whereas the second picture shows the ratio of type of transport. Noticeable is that the road transport has a significant impact on the total amount of CO$_2$ emissions. Therefore, the European commission has launched research initiatives to develop new methodology for monitoring CO$_2$ emissions from heavy duty vehicles (HDV) with as goal a reduction of 20% by 2020 (base 2005).
The legislation for CO₂ emissions will be changed into a declaration system that determines the impact of the truck on the environment. Like in the personal car industry the declaration will provide information about the amount of gram CO₂ per amount of kilometers. The difficulties, however, lie in the diversity of the vehicles since there are a lot of possibilities with respect to the construction of the truck and trailer. Therefore, the European Commission developed a simulation tool named VECTO that is able to simulate trucks with different specifications in order to determine the fuel use and the CO₂ emissions.

1.2 Problem Statement

In a global, highly competitive business context like the environment in which DAF Trucks is operating it has become increasingly difficult to acquire and develop the appropriate resources, competences and capabilities. Beattie et al. (2012) note that relationships between supply chains of automotive OEM’s are complex, hard to understand, and difficult to predict. This makes it more difficult to respond to customer demands while at the same time to fulfill the legislation. Therefore, in order to obtain the different kinds of expertise for the different commodities, suppliers need to be involved in the product development process.

CO₂ emission reduction management within supply chains is being studied more frequently. It is argued that selection and collaboration with suppliers can be a helping factor to reduce the emissions with respect to logistics within the complete supply chain. However, these studies are focused on supply chain level. For this research project it is important to find the contribution that a supplier can give on solutions for reducing CO₂ emissions of a truck, which is getting increasingly important. The upcoming legislation is an example of this importance.

DAF Trucks, who is facing a strict legislation with respect the greenhouse gases, needs to get her truck more sustainable since this might increase the innovativeness and competitiveness of the end-product. Known the fact that more than 80% of the the value of the truck is outsourced, DAF Trucks is very dependent on the market and the suppliers’ innovations and thus also on the purchasing department. Therefore, the following problem statement can be drafted:

- It is important for DAF Trucks to mobilize the knowledge and experience of the supplier base with respect to sustainable solutions.
Or in the form of a question:

- How and on what topics can DAF Trucks mobilize the knowledge and experience of suppliers with respect to sustainable solutions?

### 1.3 Research Questions

Based on the background and problem statement, as described above in section 1.1 and 1.2, the main research question of this project can be formulated as the following:

- How can suppliers contribute to develop the most sustainable truck in the world?

In order to determine to what extent DAF is currently operating in a sustainable manner the first research question is as the following:

- What is the current mindset and situation with respect to sustainability within DAF Trucks and which activities are currently performed within the entire company?

A DAF truck can be divided in different commodities. These commodities are parts of the truck on which measures can be taken in order to reduce the fuel use and/or energy lost by re-using energy and thus in turn minimize the carbon footprint of the truck. As mentioned in the problem statement it has become increasingly difficult to acquire resources. Therefore, in order to obtain the different kinds of expertise for the different commodities, suppliers need to be involved in the product development process. The department at Advanced Technology DAF Trucks N.V. executes projects in order to reduce the carbon footprint of the DAF truck. The problem is, however, that these projects contain products or parts that cannot be produced in-house and need to be purchased. Within DAF it is known that 80% of the value of the truck is purchased; this emphasizes the importance of the cooperation between such departments and procurement. Furthermore, if supplier involvement in such projects lacks, there could be a risk that knowledge and expertise that suppliers have might be overseen. In this case valuable knowledge and expertise might be missed out. Before the thesis focuses on the collaboration with suppliers there needs to be an overview of the possible contributions that reduce the carbon footprint of the truck in the use-phase. Therefore the following research question needs to be asked:

- Which commodities/parts of a DAF truck produce the biggest carbon footprint in the use-phase?

Kibbeling (2010) has shown the importance of developing relationships with those suppliers that are capable of anticipating environmental change through innovation [52]. This innovation would be profitable with respect to the ability of serving customers, responding to society and achieving superior firm performance. The selection and assessment of those suppliers is therefore critical in order to find solutions that are promising and unique. In order to determine how the purchasing department of DAF can respond, the following question could be asked:

- How to engage suppliers in CO2 projects?
1.4 Methodology

This exploratory research adopts a science-based design perspective which links academic research with managerial practices [15]. A literature study specifies what is being explored and it provides the possibility to generalize the results to other cases [99]. The practical side of the research can be defined by the regulative cycle, which is a classic problem-solving cycle that has five basic process steps as seen in figure 1.4.1. In this cycle the problem can be defined as the result of a certain perception of a state, or in this case the change of GHG legislation due to dissatisfaction of several stakeholders. A business problem, and also in this case a case study, is the result of choices of influential stakeholders [2]. It is the goal to investigate a contemporary phenomenon in an exploratory manner within its real-life context [98]. In contrary to an experimental research the case study method is useful as the researcher has no control over the choices that are made and will be made by influential stakeholders. Interviews and literature will be used to gather data for the analysis and diagnosis. This information can then be used in order to design a solution for the specific case, which will be discussed in chapter 4 and 5.

![Figure 1.4.1: Problem Solving cycle](image)

The research will be approached by using the problem solving cycle, or regulative model cycle, where the problem definition, analysis and diagnosis, and the solution design lie within the scope of the study.

1.4.1 Main Goals of the Research

This thesis has two main goals for which one has a theoretical point of view and the other a more relevant and practical output. The theoretical research will be used to underpin the practical statements. It may contribute to the existing knowledge in the specific area. The practical research might refute or support the theory and will provide a solution for the company where the final thesis will be executed, namely DAF Trucks NV (inductive approach). This research will retain a science-based design methodology. The goal of this research is to improve practice [15], which in this case will be a design for a practical implication towards the engagement of suppliers at DAF Trucks.
This study will be executed in order for DAF Trucks to gather knowledge to know how to react on this environmental change. In this way, research can be performed for DAF trucks in such a way that they are able to position themselves for the future with a "green" truck in order to satisfy stakeholders in the value and supply chain but also to strive for competitive advantage. Kibbeling (2010) has shown the importance of developing relationships with suppliers that are capable of anticipating environmental change through innovation. This innovation would be profitable with respect to the ability of serving customers, responding to society and achieving superior firm performance [52].

1.4.2 Unit of Analysis

According to van Aken et al.(2007) the unit of analysis is the type of object that is the focus of interest. Yin (2009) adds that the unit of analysis is related to the way the research questions are defined [2][98]. Currently, there is a project in progress at DAF trucks that has its focus on the upcoming environmental legislation for 2020 that requires a \( CO_2 \) declaration for each truck sold, which needs to be operational in 2018. The research will focus on possible contributions towards \( CO_2 \) reduction of the truck in the use-phase and the involvement of the procurement department in this project.

1.4.3 Data Collection

Within this research, the main method of data collection will be the execution of interviews, which is the most widely used qualitative method in organizational research [21]. According to Cassell et al. (1994) a qualitative research interview will generally have a low degree of structure. The interview section of the research will be divided in two rounds. The first round serves to understand the most important themes for the researcher where the only guideline is the topics. These are derived from the literature and the focus is on several departments within DAF and its current mindset with respect to sustainability. In this way the researcher can learn from the interviewees in such a way that following interviews can have more depth. The second round will contain interviews that will be more specific and will contain questions that are derived from the first interview sessions. These interviews will be more focused on possible contributions towards \( CO_2 \) reduction, where the researcher will execute interviews with experts from outside the focal company. Table 1.4.1 gives an overview of the two rounds.

<table>
<thead>
<tr>
<th>Department/Company</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviewees</td>
<td>Internal employees</td>
<td>External experts</td>
</tr>
<tr>
<td>Subjects</td>
<td>Sustainability/CSR SRM ESI</td>
<td>Sustainability/CSR Contributions</td>
</tr>
</tbody>
</table>

Table 1.4.1: Interview rounds
When recruiting interviewees it is desirable for the research to gather knowledge that is organization wide. Especially the first interviews will have the goal to gather knowledge and to find out the maturity of DAF Trucks towards sustainability. The following main question is kept in mind when executing the interview and analyzing the data:

- What is the current mindset and situation with respect to sustainability within DAF Trucks and which activities are currently performed?

The interviews in this research are semi-structured as this may result in unexpected and insightful information, however the content of the interview is in control [44]. A sound interview question should produce knowledge, the 'what' of a question, but also promote a good interview interaction, the 'how' of the question, by using a thematic and dynamic dimension respectively [53].

In exploratory studies the quality of the interview might improve along the project. The interviewer gets to know more about the topic which can result in a more sophisticated way of interviewing that is sensitive to the nuances and complexities of the topic explored.

The interview contained a certain amount of open questions with a focus on the unit of analysis as described in the previous paragraph. A sound interaction with the interviewee is established by a good first impression, attentive listening, showing interest, understanding and respect for what the interviewee says. The interviewer is at ease and clear about what he or she wants to know. The interview is introduced by a briefing where the research objective is explained. Furthermore, it is important to mention the confidentiality and the way the interview will be used for analysis. The interviewee must have the authority or the knowledge of the process that is involved when setting up technical requirements for the product until searching for and selecting a new supplier.

A second way of internal documentation. Van Aken et al. (2007) mention that this is often a more reliable source than an opinion of an interviewee or employee. Finally, when the researcher was able to observe certain gatherings around the research topic, he used this as a source for information.

**Interview Guidelines**

Table 7.1.1, 7.1.2, 7.1.3, and 7.1.4 in appendix 7.1 gives an overview of the first round interviews. Central topics like sustainability and SCM were discussed in order to explore the topics and the current situation at DAF Trucks NV. The first round contained five interviews and covered the current mindset of DAF Trucks with respect to sustainability. Therefore, the goal of the first round interviews was to provide an overview of the current mentality and situation at DAF Trucks. The topics that are discussed in the first interviews are derived from the literature study. In the end, the interview was closed by the interviewer by saying “I have no further questions”. Subsequently, the interviewer asked if the interviewee had any further questions or comments [53]. The topics that were to be discussed in the second round needed to be defined according to the first round interviews since the researcher was then better able to probe on insights and statements of the interviewee.

---

1Ecodesign is a department that attempts to minimize the environmental impact of the products as an integrated part of the development process.
1.4.4 Data analysis

The data from the interviews needed to be analyzed in order to understand and make conclusions from the insights and information that the interviewees gave. The recorded conversation needed to be converted to text, whereby the key themes are highlighted. These themes became the basis of the findings chapter in this thesis. Coding is a way of analyzing large pieces of text that involves attaching keywords, or themes, to a certain part of the text. This entails a systematic way of analyzing. Rowley (2012) writes that different parts of text can be drawn together and compared. In this way there exists an understanding of the things that the interviewees say about a theme. She discusses that it is advisable to keep the number of themes to six to eight, but the main themes may contain sub-themes. As the name of the analyzing method indicates, these themes need codes. For this research the coding method is simplified and the main themes are formed by a protocol that is used to execute the interview. Thus, the main themes are aligned with the subjects of the semi-structured interview. By using the protocol, segments that covered similarities or differences are drawn together or compared. In this way the translation to the findings is direct and logical. Section 7.1.3 shows the protocol with the topics that is used to set up the results.

Quality Criteria

The reliability of a research can be defined as the degree of consistency with which the researcher executes the data collection and analysis and the way he interprets at different times. The validity, also called credibility or trustworthiness is also a point of attention. In order to achieve high validity the researcher adopted a systematic process for collecting and analyzing the data. A second point to ensure valid methods and results was to adopt theory triangulation by substantiating the actions and findings with the literature research. Yin (2009) discusses four tests in his book to establish the quality of an empirical social research. He divides the validity of a research in the construct validity, the internal validity, and external validity. Table 1.4.2 is used as a guideline for the assurance of the quality of the research.
### Table 1.4.2: Tests for ensuring the quality of the research [98]

<table>
<thead>
<tr>
<th>Tests</th>
<th>Case study tactics</th>
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<tbody>
<tr>
<td>Construct validity</td>
<td>Use of multiple sources of evidence</td>
</tr>
<tr>
<td></td>
<td>Establish chain of evidence</td>
</tr>
<tr>
<td></td>
<td>Have key informants review draft case study report</td>
</tr>
<tr>
<td>Internal validity</td>
<td>Do pattern matching</td>
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<tr>
<td></td>
<td>Do explanation building</td>
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<tr>
<td></td>
<td>Address rival explanations</td>
</tr>
<tr>
<td></td>
<td>Use logic models</td>
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<tr>
<td>External validity</td>
<td>Use theory in single-case studies</td>
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<td></td>
<td>Use replication logic in multiple-case studies</td>
</tr>
<tr>
<td>Reliability</td>
<td>Use case study protocol</td>
</tr>
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<td></td>
<td>Develop case study database</td>
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</table>

### 1.5 Structure of this Thesis

The first topic that is discussed in this thesis is the importance of the carbon footprint for DAF Trucks as an organization. The first section gives an introduction about DAF Trucks NV. After the introduction the term Corporate Social Responsibility (CSR) is shortly introduced and reflected to the company where this research will be executed. It describes the activities DAF performs on CSR based on the whole supply chain. After this, the focus is on the use-phase of the truck and especially on the carbon footprint of the truck itself. Subsequently, the focus of the research is on the Supplier Relationship Management (SRM) at DAF Trucks and the systems they have on supplier selection and supplier evaluation.

Chapter three contains the literature and its definitions, concepts, and models about the topics CSR, SRM and Early Supplier Involvement (ESI). The literature study focuses on maturity models of CSR and ESI that can show on what level an organization is operating on the corresponding topics. Another topic that is considered in the literature study is the collaboration towards suppliers.

Chapter four defines the $CO_2$ critical parts of the truck by means of input of the VECTO tool, literature and the external interviews. These contributions towards $CO_2$ reduction are placed in a priority matrix.

Chapter five uses the theoretical background to discuss the possibilities of engaging suppliers in combination with the contributions of the chapter four. The study gives an insight on the contributions with possible (existing) suppliers and the approach towards collaboration.

Finally, the research concludes with recommendations towards DAF Trucks and possible fields of future research.
1.6 Deliverables

The first main deliverable is the current state with respect to sustainability and SRM that DAF is operating in. It provides insights into the maturity level of the company and the truck. The possible contributions for $CO_2$ reduction of the truck in the use-phase is the second main deliverable of this research project. Out of this overview derive the critical components. The final main delivery is a recommendation towards supplier engagement and collaboration with respect to sustainable projects.
Chapter 2

Importance of CO2 for DAF Trucks

This chapter gives a broad overview of the company and it’s industry where this case-study is executed. Besides a company specific description it also focuses on the impact of a truck of vehicle category N2 and N3 on the environment and eventually gives an insight in the scope of the study. Furthermore, this chapter gives a study on the current mindset of DAF trucks towards sustainability in the product development. In this way the chapter provides the researcher and reader a background of the environment of the case-study, of which CO$_2$ stands central.

2.1 DAF Trucks NV

The thesis and research is executed in a company that is operative in the automotive industry. DAF Trucks, together with Peterbilt and Kenworth part of PACCAR, is an international organization that operates globally within a highly competitive environment. DAF develops and produces trucks for which the headquarters is located in Eindhoven, where the core-activities are development, marketing, distribution, and services. Other manufacturing sites are located in Westerlo (Belgium), Leyland (the United Kingdom) and Ponta Grossa (Brasil). Divided over these locations DAF Trucks employs around 8800 employees. Within the truck industry DAF is operating in three segments, namely light duty trucks for urban and regional transport (LF-series), trucks for regional and national transport (CF-series), and trucks that are developed and produced for national and international transport purposes (XF-series).

Since this research is focused on the profession procurement it will be executed on the purchasing department of DAF Trucks in Eindhoven, the Netherlands. The department under study includes the product-related purchasing groups that purchase production goods, ”Purchasing Parts”, which is responsible for the procurement of after sales parts, and ”Purchasing Non-Production Goods”. A third sub-group of the procurement department is purchasing projects, which can be seen as the representation of purchasing within large-scaled DAF Product projects. The last group of the purchasing department is ”Supplier Quality Assurance”, which is in charge of supplier rating and assessment.

Like every organization in the automotive industry, the company is forced to comply with strict regulations with respect to the environment, especially greenhouse gases (GHG). The European commission has launched research initiatives to develop a tool for monitoring CO$_2$ emissions of heavy duty vehicles (HDV) with as goal a reduction of 20 % by 2020 (base 2005). The tool is named VECTO [10]. The legislation will eventually be changed into a system...
that determines the classification of a truck whereby the Original Equipment Manufacturer (OEM) will give a \( CO_2 \) declaration to the customer. Like in the personal car industry this declaration will provide information about the amount of gram \( CO_2 \) per amount of kilometers, however unlike the personal car industry the HDVs are extremely divers, which make it difficult to label each truck.

To comply to the regulations that are upcoming DAF needs to find innovative solutions to be more sustainable and competitive. Literature shows that cooperation with suppliers might have a positive correlation \([52]\), however finding innovative solutions at suppliers requires a sound selection and assessment. Furthermore, a selling party, in this case the supplier, can add value to a product that might fulfill the customer’s preferences, however when knowing that the buying party values or is forced to acquire certain products, this can be used as a selling strategy and thus the products can be overvalued, considering the fact that the production costs might not be higher than an alternative product. Therefore it is key for DAF to know their position towards the supplier with respect to the \( CO_2 \) declaration.

2.2 Sustainability in the Automotive Industry

In the automotive industry, sustainability is getting a more and more thriving topic \([60][10]\). In the Netherlands for example there are different projects that receive subsidies in order to succeed. Think about projects where \( CO_2 \) emissions are main topic like the package delivery service TNT that provides a \( CO_2 \) report on demand of a customer that shows how much \( CO_2 \) is emitted during the delivery. Also, a research of the ministry of economical businesses in the Netherlands showed that since 2013 the number of electrical vehicles on the road is tripled \([70]\). Recently, one happening in this dynamic industry in particular led to a situation where the automotive industry and even the general economy in Germany turned upside down. In 2015 Volkswagen AG was caught on using software in their cars that was able to bypass regulations on emissions of GHG by performing better on tests than the cars really do in the field. This led to an extra awareness in the industry towards emissions and consequences that can have an impact on the different OEMs in de automotive industry. However not only because this happening the automotive industry is already aware of the urge to be corporate social responsible with respect to the environment. There were already strict regulations for the personal car industry, however, were they maybe to strict? Such regulations also exist for the HDV industry, which will be discussed in section 2.4.

Big automotive OEMs write sustainability reports in order to show stakeholders to what extent they are CSR and are implementing sustainable activities in their daily processes and describe their sustainable goals. When we look to the sustainability report of the Volkswagen group, the first thing noticeable is the table of content. They cover the three pillars of sustainability as described above and one of the sections in the strategy chapter is called stakeholder management. Here they stress the importance of being aware of the different stakeholders’ needs and expectations since this is a precondition of business success \([91]\). A second leader in the automotive industry, Toyota, also starts its sustainability report with mentioning many stakeholders they have to take into account where the environmental pillar and social pillars are central \([87]\). Both companies emphasize the importance of the stakeholder view as their reports are build around it. Also Truck OEM MAN Truck & Bus and Scania, both competition of DAF Trucks NV, describe their corporate responsibility in a report that is available on their website. This indicates that sustainability in the HDV industry too is getting increasingly important.
2.3 CSR at DAF

The environmental activities and certifications that are currently being conducted and pursued in the organization of DAF Trucks are either determined by the mother company PACCAR, governmental organizations or DAF itself. This combination of parties leads to several points where DAF is paying attention towards the environment or the well-being of stakeholders. Compared to the personal car industry it is noticeable that the attention within the HDV industry is less focused towards sustainability of the environment when looking to annual or sustainability reports of the personal car OEMs. To get an overview to what extent DAF is currently operating in a sustainable matter the following subsections describe the activities that are exposed to the outside of the company via the global website of the company. It is noticeable that DAF Trucks is also executing a significant amount of activities towards a cleaner environment, however this is not externally communicated towards the customer or other stakeholders. Therefore, the activities are split up in public and non-public sustainable activities. In the end of this section the researcher discusses the current mindset towards sustainability within the organization based on interviews and observations.

2.3.1 Public Sustainable Activities

In order to find out what DAF currently is undertaking with respect to environmental and sustainable activities the focus is first on the corporate website [27].

Environmental policy

DAF Trucks has since 1995 an official environmental policy statement that states of which in 1999 a separate policy was added to it for EcoDesign which is an unique approach of product development that has an environmentally orientation. In 2003 they added a recycling policy. Within the environmental policy DAF Trucks ensures that is a social responsibility for the entire company. This means that the complete Product Life Cycle (PLC) is considered in the activities of DAF, which means from initial design to disposal. They try to find an optimal balance between two of the tree pillars of the TBL approach, namely the ecological and economical interests. The final principle that fills this policy is the ISO 14001 certificate that will be discussed in the next paragraph.

Environmental certification

In order to be environmental friendly DAF Trucks is operating, besides policies, with certifications that determine regulations with respect to the output products and input products. One of the certifications is the ISO 14001 certified Environmental Management System. This norm specifies the requirements of a environment management system to enable an organization for construct and implement an environmental policy and goals that take into account the legislation and information about relevant environment aspects [85]. Showing a successful implementation of this norm by an organization can assure stakeholders that the organization possesses an appropriate environmental policy. The norm is based on the well-known ‘plan-do-check-act’ cycle. The certification ensures that the company satisfies the legal regulations and other regulations that the company needs to support, preventing any environmental pollution, and continues improvement. In 2015 the norm is updated and
should make it more easier for organizations to implement the environmental management system.

**Product Life Cycle**

As already mentions DAF claims to consider the environment or sustainability throughout the whole PLC. They divide the PLC in three phases: Production, Use, and Disposal. The EcoDesign principle and its team develop options during the development that consider the impact of the product on the environment in combination with the efficiency of the truck. In order to realize such developments there is a tool at DAF that specifies factors the engineers must consider to optimize the recyclability of the product, how the weight can be reduced, or how the environment can be considered during production. The production facilities of DAF contain environmental aspects that relate to air, water and energy consumption, raw materials, noise, and additives and residual substances where, based on requirements, targets are set. In order to monitor the targets, continues measurements are taken and claim that emissions per truck are reduced by more than 50%, the chemical waste per truck is reduced by 25% and the drinking water used during production is reduced by almost 65%.

Sourcing is also an area within the organization where environmental issues are considered. Each supplier that cooperates with DAF is required to be in possession a ISO 14001 certificate. Furthermore, contract requirements that correspond to the environment, and will be monitored, are part of the agreement and relationship between DAF and the suppliers where continuous improvement is maintained.

**Zero waste to landfill and reducing waste**

In 2009 DAF realized to reduce the waste to landfill to zero where the organization no longer disposes its waste to landfill, but processes it by recycling it, use it as raw material, or use it for generating new energy. The re-use of materials is realized in process level as well as on product level. Based on material codes plastic parts dealers and recycling organizations will be able to sort and segregate plastic waste. In order to make this more convenient for the concerned parties DAF provides guidelines that show the type of material per truck.

**2.3.2 Non-public Sustainable Activities**

Besides the activities that are made public on the corporate website, DAF Trucks is also undertaking activities that are not communicated to the outside. Note that although DAF is already practicing sustainable activities, they do not communicate as much towards the market in comparison to the competitors. Although the documentation is available at DAF Trucks the decision is made not to publish this information on the website or in sustainability reports since there is no capacity to realize this. The main activities of these topics are summarized in the next sections. DAF Trucks divides the activities in 3 phases of the product life cycle: Production including development and procurement, Product use, and disposal.
Production

On the production locations of DAF there are several emissions into the air of relevance. The most important is the emissions of carbon-hydrogen that are emitted due to painting and cleaning. In recent years new paint plants are built for the painting of axles, engines and chassis. Furthermore, waterbased low-emission paint is introduced for painting the parts. The introduction of new facilities furthermore led to a reduction of soil risk, noise, paint smells. Next to carbon-hydrogen DAF is also active in the reduction of particular matter.

On several locations filter systems are replaced. In this research are the CO\textsubscript{2} emissions of high importance. On the production sites of DAF is this GHG emitted due to the use of natural gas in heating installations and liquid propane gas (LPG) in forklifts. In order to reduce the emissions, forklifts in Einhoven are replaced by electric powered forklifts since 2013. In 2015-2016 there will be a replacement of the boilers on the site that are operating on natural gas with boilers that are more energy efficient. Since 2008 DAF is cooperating with the CO\textsubscript{2} Emissions Trading system\footnote{The Emission Trading system is an international system for trading GHG emissions to combat climate change and is a key tool for reducing industrial greenhouse gas emissions in a cost-effectively manner [40].}. Finally, the last point with respect to emitted gasses by building or sites are the refrigerant gasses (HFK and HCFK). Measures are taken in order to reduce the emissions of refrigerant gasses as all installations using the coolant R22 are replaced. Since 2015, the use of R22 is not allowed.

Considering the environment during procurement of production goods, materials is already shortly discussed in the public activities in section 2.3.1. The supplier is expected to comply with the EG REACH legislation concerning Substances of Very High Concern. An EG is a declaration to ensure that the supplier and its product satisfy the essential demands of the applicable directives. REACH is a regulation about the production and transportation of chemical materials and thus DAF uses this in order to be sure that there are no chemical materials in the truck that are not allowed according to the regulations. Such kind of declaration also exists for the re-use and recycling of packaging materials. The procurement department ranks the suppliers’ environmental performance. In order to do so the suppliers receive a Vendor Rating Environment (VRE) questionnaire whereby the suppliers get assessed on the three environmental areas ‘Certification’, ‘REACH’, and ‘Environmental Performance’. This potentially provides insights for the supplier to improve on certain aspects with respect to the environment.

Product use

The environmental load is the largest during the use of the truck. The fuel use and the emitted exhaust gases are the main players in this load. Besides the GHG a truck emits there are other topics like the wear of tires and the replacement of parts for maintenance. During the product development DAF has a strong focus on these topics and tries to minimize these.

Disposal

Since 2002 DAF has a formal recycling policy. This is on the one hand based on the environmental policy as described before in the public activities and on the other hand it is based on the European directive for vehicles at their end-of-life (2000/53/EC End of Life Vehicles). The recycling policy contains the following standpoints:
• Possibilities for re-use and recycling are considered in the development process.

• DAF joins the market economical developments with respect to the re-use and recycling.

• The complete lifecycle is considered when evaluating the environmental performance of materials.

• Dealers and customers are informed about the applied synthetic materials by means of sorting guides.

Other activities with respect to disposal are already covered in the public activities in section 2.3.1.

Sites and Buildings

Besides the activities and processes described above DAF furthermore has an environmental focus on sites and buildings. First, the energy produced during engine test in the engine test center on the plant of DAF Trucks is regenerated and DAF is able to provide 20% of the electricity that is required for the plant in Eindhoven. Second, the Paccar Parts distribution center in Eindhoven contains several technologies in order to keep the CO₂ emission as low as possible. The internal transport is electrical powered en the lighting is energy saving. Furthermore, sun energy is used for warm water supply.

2.3.3 Current mindset of DAF Trucks

The interview protocol of the first round, which is held in the company, is divided in several segments. The different insights given by the respondents during the interviews are collected and summarized in the table in figure 2.3.1. This section will discuss the main findings that are noticeable when observing the data.

The first point that stands out is the sustainable mindset of the respondents and DAF since the majority of the respondents believe that the customer is not ready yet for a truck that might get more expensive and is more environmental friendly in return. Four out of five respondents believe that there is need for a business case and if there is no business, the company will not invest in such kind of activities. Especially the respondents from procurement stress that the focus is still on the search for the cheapest supplier that delivers the best quality instead of selecting suppliers that can contribute to CO₂ reduction in order to be prepared on the CO₂ declaration. The organization LIDL supermarkets and their transport organization started a pilot in 2015 to supply the stores in Amsterdam with electrical driven vehicles where LIDL has the ambition to be fuel independent in Amsterdam in 2025. This case is an example of a customer that in fact does demand greener transportation. Besides Amsterdam, LIDL executed this pilot also in Stockholm, Zürich and Berlin. Respondent three, who works in the department advanced technology, seems to be more open about the topic, however, also emphasizes the fact that this is an industry where the topic is not that alive as for example in the personal car industry or any other business to consumer industry. Furthermore, the respondent stresses that the vision of DAF is still to deliver a reliable and efficient truck considering the TCO. Nevertheless, he acknowledges that the topic is an important social theme. The last respondent is involved with sustainability in her daily activities within the company. She notices that the awareness for the need of sustainability
is increasing, however, there is no clear vision yet and therefore there is a lack of overview in the company. Nevertheless, she stresses that it is important to focus now.

A second segment in the interviews was the view on supplier involvement with respect to sustainability, or more precise, the contribution on CO2 reduction. The question to the respondent was focused on whether they think that sustainability can be linked to supplier involvement. On this topic the opinions are spread. The first respondent believes that this can be important however it is necessary to focus on sustainability during the selection of suppliers. When the supplier is selected and the business is running it will be hard to alter the organization in practice. A second point of view of one of the respondents is that when suppliers will be involved in sustainable activities it is important for DAF to develop Key Performance Indicators (KPI). Furthermore this interviewee believes that suppliers are not ready yet to be involved on sustainability on product level. The last respondent of this interview round believes strongly that SI is important and can have a big impact. Comparing the insights of the respondents with the literature, which will be discussed in Chapter 3 the author believes that much knowledge and experience can be derived from external companies and thus also (potential) suppliers, especially known the fact that the value of a DAF truck is outsourced for more than 80%.

During the time span of the interviews the researcher noticed that DAF executed several sustainable activities, which are also shown in the table, however DAF does not communicate these to the outside. The last two respondents agreed on this and added that competitors use more of their sustainable activities in their marketing activities. The interviewees furthermore mentioned that there was no budget exempted for the communication of sustainability. Next to this, the table also gives an overview of the stakeholders that might deliver pressure on the organization with respect to sustainability in order to show big environment DAF is operating in and that there are many sides that can deliver input or in this case pressure towards DAF. When the communication around sustainable activities towards stakeholders increases, it might have a positive effect on the image of the company or even on the competitive position.

The last topic that is discussed during the interviews is the expectation of the interviewees with respect to the sustainability and the upcoming CO2 declarations. They emphasize again that the TCO or costs will stay very important and respondent two stresses that if there will be no incentive by the EU to set up limitations the urge for sustainability will not be there. Respondent three stresses that DAF needs to be careful to compete since competitors are bigger companies and might have more resources they can use to respond on the CO2 declaration. Respondent four believes that if the government is going to implement a selection system based on CO2 labels, the better the label the more opportunities there are for transporters. However, the respondent believes that there are other topics that can have a bigger impact on the CO2 reduction. He believes that the CO2 reduction can be better achieved by more efficient behavior and ways of transporting than by technological contribution. Think about transporting more freight with the same Truck. This would lower the emissions per kilogram freight. For example, DAF developed a truck, the Tellisy, with a 20% increase in cargo volume due to the lowering of the fifth wheel. This kind of contributions, however, can not be achieved by the VECTO tool and DAF therefore has to do deal with GOs and legislation. Therefore it is valuable for DAF to participate in bodies of multiple organizations that include GOs.

In summary, different employees of different departments believe that there is no demand from the customer yet. As long as there are no incentives from the EU or any other GO, the
customer will not feel the urge to obtain a vehicle (yet) because of its environmental friendly image. The second remarkable finding was that DAF is performing sustainable activities, however, is not communicating it to the outside and thus might miss out opportunities towards competitive advantage and image. A final noticeable outcome was the insight of the last respondent who stressed the fact that the focus should be on the application of the truck instead of on product level and the contributions should be matched according.

During observations of workgroups of the $CO_2$ project that is currently ongoing as preparation for the VECTO tool the participants of the meeting are actually aware of the need for preparation of the VECTO tool since this might be an opportunity for obtaining competitive advantage. They furthermore recognize that the demand from the customer is there when the GO have incentives to draw restrictions or making arrangements that combine existing incentives with restrictions or rewards with respect to $CO_2$ emissions. Noticeable is that the current mindset within DAF is twofold since the people that are not involved in the $CO_2$ declaration project do not see the urge to focus on the $CO_2$ unless there are incentives or legislation from GOs.
<table>
<thead>
<tr>
<th>Code</th>
<th>Resp. 1</th>
<th>Resp. 2</th>
<th>Resp. 3</th>
<th>Resp. 4</th>
<th>Resp. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectations</td>
<td>* TCO/costs will stay (most) important</td>
<td>* Need for incentive by EU</td>
<td>* Opportunity for government</td>
<td>* Impact of Vans minimal at beginning</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* DAF needs to be profitable to compete</td>
<td>* Opportunity for transporters</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* Need for being standby</td>
<td>* Impact of supplier limited</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stakeholders</td>
<td>* Customers</td>
<td>* Government</td>
<td>* Competition</td>
<td>* Every sort of organization</td>
<td>* Government</td>
</tr>
<tr>
<td></td>
<td>* Government</td>
<td></td>
<td></td>
<td></td>
<td>* Society</td>
</tr>
<tr>
<td></td>
<td>* Inspection authorities</td>
<td>* Municipalities</td>
<td></td>
<td></td>
<td>* Shareholders</td>
</tr>
<tr>
<td></td>
<td>* Suppliers</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier involvement</td>
<td>* Relationship will not alter when business is running</td>
<td>* Need for KPIs</td>
<td>* Important</td>
<td>* Can have big impact</td>
<td>* Supplier involvement sessions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Supplier is not ready yet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable activities</td>
<td>* Agreement on quality, Health &amp; Safety, Environment</td>
<td>* REACH Program</td>
<td>* Suppliers show roadmap</td>
<td></td>
<td>* Eco-design tool</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* ORM shows vision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable mindset</td>
<td>* Importance of fuel price, Customer not focused (yet)</td>
<td>* Need for customers</td>
<td>* Need for business case</td>
<td>* Increasing awareness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Cheapest suppliers, best quality</td>
<td>* DAF will not be first</td>
<td>* More impact from other companies</td>
<td>* Company is fast follower only when need is urgent</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Responsibility at supplier</td>
<td>* Not profitable</td>
<td>* More impact from other topics</td>
<td>* Facelift of CDP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Greener as price premium</td>
<td>* Suppliers not ready yet</td>
<td></td>
<td>* No clear vision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Focus on processes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Balance demand and costs</td>
<td></td>
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</tr>
<tr>
<td>Communication</td>
<td>-</td>
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<tr>
<td>of sustainability</td>
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</tr>
</tbody>
</table>

**Figure 2.3.1: Results interviews round 1**
2.4 CSR of a DAF Truck

Based on the literature the scope in which sustainability can be implemented in the supply chain is very broad. Only thinking about the supply chain sustainable activities can be implemented in a production phase, the operation phase or use-phase, and eventually the reuse of the product in its end-of-life phase. The following figure gives an overview of possibilities that reduce environmental impact of the production phase and the end-of-life phase. The use-phase will be discussed in section 2.5.

![Sustainability scope](image)

**Figure 2.4.1: Sustainability scope [76] [22] [55]**

Procurement plays an important, if not the most important, role in acquiring the materials and products for production and assembly. In order for manufacturers to control or monitor the sustainable processes/activities of their suppliers there is the possibilities for OEMs to demand certifications from their suppliers. The discussion of the different certifications are not within the scope of this research, however one example can be given. The certificate ISO 14001 specifies the requirements of an environment management system to enable an organization for construct and implement an environmental policy and goals that take into account the legislation and information about relevant environment aspects (EN-ISO 14001:2015). Showing a successful implementation of this norm by an organization can assure stakeholders that the organization possesses an appropriate environmental policy. Besides demanding such certificates from suppliers OEMs also might have their own demands on sustainable activities and might use this as knockout criteria as well as criteria to weigh the supplier during selection. This emphasizes the importance of supplier selection and assessment [76].

The certification ISO 14001 described in the previous paragraph is among other things a guideline for an environment management system that might contain activities that are implemented in order for production processes and assembly processes to be sustainable, think about reduction of green house gases (GHG) and waste. Linton (2007) discusses that reduction and elimination of certain by-products can be realized by cleaner process technologies and quality and lean production techniques. Next to reduction of by-products Sarkis (2003) discusses several activities like the use of certain materials and the capability of integrating reusable of remanufactured components or materials. Subsequently Sarkis (2003) describes that the focus of most organizations is on these kind of activities since the
activities are internal and any new technology or process that is introduced can be observed directly.

Sustainable processes in the distribution and transportation of products can exist of activities like deciding the mode of transport, the control of systems, and Just In Time (JIT) policies[76]. The latter is an activity that DAF Trucks already well implemented in their distribution and transportation operations. A second possibility to implement sustainable activities in the supply chain that Sarkis mentions with respect to distribution and transportation is the packaging. Specifications of the package like size, weight, and material of the packaging all have an impact on the way of transporting and distributing. Think about the space utilization and the process of packaging waste. The space is a significant factor for the way of transporting and the amount of entities used to transport.

End-of-life recovery needs a number of systems and processes for the different stages in the reverse logistics or end-of-life recovery that go back into the supply chain[76]. Sarkis defines the reverse logistics as "the return of recyclable or reusable products and materials into the forward supply chain". A model of the supply chain in his article shows four manners of reverse logistics, namely reuse, remanufacture, recycle, and disposal. Linton et al. (2007) and Srivastava (2007) recognize that extending the supply chain with such activities, however, adds an additional level of complexity to the existing supply chain and, although, sustainability in the supply chain opens possibilities and opportunities, it may require short-term investments. Furthermore they argue that the initial product design already has great influence on the degree to which a product can be recovered and therefore sustainability at the end of the supply chain already needs to be considered at the beginning. Srivastava (2007) describe that the recovery of product at the end of its useful life refers to a broad set of activities designed to reclaim value from a product, however, Srivastava mentions that the recovered products’ quality is generally lower than of new products[82].

In each phase of 2.4.1 sustainable activities can occur on different levels. For this it is possible to make a stacked Venn diagram that shows these different levels.

![Figure 2.4.2: Levels of sustainability scope](image)

This thesis focuses on the impact of the product of DAF Trucks NV on the environment, namely a truck for the HDV industry, in the use-phase. As discussed in the introduction of this thesis a truck can have impact on the environment by emitting GHG. In order to control this pollution the governmental organizations set up regulations that trucks have to comply.
Legislation Europe

The European emission standard for commercial vehicles was introduced in 1992 with the Euro I standard. Due to new internal combustion engine technologies the industry was able to lift the emission standards, therefore, the current emission standard DAF Trucks is operating in Euro 6, which is launched in September 2014. Each euro standard demands cleaner emissions with respect to the carbon oxides, particles, nitrogen oxides, and carbon hydrogen. Commission regulation 459/2012 states the most recent regulations concerning light passenger and commercial vehicle emissions. Table 2.4.1 shows an overview of the limits with respect to the harmful emissions of commercial vehicles for human and environment in the vehicle category N3. This is a category that contains vehicles for commercial use with a weight above 1760 kilograms.

Table 2.4.1: Euro 6 Emission limits for HDVs [38]

<table>
<thead>
<tr>
<th>Vehicle category</th>
<th>Mass of Carbon monoxide (CO) (mg/km)</th>
<th>Mass of oxides of nitrogen (NOx) (mg/km)</th>
<th>Mass of hydrocarbons &amp; oxides of nitrogen (THC + NOx) (mg/km)</th>
<th>Mass of particulate matter (PM) (mg/km)</th>
<th>Number of particles (PN) (# /km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N3</td>
<td>740</td>
<td>125</td>
<td>215</td>
<td>4.5</td>
<td>$6.0 \times 10^{11}$</td>
</tr>
</tbody>
</table>

Legislation North America

The mother company PACCAR is a company that is operating globally, whereby also DAF has manufacturing locations in North America and the engines that are going to be sold there need to meet regulations currently active in America. Federal regulations in subpart B of part 1037 - Control of emissions from new heavy duty motor vehicles state that the emission standards are as shown in table 2.4.2 which apply to HDVs that have a Gross Vehicle Weight Rating (GVWR) above 14000 pounds or 6350 kilograms [39].
Table 2.4.2: USA Emission limits for HDVs [38]

<table>
<thead>
<tr>
<th>GVWR (pounds)</th>
<th>Mass of Carbon monoxide (CO)</th>
<th>Mass oxides of nitrogen (NO&lt;sub&gt;x&lt;/sub&gt;)</th>
<th>Mass of hydrocarbons (THC)</th>
<th>Mass of particulate matter (PM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,000 ≤ GVWR</td>
<td>15.5</td>
<td>0.2</td>
<td>0.14</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Compared to the European legislation, the principles in America already have limits to the CO<sub>2</sub> emission limits. Table 2.4.3 shows the principles with respect to the GHG CO<sub>2</sub>. In order to show compliance with the following CO<sub>2</sub> standards there is the Greenhouse gas Emissions Model (GEM) simulation tool. The difference is thus that in America the tool has a monitoring function. The VECTO tool is more than likely there to, eventually, determine any limits with respect to CO<sub>2</sub> emissions and thus exceeds the monitoring function.

Table 2.4.3: USA CO<sub>2</sub> Emission limits for HDVs [38]

<table>
<thead>
<tr>
<th>GVWR (pounds)</th>
<th>CO&lt;sub&gt;2&lt;/sub&gt; Standard for model years 2014-2016 (g/ton-mile)</th>
<th>CO&lt;sub&gt;2&lt;/sub&gt; Standard for model year 2017 and later (g/ton-mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVWR ≤ 19,500</td>
<td>388</td>
<td>373</td>
</tr>
<tr>
<td>19,500 ≤ GVWR ≤ 33,000</td>
<td>234</td>
<td>225</td>
</tr>
<tr>
<td>33,000 ≤ GVWR</td>
<td>226</td>
<td>222</td>
</tr>
</tbody>
</table>

2.5 Impact of a DAF Truck on CO2 footprint

As mentioned in the introduction and section 2.4, a truck can have an impact on the CO<sub>2</sub> footprint on many different levels. When looking to the truck itself in the use-phase there are different commodities where measures can be taken towards CO<sub>2</sub> reduction. Firstly, what is important to mention is that the CO<sub>2</sub> emissions are linearly correlated to the fuel use of the vehicle [68]. In order to visualize the importance of the different possible contributions,
the following formula, which expresses the effect of vehicle design on fuel consumption, gives by means of different variables an overview of the areas that have an influence on fuel use.

\[
B_c = \frac{1}{\eta_u} \int \left( \frac{m \cdot f \cdot g \cdot \cos \alpha}{2} + c_d \cdot A \cdot v^2 \right) + m(a + g \cdot \sin \alpha + B_r) \cdot v \cdot dt
\]

Where,

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B_c)</td>
<td>Distance consumption</td>
<td>g/m</td>
</tr>
<tr>
<td>(b_c)</td>
<td>specific fuel consumption</td>
<td>g/kWh</td>
</tr>
<tr>
<td>(m)</td>
<td>Vehicle mass</td>
<td>kg</td>
</tr>
<tr>
<td>(A)</td>
<td>Frontal area of vehicle</td>
<td>m²</td>
</tr>
<tr>
<td>(f)</td>
<td>Coefficient of rolling resistance</td>
<td>-</td>
</tr>
<tr>
<td>(c_d)</td>
<td>Drag coefficient</td>
<td>-</td>
</tr>
<tr>
<td>(g)</td>
<td>Gravitational acceleration</td>
<td>m/s²</td>
</tr>
<tr>
<td>(t)</td>
<td>Time</td>
<td>s</td>
</tr>
<tr>
<td>(v)</td>
<td>Driving speed</td>
<td>m/s</td>
</tr>
<tr>
<td>(a)</td>
<td>Acceleration</td>
<td>m/s²</td>
</tr>
<tr>
<td>(B_r)</td>
<td>Braking resistance</td>
<td>N</td>
</tr>
<tr>
<td>(\eta_u)</td>
<td>Transmission efficiency of drivetrain</td>
<td>-</td>
</tr>
<tr>
<td>(\rho)</td>
<td>Density of the air</td>
<td>kg/m³</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>Gradient angle</td>
<td>°</td>
</tr>
</tbody>
</table>

The five dimensions that are shown in the numerator of the equation serve as five dimensions for possible contributions towards the reduction of CO₂ emissions.

The focus on technical contributions towards CO₂ reduction is one side of this thesis, the way of engaging suppliers is another. As mentioned before, there is many knowledge at the supplier and involving them could be profitable for the organization. Therefore, before this thesis is going to focus on the contributions towards a greener truck, the following section describe the current procedures of Supplier Relationship Management (SRM) at DAF Trucks NV.

### 2.6 SRM at DAF Trucks

Although DAF Trucks’ purchasing processes and activities are complex and extensive the focus of this research is on the selection and assessment of suppliers. The following section
will describe the rational processes that purchasers pursue during their daily activities.

**Supplier selection and assessment**

When buyers search for a new supplier they make use of a market scan called Supply Market Analysis (SMA). This analysis is based on Six Sigma methodology where the supplier selection is based on data and thus a choice can be made on a rational basis. The goal of this process is to increase the Six Sigma activities within purchasing and to standardize the SMA procedure. The SMA is build up in six phases. A coarse overview of this process is shown in figure 2.6.1. The first phase contains the definition and scope of the project.

![Figure 2.6.1: Project overview Supplier Market Analysis](image)

The definition of the project includes the problem statement, the composition of a project team and the project parameters. The problem statement might be an improvement of supplier profile with respect to quality, know how, and total cost. Next to the purchaser, the team of the project contains a supplier quality manager, a marketeer and sales person, an engineer and someone that is responsible for the logistics. The first task to define the scope, or strategy, of the project is to specify the concerning commodity of the truck where, subsequently, other stakeholders within the company are defined. The following step is to define the turnover commodity level that is given in a 12 month forecast and a turnover split to supplier for the corresponding commodity and the quantity of the part that is needed. By this number, in combination with the Kraljic matrices, DAF is able determine the negotiation power and purchasing strategy. In this way they are able to determine their position.

2The Kraljic matrix, or purchasing product portfolio-approach, is a way of analyzing the purchasing turnover and the supplier base. The analysis is based on the purchasing’s impact on the bottom line to the company and the supply risk involved when sourcing the product.
towards the possible suppliers and this influences the next steps in the process. Backed up with this information, the project team performs a market research, use previous market scans, and execute team discussions and supplier interviews. Based on the previous steps, the next step is to set up a request for quotation (RFQ) format where the context of the project is summarized.

Phase 2 and 3 in the SMA process are allowed to run parallel. The central goal of phase 2 is to make a supplier selection, where the first step is to create a supplier long list. Potential suppliers are selected and a request for information (RFI) is sent to each supplier on the long list. This RFI can ask for general technical information in order for the supplier to show their capabilities with respect to the specific commodity or component. In order to reduce the amount of suppliers in the long list, and to make a supplier short list, knock-out criteria are determined by the project team. Every supplier within this short list receives a RFQ. This RFQ contains a Supplier Quality Assurance (SQA) questionnaire that treats the topics quality and environment, logistics, know-how, competitive position, and price. After receiving the RFQs back from the suppliers of the short list the suppliers can be assessed based on the RFQs. Parallel on the supplier selection (phase 2) the team also thinks about the supplier profile (phase 3) where the profile succeeds out of several decision criteria. These criteria are subdivided into six main topics, namely:

- Quality and Environment
- Logistics
- Know How
- Competitive Position
- Total Cost
- Aftermarket Approach.

The detailed level decision criteria within these topics are determined in consultation by the cross-functional project team members. Subsequently, the suppliers are scored based on the criteria and a norm score on a scale of 1 to 5. The scored high level and detailed level criteria are weighted in a percentile value in order to make decisions that are based on a numerical value and thus the team is able to make rational decisions with respect to selecting the best fitting supplier where they use the scoring in order to make a pairwise comparison. After the scoring of each supplier on the short list, a supplier profile exists in phase 4 that indicates which supplier has the best capabilities. After selection of the supplier the SMA requires a supplier risk analysis that gives an overview of possible risks on the detailed level criteria where the supplier does not meet the norm score, where the product does not meet DAF specifications, possible risks of reallocation, and risks that come out of an audit performed at the supplier’s plant. The next step in phase 4 is to make a proposal to management that contains a judgment of the quotation that was received by the supplier. The last phase contains the validation and implementation of the supplier by signing a long term agreement (LTA).

3The goal of a pairwise comparison is to create relative preferences for a situation or object by means of a quantitative method [46].
DAF Trucks Quality Ranking System

Within the purchasing department there is a group which is called Supplier Quality Assurance (SQA). This group is occupied with the quality that suppliers deliver to DAF Trucks. The procedure used by the employees is based on the ISO/TS 16949 guideline. They use procedures like Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP). APQP is a structured method of defining and establishing the steps necessary to assure that a product satisfies the customer. Part of the APQP is the PPAP document that continues to provide the evidence that all customer engineering design records and specifications are properly understood by the organization and that the manufacturing process has the potential to produce products consistently meeting the requirements during an actual production run at the quoted production rate. The eventual quality rate within DAF towards suppliers is based on the Parts Per Million (PPM) rate. This rate is a ratio of the amount of products that did not satisfy the requirements of DAF to the amounts of products delivered in total, normalized over one million parts. The LTA that DAF closes with its suppliers says that the supplier needs to satisfy the criteria of 50 PPM. DAF trucks aims, however, for a PPM rate of 10. Together with the suppliers they try to accomplish that by improving processes in a collaborative way. These numbers emphasize the importance of quality for DAF Trucks NV.

2.7 Conclusions

The sections of this chapter give insights and background information on the topic $CO_2$ emissions and the topic SRM within the focal organization DAF Trucks. It became clear that the importance of $CO_2$ is of high importance for the automotive industry and thus also for DAF Trucks. The subject is dynamic and things are changing, also for DAF. One reaction is the VECTO tool which is initiated from the European commissions and in turn the $CO_2$ project that is currently active at DAF Trucks. However, not all the employees are aware of the growing importance of $CO_2$, especially not the people that are not confronted on a daily basis. The current mindset of DAF Trucks towards sustainability of different employees is that there is no demand from the customer yet and as long as there are no incentives from governmental organizations, the customer will have no intention to obtain a vehicle because of its environmental image. Nevertheless, DAF Trucks is active on certain areas in order to reduce pollution of the environment but most of these activities are not communicated to the outside, whereas competitors do. This is apparent from the sustainable reports from MAN and SCANIA.

The impact of a DAF truck on the $CO_2$ footprint is based on the equation that expresses the fuel use of a vehicle. The possible contributions that are going to be discussed in this thesis will be divided in the dimensions that are derived from this equation \[ 2.5.1 \]

Since the second focus of this study is to answer the question how DAF Trucks should engage suppliers with respect to contributions towards $CO_2$ reductions, the last two sections of this chapter discussed the internal processes of SRM at DAF Trucks. Out of this background research seemed that the current processes are not focused yet on $CO_2$ reductions and thus this thesis will focus on how DAF should alter or add certain processes towards supplier engagement. In order to do this, the following chapter will discuss the background of the topics that are needed to advise DAF as good as possible.
Chapter 3

Theoretical Background

This literature study will be executed in order for DAF Trucks to gather knowledge in order to react on this environmental change. In this way, research can be performed for DAF trucks in such a way that they are able to position themselves for the future with a "green" truck in order to satisfy stakeholders in the value and supply chain but also to use this position as a competitive selling point. Kibbeling (2010) has shown the importance of developing relationships with those suppliers that are capable of anticipating environmental change through innovation. This innovation would be profitable with respect to the ability of serving customers, responding to society and achieving superior firm performance [52]. Therefore, the first part of the study discusses the recent theories that are involved with the sustainability within the modern supply chains like CSR and sustainability. In these sections important subsections like adopting sustainability and difficulties of implementation will be discussed. Second, this research will focus on relationship management within the supply chain. The involvement of suppliers in the development can be beneficial for gathering knowledge or finding new innovative solutions to respond to the demand of greener vehicles, which will be discussed in the third topic of the literature study. The way of involving suppliers will be covered in the fourth section by discussing the do and don’ts when collaborating with suppliers. Finally, out of this study derives a research framework that functions as a base for the continuation of the thesis.

3.1 Corporate Social Responsibility

In global highly competitive supply chains companies have to deal with environmental pressures from (non-)governmental organizations ((N)GO). Also, within the literature more and more research is executed on the sustainable supply chains, which shows that sustainability in this sense is a thriving topic for research [24] [12], also within the automotive industry [10] [60]. For example, the full electric vehicle of BMW, the I3, consists of natural, renewable and sustainable materials. The interior consists for 25% of renewable raw materials and recycles plastics. The exterior uses 25% of recycled plastics. Furthermore, looking down in the supply chain, during the production 100% of the power that is used to produce the I3 is sourced from renewable energy sources. These are only a few of the facts within the sustainable supply chain of the I3.

The step from the "regular" supply chain and the sustainable supply chains is due to the growth of environmental issues, which is partly due to pressure from external organizations [102] [78]. Beske and Suering (2013) use the Tripple Bottom Line (TBL) approach [32] to
define the sustainable supply chain management (SSCM). They emphasize the fact that the management entails activities of sustainability in supply chains which considers three topics of sustainability, namely economy, ecology and society [12]. Carter and Rogers (2008) define SSCM as:

[...] the strategic, transparent integration and achievement of an organization his social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains.

Seuring and Müller (2008) define SSCM as:

[...] the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements.

Similar to Beske and Suering (2013), both articles based their definition on the TBL approach. Therefore, based on the literature and their common approaches sustainability in modern supply chains is defined as the following:

- The management of regular activities in the supply chain plus managing the activities related to the three environments of the TBL approach, which are defined by either customer or stakeholder, by finding an optimal balance between these three.

![Figure 3.1.1: Balance in Economy, Ecology, and Society](image)

It can be concluded that companies that solely value their own benefits, mostly economic, are no longer accepted by the general public. The traditional focus on shareholders is outdated and it is expected from a company to have a wider stakeholder view. Taken aforementioned into account companies try to balance interests, besides the shareholders, of customers, employees, and the environments the company is operating in [93], like the examples of the sustainability reports mentioned in 2.2. Also, van Weele (2010) mentions three main P-categories in which the stakeholders can be placed, namely People, Planet, and Profit. Think about providing good labor conditions, efficient use of natural sources, and keeping eye on the interests of every stakeholder with respect to profitability. These three pillars are in line with the TBL approach.

Companies suffer from more and more pressure and risks, as well as from governmental
organizations (GO) but also non-governmental organizations (NGO). Think about the pressure Greenpeace can execute on the OEM. One example is the video campaign "Volkswagen Dark Side" on youtube where they exhibit VW as the 'bad guys' in context of the Star Wars parody and expose proposals to make cars more environmental friendly. A second example happened on the IAA in Frankfurt, Germany, in 2013 where Greenpeace managed to get on the roof of the building of the VW group and showed a large banner that referred to the than recently published VW UP! and stated "VW, not UP! to date; Klimazerstörung, made in Germany". According to Beske and Seuring (2014) this can be a source of pressure, and thus be a risk for a company. They might use corporate vulnerability to promote environmental and social issues. However, it is important to recognize the fact that they also can be a valuable partner. Such kind of partnership might be desirable to have in the supply chain as they might provide knowledge of possible risks and can add legitimacy [12]. Linking this with the definitions of sustainability we can say that by implementing sustainability in the supply chain the balance that the company needs to find to be social responsible can be realized. Before this balance is realized completely the organization goes through several stages of mindset and activities. The following section discusses this path to sustainability.

3.1.1 The importance of sustainable activities

Expanding on section 3.1 this section stresses the urge and advantages of implementing sustainable activities. Beske and Seuring (2014) argue that by attaining sustainable goals, a company can differentiate itself which can lead to a competitive advantage and thus performance[12]. Firms may respond sooner and with more knowledge than competitors to arising issues and changes in stakeholder expectations when continuously developing efforts with respect to sustainability [69]. Companies increasingly recognize that social factors may affect the development of new products or technologies [58].

Santiteerakul et al. (2015) itemize seven categories that summarize the goals of sustainability within supply chains whereby increasing economic performance, encouraging innovation and technology development, and reduction of environmental pollution [73] are notable and match the culture of DAF Trucks and are attractive goals for a company that is in the beginning of adopting sustainability in supply chains [94]. Besides these categories they discuss the reduction of depletion, reduction of negative impacts on humanity, the encouragement of ethical management in the Supply chain, and the encouragement of human capability development. Section 3.3 will introduce one of the practices that Santiteerakul et al. find importance. The advantages and opportunities that are attached to Early Supplier Involvement (ESI) within supply chain management will be discussed since the end focus of this final thesis is on supplier selection and assessment. Santiteerakul et al. furthermore highlight the importance of SSCMs as they mention that sustainable strategies will emerge almost automatically. This puts an emphasis on the importance of becoming more sustainable otherwise the competition might be having their advantage.

Carter and Easton (2011) recognize, like in the TBL approach described above, that a company that is in a early face of implementing sustainable activities attaches high importance to the economic performance. They mention that SSCM involves the improvement over a longer time span of an economic bottom line [19] and competitive advantage [69]. Coligic and Smith (2013) studied the relationship between sustainable activities within the supply chain and conclude with findings that showed significant performance results from practices that occur early in the supply chain. Subsequently, they discuss the fact that many firms seem skeptical about implementing sustainable activities, however this was also the case with qual-
ity twenty years ago. Their meta-analysis showed evidence that organizations will acquire positive financial results from environmental activities that are integrated in their supply chain [43]. Beske and Seuring (2014) acknowledge that for achieving sustainable performance some aspects and practices in the current supply chain of the focal company may have to be altered and managed in a different way. Subsequently, they mention that to implement sustainable management of the supply chain the company needs to have a foundation on strategic level. As described in section 3.1 DAF Trucks itself and the mother company PACCAR are already operating in a sustainable way on a more general level. It is therefore worthwhile searching for opportunities for DAF to be more sustainable with respect to the supply chain and supplier selection. However, the author of this thesis is well aware of the fact that this is not achievable in a short time span. Nevertheless, making the company and employees aware of the possibilities might be a start of the implementation. The way of adopting sustainability in an organization will be discussed in section 3.1.2. To find opportunities for driving sustainability in the supply chain it requires knowledge about the sustainability problems, the ranking of possible solutions and for the purchasing department insights into the possible market and business successes [77]. Performance management with respect to sustainability might be a step ahead since a train of thoughts and implementation of activities must be realized first. However, discussing the possible outcomes in this research might provide an understanding for the ones that are skeptical towards implementing sustainable activities.

3.1.2 Adopting sustainable activities

As mentioned in section 3.1.1 implementation of sustainable activities requires decisions on strategic level [12]. The focus of this thesis needs to be on short term measures because implementations on strategic levels at DAF Trucks is not achievable in the time span of this research. The researcher believes that it is important to make relative small steps for the company towards sustainable activities. Before the company is able to implement sustainability in the strategy the company goes through several stages. Nidumolu et al. (2009) describe the following five stages [64]:

- Stage 1: Viewing compliance as opportunity.
- Stage 2: Making value chains sustainable.
- Stage 3: Designing products and services to become eco-friendly.
- Stage 4: Developing new business models.
- Stage 5: Creating next-generation practice platforms that enable customers and suppliers to manage energy in radically different ways.

These stages can be used to determine the position of DAF with respect to CSR or sustainability; what stage is DAF operating in? These stages can also be used to determine if the supplier is ready to be involved in activities that have a sustainable purpose, namely the design of products or systems that has its focus on \( CO_2 \) reduction.

Van Weele and Tubergen [94] used this model in order to elaborate on the topic and they suggested six stages that a company goes through when adopting sustainability in supply chain relationships, as can be seen in figure 3.1.2.
Figure 3.1.2: Different stages of adopting sustainability in the supply chain[94].

- **Stage 1: Denial.** The mindset on board level is that adopting CSR will increase cost and complexity. CSR practices are only adopted if there is a positive balance between revenues and costs of the extra activities.

- **Stage 2: Opportunism.** Although the board is expressing and thinking about CSR as a concept to enhance the company’s image and to use it as a defense for external pressure, it does not integrate it in its business and processes.

- **Stage 3: Compliance to the law.** As the company is facing pressure from external stakeholders, the board gets aware of the possible risks. Business managers are instructed to operate according to social and environmental laws. Purchasing, however, is still passive, traditional, and cost driven.

- **Stage 4: Sustainability as a driver for lower cost.** The board of the company is aware of the fact that sustainable operations can drive down internal costs. A decrease in energy consumption leads to lower energy bills. Subsequently the company is getting aware of the external costs, whereby initiatives reach down to the purchasing department to pursue similar programs in supply chain relationships. Sustainability audits are created in order to make sure that suppliers comply with social and environmental regulations.

- **Stage 5: Sustainability as a driver for product and business innovation.** The company is experiencing that sustainable activities in operations lead to new products, processes, and customer solutions. Supplier relationships alter from being competitive to collaborative. Next to cost and savings measures, CSR performance measures are integrated in the procurement dashboard.

- **Stage 6: From corporate social responsibility to creating shared value.** Sustainability is now part of the business strategy, including supply chain and operations strategy. The number of supply chain relationships is reduced and turned into a more collaborative
and transparent partnership. The companies exchange ideas for growing profitable and implementing sustainable business while creating value for all stakeholders.

When implementing sustainability in the supply chain, companies move from stage 1 to stage 6 while procurement is getting more integrated with a shift from cost driven purchasing to value driven supplier development. Furthermore, as is proven in literature, sustainable activities in supply management can play a major role in the production of sustainable products. Therefore, this research will focus on the supplier involvement and their contributions on product level. However, before converging to the supplier involvement the following section first gives a broad overview of the possibilities in sustainable activities and the implementation on different levels.

### 3.1.3 Difficulties of implementing sustainability

After discussing the way sustainability is adopted into an organization, it is also important to stress the complexity of implementing sustainable activities. Wu and Pagell (2011) introduce their article with the fact that environmental practices might bring cost savings, however some might increase costs, especially in the short term. They recognize the challenge that companies might encounter when implementing sustainable activities in a dynamic, complex and uncertain setting.

Van Weele and Tubergen (2014) emphasize the importance of the commitment and involvement of the focal company as well as the supplier in order to implement sustainable activities with respect to purchasing. They stress the importance of commitment from the purchasing department as well as other departments like marketing and R & D. Furthermore they discuss that major differences can exist among suppliers and the focal company but also their environment. Think about the differences in laws and environmental standards per country. Matos and Hall (2007) recognize that the sustainability is getting increasingly important however they also discuss the complexity of sustainability in the supply chain because of the interaction between the three types of issues of the TBL approach. The pressure that can be executed from the various stakeholders are hard to identify and are a rich mix of technical and non-technical issues. There might be a large number of interactions and therefore finding solutions that will satisfy all the stakeholders will be difficult. From this can be concluded that the implementation of sustainable activities requires commitment and time and the researcher of this thesis should be aware of the difficulties involved.

These difficulties raise questions about how to involve the supplier and in what way the suppliers need to be approached. As discussed in section 3.1.2 procurement is getting more integrated organization wide when implementing sustainability and supply management can contribute to sustainable solutions. Therefore, since engagement of the suppliers is one of the main topics of this thesis, the following sections will focus on the overarching topic Supplier Relationship Management (SRM) with a sharper focus towards supplier involvement and collaboration.

### 3.2 Supplier Relationship Management

Supplier relationship management is seen as highly important with respect to ensuring the supply of reliable and frequent deliveries. SRM activities eventually might ensure that both parties are engaged in a long-term relationship with high commitment. This provides
mutual interests and establishment of close collaboration when developing joint products and cost reductions that are of mutual interest [88]. Al-Abdallah et al. (2014) describe in their article that Supplier Relationship Management (SRM) has long-term and short-term objectives. The long-term objectives, like creating customer value, increase profits, and the improvement of efficiency can be seen as the objects that can be achieved with the short-term objects, which can include improvement of productivity, reduction of cycle time, and the reduction of inventory.

The impact of supplier relationship on the financial performance is described as positive. According to Sjoerdsma and van Weele (2015) a better knowledge transfer, for example, between the buying and selling company results in a reduction of the costs [80] which might directly result in a better profit. Cao and Zhang (2011) discuss that collaboration between buyer and seller can reduce and avoid costs like inventory costs and costs involved with the bullwhip-effect [18].

Besides costs, Tseng (2014) furthermore mentions that buyers and suppliers that share their resources can enhance competitive advantage, and subsequently again enhance the relationship between the firms. The corporate performance of the focal company can increase when she is able to identify, acquire, and classify suppliers in order to demand customized products and services. Cao and Zhang (2011) mention that investing in relation specific assets in the supply chain provides assets that can be seen as rare, valuable and hard to imitate resources. Looking at this through a resource based view (RBV) gives a reason to show this as an advantage. A RBV strategically uses resources like knowledge as described above in order to create competitive advantage over companies that do not have such connections or resources. This emphasizes the importance of the selection and assessment of suppliers and supplier relationship management.

Besides advantages, there are also consequences that are undesirable or situations where the focal company needs to be aware of. In order to reduce speculations and behaviors that do not have mutual interest, which might counteract, companies should nurture trust, commitment, and interaction among partners [88]. Al-Abdallah et al. (2014) discuss five major dimensions of SRM: Supplier Quality improvement, trust-based relationships with suppliers, supplier lead time reduction, supplier collaboration in new product development, and supplier partnership/development. In the next section the literature research will elaborate on supplier involvement and its consequences. Al-Abdallah et al. (2014) conclude with the prove that supplier partnership and development is associated with competitive performance of the buying firm. Also Johnston et al. (2004) argue that partnership relations between buyer and supplier can have a positive relationship with financial performance of the focal firm [51].

Sjoerdsma and van Weele (2015) study the relationship between the quality of the relationship, knowledge transfer, and NPD performance and confirm that there is a positive relationship. The constructs in their research that effect this relationship and are on individual level seem to have the greatest impact on the relationship quality. This stresses the importance of the face-to-face contact with suppliers. All the articles mentioned above emphasize the importance of trust and the relationship that exists or needs to be build within Supplier Involvement (SI).

As already mentioned SI is one of the major topics of SRM [3]. Many studies emphasize the increasing importance of external knowledge with respect to the competitive advantage, how-

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1 The Bullwhip effect in a supply chain might appear when the variance of the supplier’s orders tends to be bigger than the variance of the sales to the buyer [54].
ever also stress the difficulties like dependency and vulnerability. Therefore the following section will elaborate on supplier involvement with respect to the objectives, advantages and disadvantages.

3.3 (Early) Supplier Involvement

The objective of supplier involvement is to use their skills and expertise that can provide benefits for the customer and strengthening the supplier as well. To realize a sound collaboration, organizations need to work closely together in order to create values that are of interest for both sides that generate common benefits.

Companies are increasingly dependent on knowledge and expertise of external parties. Since new technologies will be key to lower transport emissions, according to the European commission, it might be valuable to involve suppliers to find opportunities. Sharing information, providing assistance and the involvement of suppliers increases this willingness. Among others, Yoo et al. (2015) discuss that the involvement of suppliers can have a positive correlation with innovations, the success of a new product, and firm’s financial performance and is seen as a resource that cannot be imitated, which can provide a competitive advantage. According to Cao and Zhang (2010) other advantages are process efficiency, flexibility, business synergy, and quality.

According to Yoo et al. (2011) a NPD project in an industry that demands products with a higher level of design and quality requires a high degree of supplier involvement. Nevertheless, if the supplier possesses capabilities of manufacturing products economically and if, during the early supplier involvement, the focal company helps to lower production costs and improve the quality, the benefit of the SI program will even have a bigger impact.

According to Petersen et al. (2005) the possibility to involve suppliers can be realized in every stage of the new product development process (NPDP), as can be shown in figure 3.3.1. They emphasize that earlier involvement is better. This can be underpinned by the fact that involvement can have a positive correlation with innovativeness since innovation that takes place at the front end of the process significantly contributes to NPD success. Furthermore, integrating environmental issues should also be realized at the front end.

![Figure 3.3.1: New Product Development Process & Supplier Involvement](image)

In the earlier stages of the NPDP suppliers are involved that deliver more complex items or (sub)systems that are more critical. Such kind of partners are strategic alliance suppliers. Next to the moment of supplier involvement, Petersen et al. also discuss the level of responsibility a supplier can have when involved in the development process. Figure 3.3.2 shows...
the different levels where from no involvement to the white box, which is the least amount of involvement, the grey box and eventually the black box that constitutes the highest level of integration of the supplier where sharing is key. Therefore suppliers should be involved based on the knowledge and expertise they have. It is proposes that with no supplier involvement the focal company should be 100% in possession of the knowledge or is able to obtain the knowledge before or during the process. In the "White Box" the focal company "consults" with the supplier and therefore the supplier is in possession of 25% of the knowledge. In the "Gray Box" the knowledge and expertise is equally divided, 50-50, and a joint development takes place. In the "Black Box" the design is primarily supplier driven and the knowledge distribution is 75-25. In the case for DAF it is assumed that the knowledge distribution will not be 100-0 since the integration of the products that are outsourced need to be integrated into the systems of the end-product.

<table>
<thead>
<tr>
<th>None</th>
<th>&quot;White Box&quot;</th>
<th>&quot;Gray Box&quot;</th>
<th>&quot;Black Box&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>No supplier involvement. Supplier &quot;makes to print.&quot;</td>
<td>Informal supplier integration. Buyer &quot;consults&quot; with supplier on buyer's design</td>
<td>Formalized supplier integration. Joint development activity between buyer and supplier.</td>
<td>Design is primarily supplier driven, based on buyer's performance specifications.</td>
</tr>
</tbody>
</table>

Figure 3.3.2: Level of Supplier Involvement [66]

There is many literature discussing the possibilities for companies to involve or collaborate with parties in the supply chain to find green and sustainable solutions. However the focus is not yet on creating a shared view on sustainability of the end products in the use-phase. This might enhance the competitive advantage since the social image of the firm is getting increasingly important. Especially since the the European commission now initiates the new goals with respect to reduction of GHGs towards 2020 and 2050 in the automotive transport industry [36] [37].

As already mentioned the collaboration with suppliers is crucial for creating values for the interests of both parties. This collaboration is key in this thesis since the focus of the last research question is on the engagement of suppliers. The following section thus focuses on the way of collaborating suppliers.

3.3.1 Supplier Collaboration

Collaboration between firms can be seen as a unique bundle of benefits perceived by buyers and suppliers with respect to their expectations from that specific relationship [23]. Especially when the technology nowadays becomes more and more complicated it can be a wise decision to search for collaboration with suppliers or customers that are of possession of the knowledge, think of early involvement of the suppliers in the development process. This
section discusses some do’s and don’ts towards the collaboration of suppliers when involving them into product innovations.

Based on the literature already discussed the author of this thesis would like to put some emphasis on trust-based relationships and on supplier collaboration in new product development since the research has its focus on the collaboration between the companies towards innovations for CO₂ reduction. Like Tseng (2014), Al-Abdallah et al. (2014) also stress the importance of building trust as it leads to strong, successful, and long-term buyer-seller relationships, although it is costly, difficult, and time consuming. Nevertheless it would improve cooperation, enhance satisfaction, reduce conflicts, and facilitate information exchange. Supplier collaboration during the development of new products might provide reduction of development costs, early available prototypes, increase of quality, reduction of development time, and corresponding to this research, an increase of product innovation.

A second important dimension is the development of the supplier since it is imaginable that for implementing sustainable activities, adaption on the supplier’s side might be required. It involves efforts, with continuous improvement, that have mutual benefits with respect to technology, quality, delivery, and cost [3]. Like the authors mentioned above, Henke and Zhang (2010) also discuss the difficulty of collaborating with a supplier, while taking the competition between customer and supplier into account. They argue that focusing less on price reduction can reduce relational stress on short term [13]. They furthermore mention difficulties like conflicting functional objectives and late changes in engineering and specifications that can lead to stress points in the collaboration, however these points are more difficult to resolve on short term. They argue that the focal firm needs to implement or invest in their collaborative actions in order for the relational stress to mitigate and the supplier willingness to be higher.

Within the automotive industry the willingness of suppliers to invest is considered as a major factor of success in the collaboration between customer and supplier [13]. Cao and Zhang argue in 2011 that the timing and frequency of that collaboration must be carefully considered. Therefore, a careful assessment and selection of the supplier, which will be discussed in the next section, must be considered since the selection of the right partners might reduce inefficiency problems. After the selection, a sound alignment of the goals and benefits might have a positive effect on the financial performance for the parties in the collaboration [18]. Kibbeling (2010) discusses that the focal firm needs to be well aware of the strategic objectives of the firm with respect to sustainable activities in order for the collaboration towards innovativeness.

### 3.3.2 Green Supplier Selection

In order to find the suppliers that are suitable to the requirements and demands of the focal company in order to be green, supplier selection is an important problem in GSCM, as described in the introduction of this chapter. Among others, Bali et al. (2013) and Awasthi et al. (2010) analyzed the studies related to green supplier selection and summed up the most commonly referred criteria [9, 7]. In order to execute the model Bali et al. (2013) have developed they asked a management board of an automotive company to assign criteria out of a list that are commonly referred to in the literature. Out of these commonly referred criteria, the following criteria fit to the case of this final thesis:

- Green design or R & D: Whether the suppliers develop new green designs.
• Green Image: Whether the suppliers meet expected performance and recognize the importance of environmental and social responsibilities.

• Green competencies: whether the supplier recognizes the importance of resolving sustainable issues and is capable of promoting of environmental behavior and is able to meet the specified performance criteria demanded from participant in the SSC [16].

• Use of green technology.

In the literature many green supplier criteria are based on the processes of the supplier, e.g. reverse logistics, and the pollution of the product or production in the supply chain [9] [4]. Few literature is focused on the pollution of the product during the use-phase. Therefore, the criteria 'Green design or R & D' and 'The use of green technology' is of high importance for this case. Where Amin and Zhang focus on the three pillars supplier-related, part-related, and process-related and only involve the environmental subject in the process-related criteria. This study tries to focus on green criteria in the part-related pillar.

Lee et al. (2009) made a list of criteria and sub-criteria for evaluating traditional suppliers and a list for evaluating green suppliers. The first difference between those two lists is that the number of green criteria is higher in the second list with more importance but even more noticeable is that criteria for costs are not even included in the second list. However, this study tries to focus on the existing tools and processes of the company where costs is still of great importance. Nevertheless, the criteria discussed in the article of Lee et al. correspond to the criteria selected from the articles of Awasti et al. and Bali et al. where Lee et al. (2009) discuss the following criteria based on a green perception where Lee et al. (2009) subdivides the criteria into sub-criteria in such a way that different levels can be assessed:

• Technology capability: The factors that can provide new and upgraded products to the firm.

• pollution control: The factors that can show the control of suppliers in producing pollution.

• Environment management: The factors that show the effort of suppliers in environment management.

• Green product: The factors that show the effort of supplier in producing green products.

• Green competencies: The factors that show the competencies of the supplier in improving green production.

Using weights on the criteria can lead to quantitative results so that the buyer is objectively able to assess the supplier on capabilities and possibilities. This is a method that DAF Trucks is currently using in their Supplier Market Analysis (SMA).

3.4 Conclusions & Research Framework

Based on the literature on sustainability [12][75][20] this research project defines sustainability as the management of regular activities in the supply chain. In addition to this
sustainability contains managing and finding an optimal balance between the three pillars of the TBL approach, namely Ecology, Economy, and Society. For large organizations it is important to focus on sustainability and to be corporate social responsible since the traditional focus on shareholders is outdated and is shifting towards a wider stakeholder view.

In order to summarize the findings of the literature about CSR in the automotive industry with respect to sustainability table 3.4.1 is drafted. This will give an overview of the reasons why an organization should implement sustainable activities but also shows the difficulties of implementing these. Noticeable is that the pressure from stakeholders can be a reason to implement sustainability but might be an unfavorable reason to do so.

Table 3.4.1: Implementing Sustainability

<table>
<thead>
<tr>
<th>Why sustainability</th>
<th>Difficulties</th>
</tr>
</thead>
<tbody>
<tr>
<td>(+) Valuable partnership results in source of knowledge</td>
<td>(-) Supply chain activities may have to be altered</td>
</tr>
<tr>
<td>(+) Competitive advantage</td>
<td>(-) Sustainability might need to be implemented in strategy</td>
</tr>
<tr>
<td>(+) Increasing (financial) Performance</td>
<td>(-) Possible cost increase</td>
</tr>
<tr>
<td>(+) Encourages innovation</td>
<td></td>
</tr>
<tr>
<td>(+) Finding balance to be social responsible</td>
<td></td>
</tr>
<tr>
<td>(-) Pressure from stakeholders</td>
<td></td>
</tr>
</tbody>
</table>

However, before organizations become more sustainable or grow in their view on CSR, they go through several stages where a shift takes place towards a more integrated purchasing department that will become more value driven than cost driven. During the research at DAF Trucks NV and based on several interviews it became clear that the purchasing processes are still very cost driven. The results of the first round interviews can be linked with the CSR stages of figure 3.1.2. Considering the requirements mentioned at each stage it can be concluded that currently DAF is operating in stage four. First, DAF implemented several sustainable activities in their supply chain that drove down internal costs and have positive effects on the environment. Think about the filter systems for particles and the facilities that reduced soil risk, noise, and paint smells. The various activities can be seen in figure 2.3.1. Second, they are aware of the urge to develop trucks that contribute as little as possible to the greenhouse gases. Besides this, the department Advanced Technology is currently doing research with respect to new possibilities in order to make the truck as green as possible. However, the reason that such kind of developments take place is mostly because of legislation and incentives from GO’s. In order for business to change there needs to be
a demand from the customer. The need for a business case is multiple times mentioned, as can be seen in figure 2.3.1. The insights of the respondents with respect to the need for sustainability are shown in the row ‘sustainable mindset’. Third, the initiatives reach to the purchasing department until a certain level, think about the REACH legislation. CSR performance measures for suppliers in the current procurement dashboard are limited to legal requirements. DAF does not completely fulfill the requirements for stage 5. According to the interviews there is not yet a fixed focus on sustainability.

The involvement of suppliers leads to using their skills and expertise so that this can provide benefits for both parties. To realize a sound collaboration, organizations need to work closely together. This is key since organizations are increasingly dependent on knowledge of and expertise of external parties, also in contributing to reduction of CO\textsubscript{2} emissions. Suppliers can be involved on two dimensions. First, the time in the development process is variable and second, the extent of the supplier involvement, which varies from no involvement to supplier driven projects. This research project attempts to find an answer on how suppliers can contribute in developing the most sustainable truck in the world. The involvement of suppliers can have a positive influence on innovation, success of new products, and might increase the firm’s financial performance. Furthermore looking at this through a resource based view it can be seen as a resource that is hard to imitate, which subsequently can provide competitive advantage.

Based on the conclusions of the literature study the framework in figure 3.4.1 can be drafted out of the literature and the problem statement.

![Figure 3.4.1: Research framework](image)

This research studies the relationship between the capabilities of the suppliers on the CO\textsubscript{2} performance of a truck. The researcher believes that CSR maturity and supplier involvement act as moderating variables and have an impact on this relationship. Furthermore, this thesis will discuss in what way these factors can influence this relationship. In order to set boundaries for this research, the contributions towards CO\textsubscript{2} reduction that is discussed in the introduction are only focused on the truck in the use-phase where the VECTO tool serves as an input.
Chapter 4

Defining the CO2 Critical Parts of a Truck

The main goal of this chapter is to give an overview of the possible contributions that a truck OEM can make. This will be based on the existing literature and the interviews that are held in this research. The possible $CO_2$ contributions that will be given below will be built on the dimensions of the equation [2.5.1] and the input data of the VECTO tool. The VECTO tool is shortly mentioned in the introduction, however, the following section will give a broader understanding of the tool.

4.1 VECTO: Implications

VECTO tool

Noticeable is that the $CO_2$ emissions are not incorporated in the tables that show the emission regulations in the EU, table [2.4.1]. In order to get insights and to control the $CO_2$ emissions the European commission developed a simulation tool. The purpose of the simulation tool, VECTO, is to establish a certification system for fuel consumption and $CO_2$ emissions of commercial vehicles. The numerical values that come out of the simulation tool, After inserting specifications of several commodities of the truck numerical values come out of the simulation These numbers are relevant for the customer and for monitoring the efficiency of the vehicle fleet of the OEM. Every truck that will be produced will be provided with a $CO_2$ declaration corresponding to that specific truck. This declaration shows the $CO_2$ emissions and fuel consumption in gram per tonne kilometers. The completion of the methodology of the simulation will be realized in 2017 and the VECTO tool will be operational in 2018. During the first years there will be no restriction or limits. However, the expectation is that on longer term limits on the $CO_2$ emissions will be established.

In order to simulate output values the OEM and the supplier need to provide technical input data for the simulation tool. However, before the data is ready to use, the data needs to be certified by a type approval authority according to principles of the European Commission, 2007/46/EC. There needs to be a clear responsibility for the data transfer between the OEM and the supplier. Figure [4.1.1] gives an overview of the simulation tool VECTO.
The input data of the VECTO simulation tool can be itemized as the following nine input parameters [1]:

1. Engine characteristics
2. Vehicle air resistance
3. Transmission ratio/resistance
4. Rear axle ratio/resistance
5. Rolling resistance
6. Eco-Technology
7. Weight
8. Vehicle configuration
9. Auxiliaries drag

All of these parameters can be divided into the equation 2.5.1 which is shown in section 2.5. The five dimensions in the numerator of the equation will serve as the five dimensions for the possible contributions that suppliers can make, namely:
The following subsections will describe contributions that fit within the nine parameters of the VECTO tool. These are built on the five dimensions shown in Figure 4.1.2 in order to elaborate on the possibilities and goals towards $CO_2$ reduction. The contributions described below are based on the insights of the experts that are interviewed and also based on papers from literature. The goal of the following topics is to highlight technical contributions towards $CO_2$ reduction. This paper does not intend to address all the complex issues involved in reducing $CO_2$ emissions. It simply intends to put forward the key guiding principles recommended by the experts and literature. The tables in Figure 4.1.3 and 4.1.4 represent the results of the interviews and will be discussed in the upcoming subsections.

4.1.1 Internal Combustion Engine characteristics

The first thing someone might think about when talking about the $CO_2$ emissions is to take measures on the engine. In order to change the characteristics of the engine there are different contributions. Some people are pessimistic towards further optimizing the engine since the measures that are taken are relatively low in terms of percentages. The fuel, however, is a drastic change in $CO_2$ reduction as is mentioned many times in the interviews. In order to reduce the greenhouse gasses of the truck emissions there are several fuel kinds that act as an alternative to diesel. The following subsection describes the fuels that the experts and literature expect to be implemented and remarkable alternative fuels that are attractive with respect to $CO_2$ reduction.

Fuels

It seems that the truck would still be dependent for a long time on liquid fuels because of the energy demand of truck. A second aspect is the range of the truck. Because of financial reasons, it is undesirable that the truck is non-operational. The range of the truck needs to be as long as possible. The offer of batteries is not capable yet to satisfy this demand with an electrical powertrain. The fuels that can be used for an Internal Combustion Engine (ICE) in the truck industry can be divided in liquid and gaseous fuels. The most common liquid fuel in the truck industry is diesel. A second fuel which is already used in truck applications...
<table>
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<th>Resp. 3</th>
<th>Resp. 4</th>
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<td>Visible technologies for customer</td>
<td>Multiple roads to CO₂ reductions</td>
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<td>Doubts about electrical drivetrains</td>
<td>Diversity of drivetrains</td>
<td>Questions about diesel engines</td>
<td>Technologies for VECTO outcomes</td>
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<td>Eco-combi</td>
<td>Fastmat</td>
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<td></td>
<td>Recuperated braking energy</td>
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<td>Alt. fuels</td>
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<td>Tires</td>
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<td>Multimodality</td>
<td>Driver behavior aids</td>
<td>Route planning</td>
<td>Smart mobility</td>
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<td>Corporate driving</td>
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<td>Route planning</td>
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<td>Engine</td>
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<td>Weight</td>
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<tr>
<td>Comments</td>
<td>Incentives might lead to demand</td>
<td>Different ways of approaching CO₂ reduction</td>
<td>Focus of contributions on complete vehicle (system level)</td>
<td>Contributions need to be matched with application</td>
<td>Sustainability starts in urban environments</td>
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<td></td>
<td>Suppliers have a broad knowledge, DAF gives design</td>
<td>Long haul transport to distribution to urban transport</td>
<td></td>
<td>Focus of contributions on complete vehicle</td>
<td>Needs for several different solutions based on different applications</td>
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**Figure 4.1.3:** Results interviews round 2 respondent 1 to 5
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<td>• Long haul: fossil fuels</td>
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<td>• Transport in city moves outwards</td>
<td>• Reduction in road transport?</td>
<td>• Bio fuels</td>
<td>• Short distances: Electrical</td>
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<td>• Electrical drivetrain for urban applications</td>
<td>• Applications for local transport</td>
<td>• Reduction of total impact on society</td>
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<td>Cases</td>
<td>• Cargo hopper</td>
<td>• USE (TU/e)</td>
<td>• The Green Deal</td>
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<td>• Aerodynamics</td>
<td>• Rolling resistance</td>
<td>• Weight</td>
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<td>• Rolling resistance</td>
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<td>• Drivetrain</td>
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<td>• Recuperative braking energy</td>
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<td>• Optimizing freight</td>
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<td>• Speed profile of the truck</td>
<td>• Corporatedrtting</td>
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<td></td>
<td>• Route planning</td>
<td>• Geographic location of suppliers</td>
<td>• Engine</td>
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<td>• Geographic location of suppliers</td>
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<td>• Vehicle aspects</td>
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<td>• Engine</td>
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<tr>
<td>Comments</td>
<td>• Biggest reduction can be realized on application level</td>
<td>• Innovations are collaboration between GO and OEM</td>
<td>• Truck industry needs incentives to stimulate CO2 reduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Modular thinking</td>
<td>• Contribution is dependent on the application of the truck and the geographical location</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Tesla or google of truck industry?</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.1.4: Results interviews round 2 respondent 6 to 9
by IVECO is liquid natural gas (LNG). Daimler has a truck with a Compressed Natural Gas (CNG) engine. Volvo Trucks developed a truck that drives a combination of LNG and diesel.

Bio-LNG (renewable gases) is according to the Fuel Vision of the ’Ministerie van Infrastructuur en Milieu’ for a truck and trailer combination the fuel with the most chance to succeed until 2050 [63]. The Fuel Vision gives an overview of different possibilities per application where (bio)diesel and (bio)CNG are current possibilities to reduce the CO\textsubscript{2} emissions. Natural gas has a higher hydrogen to carbon ratio than any other hydrocarbon fuel and therefore emits less CO\textsubscript{2}. According to Boretti et al. (2013) CNG in combination with diesel is a promising contribution for HDV. This is realized by igniting the natural gas with diesel. One of the problems that can occur when using natural gas is the emission of unburnt methane, "methane slip" [59]. A second disadvantage is the reduction of power due to a lower density of the fuel [13]. Besch et al. (2015) show that an engine with dual fuel (natural gas and diesel) can reduce the CO\textsubscript{2} emissions 3\% to 8\% compared to a regular modern diesel [11].

Another upcoming fuel is hydrogen (H\textsubscript{2}). Shell is investing in H\textsubscript{2} tank stations and has the mission to have installed 400 stations in 2023. The most likely way of using the H\textsubscript{2} is with a fuel cell that drives an electric engine. This type of propulsion will not have any CO\textsubscript{2} emissions from the vehicle [67]. The only emissions are water (H\textsubscript{2}O) and hydrogen (H\textsubscript{2}). The Fuel Vision expects that hydrogen might be applicable for smaller trucks in an urban and national application from 2020 and for long haul vehicles from 2030.

An interesting fuel kind that led out of the interviews are the solar based fuels. This type of fuel, which is imitated from the nature’s reaction of photosynthesis, can be CO\textsubscript{2} neutral since CO\textsubscript{2} is used in order to create solar fuels. These solar fuels are derived from a reaction where CO\textsubscript{2} and H\textsubscript{2}O transforms in a carbon-hydrogen fuel (C\textsubscript{x}H\textsubscript{y}) and oxygen [74].

4.1.2 Aerodynamics

According to the ACEA the air resistance is almost 55\% of the total of the energy consumption. Therefore, it is understandable that this commodity is often mentioned in the interviews as it can be seen in both the tables. Therefore, this subsection will elaborate on the contributions with respect to aerodynamics. As can be seen in figure 4.1.5 the CO\textsubscript{2} reduction can be reduced up to 9\% on aerodynamics of which 1-3\% in the front and 5-6\% in the back. The boundaries concerning the measures of the truck are set by legislation. This might be a problem when implementing aerodynamic changes. Changes on aerodynamics like a boat tail can be detrimental on the cargo space. The maximum length of a truck and trailer combination is 16,5 meters. Contributions as shown in the figure can take away valuable cargo space. Because DAF does not make trailers this study focuses on the contributions that can be realized to the vehicle itself. However, when considering the combination there is much more potential to reduce the CO\textsubscript{2} emissions. There are also measures that can be taken on the trailer with respect to aerodynamics, for example, trailer side skirts.

Several possibilities on the aerodynamic are side cab extenders, a roof spoiler and side skirts [34]. Changing the front of the cabine, which would probably be possible after 2021 [39], can have a significant effect on the aerodynamics. However, it takes many years before a new cab is fully developed. These are all contributions that are not unknown for DAF and its competitors. Mirrors, however, also have a significant impact on the drag coefficient of the truck. Replacing the mirrors for cameras can result in a fuel reduction of almost 1200 liters
per year [61].

Figure 4.1.5: Aerodynamic contributions [35]

4.1.3 Drivetrain

The expectations are that there is going to be a diverse offer with respect to drivetrains in the automotive industry as mentioned by multiple respondents and as the diversity in the responses show. Furthermore, the expectations for the truck industry are that the combustion engine will be applied for a long time. Expectations are, especially for long haul applications, the truck will have to be in possession of a liquid fuel [47] [63]. Battery packages used for a heavy duty application will still have too much downsides. The energy demand of a 16 tonnes truck will be too high and therefore the size of the battery too big. This in turn leads to space shortage and an increase in weight.

Hybrid

Hybrid drivetrains have two separate energy sources and can be realized in different forms. Several types that have been derived from the interviews and literature are based on two main engines that transfer the energy to the wheels. This is an ICE or an Electric Motor (EM). Both these types of actuators can also serve in a supportive role of one and another. The ICE is then used as a range extender and the EM is used to filter out the weak spots of the ICE. When the ICE serves as a range extender, the vehicle is in possession of a battery pack that provides the electric motor with energy. A second source of energy for the EM can be a fuel cell. In this way the vehicle always needs to be in possession of a liquid or gaseous fuel. One of the most familiar fuels for fuel cells is $H_2$. In this way the vehicle will not emit any $CO_2$. Two disadvantages are the immature infrastructure [62] and the safety of the $H_2$ with respect to storage on the vehicle. A third point that needs to have attention is the source of the $H_2$ [30].

Waste Heat Recovery

Holmberg et al. (2014) shows that 50% of the fuel energy of an ICE in trucks is waste in terms of thermal losses in an ICE [47]. Therefore, trying to recuperate energy flows with respect to thermal energy might increase the efficiency of the engine. This will in turn reduce the fuel use and thus the $CO_2$ emissions. One way of reducing thermal losses is Waste Heat Recovery (WHR). A WHR system is based on capturing energy at a source that emits heat and then transforms as much of that energy into an useful form [33]. An example of WHR is a system that uses heat from the exhaust gases where an expander transforms the thermal heat into mechanical energy. Adding a WHR system to the engine can reduce the $CO_2$ emissions by 3% [92].
Drivetrain resistances

According to Holmberg et al. (2014) 33% of the energy losses are due to frictions on the whole vehicle, including tire-road contact (42%). Other frictions are engine, transmission, brake contact, and auxiliary equipment frictions. These frictions occur in bearings, gears, and sliding-rolling contacts. The reduction of these frictions can be realized by an improvement on greases and oils in the corresponding parts of the truck. Think of the engine, the gearbox, and the differential in the final drive. Although the article of Holmberg et al. (2014) shows that the friction losses as a whole count as a significant part of the total losses that occur in the truck, it is expected that the improvements are only minor measures towards CO₂ emissions.

The engine, the gearbox, the differential or final drive, and the auxiliaries are a relative small part in these friction losses. Such frictions can only be completely removed when the parts are removed, which asks for drastic changes in the drivetrain, e.g. electrification.

4.1.4 Rolling resistance

The majority of the respondents were convinced that reduction of the rolling resistance has a significant impact on the CO₂ reduction. As mentioned above, more than 40% of the friction losses of a truck is because of the tire-road contact. According to one of the interviewees, it is expected that there will be no revolutionary changes in the development of tires anymore since tires are already well developed. It is important however to keep the tires on the right pressure. Keeping the right pressure can be as important as choosing the right tires [83]. Surcel and Michaelsen (2010) show that a reduction of 15% in the tire pressure of a truck can decrease the fuel efficiency by 3%, assuming that the tire pressure is 7 bar. Over-inflating the tires is not recommended for reducing the CO₂ emissions. A tire pressure monitoring system can be installed in order to keep the tire pressure optimal. Low rolling resistance tires can reduce the fuel consumption by 1 to 3%. The downsides, however, might be the reduced traction, reduction of useful life, and the reduction of braking performance [79].

Another remarkable contribution on rolling resistance mentioned by one of the respondents can be a measure on the axes. Aligning the axes in an optimal position can reduce the friction with the tires on the road. It is also possible to use axles that can steer along with the truck. Furthermore, unnecessary contact of lift axles with the road can increase the fuel use up to 5% [83].

4.1.5 Driving resistances

The equation of fuel use discussed in section 2.5 shows that weight is a factor that can influence the driving resistances and thus also the CO₂ emissions. An important note is that systems like WHR, as discussed above, and heavy battery packages might reduce CO₂ emissions, however can increase the weight of the truck. Implementing such systems into the truck should be considered first because it might influence the weight of the truck.

Besides the elimination of parts or systems, the use of lighter materials might be considered in order to reduce the weight of several parts. However, according to Breemersch and Akkermans (2015) weight reduction only has an effect of 0.5% on CO₂ reduction [14]. Therefore, this might question the priority of weight reduction. It might be an idea to start developing from scratch since over the years the amount of systems on the truck are built up and are part of a significant number of the total weight of the truck. Now the question raises if there are single solutions that can replace multiple systems.
Braking resistance occurring during transport is another point of attention in the driving resistances. Various systems exist that are designed to reduce these resistances. They will be discussed in section 4.4.

4.2 A proposed CO2 priority matrix

The contributions discussed in the interviews and the ones that are elaborated on above can be placed in the matrix in figure 4.2.1. This displays the contributions with respect to CO$_2$ Reduction and Effort. Contributions towards CO$_2$ reduction can be made on different levels that cost a certain amount of effort or investment. Therefore the y-axes shows the potential CO$_2$ reduction while the x-axes shows the amount of effort needed to implement the contribution with respect to time. This is illustrated in 4.2.1.

![Figure 4.2.1: Contribution Matrix](image)

Contributions that have little effect on CO$_2$ reduction are seen as a contribution with a low level of sustainability whereas contributions with a significant effect on CO$_2$ reduction can be seen as possibilities. Considerations must be made in order to determine whether it is worth the time and money.

The left bottom part of the matrix shows contributions mainly based on the rolling resistance of the truck, namely Low Resistance (LR) tires and implementing a Tire Pressure Monitoring System (TPMS). Weight reduction has a wider scope on effort since it is very dependent on which part of the truck this will be applied. Therefore it does not have to cost much effort, however it seems that not much reduction can be achieved. Waste Heat Recovery (WHR) requires some more effort in comparison to the contributions on the rolling resistance since there is a higher level of implementation required. Think about adaptations on the engine as mentioned above. The upper right part of the matrix requires relatively much effort but
results in a higher $CO_2$ reduction. The reason that contributions on the Aerodynamics (Aero) are (partly) in the upper right part is because the reduction is relative high, however so is the amount of effort. Furthermore, an OEM is dependent on the regulation of GO about the dimensions of a truck. Fuel changes and hybridization of the driveline require much time for development but in turn lead to high $CO_2$ reductions. Based on the contributions described and figure 4.2.1, the portfolio in figure 4.2.2 is set up. This shows contributions that have priority with the corresponding actions and the impact on $CO_2$ reduction.

Figure 4.2.1 shows that the interviews and the literature in this research did not bring any radical contributions that require a low effort where a high $CO_2$ reduction can be achieved, which should be seen in the left upper part of the matrix. This is due to the fact that experts believe in contributions or measures that have an impact on the behavior or the application of the truck rather than a tangible technical solution fitted on the truck, as can be seen in the answers of the respondents in the row of ’intangible solutions’.

4.3 Vehicle configuration & application

It can be concluded that out of the interviews did not result in any distinctive technical solutions for DAF that the department ”Advanced Technology” could not think of. Also, as can be noticed in the contribution sections, the focus is not on electrifying the vehicles since this was (maybe surprising) not the main topic of conversation during the interviews. The interviewees believed that this was not (yet) the solution, especially not for long haul applications. However, there are main points of attention that might be interesting for DAF.

One point of attention is that the trend of contributions will be enacted by incentives made by cities or municipalities. This means that the need for different kind of transportation will start at cities like Amsterdam or Utrecht. Sustainability will start in the city center by innovations in the urban accommodations and will be backed-up by incentives of the government. The sustainability demand is linked to the logistic demand and thus to the total stake of the vehicle. The interviews showed that the type of contribution towards $CO_2$ reduction is highly dependent on the way the truck will be used and thus also the geographic location. For example, Brazil has many sources for bio-ethanol [42]. This makes it attractive to use engines in Brazil that are able to run on this type of fuel. Furthermore, ’green zones’ exist in cities where for certain types of trucks or cars it is not allowed to drive. In cities like Amsterdam and Utrecht trucks with a diesel engine need to have at least a Euro 4 label. The municipality of Rotterdam wants in certain areas only trucks with a Euro 6 label [72].

Furthermore, multiple interviewees believed that trucks remain dependent on fossil or other liquid fuels. For shorter distances, propulsion systems like hybrid drivetrains or electrification is more feasible. Moreover, there are cities that have green zones and strict legislation about the type of vehicles that are allowed. This could be a situation where a complete electric or hybrid vehicle is demanded. The downside of designing the contributions to the applications of the truck, however, is that the advantage of economy might be missed out. Multiple types of drivetrains need to be developed for multiple applications. Furthermore, collaborating with competitors or other stakeholders might enhance this advantage of economy. This thought, however, should be very well considered as it requires consistent effort and time to realize.

The following subsections describe several possibilities or incentives, which seems out of the conversations with the external experts, but proposes a more environmental friendly stake of a truck.
<table>
<thead>
<tr>
<th>Priority</th>
<th>Suggested Actions</th>
<th>CO2 reduction to be expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low resistance tires</td>
<td>- The purchase of tires with low resistance profile.</td>
<td>LOW</td>
</tr>
<tr>
<td>2. Tire pressure monitoring system</td>
<td>- The purchase and implementation of a TPM system.</td>
<td>LOW</td>
</tr>
<tr>
<td>3. Weight reduction</td>
<td>- Reduce the weight on different commodities by elimination or using other materials.</td>
<td>LOW</td>
</tr>
<tr>
<td>4. Reducing thermal losses</td>
<td>- Develop and implement waste heat recovery systems.</td>
<td>LOW</td>
</tr>
<tr>
<td>5. Aerodynamics back</td>
<td>- Develop boat tail.</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td>- Develop side skirts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Collaborate with trailer producer.</td>
<td></td>
</tr>
<tr>
<td>6. Aerodynamics front</td>
<td>- Develop and implement side cab extenders</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>7. Hybridization</td>
<td>- Develop a (partly) electrical drivetrain based on the demand of the cities.</td>
<td>HIGH</td>
</tr>
<tr>
<td>8. Fuel</td>
<td>- Develop changes into existing ICE.</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

**Figure 4.2.2: Green action portfolio**
Vehicle configuration

Contributions on the vehicles of which an OEM firstly will not have influence are the possibilities for more freight per truck. This can be realized by longer trailers, more trailers behind a truck, or low deck trucks. The DAF TeliSys truck is one example of a low deck truck. This truck has 20% more cargo space than a regular truck-trailer combination because of a lower fifth wheel \cite{28}. These contributions will result in less CO$_2$ emissions per kilogram freight. When normally multiple vehicles are used only one truck might be needed. The issue, however, for such contributions is that OEM’s need to satisfy regulations or directives from GO’s. In order to utilize as much as space in the current truck and to be in line with the permitted length, the truck needs to be as compact as possible. This might be one of the reasons that the truck has its current shape in Europe, block-shaped. Currently there is a process on-going to set up a new directive that allows the nose of truck to be lengthened with 0.5 meters \cite{39}.

Multimodality

One expectation and intangible solution that is mentioned multiple times in the interviews is multimodality. Multimodality in freight transport is the combination of two or more ways of transporting goods from one destination to another in order to reduce cost, lead time, risk, and CO$_2$ emissions \cite{6}. This way of reducing is mentioned in this thesis because this might be a warning for DAF and every other OEM in the truck industry since this is a way of finding other possibilities of transporting freight. However, experts that this might be a solution because of the inefficiencies that occur during transport on the road. Trucks are not always utilized in an optimal way or are even driven while empty. In order to eliminate such situations, there is a need optimization of logistics of freight transport, standardizing trailers, and dividing freight. In this way every truck is utilized in an optimal way, Smart Mobility \cite{84}. These types of contributions, however, is on a level where on most contributions the OEM does not really have any impact. These contributions or incentives that determine the behavior of a truck on application level are determined by GOs, market demand, or are law-based. In order to influence such incentives an OEM should cooperate with GOs or collaborate with other OEMs in order to set up initiatives.

4.4 Contributions on system level

In the sections above, two different levels of contributions are discussed that can reduce the CO$_2$ emissions. First, on product level, and second, measures that can be taken in order to influence the application or the behavior of the truck. Besides these contributions the author wants to introduce a third level of CO$_2$ contributions, namely on system level. These systems are technical measures on a truck in the form of embedded software, and therefore approachable for the truck OEM. System level contributions ensure a more efficient behavior of the truck during transport. Embedded software is a software system that permanently resides in a device whose operations it controls \cite{65}. Such measures towards CO$_2$ reduction is on system level and thus the integration of different parts and systems is crucial.

Several systems on the market exist that can assist the truck or the driver in order to drive more efficient. These systems are called Advanced Driver Assistant Systems (ADAS). Platooning is a system that ensures that two or more trucks can drive in a corporate manner.
The second and third truck can follow the truck that is driving in front of them with the use of sensors in three ways as can be seen in picture 4.4.1. \(d\) stands for distance and \(v\) for velocity.

![Platooning: Cooperative riding through sensors](image)

A second contribution on system level that evolved out the interviews is planning the route ahead with respect to the vehicle speed. When the truck knows when to accelerate, decelerate, or coast, it can increase the efficiency of the truck and therefore the impact on the environment by influencing the behavior of the driver. This can be realized by a Global Positioning System (GPS). Driver behavior can have an effect of up to 7% reduction on the \(CO_2\) emissions.

4.5 A Switch from Technical to Behavioral Contributions

Based on the findings as described above the researcher proposes a framework that enables to sort the \(CO_2\) reduction contributions in the different levels of \(CO_2\) reduction, which is recognized in February 2016 by the European Automobile Manufacturing Association in Brussels [14] [56]. The contributions can be divided in the three levels as shown in figure 4.5.1. The expectations are that most \(CO_2\) reduction can be realized on contributions that affect the behavior of the truck, namely on system level and on application level. Therefore, the focus should be on shifting from developing products to developing complete solutions on application and thus behavioral level.

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1Coasting is using the kinetic energy of the truck when the driver neither uses the throttle, brake, nor the retarder of the truck [29].
The different levels in the possible contributions also require different levels of effort. The contributions discussed on product level are in this case relatively easy to implement. The contributions on system level, however, require more effort from the suppliers and also DAF since they need to be integrated in the truck as a system. It can be concluded that the contributions on system level and on application level in general match the higher sustainability levels as discussed in section 3.1.2. Sustainability is then more integrated in the strategy of the company and suppliers are more likely eager to think beyond their physical product and think of the integration as a whole. A company in a lower stage will put fewer effort in implementing CO₂ reducing contributions. In this way contributions on system and even application level are less likely to be achieved or even aimed for. Companies in lower stages of sustainability are less likely to think in solutions and thus will stay put on product level. However, as discussed the potential of CO₂ reduction is more likely on system and application level. Therefore, it is concluded that when a company is going through the different stages of sustainability, the company is more likely to make the switch from developing technical contributions towards behavioral contributions. Instead of thinking on product level the focus will be on designing solutions.

4.6 Conclusions

As seen in the contribution matrix in section 4.2 there are no contributions found in the area where only little effort is required in order to have a high CO₂ reduction. The only low effort contributions are the change to low resistance tires and implementing a Tire Pressure Monitoring System (TPMS). The empty area in the matrix is due to the fact that experts believe that the focus should not be on tangible adaptations to the truck. The main finding of this chapter is that the focus is shifting from contributions on product level towards solutions on system level and even a step further on application level. The focus shifts from technical tangible solutions to intangible solutions that have an impact on the behavior of the truck. However, the focus thus shifts into an area where DAF is less familiar and thus it is valuable to involve suppliers. The next chapter will elaborate on this insight. Furthermore when sustainability is more integrated into the company it will probably be more eager to think beyond product level.
Chapter 5

Supplier Engagement in CO2 Projects

The interviews showed that DAF is a fast follower in the truck market with respect to technology. A possibility to get new innovations into the company is to involve suppliers early in the new product development process, see section 3.3. However, the main contributions as seen in figure 4.2.1 might not directly be linked to the existing suppliers, except for tires. This makes it interesting to search for other suppliers that might come from non-automotive industries.

A second thought could be that the focal company and the supplier start a collaboration in order to find solutions for CO2 reductions. In order to engage suppliers and to see whether suppliers have innovations or technical solutions, DAF organizes 'Tech-days'. During these events (future) suppliers are invited to the focal company where they can present themselves with their newest and future innovations. The researcher believes that these kind of events are a good base to let suppliers show how they believe the CO2 emissions of a truck can be reduced. This applies not only for existing suppliers but also for suppliers that are completely new for DAF or even for the automotive industry. The following sections will elaborate on the insights discussed above and the chapter eventually will end with possible actions towards supplier involvement.

The table in figure 5.0.1 gives an overview of the actions for DAF or more specific, purchasing. Furthermore it shows the need to focus on system level since the contributions on product level have a relative low influence and in general the contributions on application level cannot be directly influenced by the focal company.
5.1 Supplier Tech-days

The researcher believes that it might be important for DAF to focus on suppliers that are not directly involved in the manufacture of a truck. This might lead to innovative solutions of which DAF or even the truck industry did not think of. Having workshops with suppliers that are not familiar in the truck industry, or even automotive industry, can lead to new insights since the supplier might have a different view or a fresh insight and perspective with respect to the purpose of a truck. This collaboration might be attractive since the objective of supplier involvement is to benefit from the skill and expertise of both parties. Holton (2012) recognizes cross-industry collaboration and discusses that the possibilities for innovation in this way might be limitless [48]. In this way both parties can develop their expertise in an area they are not familiar, but can be attractive opportunity wise. However, as discussed in the literature, it is important to be aware of the strategic objectives of the possible supplier with respect to sustainability in order for a sound collaboration towards innovation [52].

The Boston Consultancy Group published a report that state the most innovative companies of 2015 [71]. Among these companies a lot are not involved in the automotive industry and might have a complete different perspective on a truck, see figure 5.1.1. Noticeable is that, besides Tesla Motors, the main business of the most innovative companies is to develop and produce software and systems.
In order to arrange 'tech-days' focused on CO₂ reduction, DAF can ask from the supplier how the supplier believes to reduce the CO₂ emissions of a truck. For suppliers that are not familiar with a truck DAF could brainstorm with them for solutions as described in the previous chapter from section 4.3 and 4.4. It might make sense to have brainstorm sessions with companies that have a complete different view on a truck in order to create innovations that are out of the comfort zone for DAF, 'out of the box' thinking. For the development of Advanced Driver Assistance Systems (ADAS) such kind of events were already realized. However, the focus was not yet on CO₂ emissions or the VECTO tool.

In order to arrange more tech-days that have a green focus, the purchasing department should have a dedicated effort in involving the suppliers that possibly have technologies or solutions that can contribute to better performance of the truck with respect to CO₂ emissions. Thus for this thesis the term green is defined as either a focus on reduction of fuel or a reduction on CO₂ emissions. Purchasers can execute a supplier market analysis until phase 3 where green criteria can be used as described in section 3.3.2. Constraining criteria like cost and quality can be left behind for this SMA, which ensures there is a full focus on the solutions and creativity will not be hindered. Section 5.2 will elaborate on this aspect. Commodity groups like ‘Engine and Transmission’ and ‘Electrical and Electronic Systems’ in the purchasing department of DAF Trucks can play a significant role in finding (existing) suppliers that are suitable for the ‘tech-days’. These are the commodities that correspond with the most promising contributions as showed in figure 4.2.1 and 5.0.1. Since purchasing is the direct link with the suppliers purchasing plays an ever more important role. The department can and needs to contribute to the CO₂ reduction of the truck. After stressing the importance of the tech-days and using the knowledge and experience of suppliers with respect to sustainability, the following agenda is proposed in order to arrange the tech-days and to give a direction of focus.
There are tire suppliers in the market that are able to deliver a TPMS and this could be combined in one tech-day. In that case, the topic can be more general, namely rolling resistance. The rolling resistance topics are contributions that are relatively easy to realize. The contributions on system level will require more supplier involvement and more effort from DAF.

### 5.2 Green Supplier Criteria

The focus of the tech-days should be on the three contribution levels discussed in section 4, not particularly on product level, see section 4.3 and 4.4. However, it is important for DAF Trucks to keep in mind that the solutions on system level always need to be integrated into the truck. With suppliers or companies that are not familiar in the truck industry this might cost more effort. Before DAF decides to invite companies that can present their innovations there should be a pre-selection based on green supplier criteria that can determine whether the company has objectives with respect to sustainability. Criteria of such kind is discussed in the literature study, section 3.3.2. These criteria are chosen as a basis and are elaborated on in the following subsections. The final set criteria are further extended to the main topics of this thesis. The criteria focus on the contributions suppliers can make in order to reduce the CO\(_2\) emissions of the truck.

#### Green competencies

This criterion checks whether the supplier recognizes the importance of resolving sustainable issues and is capable of promoting environmental behavior. Furthermore it determines whether the supplier is able to meet the specified performance criteria demanded from participants in the sustainable supply chain [16]. As already mentioned it is important to be aware of the strategic objectives of the possible supplier with respect to sustainability in order for a sound collaboration towards innovation [52]. The green competencies of the supplier can...
be determined by comparing the supplier with the different stages of sustainability discussed in section 3.1.2. In this way it can determine the CSR maturity of the supplier. Criteria that can be considered are the following:

- CSR practices are performed by the supplier in its own processes.
- The supplier operates according to environmental laws and is in the possession of environmental management systems and certifications.
- To what extent does the supplier create audits to external companies?
- Sustainability is a part of the supplier’s strategy.

**Green design or R & D**

This criterion determines whether the supplier develops innovative green designs. It assesses whether the supplier is capable to develop solutions with respect to $CO_2$ reduction on at least one of the following contribution levels:

- Product level
- System level
- Application level

For a tech-day the OEM should decide on what level(s) solutions are required based on the contribution. Once decided what level is necessary, the OEM should determine whether the supplier is able to collaborate with the OEM to ensure that the solution will be well implemented in the truck.

Furthermore, within this criteria it should be determined whether the supplier uses technology and tools that can assist them in developing green designs and solutions. When the supplier is in possession of such tools this might testify that the supplier is willing to invest in sustainability and has experience in green design.

The table in figure 5.2.1 provides an overview of the proposed green supplier criteria:
5.3 The intermediate role of the purchasing department

Chapter 5 emphasizes the relationship between sustainability and supplier involvement where the purchasing department should have an intermediate role. This role can be defined as arranging tech-days as described in section 5.1 until selecting suppliers based on green supplier selection criteria, 5.2. The literature study of this thesis showed that an increase of sustainability into the organization needs more engagement of the purchasing department that should be able to ensure more supplier involvement. Supplier involvement might in turn lead to more innovative solutions towards sustainability. Hence, based on the outcomes, the following iterative cycle is proposed.
The innovations or contributions on system level need to be implemented in the truck. This requires effort from the supplier as well as from the Product Development department in DAF. Therefore, purchasing should secure a mediating role between the suppliers and Product Development, which further requires dedicated effort in order to ensure a solid relationship between purchasing and Product Development.

As seen in subsection 3.3.1, companies or suppliers can be involved in the very beginning of the new product development process where suppliers can deliver more complex systems. Therefore, the researcher recommends to involve the suppliers as soon as possible. Furthermore, since the focus should be on systems and solutions that are derived from 'out of the box' thinking with the supplier, it is also recommended to involve the supplier as described in the Gray Box or Black Box. Here, the supplier has a significant amount of input into the development. However, the joint development should be the key since the solutions need to be implemented in the complicated technology of a truck.

The focus on suppliers that can contribute to the reduction of $CO_2$ emissions can bring the company in the next stage of the sustainability levels as described in section 3.1.2. The position of DAF Trucks in these stages is discussed in section 2.3.3 and it is found that the current level is stage four. Implementing CSR performance measures in the procurement dashboard might bring the company to the next stage. Supplier selection criteria, Key Performance Indicators (KPI) for suppliers, and green 'tech' days are examples of topics that can be implemented or changed in the current procurement dashboard of buyers. Furthermore, DAF should think about adding a seventh main criteria in the SMA, named 'Environment & Sustainability'. Existing environment criteria in the current main criteria Quality & Environment can be replaced in 'Environment & Sustainability' and the new green selection criteria can also be integrated. All these changes in the procurement dashboard will give an extra dimension and a focus on sustainability.

5.4 Conclusions

This chapter discussed the importance of the purchasing department with respect to finding innovations and solutions that can reduce the $CO_2$ emissions of the truck on three levels. First, the focus is on the 'tech-days' that DAF is currently executing in order to give the suppliers the chance to show what their roadmap is. In this chapter it is recognized that expertise and knowledge exist at external companies and it supports the way of working of DAF by involving suppliers in the extent they do. However, this research gives a new focus for DAF to concentrate on. When organizing the 'tech-days' and involving the supplier there should be a focus on sustainability with respect to the three levels of contributions with a priority on system level. In this way the purchasing department is able to contribute in an intermediate way between suppliers and development. The purchasing department can use the green selection criteria in order to find companies or suppliers that are able to show DAF sustainable solutions. For this thesis the term green is defined as either a focus on reduction of fuel or a reduction on $CO_2$ emissions. Integrating green suppliers criteria, KPI's, and green tech-days into the current procurement dashboard will give an extra dimension and a focus on sustainability of the truck. Furthermore, another way of involving companies or other sources of knowledge is to maintain the relationship with universities, their student projects, and spin-off companies.
Chapter 6

Conclusion

The final chapter of this thesis will discuss the main findings and concluding insights. First, there will be a short reflection on the research questions with respect to the eventual results. Subsequently, the conclusions are summarized in the corresponding topics of this thesis. Furthermore, section 6.3 will give recommendations in the form of bullet points in order to provide a short overview of the possible implications for DAF and the heavy duty truck industry. Section 6.4 will elaborate on these bullet points. Finally, this chapter will conclude with the limitations of this thesis and provides recommendations for future research for DAF Trucks as well as for the literature.

6.1 Feedback on the Research Questions

The results derived from the interviews deviate from the question concerning the contributions towards carbon dioxide (CO$_2$). The goal was to find contributions towards CO$_2$ reduction on product level and thus the research was devised with this purpose. The findings relate to the truck however are subdivided into different levels. The focus of finding new contributions towards CO$_2$ reduction should be more on system level, aimed at designing solutions instead of products.

6.2 Conclusions

Corporate Social Responsibility

Section 3.1 shows that there are positive effects of implementing sustainability into an organization. Sustainability implementation might provide valuable partnerships, which results in sources of knowledge. This knowledge can in turn provide innovations. Since such relations are hard to imitate, they can be seen as a competitive advantage. Furthermore, literature states that implementing sustainable activities in the organization can increase (financial) performance [12], [69], [19]. Although the pressure from customers to be more sustainable is less than in the personal car industry, image with respect to the environment is increasingly important in the truck industry. Integration of sustainability needs to be implemented in the strategy of the company and this might take time. In addition, a possible cost increase at the start is unavoidable. Supply chain activities at DAF may have to be altered, however, DAF is well aware of the advantages such as decrease of internal costs. Therefore, DAF already
have implemented many of such activities in their organization, think about reduction of waste and lean production processes.

Before organizations become more mature with respect to sustainability or grow in their view on Corporate Social Responsibility (CSR), they go through six stages. Within this process the purchasing department makes a shift towards a more integrated purchasing department. The results of the first round interviews can be linked with the CSR stages of figure 3.1.2. Considering the requirements mentioned at each stage it can be concluded that currently DAF is operating in stage four. First, DAF implemented several sustainable activities in their supply chain that drove down internal costs and have positive effects on the environment. The various activities can be seen in figure 2.3.1. Second, they are aware of the urge to develop trucks that contribute as little as possible to the greenhouse gases. However, the reason that such kind of developments take place is mostly because of legislation and incentives from GO’s. In order for business to change there needs to be a demand from the customer. The need for a business case is multiple times mentioned, as can be seen in figure 2.3.1. The insights of the respondents with respect to the need for sustainability are shown in the row 'sustainable mindset'. Third, the initiatives reach to the purchasing department until a certain level. CSR performance measures for suppliers in the current procurement dashboard are limited to legal requirements. DAF does not completely fulfill the requirements for stage 5. According to the interviews there is not yet a fixed focus on sustainability. The following figure shows their position in sustainability adoption:

![Figure 6.2.1: The CSR maturity of DAF Trucks NV.](image)

**CO2 Reduction Contributions**

The second topic of this thesis was about the possible technical contributions an OEM can make in order to reduce the CO₂ emissions of the truck. The focus was on the five dimensions that deviates from the concept of fuel-use, since this is proportional with CO₂ emissions. Also the VECTO tool obtains input out of these dimensions. The results of the interviews claim that the focus should not be on contributions that are based on the commodities of the truck. In order to reduce CO₂ emissions more effectively, one must think in solutions. Figure 4.5.1 shows that contributions on the vehicle can be divided on three levels, namely product level, system level, and application level where the focus shifts from technical contributions to behavioral contributions. DAF should focus on system level since this ensures the highest
impact that DAF can influence. Contributions on application level might be out of reach for DAF as incentives and also demand are mostly initiatives from GOs.

DAF is aware that the VECTO tool, which calculates the CO$_2$ emissions on product level, will empower customers to compare customized offers and choose the most fuel-efficient vehicle. The outcome of the VECTO tool thus can be a deciding factor for the customer to choose one truck or another.

![CO$_2$ reduction roadmap](image)

**Figure 6.2.2: CO$_2$ reduction roadmap**

Figure 6.2.2 shows the contributions that DAF can focus on in the upcoming years. These contributions are based on the findings from the interviews with external experts as discussed in [4]. In order to reduce CO$_2$ emissions as fast as possible DAF could focus on the rolling resistance and change tires for low resistance tires and implement a Tire Pressure Monitoring System (TPMS). After the contributions with low effort are realized, DAF can focus on the contributions that require a sound integration in the truck, for example integrating driver assistant systems. Since it is hard for DAF to focus on the application level as described in the previous paragraph, the contributions are not included in the figure. However, it is expected that the alternative fuels like CNG and LNG are a good replacement for diesel on the long haul application and hybrid solutions for urban applications. Some interviewees were critical towards full electric vehicle in the heavy duty industry and especially on the long haul application. However, there is the possibility that the battery industry would develop in such a way that full electric driving will be applicable for a truck-trailer combination.

In general, the contributions on system and application level match the higher sustainability levels a company goes through when implementing sustainability. A company in the lower stages of sustainability will put fewer effort in implementing CO$_2$ reducing contributions.
Contributions on system and application level are less likely to be aimed for.

**Supplier Involvement**

Organizations are increasingly dependent on knowledge and expertise of external parties. In order to find innovative solutions for CO$_2$ reduction suppliers can be involved into the product development process. Literature shows that an increase of sustainability in an organization needs more engagement of the purchasing department, which in turn should be able to ensure more supplier involvement. Supplier involvement might in turn lead to more innovative solutions towards sustainability.

Furthermore, a recommendation of this research project is to connect with non-automotive suppliers that DAF does not think of in the first place. Both sides can develop expertise in an area that they are not familiar with and thus can be attractive opportunity wise. It is important, however, to be aware of the strategic objectives of the possible supplier with respect to sustainability in order for a sound collaboration towards innovation. The results will be limited when the supplier does not have the mission to develop sustainable innovations. In order to select suppliers for a green tech-day some possible green selection criteria are created. The criteria are focused on the contributions that suppliers can make in order to reduce the CO$_2$ emissions of the truck. Thus, for this thesis the term green is defined as either a focus on reduction of fuel or a reduction on CO$_2$ emissions. DAF can execute a small Supplier Market Analysis (SMA) in order to find companies that can provide innovative solutions. In order to maintain creativity it is important not to constrain the search with criteria on costs and quality from the start.

Finally, this research project gives several insights that can alter the current purchasing dashboard. An overview of the possible changes to the purchasing dashboard can be seen in section 6.3, figure 6.3.1.

### 6.3 Recommendations

The following bullet points require attention or implementations.

- Communicate the current sustainable activities in the processes to the market in order to create a competitive advantage. This might be a next step with respect to sustainability and the company’s image.

- There should be a bigger focus on CO$_2$ reduction of the truck in the use-phase on product level, system level, and application level.

- Invite and involve companies for green tech-days that have experiences in non-automotive industries since cross-industry collaboration might lead to new innovations.

- Since the contributions on system level seem to have the highest impact, within the span of control of DAF, it would be interesting to see how these contributions relate in the VECTO simulation tool.

- In order to implement the innovative solutions derived from suppliers, there needs to be a dedicated effort in the collaboration between Product Development and Purchasing: Supplier Technical Engineering.
• Integrate CSR performance measures in DAF’s purchasing dashboard. Think about integrating green supplier criteria into the SMA and make it part of the main criteria topics. The table in figure 6.3.1 gives an overview of the different topics that can be added to the current procurement dashboard of the purchaser.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution level</td>
<td>Think out of the box on the following levels:</td>
</tr>
<tr>
<td></td>
<td>• Product level</td>
</tr>
<tr>
<td></td>
<td>• System level</td>
</tr>
<tr>
<td></td>
<td>• Application level</td>
</tr>
<tr>
<td>Contribution grid</td>
<td>Possible contributions towards CO₂ reduction:</td>
</tr>
<tr>
<td></td>
<td>• Low resistance tires</td>
</tr>
<tr>
<td></td>
<td>• Tire pressure monitoring system</td>
</tr>
<tr>
<td></td>
<td>• Advanced Driver Assistant systems (ADAS)</td>
</tr>
<tr>
<td></td>
<td>• Alternative fuels</td>
</tr>
<tr>
<td></td>
<td>• Hybrid</td>
</tr>
<tr>
<td></td>
<td>• Fully electric driving</td>
</tr>
<tr>
<td>Green supplier criteria</td>
<td>Recognition of importance of sustainable issues:</td>
</tr>
<tr>
<td></td>
<td>• CSR practices are performed by supplier</td>
</tr>
<tr>
<td></td>
<td>• Suppliers operates according to environmental laws and possesses EMS and certifications</td>
</tr>
<tr>
<td></td>
<td>• Supplier executes external audits</td>
</tr>
<tr>
<td></td>
<td>• Sustainability is part of supplier’s strategy</td>
</tr>
<tr>
<td></td>
<td>The supplier develops green product designs:</td>
</tr>
<tr>
<td></td>
<td>• Asses with the contribution levels</td>
</tr>
<tr>
<td></td>
<td>• Supplier is able to integrate solution in the systems of the truck</td>
</tr>
<tr>
<td></td>
<td>• Supplier uses technology and tools that contributes to development of green design</td>
</tr>
<tr>
<td>Tech-days</td>
<td>Known suppliers:</td>
</tr>
<tr>
<td></td>
<td>Delphi, Valeo, Mentor Wabco, Denso</td>
</tr>
<tr>
<td></td>
<td>Unknown suppliers:</td>
</tr>
<tr>
<td></td>
<td>Microsoft, Google, IBM, Philips, ASML, Dassault Systèmes</td>
</tr>
<tr>
<td>KPI</td>
<td>• Include a KPI that calculates the possible impact on VECTO</td>
</tr>
<tr>
<td></td>
<td>• Suppliers compared to green criteria</td>
</tr>
<tr>
<td>SMA main criteria</td>
<td>Include a 7th main criteria in the VECTO named Environment and Sustainability. Include the green supplier criteria.</td>
</tr>
</tbody>
</table>

Figure 6.3.1: Proposed topics and actions for a new procurement dashboard

6.4 Implications for DAF Trucks NV.

Based on the interviews held, it seems that the company practices many sustainable activities in their processes, however the impression exists that DAF is very reserved in communicating this to the market. With respect to sustainability the author believes that this would be a next step since this might have a positive impact in the image of DAF as a green company.

The type of supplier that matches the results from the contributions in this thesis is the tire supplier that can have a small impact on the CO₂ reduction by providing low resistance tires. According to literature and ACEA low resistance tires deliver up to 3 to 4 % CO₂ reduction, however, such tires also have disadvantages. Other parts like gearboxes are only a small part in the CO₂ reduction or need to be implemented on system level in order to
profit from CO₂ reduction. Results of the analysis show that the contributions that have the most impact on CO₂ reduction are contributions that need supplier involvement and more importantly, collaboration.

In order to get familiar with innovations currently evolving on the market or at suppliers, DAF organizes tech-days that give suppliers the opportunity to show their developments. It is recommended to invite and involve companies for green tech-days that have experiences in non-automotive industries since cross-industry collaboration might lead to new innovations. In order to find these organizations DAF can execute a search in the form of a small Supplier Market Analysis (SMA) with green supplier criteria, as discussed in 3.3.2. This can be focused on finding suppliers that are able to provide solutions on system level designed to reduce the CO₂ emissions of the truck. In order to keep the innovation and creativity as high as possible, cost criteria should not be implemented yet.

On top of the CSR performance measures in their current purchasing dashboard DAF can integrate measures that are designed to find, assess, and select suppliers. DAF can also think about integrating green supplier criteria into the current SMA and make it part of the main criteria topics. In order to create awareness for sustainability in the purchasing department DAF can think about adding a seventh main criteria in the SMA, named 'Environment & Sustainability'. Existing environment criteria in the current main criteria 'Quality & Environment' can then be replaced in 'Environment & Sustainability' and the new green selection criteria can also be integrated. It is important that the weights of the criteria should be well considered. Integrating green supplier criteria, KPI’s, and green tech-days into the current procurement dashboard will give an extra dimension and a focus on sustainability of the truck.

Furthermore, the researcher believes that maintaining relationships with universities can be favorable to be up to date of starting innovations from student projects, start-ups, or spin-offs, just like Cooper (2008) describes in his 'Open Innovation' model [25]. Think about the relationship with the Technical University of Eindhoven. As described in section 3.2 such relationships provides assets that can be seen as rare and valuable and are hard to imitate. This might bring a competitive advantage.

The final point of attention is the way contributions on system and application level are implemented in the VECTO tool. Since these contributions seem to have the largest impact it would be interesting for DAF to see whether they can have an impact on the results of the VECTO. Think about the input parameter of Eco-technology. The results of the VECTO tool might be a reason for customers to choose a DAF truck instead of a competitor.

### 6.5 Limitations & Future Research

Sustainability needs to be implemented into the strategy of the company to fully benefit from the advantages. This thesis only provides a minor part to being more sustainable, however, in an organizational culture like DAF Trucks the right way is to take small steps towards a bigger goal. Therefore, more research should be done in the topic of sustainability in the (commercial) automotive industry since it is still a very dynamic subject. This is a reason why this thesis is exploratory. Although this thesis provides well-thought insights it does not provide a designed solution for DAF.

The thesis is based on a problem statement that is particularly for the heavy truck industry. Besides this, the starting point was an interview round with respondents that are employed
at DAF trucks and based on these interviews, several recommendations are made. This is a case study for DAF and thus readers should be careful to apply recommendations or solutions to other organizations.

In order to generalize the thesis, and especially section 2.3.3 and chapter 4 further research should have a wider focus on one or more organizations. This can be achieved by executing interviews at other automotive heavy duty industry. The lack of focus on demand and sustainability especially exists in the commercial vehicle industry. More research on this topic can give a deeper insight in the position of OEMs with respect to this thriving topic.

Although there is abundant research on reduction of $CO_2$ emissions with respect to GHG within supply chains, little research has been done on the impact of suppliers with a sustainable mindset on product development. Furthermore, more research can be done in order to show whether creating a sustainable image can have a positive impact on the performance of an organization in the automotive industry, especially in the commercial vehicle industry. Using a survey makes it possible to reach for a bigger group of respondents and maybe also from different companies. In this way the results can be generalized more easily.

During this research project it is tried to give an insight on contributions with respect to $CO_2$ reduction on product level. Instead of finding new contributions this research found that the focus should not only be on product level but also on system and application level. More research should be done on finding contributions that are attractive to OEMs in the heavy truck industry with respect to costs but also have a significant effect on $CO_2$ reduction.
Bibliography


[27] DAF Trucks N.V. Attention to the environment as a matter of course, 2015.


[36] European Commission. Communication from the commission to the european parliament, the council, the european economic and social committee and the committee for the regions. Official Journal of the European Union, 2011.

[37] European Commission. Roadmap to a single European transport area - Towards a competitive and resource efficient transport system, 2011.


Chapter 7

Appendix

7.1 Appendix A

7.1.1 Interview guidelines and questions

Purchasing

Table 7.1.1: 1st round interview guidelines purchasing

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comments/Questions</th>
<th>Approximate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Brief the participant. Introduce self. Explain goals of interview. Review interview method, use of data, confidentiality, etc. Introduction CO2 Declaration.</td>
<td>5 min</td>
</tr>
<tr>
<td>General questions and open dialogue with participant.</td>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td>Closing comments.</td>
<td></td>
<td>5 min</td>
</tr>
</tbody>
</table>
Q1: What is your definition of sustainability in your field of experience?  Wat is uw definitie van Sustainability in supply chains?

Introduction Sustainability (TBL)

Q2: Can you describe the role that DAF Trucks has within the current HDV sector? In the Netherlands? Globally? Kunt u de rol beschrijven die DAF Trucks speelt in de HDV sector? In Nederland? Global?

Q3: Which stakeholders have influence on your organization? How? Are there many (conflicting) pressures from stakeholders? Can you give examples? Intro stakeholders; zijn er partijen/stakeholders volgens u die DAF beïnvloeden? Voeren deze druk uit op DAF? Kunt u voorbeelden geven? (Huidige situatie)

Q4: What tools are applied to address sustainable processes in your organization? Hoe wordt sustainability doorgevoerd wanneer u kijkt naar interne huidige (inkoop/ontwikkelings) processen? (huidige situatie)

Q5: To what extent are you knowingly occupied with CSR activities during work time? In welke mate bent u volgens u bewust bezig met CSR activiteiten tijdens uw werkzaamheden? (huidige situatie)

Q6: What is your view upon sustainability with respect to SRM? and with respect to supplier involvement? Hoe kijkt u aan tegen sustainability tov SRM? (denkwijze) en hoe zit het met supplier involvement? Worden daar maatregelen getroffen tov sustainability? (huidige situatie)

Q7: In what scope occurs sustainability within the organization? And in your organization? Wat is de scope waarin sustainability voorkomt? (huidige situatie)

Q8: Do you see any reasons not to implement/perform sustainable processes for DAF? Heeft DAF te maken met onzekerheden die komen kijken bij het uitvoeren/implementeren van sustainable processen?

Q9: What is your view on the upcoming CO2 declarations? What are your expectations? Hoe kijkt u tegen de aankomende CO2 declaraties? Wat zijn uw verwachtingen? (denkwijze)

Q10: Are there, according to you, any more subjects to discuss that are of importance? Zijn er volgens u nog onderwerpen die van belang zijn om te bespreken?
### Advanced Technology

#### Table 7.1.2: 1st round interview guidelines Advanced Technology

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comments/Questions</th>
<th>Approximate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Brief the participant. Introduce self. Explain goals of interview. Review interview method, use of data, confidentiality, etc. Introduction CO2 Declaration.</td>
<td>5 min</td>
</tr>
<tr>
<td>General questions and open dialogue with participant.</td>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td>Closing comments.</td>
<td></td>
<td>5 min</td>
</tr>
</tbody>
</table>

Q1: What is your definition of sustainability in your field of experience? **Wat is uw definitie van Sustainability in product development? (denkwijze)**

Introduction Sustainability (TBL)

Q2: Can u describe the role that DAF Trucks has within the current HDV sector? In the Netherlands? Globally? **Kunt u de rol beschrijven die DAF Trucks speelt in de HDV sector? In Nederland? Global? (Huidige situatie)**

Q3: Which stakeholders have influence on your organization? How? Are there many (conflicting) pressures from stakeholders? Can you give examples? How can they be resolved? **Intro stakeholders; zijn er partijen/stakeholders volgens u die DAF beinvloeden? Voeren deze druk uit op DAF? Kunt u voorbeelden geven? (Huidige situatie)**

Q4: What tools are applied to address sustainable processes in your organization? **Hoe wordt sustainability doorgevoerd wanneer u kijkt naar interne huidige (inkoop/ontwikkelings) processen? (huidige situatie)**

Q5: To what extent are you knowingly occupied with CSR activities during work time? **In welke mate bent u volgens u bewust bezig met CSR activiteiten tijdens uw**
werkzaamheden? (huidige situatie)

Q6: What is your view upon sustainability with respect to SRM? and with respect to supplier involvement? Hoe kijkt u aan tegen sustainability mbi early supplier involvement? Worden daar maatregelen getroffen tov sustainability? (huidige situatie)

Q7: In what scope occurs sustainability within the organization? And in your organization? Wat is de scope waarin sustainability voorkomt? (huidige situatie)

Q8: Do you see any reasons not to implement/perform sustainable processen voor DAF? Heeft DAF te maken met onzekerheden die komen kijken bij het uitvoeren/implementeren van sustainable processen? Q9: What is your view on the upcoming CO2 declarations? What are your expectations? Hoe kijkt u tegen de aankomende CO2 declaraties? Wat zijn uw verwachtingen? (denkwijze)

Q10: Are there, according to you, any more subjects to discuss that are of importance? Zijn er volgens u nog onderwerpen die van belang zijn om te bespreken?

Product Planning

Table 7.1.3: 1st round interview guidelines Product Planning

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comments/Questions</th>
<th>Approximate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Brief the participant. Introduce self. Explain goals of interview. Review interview method, use of data, confidentiality, etc. Introduction CO₂ Declaration.</td>
<td>5 min</td>
</tr>
<tr>
<td>General questions and open dialogue with participant.</td>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td>Closing comments.</td>
<td></td>
<td>5 min</td>
</tr>
</tbody>
</table>

Q1: What is your definition of sustainability in your field of experience? Wat is uw definitie van Sustainability (in Product Planning)? (denkwijze)
Introduction Sustainability (TBL)

Q2: Can u describe the role that DAF Trucks has within the current HDV sector? In the Netherlands? Globally? Kunt u de rol beschrijven die DAF Trucks speelt in de HDV sector? In Nederland? Global? (Huidige situatie)

Q3: Which stakeholders have influence on your organization? How? Are there many (conflicting) pressures from stakeholders? How can they be resolved? Intro stakeholders; zijn er partijen/stakeholders volgens u die DAF beinvloeden? Voeren deze druk uit op DAF? Kunt u voorbeelden geven? (Huidige situatie)

Q4: What tools are applied to address sustainable processes in your organization? Hoe wordt sustainability doorgevoerd wanneer u kijkt naar interne huidige (inkoop/ontwikkelings/product planning) processen? (huidige situatie)

Q5: To what extent are you knowingly occupied with CSR activities during work time? In welke mate bent u volgens u bewust bezig met CSR activiteiten tijdens uw werkzaamheden? (huidige situatie)

Q6: Do you see any reasons not to implement/perform sustainable processen voor DAF? Heeft DAF te maken met onzekerheden die komen kijken bij het uitvoeren/implementeren van sustainable processen?

Q7: What is your view on the upcoming CO2 declarations? What are your expectations? Hoe kijkt u tegen de aankomende CO2 declaraties? Wat zijn uw verwachtingen? (denkwijze)

Q8: Are there, according to you, any more subjects to discuss that are of importance? Zijn er volgens u nog onderwerpen die van belang zijn om te bespreken?
### Eco-design

#### Table 7.1.4: 1st round interview guidelines Eco-design

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comments/Questions</th>
<th>Approximate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>Brief the participant. Introduce self. Explain goals of interview. Review interview method, use of data, confidentiality, etc. Introduction CO₂ Declaration.</td>
<td>5 min</td>
</tr>
<tr>
<td><strong>General questions and open dialogue with participant.</strong></td>
<td></td>
<td>10 min</td>
</tr>
<tr>
<td><strong>Closing comments.</strong></td>
<td></td>
<td>5 min</td>
</tr>
</tbody>
</table>

Q1: What is your definition of sustainability in your field of experience? Wat is uw definitie van Sustainability (in Eco-design/development)? (denkwijze)

Introduction Sustainability (TBL)

Q2: Can u describe the role that DAF Trucks has within the current HDV sector? In the Netherlands? Globally? Kunt u de rol beschrijven die DAF Trucks speelt in de HDV sector? In Nederland? Global? (Huidige situatie)

Q3: Which stakeholders have influence on your organization? How? Are there many (conflicting) pressures from stakeholders? Can you give examples? How can they be resolved? Intro stakeholders; zijn er partijen/stakeholders volgens u die DAF beinvloeden? Voeren deze druk uit op DAF? Kunt u voorbeelden geven? (Huidige situatie)

Q4: What tools are applied to address sustainable processes in your organization? Hoe wordt sustainability doorgevoerd wanneer u kijkt naar interne huidige (inkoop/on- twinkelings/product planning) processen? (huidige situatie)

Q5: To what extent are you knowingly occupied with CSR activities during work time? In welke mate bent u volgens u bewust bezig met CSR activiteiten tijdens uw werkzaamheden? (huidige situatie)
Q6: What is your view upon sustainability with respect to SRM? and with respect to supplier involvement? **Hoe kijkt u aan tegen sustainability mbt early supplier involvement?** Worden daar maatregelen getroffen tov sustainability? (huidige situatie)

Q7: Do you see any reasons not to implement/perform sustainable processen voor DAF? **Heeft DAF te maken met onzekerheden die komen kijken bij het uitvoeren/implementeren van sustainable processen?**

Q8: What is your view on the upcoming CO2 declarations? What are your expectations? **Hoe kijkt u tegen de aankomende CO2 declaraties? Wat zijn uw verwachtingen?** (denkwijze)

Q9: Are there, according to you, any more subjects to discuss that are of importance? **Zijn er volgens u nog onderwerpen die van belang zijn om te bespreken?**

7.1.2 Interview guidelines and questions Round 2

eexternal experts

<table>
<thead>
<tr>
<th>Activity</th>
<th>Comments/Topics</th>
<th>Approximate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Brief the participant. Introduce self. Explain goals of interview. Review interview method, use of data, confidentiality, etc. Introduction CO₂ Declaration and background project</td>
<td>5 min</td>
</tr>
<tr>
<td></td>
<td>General questions and open dialogue with participant.</td>
<td>10 min</td>
</tr>
<tr>
<td></td>
<td>Closing comments.</td>
<td>5 min</td>
</tr>
</tbody>
</table>

Q1: What is your definition of sustainability in the truck industry? **Wat is uw definitie**
of visie van Sustainability in de truck industrie?

Q2: (QR01) How do you see the future 'green' truck industry (with respect to \( CO_2 \) emissions)? Wat is uw perspectief op de toekomstige 'groene' truck industrie, en mbt \( CO_2 \) emissies?

Q3: (QR01) Do you think that there is already a demand from the customer for a greener truck? why (not)? Denkt u dat er al vraag is vanuit de klant naar een 'groene' truck? Waarom (niet)?

Q4: (QR01) When do you think there is the need to focus on \( CO_2 \)? Wanneer denkt u dat het noodzaak is om op \( CO_2 \) te focussen?

Q5: What parts of the truck are most promising for reducing the \( CO_2 \) emissions?/What kind of contributions are imaginable? Welke commodities van de truck kunnen volgens u het meest bijdragen om de \( CO_2 \) te reduceren? Welke bijdragen zijn volgens u mogelijk?

Q6: What do you think of supplier involvement with respect to contributions towards \( CO_2 \) emission reduction of the Truck?/How do you think that suppliers can contribute to \( CO_2 \) reduction of the truck with respect to materials or know-how? Wat denkt u van SI mbt het reduceren van \( CO_2 \) emissies van de truck?/Hoe denkt u dat suppliers kunnen bijdragen aan de \( CO_2 \) reductie, denkend aan materialen en know-how?

Q7: Are there, according to you, any more subjects to discuss that are of importance? Zijn er volgens u nog onderwerpen die van belang zijn om te bespreken?

7.1.3 Protocol Interview Round 2 and Results

In order to make an overview of the results derived from the interviews held in round 2, the following topics are used:

- Future perspective
- Cases
- Commodities
- Contributions
- Intangible solutions
- Priority
- Comments

7.2 Appendix B

7.2.1 Communication towards respondents

E-mail:
betreft: Interview voor onderzoek naar leveranciersselectie

Beste,
Sinds 3 augustus ben ik begonnen aan mijn afstudeerscriptie aan de Technische Universiteit in Eindhoven. Ik voer mijn onderzoek uit op de afdeling Purchasing in de groep Projects onder begeleiding van Adriaan Knobbe. De vraag van mijn onderzoek leidt uit het project dat momenteel loopt betreft de CO2 declaratie. Het doel van de initiatief nemer, de europese commissie, is om een certificatie systeem op te stellen voor brandstof verbruik en CO2 emissies. Met behulp van een simulatietool zal bij elke truck die de band af rolt een certificaat meegeleverd worden afhankelijk van de samenstelling van de truck. De simulatietool die hiervoor gebruikt wordt heet VECTO en is ontwikkeld in samenwerking met TU Graz. Ik zal voor DAF onderzoek doen welk effect dit nieuwe certificatie systeem heeft op de selectie en beoordeling van leveranciers. Tijdens dit onderzoek zal ik interviews afnemen en hoop van harte dat u mij hierbij kunt helpen. Het \(\pm 45\) minuten durende interview zal opgenomen worden in verband met de betrouwbaarheid van het onderzoek. De informatie die u vrij geeft wordt vertrouwelijk en anoniem behandeld.

Ik hoor graag of en wanneer het u schikt.

Met vriendelijke groet,

Niek van den Berge +31610073593