MÄLARDALEN UNIVERSITY
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School of Business, Society and Engineering

THE PROCESS OF OBD CERTIFICATION

A Comparative Study Between Euro VI and CARB

Master Thesis
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ABSTRACT

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Title: The process of OBD certification – a comparative study between Euro VI and CARB

Keywords: On-Board-Diagnostics, certification process, EURO VI, CARB, heavy-duty engines, organisational change, coordination, distribution of responsibility.

Supervisor: Roland Hellberg (MDH) & David Rodríguez (Scania)

Purpose: The purpose of this study is to compare the legal requirements for Euro VI and CARB regarding OBD certification in order to identify the challenges that may come for a manufacturer's move from Euro VI classified heavy-duty engines to engines that meet the requirements of CARB. Furthermore, the study also aims to identify the effects that these challenges will have on the organisation.

Research question: What type of challenges arise for a manufacturing company when developing an OBD certification process according to the requirements from CARB compared to Euro VI and how do these challenges affect the organisation?

Method: The nature of this study was qualitative with a deductive method as an approach, where theories and empirical findings interacts. The theoretical framework is divided into two parts, in which the first part is obtained from scientific articles and books and the second part from legislations. The empirical data was gathered from interviews at a case study company and the information was thematically analysed.

Conclusion: This study concludes that the movement from Euro VI to CARB standards will result in comprehensive changes for a company's OBD process itself as well as organisational changes within the company. There will be a need to establish new processes and new ways of working within the organisation which can lead to comprehensive coordination difficulties that should be taken into consideration. In conclusion, it is as important to consider the effects of the changes that this movement will bring on the company and the actors within, as it is with the implementation of the process itself.

SAMMANFATTNING

Datum: 2019-06-04

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Nyckelord: On-Board-Diagnostics, certifieringsprocess, EURO VI, CARB, tunga fordon, organisationsförändring, koordination, ansvarsfördelning.

Handledare: Roland Hellberg (MDH) & David Rodríguez (Scania)

Syfte: Syftet med denna studie är att jämföra lagkraven för Euro VI och CARB angående OBD certifieringen och därmed identifiera de utmaningar som kan uppstå i och med övergången från Euro VI klassificerade motorer till motorer som uppfyller kraven från CARB. Vidare syftar studien även till att undersöka hur dessa utmaningar påverkar organisationen.

Forskningsfråga: Vilka utmaningar uppstår för ett tillverkande företag vid utveckling av en OBD certifieringsprocess enligt lagkrav från CARB i jämförelse med Euro VI och hur påverkar dessa utmaningar organisationen?

Metod: Denna studie är av en kvalitativ karaktär som är baserad på en deduktiv forskningsmetod. Den teoretiska referensramen är uppdelat i två sektioner, vari den första är baserad på vetenskapliga artiklar och böcker och den andra från lagkrav. Empiriska data har samlats från intervjuer på fallstudieföretaget och metoden som har använts för att analysera materialet är tematisk analys.

Slutsats: Denna studie konkluderar att övergången från Euro VI till CARB lagkrav resulterar i omfattande förändringar för företagets OBD process och bringar organisationsförändringar inom företaget. Det kommer att finnas ett behov av att etablera nya processer och nya arbetssätt inom organisationen som kan leda till omfattande samordningsproblem som bör has i åtanke. Sammanfattningsvis är det av yttersta vikt att ta hänsyn till de organisationsförändringarna som förväntas uppstå i och med denna förändring och inte enbart fokusera på att implementera en ny process.

PREFACE

This master thesis is a part of the Master of Science program in Industrial Engineering and Management at the School of Business, Society and Engineering at Mälardalen University. During the time working with this thesis, our knowledge about the transportation industry has evolved and so has our interest. Thanks to this thesis work, we understand the function of an OBD system and the importance of it in today's vehicles.

First of all, we would like to thank Roland Hellberg, our supervisor at Mälardalen University, for the support and guidance he has given us during this study. Thank you for all of the interesting discussions and important inputs that you have provided us. To David Rodríguez, our supervisor at Scania, a big thank you for your time and encouragement and for providing us with the necessary guidance for completing this project.

To our respondents that have voluntary participated in this study, thank you. Without you and your valuable inputs, this study would not be. Our fellow students, thank you all for your valuable feedback and inputs to our study.

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Västerås, June 2019

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Mohammed Gaber *Shilan Anayati*

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1 INTRODUCTION

> "*Change is the only thing that will never change so let's learn to adopt by change management*" (Kansal & Chandani, 2014, p. 208).

We are constantly told how we live in times of change and factors such as globalisation, technological innovation and product renewal are occurring at an ever-accelerating rate. Simultaneously, the requirements of society are becoming increasingly tougher and the message to organisations is that they need to respond to these changing conditions for the sake of their survival. In light of this, change management has become crucial and there has been an explosive development of theories, models and concepts in the last decade with the intention of guiding companies through organisational change. (Alvesson & Sveningsson, 2012; Paul 2015) However, despite this, studies show that nearly 70% of change within organisations fail in practice. Authors are in disagreement over the reason behind this but one thing that they are in agreement of is the fact that change is inevitable, and the management of change is crucial for the survival of organisations. (Balogun & Hope Hailey, 2004; Kotter, 2008; Hughes, 2011)

One type of organisational change occurs as a result of the movement for a manufacturer selling vehicles in one market to another. When developing an engine for a vehicle there is a need for the engine to be certified according to the authorities wishes concerning emission standards. In order to show compliance to the regulations, manufacturers are required to test and certify their engines to demonstrate that their engine meets the regulations. The emission standards can differ between countries and is normally designed by the government in the country for achieving air quality standards and protecting human life. (California Air Resources Board, 2007)

Since 1996, many new vehicles are equipped with an On-Board-Diagnostics (OBD) systems, which is a self-diagnostics system that monitors nearly all components that might have an effect on the emission performance in a vehicle. The OBD system gives the vehicle owner access to the different systems within the vehicle and provides the vehicle owner with the possibility to identify malfunctions within the vehicle in an easy way. More important, the system makes sure that the emission is kept at a certain level according to the emission standards. (CARB, 2019)

The European Union has its own set of emissions standards that the OBD system on all new vehicles must fulfil. Approximately 90 percent of global vehicle sales are accounted for by the G-20[1] countries and nearly all of the members are following the European regulatory for control of vehicle emission. The European pathway involves six stages with the requirements

[1] The G20 (or Group of Twenty) is an international forum for the governments and central bank governors from 19 countries and the European Union. (Mustafa, 2017)

increasing accordingly, starting with Euro I in 1992 and developing on to the latest, Euro VI in 2015. These requirements are based on the UN ECE R49[2] requirements. (ICCT, 2016) The United States, however, enforces its own standard and does not follow the European regulatory. Instead the emission standards are set by the state of California's "clean air agency" California Air Resources Board (CARB). (EPA, 2017)

Both in the US and in markets using European regulatory standards, the OBD system in the vehicles are required to undergo a series of tests in which they are evaluated to ensure that they fulfil the regulatory standard in order for the vehicle to be approved for sales. In contrast to the European regulatory where the authorities have the responsibility to attend the test demonstrations and ensure that the OBD system meets the requirements, responsibility regarding meeting the requirements in the US market is placed upon the manufacturer. However, after an approval of certification, the authorities in the US are allowed to randomly check vehicles and examine whether the manufacturer has met the requirements or not. Consequently, the manufacturer's responsibility to ensure that a vehicle sold in the US market fulfils the requirements is vital. (Schweitzer et al., 2016)

1.1 Problematisation

As mentioned, there are many theories and concepts regarding organisational change and models that can be used for a successful implementation of change within an organisation. However, when it comes to organisational change as a result of regulation requirements from a specific market, the research is lacking. Due to the fact that there are many differences between the European and US regulatory regarding the process of OBD certification, an engine manufacturing company that desire to enter the US market would face many challenges. (Schweitzer et al., 2016) Consequently, for an easy-going transition, the movement from Euro VI classified heavy-duty engines to engines that can meet the emission standards of CARB requires adjustment of the current certification process and new ways of working within the organisation. Thus, this movement will result in organisational changes for a company and in order to accomplish a successful implementation it is desirable to have a knowledge regarding the differences between this processes and the impact that this movement will have on the organisation.

1.2 Purpose and research questions

The purpose of this study is to compare the legal requirements for Euro VI and CARB regarding OBD certification in order to identify the challenges that may come for a manufacturer's move from Euro VI classified heavy-duty engines to engines that meet the requirements of CARB.

[2] Regulation No 49 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles

Furthermore, the study also aims to identify the effects that these challenges will have on the organisation. In order to fulfil the purpose of this study the following question is answered:

- What type of challenges arise for a manufacturing company when developing an OBD certification process according to the requirements from CARB compared to Euro VI and how do these challenges affect the organisation?

1.3 The contribution of the study

This study is aimed to provide additional knowledge to the already existing research regarding organisational change and fill in the missing gap regarding organisational change as a result of change in regulation. This is a study that is meant to provide guidance for an organisation that will establish a new process to certify engines according to legislation from CARB. The outcome of this study is expected to benefit all manufactures worldwide with a desire to enter the US market with Euro VI as a current process as well as for further research about this subject.

1.4 Delimitation

An engine for a vehicle has several parts that need to be certified. This study, however, focuses on the certification process of the OBD system and the research is done to this aspect. Furthermore, the study is limited to study the OBD certification for heavy-duty vehicles, which according to European legislation is defined as freight vehicles of above 3.5 tonnes (European Commission, 2014). CARB, on the other hand, defines heavy-duty vehicles as 6.4 tonnes (CARB, 2019) and consequently, this study focuses on these definitions and do not consider other definitions of heavy-duty vehicles.

Further on, when studying the current OBD certification process the study is limited to focus on the latest emission standard Euro VI and not consider the earlier standards.

There are several different types of organisational change and how it comes about. However, the change that the company studied in this study is going through is characterized as ‘planned change’, which is the process of preparing the organisation for new goals or a new direction. Therefore, the theoretical framework in this study is focused on this topic.

2 THEORETICAL FRAMEWORK

This chapter presents the theoretical framework for this study, which has been divided into two parts. The first part covers the selected theories regarding organisational change and the second part covers the theoretical background and legislation concerning On-Board-Diagnostics.

2.1 The need for change in organisations

The fast-changing environment today requires that companies change and adapt accordingly in order to satisfy the need of customers. Population is increasing, technology evolves faster than ever and new products and services enter the market frequently. The global economy impacts companies in many ways and can result in an increased demand for products and services. Companies take advantages of this increased demand by expanding which can be by entering into a new market. Such change gives the employees as well as the organisation in general an opportunity to explore new ways of working efficiently and acquire new skills and change itself is key for achieving creativity and innovation within an organisation. (Richards, 2019)

As mentioned earlier, despite the fact that there are several models for achieving a successful organisational change, many attempts to change within in an organisation fail. However, most models are generalized and are not adjusted to a specific organisation and the factor behind the change. (Alvesson & Sveningsson, 2008) The characteristics of an organisation and their working process are important parameters in the changing process and should not be neglected. According to researchers, the management team is a central part in the changing process and channels for communication and distribution of information within the organisation is crucial to obtain a successful implementation. (Jacobsen & Torsvik, 2014)

Changes in strategies and working processes is something that all operative organisation will undergo during their lifetime. Organisations undergo vital changes in order to adapt to the new requirement set by customers and governments. To succeed with a change, a readjustment in the organisational structure might be a key parameter and the distribution of tasks must be taken into consideration. (Daft, 2013)

2.2 Managing organisational change

According to Cambridge Dictionary (2019), organisational change is:

> "A process in which a large company or organisation changes its working methods or aims, for example in order to develop and deal with new situations or markets."

Another description is that organisational change studies the process of change within an organisation as well as the affects that these changes may have on the organisation and is often a result of, or a response to, internal or external pressures. (MBN, 2019)

According to Burnes (2004) change is a constant process of an organisation and the ability to recognize the organisation's future and managing the changes necessary for getting there is a key aspect for a business to survive and thrive. This is further developed by Moran & Brightman (2001), who define change management as the approach for continuously renewing the structure of an organisation to meet the ever-changing needs of customers. The increasing importance of organisational change requires management skills (Senior, 2002) and Greatz (2000) argues that due to the constantly increasing speed of technological, political and regulatory changes, the leadership of organisation change is the key task for management.

There are several different types of change and characterisation of how it come about. The literature is dominated by planned change, which is the process of preparing the entire organisation, or a significant part of it, for new goals or a new direction (Sullivan, Kashiwagi, & Lines, 2011). This model was initiated in 1946 by Kurt Lewin, who suggested that for a change and process to be effectively adopted, the previous process has to be discarded. This comprises of three steps which involves unfreezing the current process, moving to the new level and then refreezing this new level. This model has since been developed by authors in order for it to be more practical. (Todnem By, 2005). Bullock and Batten (1985) have, from reviewing numerous models of planned change, developed a model which separates the process into four phases which an organisation needs to undergo for successfully implementing a change and is according to Burnes (2004) a valid model for change. The model includes the following four steps:

- Exploration – The organisation verifies the need for change and identifies what changes and resources are required.
- Planning - This phase is about understanding the problem. The organisation needs to clarify goals and objectives and identify specific activities required to undertake change.
- Action – The changes identified are agreed and implemented. The implementation is evaluated, and results are communicated and acted upon and wherever necessary, modifications are made.
- Integration – This phase involves stabilizing and embedding the change by continuously developing employees through education and training.

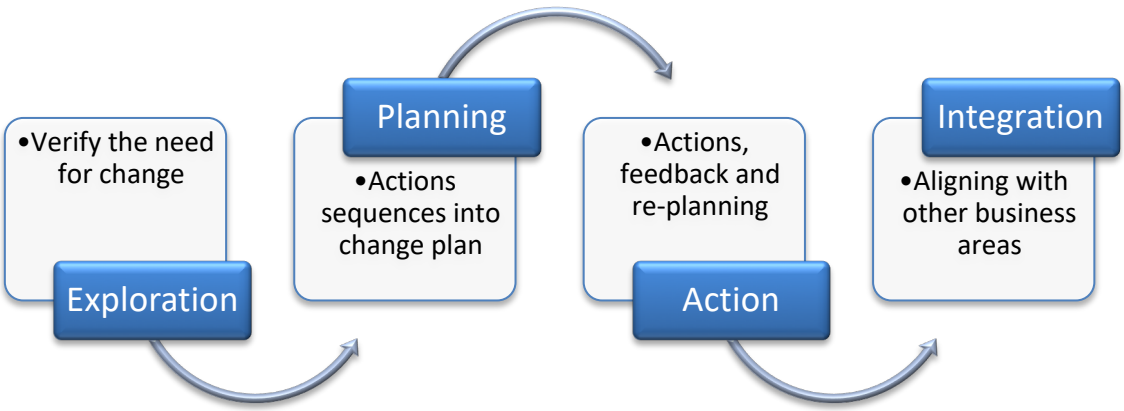

Figure 1. Bullock & Batten's four-phase model for successfully implementing change within an organisation (own construction).

2.2.1 The importance of coordination

In order for a change in the ways of working within a company to be successfully implemented, management of the dependencies amongst tasks and resources is required. Coordination theory can be used for studying developments of new processes. A fundamental characteristic of a process is how individual tasks are designed, broken down and assigned to actors, where coordination plays an essential role. (Malone, 1988)

In the case of redesigning a process, a vast variety of approaches exists, and the tasks can be divided in several different ways. Despite the fact that the general activity may be the same, the process of which the tasks are performed can differ significantly. (Malone, 1988) Malone (1988) further describes the importance details in how the tasks are broken down into activities and who is responsible for a specific activity can vary widely and thus the coordination of the process differs.

Coordination theory tells us that the dependencies that constrain how tasks can be performed cause coordination problems for actors in an organisation. These dependencies can be either inherent in how the task is structured (e.g., tasks that interact with each other can constrain the kinds of changes that can be made within a certain task without interfering with the functioning of others) or they may be the outcome from the breakdown of the goal into activities or the assignment of activities to actors and resources (e.g., two actors working on the same task can face constraints of the activities they perform without interfering with each other). (Malone, 1988) According to Malone and Crowston (1994), these coordination problems can be overcome by performing additional activities, which comprise what they call coordination mechanisms. An example of this is that before an actor can perform a certain task, the actor must first make sure that his actions do not affect other actors' activities. Similarly, two actors working on the same task must check with one another in order to not affect each other's work.

One of coordination theory's main claims is that dependencies and the management of these are generic. In other words, a certain dependency and the mechanism for managing it exists in a variety of organisational types. An activity that needs to be performed by an actor with a special kind of skill is a typical coordination problem which can restrain the flexibility of the distribution of tasks and this dependency between an activity and an actor is a common phenomenon within organisations. Another key claim is that a dependency can be managed by a number of coordination mechanisms. Similar goals within organisations can be fulfilled by performing similar activities and thus the same dependencies have to be managed. These dependencies can, however, be managed by using different kind of coordination mechanisms, therefore resulting in different processes. (Crowston, 1997)

These two claims indicate together that, by first identifying the dependencies along with the coordination problems within an organisation and then consider what alternative coordination mechanisms could be used to manage them, alternative processes can be developed. According to coordination theory there are two types of activities in a process: those that are necessary to achieve the goal of the process and those that serve for managing dependencies between resources and activities. (Crowston, 1997)

2.2.2 *Organisational responsibility*

Organisations in general consists of several individuals working separately or together in order to achieve stated organisational goals (Selznick, 1948). These organisational goals can be formulated to accomplish an obligation aimed for the whole group, also called collective obligation. The capacity of individual work is not enough to reach collective obligations. Instead it requires the entire group to cooperate, coordinate, communicate and negotiate with one and other in order to complete the collective obligation. Also, within an organisation sub goals are used frequently since these contribute to identification of those roles that occurs in an organisation. (Grossi & Dignum, 2003)

According to Selznick (1948), Morgenstern (1951) and Giddens (1984), the organisational responsibility structure contains three important dimensions which Gross & Dignum (2003) calls; control, power and information. These three objectives are related to basic organisational events, for example power is often described in relation to delegation of different activities, coordination asserts to be in relation with knowledge and control is generally related to recovery issues. These dimensions and their related activities are crucial for the general organisation performance. (Gross & Gidnum, 2003) In other words, power conduct the delegation of activities, the coordination structure shows in what ways the information is distributed within a company and in order to identify whether the organisational performance is kept stable or not, the control structure is studied. (Gross & Gidnum, 2003)

A subtask can be directly allocated to a role within an organisation and when an individual is assigned to the subtask in question, the individual is then said to be 'task-based responsible'. It is common that an individual within an organisation can be 'causally responsible' which means that the individual in question was delegated a subtask but perform an action that leads to a failure of the accomplishment of the subtask. An important aspect of the coordination structure is the information distribution. For example, if agent A delegate a subtask to agent B, then agent A is responsible to provide agent B with the knowledge needed in order to complete the task given. (Gross & Gidnum, 2003)

Suppose that agent A is a professor which means that he has a power relation with his PhD-students. The professor can therefore delegate his task (reviewing a study) to a PhD-student, agent B. Agent B is obligated to perform the task assigned to him, though he is not task-based responsible since it is not a task of the PhD-student. However, if the PhD-student refuses to evaluate the study he will therefore be causally responsible since he causes a delay of the reviewing process. Furthermore, as mentioned earlier the flow of information is a central aspect in the coordination relation. Such relation could be between the reviewers (professors) and the secretary at the academy. Suppose that the deadline for the reviews has been expedited, the secretary has to inform the professors about this matter. The secretary is causally responsible if the information was not distributed to him. Moreover, in this case the control relation is occurring between the secretary and the group of professors which means that if the professors do not manage to review the studies the secretary shall take control of the task. The reason to that is that if a control relation exists then the controller agent (the secretary) will have failure-based responsibility in those cases that the controlled agent (the professors) did not receive the information necessary. On the other hand, since the professor has an obligation to complete the reviews, he would be causally responsible. To summarize, these three

dimensions within the organisational structure; power, control and coordination have an important interaction for the distribution of the responsibility. (Gross & Gidnum, 2003)

2.3 Emission standards

Emission standards are used to set requirements for vehicle emissions and state the maximum permissible emissions of a number of different air pollutant for cars, trucks and buses. In order to sell these types of vehicles in a certain market, the requirements for the specific country has to be met. The emission standards differ for passenger cars, light- and heavy-duty vehicles. The limit points for an emission standard is determined by several years in advance and from a certain period it is forbidden to sell new cars that do not meet a certain emission standard. (DieselNet, 2019; Miljöfordon, 2018)

2.3.1 European emission standard

Europe first introduced emission standards for heavy-duty vehicle in 1988. From early on in the 1990s, new vehicles have had to meet the increasingly strict emission limits, known as the Euro emissions standards (see table 1). In 1992, the Euro I standard was introduced and applied to both truck engines and urban buses. Every few years new and stricter standards have been implemented and numerous countries have since developed regulations that are aligned with the European standards to a large extend. (Transportpolicy, 2018)

Table 1. EU emission standards for Heavy-Duty diesel engines (Steady-state testing) (own construction).

Stage	Year	CO *Carbon monoxide*	HC *Hydrocarbon*	NOx *Nitrogen oxides*	PM *Particle matter*
		g/kWh			
Euro I	1992	4,5	1,1	8,0	0,612
Euro II	1996	4,0	1,1	7,0	0,15
Euro III	2000	2,1	0,66	5,0	0,10
Euro IV	2005	1,5	0,46	3,5	0,02
Euro V	2008	1,5	0,46	2,0	0,02
Euro VI	2013	1,5	0,13	0,40	0,02

The European standards have undergone major revisions and changes when it comes to test conditions, duty cycles and methods of measurement. The Euro VI standard is the latest emission standard for heavy-duty vehicles and was introduced in 2013. It requires the greatest emission reductions of any previous stage along the European regulatory pathway. (ICCT, 2016)

As of the Euro IV standard, vehicles are required to be equipped with an On-Board-Diagnostics (OBD) system that notifies the driver in the case of a malfunction or deterioration of the

emission system that would result in emissions exceeding the limit. Furthermore, the system should also include an interface between the engine electronic control unit and other electrical or electronic systems in the vehicle that can affect the correct functioning of the emission control system. With the implementation of Euro VI, the OBD requirements increased stringently and several new performing monitor requirements were introduced. The latest standard also requires the OBD system to measure performance of emission control systems in use and to identify any system failures in an early stage. (DieselNet, 2018)

2.3.2 US emission standard

The federal emission standards for engines and vehicles in the US are established by the US Environmental Protection Agency (EPA). The procedure of how these standards are developed occurs in agreement with the US rulemaking process, in which regulations are published as proposed rules and after a period of public discussion, the rule is confirmed and signed into law. However, due to its pre-existing standards and the severe air pollution problems in the Los Angeles metropolitan area, the State of California has the authority to enforce its own emission regulations. These standards are often more stringent compared to the federal rules and are endorsed by the California Air Resources Board (CARB), a regulatory body within the California EPA. Since California is the only state with the right to establish its own emission regulations, other states can choose to either follow the federal emission standards or implement the stricter California standards. (DieselNet, 2016) Regardless, since the CARB regulations are more stringent and thereby covers both standards, many manufacturers choose to build their engines according to the CARB standards when delivering to the US. (Eldstein, 2017)

Table 2. California Emission Standards for Heavy-Duty Diesel Engines (own construction).

Year	CO *Carbon monoxide*	HC *Hydrocarbon*	NOx *Nitrogen oxides*	PM *Particle matter*
	g/bhp-hr			
Heavy-Duty Diesel Truck Engines				
1987	15,5	1,3	6,0	0,60
1991	15,5	1,3	5,0	0,25
1994	15,5	1,3	5,0	0,10
Urban Bus Engines				
1991	15,5	1,3	5,0	0,10
1994	15,5	1,3	5,0	0,07
1996	15,5	1,3	4,0	0,05

OBD systems have been required by CARB and applied in cars and light duty vehicles since the early 1990's and has later become mandatory for heavy-duty vehicles. The OBD system has

been fully integrated in the automotive industry and is since 2010 a mandatory part of the certification process of an engine in heavy-duty vehicles.

2.4 The development of the OBD system

An engine manufacturer has several requirements from authorities that has to be applied on the engine before installing it on a vehicle. On-board-diagnostics (OBD) is a system that is created to reduce emissions by monitoring the performance of several components in the engine. This computer-based system provides the vehicle the ability to self-diagnose as well as a capability of studying for repair purposes. (Geotab, 2017) OBD has been discussed and developed since 1960 and numerous of organisations have been involved in the groundwork for the standard of the OBD system, including the California Air Resources Board (CARB), the Society of Automotive Engineers (SAE), the International Organisation for Standardisation (ISO) and the Environmental Protection Agency (EPA). (Geotab, 2017)

Volkswagen introduced the first OBD computer-based system that had a scanning capability in 1968. Several engine manufactures created their own OBD system and integrated it in their own vehicles with their own connector types, their own unique electronic components and their own customized fault codes when studying failures. However, the SAE recommended in the late 1980s a standardisation of the OBD which have been integrated and distributed to the engine manufacturers. (Geotab, 2017) In 1996, an OBD system become mandatory for all engines manufactured or sold in the United States. The European version of OBD was introduced in the European Union (EU) in 2001 and became a requirement for all vehicles driven by gasoline and later on for all diesel vehicles. (Geotab, 2017)

The OBD system has a capability to study information about the Diagnostic Trouble Codes (DTC), which are codes that the car's OBD system use for alerting in case of an issue. Each code corresponds to a fault detected in the car and when the vehicle detects an issue, it will activate the corresponding trouble code. The main part of the vehicle covered by the OBD system are the powertrain (engine and transmission) and the emission control system. (Geotab, 2017) One of the key parts of an OBD system is Threshold Monitoring, which means that a warning light has to appear when the emissions increase which is valuable information for the driver who can check the engine before bigger malfunctions occur. (Wong, 2005)

The information provided by the OBD system is standardized which simplifies the service of the vehicle when a warning light appears. As soon as a malfunction is detected by the system, information about the non-functioning component is stored in a software, where the technicians can access the information using a scan tool and understand which part of the engine that needs service. The stored information can also be used by check inspectors when a vehicle is stopped for inspection. (Lyons, 2015)

The OBD system provides early detections of engine components that are not working as expected which can prevent total failure of a specific component. For example a detection of misfire could prevent a total failure of a catalyst that would otherwise need a replacement and cause big expenses. Also, the probability of unnecessary repairs is minimized since the fault

code gives information about the malfunctioning area or a specific component. This simplifies the technician's decisions and results in shorter service time. (Lyons, 2015)

2.5 OBD Certification Requirements for US and Europe

In the sections below, an overview of the requirements from Euro VI and CARB is given for giving an understanding of the central aspects of the requirements. The information is taken from the regulations for respective standard.

2.5.1 Euro VI requirements

The application process for approval of an OBD system within the European regulatory involves the manufacturer demonstrating to the Type Approval Authority (TAP) that the OBD systems meets the criterions listed in the regulation. An existing certificate can be modified to include a new engine if the system of that engine has common monitoring methods and diagnostician of emission-related malfunctions. The demonstration of the OBD system is organised and conducted by the manufacturer and in close cooperation with the TPA. (UNECE, 2019)

The manufacturer, in agreement with the TPA, selects an engine that can act as a representation of the rest to be demonstrated on and simultaneously presents information regarding the different malfunctions to the TPA. The TPA then selects at least four tests for the manufacturer to perform and present the results. (UNECE, 2019)

For an approval from the TPA, the manufacturer is required to hand in a documentation package describing the OBD system including the malfunction classification, the different engine types and information regarding the monitoring components and systems. This package shall be available in two parts: The first part is a formal package that shall give an overview over the functional operation of the OBD system and the malfunctions. The second part is more comprehensive and shall include any data and details concerning the system and components of the OBD as well as each monitoring strategy and decision process. This second part shall, unlike the first part which is retained by the TPA and available to interested parties, shall remain confidential and kept in the hands of the TPA. (UNECE, 2019)

An OBD system has a possibility of being approved despite containing deficiencies. A manufacturer can request for a system containing deficiencies to be approved. In order for the request to be approved, the TPA considers factors such as the technical feasibility and to what extent the OBD system will comply with the requirements as well as the manufacturer's efforts for correcting the deficiencies. The deficiency period is one year and cannot be renewed. However, if the manufacturer can prove that correcting the deficiency requires more time, the authority can approve for an additional year but not longer than three years. (UNECE, 2019)

2.5.2 CARB requirements

Unlike the process for Euro VI, the certification process according to CARB is defined as "self-certification" which means that the authorities in the US do not supervise the certification activity on site. Instead, the manufacturer is obligated to provide enough information, data, evidence and other necessary documents in order to prove to CARB that the application and the certification done for the specific engine meet all their requirements. (OAL, 2019)

Before a manufacturer can submit an application for an OBD certification, the Executive officer (EO) shall be notified about the dissimilarities between all engines within that model year. Thereafter, the EO will select a specific test engine that will act as a demonstration for all engine with similar qualities. In order to go through a certification process a manufacturer is obligated to submit emission test data from at least one demonstration test engine. For engines with model year 2016 and newer, CARB wants to ensure that the emission threshold limits are met during the vehicle's full useful life. In order to ensure this, the engine shall be tested by using a system that has undergone an aging process and the documentation of the testing process shall be studied to the EO for an approval. However, CARB allows the manufacturer to deteriorate some components electronically through a software manipulation. This allowance requires that the manufacturer can present to the EO that the results from these modifications are equal to the results from real life aged components. (OAL, 2019)

Furthermore, it is required that the components used for demonstrating testing must be provided to CARB when requested. CARB retains the right to perform confirmatory tests in order to verify the emission data submitted by the manufacturer. A manufacturer is obligated to, if requested by the EO, provide a test engine with its testing components in order to perform a test on the engine to ensure that the performance of the engine meet the standard requirements given by CARB. (OAL, 2019)

There are certain documents that a manufacturer has to submit when applying for a certification of an engine. For standardized documentation for the engines, a manufacturer may submit a set of documents that will work as a representation for the rest and shall submit these for each model year. However, if the documents are not standardized for all engines the manufacturer can consult with the EO regarding the submission of documentation which can act as a representation of all engines. This request is approved if the engine in question has the most stringent characteristics. Additionally, some requirements for documentation can be neglected if the required information is assumed to be unnecessary or redundant. (OAL, 2019)

Nonetheless, the OBD system on an engine can be certified even if the system does not fulfil all the specified requirement. However, even when approved the manufacturer can be charged with fines in specific situations and if deficiencies exist. These deficiencies require that the manufacturer must, for each model year, request an EO approval for deficiencies. Nevertheless, these deficiencies are not allowed to proceed for more than two model years unless the manufacturer can prove that the time required for correcting the deficiency exceeds two years. (OAL, 2019)

3 RESEARCH METHODOLOGY

This chapter describes the methodology of how this study has been conducted, starting with research process which gives an overview of the research and moving on the research approach and strategy for the case study and analysis. Finally, the validity, reliability and ethical considerations are discussed.

3.1 Research process

Blomkvist and Hallin (2015) argue that a research design outlines the way one approaches to conduct research and choosing the research design involves considering empirical data that should help in understanding a phenomenon. The choice of a research method is highly dependent of the nature of the problem formulation and also according to the purpose of the study (Mohd Noor, 2008).

The study began by reviewing the legalisation documents to gain an understanding regarding the OBD system and the two regulations, Euro VI and CARB for the purpose of gaining an insight of the context for this study. Further on, the study involved reviewing literature regarding organisational changes and the challenges that can come with it and followed by the empirical study. As such the working process of this study is similar to a deductive approach, where the theoretical framework controls the gathering of the empirical data and the theories are proven by testing the empirical data (Bryman & Bell, 2011).

Further on, the empirical data was gathered through a case study in which the organisation was studied in its real context. Since the purpose of this is to identify challenges regarding the movement from one certification process to another and understand how this move will affect an organisation, the method for this study is primarily qualitative. Bryman and Bell (2011) describe qualitative method as exploratory that aims to understand the underlying reasons and opinions to a certain problem and provide insights into the problem and mean that it is a common method to be used in combination with a deductive approach. The advantage of using a qualitative method in this context is specifically in its ability to produce detailed description of participants' feelings, opinions, and experiences; and interprets the meanings of their actions (Rahman, 2016).

Eventually, the empirics were analysed after structuring the empirical study and connecting it to the literature. The process of this research was iterative, meaning that the content was updated during the research process. As the understanding and insight of the problem developed, the purpose and research questions were updated and renewed.

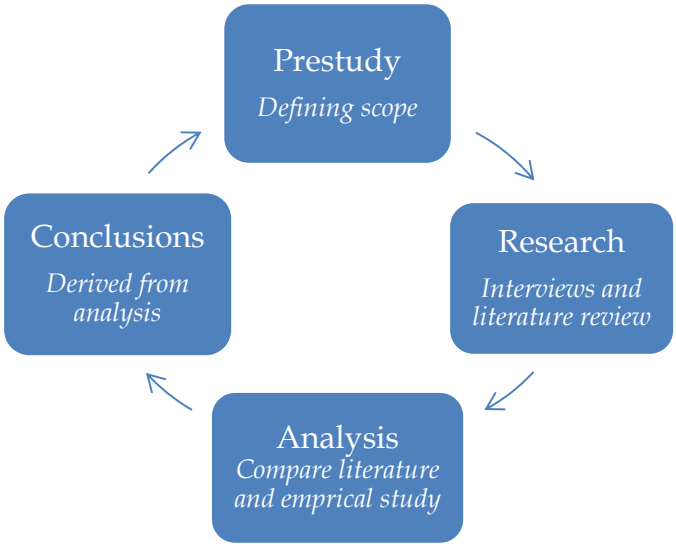

Figure 2. Research process (own construction).

3.2 Case study design

This study focuses on understanding a specific area within an organisation by investigating and determining the process of working. Therefore, the study was limited to investigating an organisation in the vehicle manufacturing industry and a case study was chosen as a research method. Using a case study as a research design means that the organisation was studied in its real context (Yin, 2013). Patton (1987) argues that such method is favourable when one wants to understand a specific issue in great-depth and according to Mohd Noor (2008), case studies are practically necessary when a researcher aims to obtain a clear view of how a certain process is done within an organisation, especially when the organisation in questions has a dynamic behaviour. Moreover, Mohd Noor (2008) argues that case study as a research method provides the researcher to develop a holistic opinion for a specific phenomenon and as Anderson (1993) claims, a case study is not supposed to reflect the entire organisation but rather focusing on an issue in particular.

In the study, an organisation has been investigated, which can be likened to a single-case design. Over the years, single case studies have often been criticized due to its incapability of presenting generalized conclusions (Tellis, 1997). However, others claim that the size of the sample taken into consideration for a study does not necessarily provide generalized conclusions and the quality of the results are independently of the number of case studies (Hamel et al., 1993; Yin, 2009). For this reason and also taken the time frame of this study into consideration, the study is conducted on a single case company. The company chosen for this case study is Scania and the reason for this choice is due to the fact that this company is undergoing an organisational change that fits the purpose of this study.

Primary data was gathered by performing interviews as well as through observations by attending meetings and workshops regarding the OBD certification process.

3.2.1 Interview method

Each interview started off by introducing the purpose of the study and the interviewer was asked open questions regarding their responsibilities and how they are involved in the planning or execution of the OBD certification process. When it comes to interviews, what you already know is as important as what you want to know. The questions you ask are determined by what you want to know and how you ask them depends on what you already know. (Leech, 2002) Hence, the first few interviews were loosely structured and had the nature of conversations rather than interviews. The discussions were open and the respondents were given the opportunity to tell about their perception, experience and management of the OBD certification process and their role and involvement in the process. They were also asked on how they believe the move from Euro VI to CARB will affect the organisation as well as any challenges or difficulties that they believe may come with this transition and change in process. These in-depth interviews were loosely structured, which allowed freedom for both the interviewer and the interviewee to explore additional points and change direction, if necessary. The purpose of this is to gather as much knowledge as possible about the subject from different perspectives for further studies. The reason for this choice, which is also backed up by Leech (2002), is that the interviewers have limited knowledge regarding the subject and are interested in gaining insider perspective.

However, as the literature process developed and as the knowledge within the area increased for the interviewers, the interviews became more semi-structured, meaning the interviews were not highly structured nor were they unstructured. This is when the interview guide was further developed based on the information gathered by this point and was used as a foundation for further interviews (Appendix 1). A blend of open- and closed-ended questions were employed, often accompanied by follow-up why or how questions, designed to bring out the respondents' thoughts and ideas regarding the subject in question to obtain in-depth information. For these reasons explained, Adams (2015) advocates for the use for semi-structured interviews and therefore became the methodology of choice.

The interviews were conducted face-to-face and on the respondent's workplace. The reason for this was that Kvale (1997) argues that when conducting in-depth interviews, direct meetings are preferred over indirect. This simplifies the interaction between the interviewer and the respondent and unspoken information can be mediated through body language, which increases the interpersonal interaction. Also, more complex questions can be formulated and the discussion becomes more rewarding. (Kvale, 1997)

The first few respondents were selected by the case company and as the interview process developed, additional respondents were selected by the authors through the so called "snowball sampling", which Vogt (1999) describes as sampling technique where the research participants suggest other participants for the study and a method that allows the researcher to reach participants that are difficult to sample. Since there were no easy way to acquire information and guidance regarding which actors in the organisation had insight and specific knowledge on this study's focus area, the use of this method was favourable. Moreover, it is also effective as the sampling of respondents comes from reliable sources. During the interviews, notes were taken by the interviewers and the interviews were also recorded upon

approvals from the respondents. Thereby, any misinterpretations or unclear notes could easily be corrected and clarified.

Kvale (1997) argues that, for qualitative methods that are based on in-depth interviews, it is essential to achieve a sufficient significance for the empirical data and the reason for this, he means, is for general conclusions to be drawn. Consequently, to ensure a sufficient basis and provide as broad a view as possible, emphasis has been placed upon securing a selection of respondents. The approach has been to find respondents from different parts of the organisation and with different responsibilities, who are all involved in the OBD certification process in one way or another. The number of respondents were not predetermined, instead when the information during the interviews repeated itself and when there were no respondents left that could provide new perspectives, the interview phase was concluded and 10 respondents were interviewed.

The table below presents the respondents for this study, their position and a brief work description. These respondents are involved in the OBD certification process for Euro VI and for CARB in different levels and thereby various perspectives are ensured.

Table 3. Respondents of the study (own construction).

Respondents	Position	Description	Duration [min]
R1	Senior engineer	Involved in the OBD certification activities for EURO VI	65
R2	Development engineer	Involved in the OBD certification activities and documentation management for EURO VI	60
R3	Object leader	Coordinates the OBD project	50
R4	OBD Team leader	Focus on Euro VI	45
R5	OBD Team leader	Focus on CARB	45
R6	Senior certification engineer	Contact with the authorities	50
R7	Senior lead engineer	Contact with the OEM	30
R8	OBD expert	Supports Scania with the movement from Euro VI to CARB	45
R9	Senior technical adviser	Interprets the regulations	50
R10	CARB regulation expert	Interprets the CARB regulation	55

3.3 Literature review

The literature review in this study was divided into two parts in which the first part involved studying the legislations regarding Euro VI and CARB and the second involved literature with relevant topics according to the problematisation regarding the organisational challenges that

a company will face when going through this type of change. In order to find the differences between the legislation regarding OBD certification for Euro VI and CARB, the requirements for each standard were overviewed. Since these regulations are quite immense, they were overviewed a couple of times and any uncertainties were discussed with legislation experts at the case study company. However, only sections concerning the requirements for the OBD system was overviewed.

The literature was extracted from data bases recommended from the university library. Firstly, search words were used according to the purpose of this study and therefore relevant articles were gathered by reading the abstract and the section titles of the study in question. Synonyms for the search words were used in order to ensure a great sample of articles. This importance of using a good combination of search words is pointed out by Bryman (2011). Thereafter, the articles gathered were reviewed by reading them more thoroughly and therefore the authors of this study could neglect the non-relevant articles. When these articles were reviewed, in some cases the original source was examined as well in order to gather additional information and ensure the quality of it.

Table 4. Process of literature review (own construction).

Search words	Organisational change, responsibility distribution, coordination theory, time management.
Data bases	Google scholar, Diva portal, Emerald Insight, Research gate, Primo.
Criterion set by the authors	Peer-reviewed.

3.4 Method of analysis

The interviews and observations in the empirical study generated a great amount of data which required that it would be processed before presented. Blomkvist and Hallin (2015) describe how the empirical findings cannot be presented in its raw form without some type of primary analysis. Thus, the information from the empirical study has been pre-analysed beforehand by identifying patterns and themes and categorizing the content based on that. Blomkvist and Hallin (2015) and Bryman (2011) describe this form of method as thematic analysis and a common form of analysis when it comes to qualitative research. Braun and Clarke (2006) claim that this method of analysis should be foundational for qualitative studies and argue, together with King (2004), for the use of thematic analysis due to its ability to examine the different perspectives of the research participants and highlighting similarities and differences. By reviewing the information gathered from the interviews, differences and similarities were identified based on the challenges addressed by the respondents. This process required re-reading of the information in order to recognize the form of pattern of the data, which is further supported by Fereday and Muir-Cochrane (2006).

When the empirical data had been sorted and categorized into different themes, the secondary analysis was performed in order to re-analyse the empirical findings and connecting to the literature for the purpose of answering the original research questions. This was established though an abductive process where the research was initiated by having iterations between the empirical and theoretical data and the research questions where reformed accordingly. (Blomkvist & Hallin, 2015) describe how through this interplay between existing literature and the empirical findings, the understanding of the information increases.

3.5 Validity, reliability and ethical consideration

In order for a research methodology to be useful and appropriate for the particular study, it is required that it is valid and reliable (Ejvegård, 2003). Ejvegård (2003) argues that if these criterions are not met, the result of the research has no scientific value. In order to retain a high quality of validity in this study, the problem has been studied from different perspectives. This has been done by interviewing different actors with different roles in the OBD certification process and learning their perception of the problem. This has been helpful to ensure that the information gathered is correct and relevant for the area of focus. This corelates with what Andersen (2009) describes as the meaning of validity, which is to ensure that relevant information for the area of focus has been gathered which later on can give qualified results. Similarly, the interviews have been conducted in a way to ensure that different perspectives have been taken into consideration by interviewing different respondents for the same subject.

According to Bell (2000), high reliability can be achieved by building a sufficient research methodology, so that the research may be done by others under the same conditions and generate the same results. Thereby, emphasis has been placed upon providing sufficient information regarding the approach and conduction of this study. Bell (2000) claims that this will reinforce the findings and ensure that the wider scientific community will accept the hypothesis. A common problem when it comes to the reliability of a study, which has been avoided throughout this study, is to form unclear questions which could lead to misleading information from the respondent (Davidson & Patel, 2011). The conduction of the interviews has been carefully thought through and evaluated before completing them. The interviews have been conducted in non-stressful environments and the respondents have been informed in time in order to prepare for the interview and contribute with accurate information. Moreover, emphasis has been placed upon formulating clear set of question and assuring that the respondent understands the question correctly and encourage discussions during interview, which Davidson and Patel (2011) means improves the reliability of a research.

To further increase the reliability of the study, at the end of each interview, the respondents have been given a summary of the interview for approval in order to ensure that the information received is correct. Furthermore, any uncertainties that arose during this study has been lifted and clarified by discussing the issue with either one of the supervisors. In the case of interpreting the regulations from Euro VI and CARB, an expert on the subject have been available for discussion in order to avoid any uncertainties and misunderstandings.

There are several principles that, according to Bryman and Bell (2011), should be used as a foundation in order to achieve ethical validity in a study. These principles include informed consent as well as the safety, dignity and anonymity of the research participants (Bryman & Bell, 2011). Throughout this study, these principles have been taken into consideration and the interest of the participants of the research have been prioritized. The respondents have been informed about the focus of this study and any necessary information was provided before the interviews and thereafter the respondents were free to choose whether to participate or not. The meaning of this, according to Kenny (2008), is for the participants to be aware of the aims, purposes, and consequences of the research. Also, the respondents had the right to withdraw from the study at any time if requested. Furthermore, the dignity and, if requested, the anonymity of the participants have been respected and emphasis has been placed upon making sure that and any classified information or data received from the participants is not published without permission.

The authors of this study have ensured the objectivity of this study by avoiding personal interests and biased sources. Great emphasis has been placed upon assuring that all communication with organisations, participants, supervisors and other actors of interest have been done with transparency and honesty. Also, for further assurance, this work has been carefully and critically examined by fellow students and supervisors. Copyrights, patents and unpublished data will be fully honoured and nothing in this study, expect classified information, will be censured since openness and shared information enhance further research which is very important for the development of the society in general (Shamoo & Resnik, 2015).

4 EMPIRICAL FINDINGS

This chapter presents the findings gathered from the case company. The chapter begins by describing the case company, the respondents in this study and the company's current OBD process. Further on, the challenges addressed by the respondents are presented in themes.

4.1 Scania CV AB

Scania CV AB, a global manufacturer of commercial vehicles – specifically heavy trucks and buses, is expecting an entry into the US market by year 2023 regarding heavy-duty vehicles. Most of Scania's current customers request vehicles certified according to the European legalisation, mostly the Euro VI requirements. These requirements are integrated in the entire organisation, from development of the engines to testing. However, as the requirements from the authority in the US, CARB, differs from Euro VI in several aspects, Scania is in need of developing a new process for the certification. The requirements from CARB requires the involvement of many departments within Scania for the developing of the engine which means that a changing in their way of working is crucial in order to achieve an easy-going transition. (R2, 2019)

Scania has developed a cooperation with a major US based original equipment manufacturer (OEM), a manufacturer of commercial trucks, to whom Scania will provide engines as well as technical solutions and after-treatment systems for the heavy-duty vehicles. The OEM's task is to interpret the legalisation in the USA and provide Scania with the information needed in order for them to develop the technical solutions for the engines to match with the specified requirements from CARB. (R7, 2019)

This table shows the departments within the case study company that are involved in the OBD certification process.

Table 5. Departments involved in the OBD certification process (own construction).

Department	Responsible for
D1	OBD certification activities
D2	Engine development
D3	Regulation and certification

4.2 Current OBD certification process

The project starts off by having a 'yellow' status which means that Scania starts to interpret legal requirements before giving the project 'green' status. When the requirements are understood, an object leader is assigned to the 'green' project. The object leader's task is to perform a plan for the entire project with all including activities as well as a time schedule for these activities. Further on, the object leader explains that D3 works with interpreting the legal

requirements in order for the software developers and other involved actors to take the requirements into consideration during the entire project. This department communicates frequently with the authorities during the project for discussion of the legal requirements. However, the object leader points out that there is a lack of an established process for the OBD certification and this is something that complicates the activities. For the current process, the software developers must inform the OBD group of how the software works and what fault codes each software contains. The list of the fault codes is called "DTC-list", and it is of a high importance that the DTC-list is forwarded to the OBD group in time since the OBD group will evaluate and approve the list. This list includes hundreds of fault codes which means that a discussion with the authorities regarding which fault codes Scania will demonstrate on the certification day is crucial. In order to avoid delays on the project the engine has to be certificated as scheduled and the adjustments of the software after this milestone should not have an impact of the functionality of it. Several fault codes can be demonstrated through a software "override" which means manually manipulation of the software on a computer. (R3, 2019)

However, the OBD certification process cannot occur before achieving several deliveries from different departments which are necessary for carrying through the OBD process. The OBD group have experienced problem such as delays of deliveries especially the DTC-list that has to be delivered to the OBD group in time. This list is delivered upon a request from the OBD group and the object leader (2019) means that the responsibility of delivering the DTC-list should be on the software developers. (R3, 2019)

In addition, a process description of the OBD process does not exist. How documents from and to the OBD group are archived and updated is unknown yet. The distribution of information is not optimal which causes uncertainties and irritations within and across departments. The reason to that is an unclear picture of the responsible distribution between departments involved in a project. (R1, 2019; R2, 2019; R3, 2019)

4.2.1 Poor integration regarding OBD activities

The certification process for OBD has not been connected to the milestones for the rest of the project (R3, 2019). This process, according to a senior engineer (2019), has always been a "happening" which means the certification activities develops as the project proceeds. There has been very little planning involved. The goal is to prevent the project from proceeding to the next milestone if the certification activities are not done. In light of this, the senior engineer expresses how it would be of great value to make the process clearer and set up the milestone for the certification by counting backward from the completion of the project. This point of view was expressed by several respondents (R1, 2019; R2, 2019; R8, 2019; R9, 2019) who all strive towards an answer to the following question:

> *"How late can the certification activities begin for delivering the product on time?" (R1, 2019)*

The senior engineer (2019) explains how in the current process, the certification activities are usually pushed forward due to unfinished software or calibration (integration of software into

hardware) which result in less time for the certification activities. It is crucial to ensure the deliveries of necessary information and document to the OBD group on time to avoid delays on start of production. The senior engineer explains how a change of this process is crucial for the process of CARB. (R1, 2019)

Since the OBD certification is dependent on finished calibration of the software, the senior engineer (2019) confirms that the certification cannot begin before the milestone for freezing calibration is completed. The reason is that an OBD certification cannot occur if the engine does not have approved emissions. (R1, 2019) At the current process, the OBD certification is triggered when D2 communicates with D3 about their emission certification activities. Thereafter, D3 communicates with D1 for coordinating the OBD certification. (R6, 2019) The senior engineer (2019) suggests that in order reach the deadline for the project and avoid delays at a large extent, the optimal action would be to integrate the OBD milestone with milestones for the rest of the project.

The senior engineer (2019) explains further that one of the big dissimilarities between the current process and the process for CARB is in the case of adjustments of the calibration. For the ongoing process of Euro VI, the adjustments for the calibration are made during the certification with the authorities, which implies that, in contrast to the process of CARB, the documentation is created after the certification has been performed. Since Scania always strive towards having the latest version of the software, updates are made continually at the current process. However, the senior engineer emphasizes the importance of how this routine must change due to the stricter requirements from CARB. According to the regulation from CARB, the manufacturer is obligated to apply for a certificate every year and all software updates, called running changes, must be approved by CARB before implementing them. (R1, 2019)

4.3 Challenges within Scania

There are several challenges that Scania will face when entering the US market and changing its process to comply with the requirements from CARB. The sections below include the main challenges addressed by the respondents.

4.3.1 Organisational changes

The OBD team leader for CARB (2019) states that the entrance into the US market will result in a comprehensive organisational change since, compared to the process of Euro VI, many more departments will be involved in the entire project. Other respondents have also expressed the same concern (R1, 2019; R2, 2019; R3, 2019; R4, 2019; R5, 2019; R8, 2019; R9, 2019). The senior engineer (2019) explains how unlike Euro VI, the OBD requirements from CARB will characterize the entire project, from early development of software solutions to the certification process. The OBD regulations from CARB are much more comprehensive and the senior technical adviser (2019) argues that it will require that the manufacturer have an adaptive process in order to ensure a successful implementation as well as to avoid misunderstanding between the manufacturer and the authorities.

For the process of Euro VI, D3 is responsible for interpreting the legislations. For the US project, on the other hand, the OEM will interpret the legalisations and requirements from CARB and inform them to Scania. Thereafter, Scania will provide technical solutions, engines and after-treatment systems to the OEM. This way of working is, according to senior lead engineer (2019), seen as very efficient since the two companies can work on their own specialties which can give great results. The distribution of responsibility is a big challenge for Scania due to the involvement of many departments, an organisational change might be required for delivering in time. (R7, 2019)

The object leader (2019) highlights that since this project is completely new and has not previously been done at Scania, there are no process to go by and instead the process is established as the project develops. Furthermore, the object leader (2019) explains that resources that have been allocated for working on this project and actors with specific knowledge regarding these have been assigned and highlights that:

> "*A new way of working requires clearness in order for the parts involved to be certain about what is required from them and when and to whom they have to deliver.*" (R3, 2019)

Moreover, the object leader emphasizes the comprehension of this specific project and compared to previous projects it will require the involvement of several departments within Scania (R3, 2019). Consequently, the object leader (2019) expresses how a good coordination between these and an agreement of milestones and deliveries for each group involved is crucial. Additionally, the object leader underlines the importance of integrating the OBD process into the whole project and describes this as:

> "*The OBD certification process will be the heart of the project and act as a separate project which will be integrated into the rest of the project." (*R3, *2019)*

According to a senior certification engineer (2019), an entirely new engine requires new set of documentation as well as new tests and certifications. After the authority has supervised the certification on site, D1 must deliver all necessary documents. This has to be done in order for D3 to evaluate and forward the documentation to the authority for an approval. The department responsible for software and hardware do not collaborate which affects D3 time schedule. The senior certification engineer also underlines the importance of information distribution between departments and especially between these two is crucial for avoiding delays on the project. The hardware group (D2) must inform D1 when the engine is calibrated and ready for certification. (R9, 2019) Furthermore, the majority of the respondents have expressed similar concerns regarding the lack of process description and specific timelines, which they mean results in that information is provided upon request and not otherwise which is unsatisfying (R1, 2019; R2, 2019; R3, 2019; R4, 2019; R5, 2019; R8, 2019; R9, 2019).

4.3.2 Documentation management

Another challenging aspect regarding the entrance into the US market is, according to the OBD team leaders, the management of the documentation and how a standardized documentation package for the whole project can be established. CARB requires that every change concerning

the engine must be documented and certified which means that Scania has to certify the changes in testing cell and submit documentation to CARB. (R4, 2019; R5, 2019) A suggestion from the senior lead engineer (2019) is for the software developers to give a plan of all components and fault codes that will be tested and a description of how these can be tested, which would result in resource saving.

All documentation created by Scania will be evaluated and approved by the OEM first and thereafter forwarded to CARB for their approval. The senior lead engineer (2019) also underlines the complexity of this process and the importance of the documentation to be correctly completed. Due to the involvement of many actors for creating and approving of the documentation, many respondents emphasizes the importance to develop standardized documents which they mean would simplify the orientation within it. (R1, 2019; R2, 2019; R5, 2019; R8, 2019; R9, 2019)

Scania must submit an application every year for each model year engine. This is a requirement from CARB which requires the documentation to be easy to update in order to avoid time-consuming work with yearly submission. (R2, 2019) The OBD expert (2019) describes Scania's approach which will be to break down this comprehensive documentation package into standardized subdocuments in order to reduce the workload. Each software developers will be responsible to provide a detailed description of their own software which, according to the senior engineer (2019), will simplify the merge of the documentation package for submission. (R8, 2019) The template for the documentation that will be used by the actors involved is standardized and adapted to CARB's way of work. Several respondents have pointed out the importance for everyone to use the same approach when creating a subdocument. (R1, 2019; R2, 2019; R5, 2019; R8, 2019; R9, 2019)

The OBD expert (2019) describes how the application for OBD has to be submitted to CARB annually and the documentation package must follow a pre-defined structure. Thereafter, CARB will examine the application and provide an Approval Letter if all requirements are met (R8, 2019). The CARB regulation expert (2019) further describes how a technical description presenting the monitoring logic and strategy is required. As a requirement from CARB, all submitted documents must be formed according to SAE J1930 or J2403 terms, abbreviations and acronyms which means that all actors involved must use the same language. The technical description should at least include the following documents (R8, 2019):

- The monitoring strategy and diagnostic idea
- All steps and decisions taken in the monitor
- The evaluation criteria
- Input signals used in the monitor logic
- How fault implementation is made
- Data and analysis supporting the monitor strategy description
- A logic flowchart

The OBD expert underlines the importance of supporting the software developers in their work to create the documentations. There will be a forum for interpretation of requirements where the software developers and other involved can attend and discuss the regulation language, receive guidance regarding questions from CARB and define solutions for implementation.

This is necessary for avoiding as much misunderstandings as possible in order to keep the deadline of the entire project as well as the deadlines for the activities within the project. (R8, 2019)

4.3.3 Time management

According to the OBD expert with experience in the OBD certification process for CARB, the certification activities must start approximately 9 months, at the latest, before desired approval. The best method for estimating the time required for completing all certification activities is, according to him, to count backwards and proceed from the point of time an approval is needed. From the day of submission to receiving an approval, the authority has 120 days for reviewing the application. This presumes that the documentation package that has been submitted is correctly conducted and in case of any questions from the authority, they must be answered within a week. The OBD expert further estimates that the time taken for performing the certification is 3 months and an additional 1 month for completing the documentation package and 2 weeks for reviewing. (R8, 2019)

Table 6 below shows that the estimated time for completing the activities and the total time for all activities to be completed is 9 months. However, this is only in the case that the documentation package is flawless and meets the requirements from CARB. In the case of shortcomings with documents, such as not enough information or not the correct setup, the process will exceed the estimated time. (R8, 2019) The OBD expert point out that:

> "*It is extremely important to establish good documentation in order for the project to meet the deadline.*" (R8, 2019)

Table 6. Time estimation of OBD certification activities (own construction).

Type of activity	Estimated time for completing the activity
Demonstration in cell	3 months
Review of document package	½ month
Compiling documentation package	1 month
Revision of documents by authority	4 moths
Answering questions from the authority	1 week/question round
Total	Approximately 9 months

4.3.4 Management of the DTC's

Another vast challenge with the change of process is, according to the senior engineer (2019), the testing of the DTC's. For Euro VI, only those DTC's that the authority chooses are examined, which means that there are several fault codes that have never been tested. (R1, 2019) The object leader points out that the software developers must inform the OBD group of

how the software works and what fault codes each software contains (R3, 2019). Additionally, the development engineer (2019) describes the inefficient way of working when it comes to managing the DTC's. The DTC-list is forwarded to the OBD group upon a request and usually the list is not completed which in most cases result in poor description quality of the fault codes and since the list needs to be reviewed thoroughly before sent to the authority, this procedure results in extra workload. (R2, 2019) The senior lead engineer, on the other hand, expresses his concern regarding the testing of the fault codes when certifying for CARB since testing such amount of fault codes will take time and requires added resources. (R7, 2019)

The time required for testing all fault codes is uncertain since Scania have only tested a few fault codes when certifying for other markets than the US. Also, other authorities for other markets than the US accepts software overrides to illustrate a fault codes and this is favoured by Scania since this method reduces the testing time. Furthermore, the OBD expert and the CARB regulation expert communicate the stricter requirements from CARB and that software overrides are not common, instead defective components need to be installed in the engine in order to show that a fault code appears. (R8, 2019; R10, 2019)

> *"The time schedule for testing the fault codes is still uncertain since this is entirely new for Scania and will require a big change in the already existing process" (R8, 2019)*

5 ANALYSIS

This chapter presents the analysis of this study where the empirical study has been analysed in context to the theoretical framework in order to answer the research questions and thereby fulfil the purpose.

5.1 Managing change in the organisation

When studying the regulations for Euro VI and CARB, it is clear that the differences between these two regulations will affect Scania as an organisation. Moreover, its entry into the US market will require change in the organisations current process of working and above all the OBD certification process. This issue has been addressed by the respondents, who are all in agreement over the fact that this movement will require a change of the current process. In order to adapt to the new market's requirements, new processes will have to be designed to fit the new circumstances and new working methods must be integrated into the organisation. Therefore, studying the impacts that these changes may have on the organisation is a crucial task for ensuring a successful entry. Burnes (2004), Moran & Brightman (2001) and Greatz (2000) are in agreement over the importance of management during organisational change and describe how managing the challenges that comes with it is a key task for ensuring a successful implementation. Therefore, the focus should not solely be on the implementation of the process change but also on the organisational impacts that this change will bring. One of these being the distribution of responsibility between the departments involved but also actors in between. The new process will require the involvement of more departments and actors in comparison to the process of Euro VI as well as involvement of new tasks for actors. Thereby, a well-developed cooperation between the departments is a great foundation for establishing a long-term working process.

The change that Scania is about to go through is characterized as planned change since the organisation is prepared for a new goal as explained by Sullivan, Kashiwagi and Lines (2011). Lewin (1946) suggests that for an effectively implementation of this type of change, it is important to discard the previous process. However, for its existing markets, Scania will continue with its current process and the new process will only apply for the US market. Consequently, the old process cannot be discarded. Instead according to the respondents, both processes will be acting in parallel and apply to separate projects. These different processes will require different ways of working and in this situation, it is crucial to avoid the common coordination problem, as Malone (1988) states, which can develop where a dependency between an actor and an activity evolves and effects the flexibility of the distribution of tasks. In order for these two parallel processes to operate successfully, there is a need to be able to assign different tasks from the two processes to the same actor and for an actor to be able to work on both tasks simultaneously. Therefore, it is important for an actor to comprehend the difference in processes and the tasks must be designed in such a way that they do not require a specific actor with a specific kind of skills to perform it.

The first stage of Bullock and Batten's model for a successful implementation of planned change comprise of the exploration phase, which Scania has already gone through. Next stage in the model includes planning and understanding the challenges that may come with this move and it is this stage that Scania is in currently. The organisation has identified that this new market will require changes to its OBD certification process and, from the interviews, it is apparent that the majority of the actors involved in this project are aware of the comprehensive work that needs to be done with this new project and the organisational changes that it will result in. The fact that Scania is aware of what the new market requires and what is needed to be done in order to establish a smooth process can simplify their entry in the new market and this comply with Burnes (2004) statement regarding a company surviving through change.

5.2 Development of new processes

The senior engineer emphasizes the importance of integrating the OBD activities into already existing milestones for the CARB project and as explained by the object leader the OBD certification process for CARB will be a central part of the US project and therefore, it is clear that the OBD process needs to be well-integrated into the rest of the project. Compared to the current process, which has been managed as a "happening" according to the senior engineer, it is clear that the new process is in need of a clear plan and the tasks need to be integrated at the start of the project. Since the legislation standards from CARB are stricter and includes requirements that are new to the company in comparison to Euro VI, there will be a need for a change of process within the organisation and the development of new processes. These processes will need to include the OBD activities into the already existing project and connect the OBD milestones to milestones in the bigger project.

When it comes to developing new processes and designing tasks, coordination and dependencies among tasks are a significant aspect to take into consideration as explained by Crowston (1997). He explains the importance of how to break down tasks into activities and how to manage dependencies between certain activities. When integrating the OBD process into the bigger project it is vital to consider the dependencies that can develop between various tasks and how these can constrain the performance of them as well as which actor can be responsible to perform it. When it comes designing the tasks for the OBD certification and breaking them down into activities the object manager and project manager will have to work in close cooperation in order to have an overview of the dependencies than can form and how to overcome these. Since dependencies between tasks are inherent in how the task is structured or a result from the breakdown of the goal into activities and the assignment to actors (Crowston, 1997), it is important to have this in mind when starting off with the project and designing the tasks. By making sure that the task is structured in such a way that changes within a certain activity does not affect another activity, it can result in increased productivity since tasks can be performed in parallel with one another.

However, wherever changes in a certain activity interfere with other activities it is important to ensure that these changes are made easily. Furthermore, it is also important to promote good communication between actors so that, in case of changes that may affect another actors

activities, it will be easily detected and communicated between the actors that may be affected. By taking consideration to this from the very start, it can help to overcome the dependencies that would otherwise develop and constrain the activities in the project.

In Scania's current process for Euro VI, calibration changes are made during the certification activities with the authorities. This way of working will not be suitable for the CARB process since these activities will affect the documentation. Due to the fact that the documentation must be done and submitted before obtaining an approval for the US project as stated in the regulations from CARB, no alteration to the software or calibrations are allowed to be performed after the submission of the documents. To ensure that the documentation is not affected, it will be required that the activities leading up to the documentation stage are freezed before the "documentation activities" can be performed and that any necessary changes are instead implemented for next model years application. The reason to postpone the implementation to the next model year's application is because according to the regulation from CARB, a submission of an individual application is required for each and every change as well as to reduce the workload and therefore meet the deadlines for the current model year's project.

5.3 The management of documents

By studying the regulations regarding the certification process for the OBD system from CARB and Euro VI, it is clear that the documentation management will be one of the main challenges. As opposed to the process of Euro VI, CARB requires a yearly renewal of the certificates for an already approved engine. This requires yearly application and submission of documents for the engines with any minor changes documented fully. This challenge is recognized by Scania and the main concern is how to establish standardized documents which will be easy to update before each application.

The documentation management of the DTC's differ for Euro VI and CARB. Although, they both require detailed information regarding the performance of the DTC's as well as information regarding the testing of these. However, for the Euro VI regulations, not all DTC's are required to be tested, only a few are chosen by the authorities to be tested in cell and are therefore not required to be documented. Therefore, an establishment of a comprehensive document package for all DTC's is not a common way of working within Scania. CARB, on the other hand, requires documentation of each and every DTC's and information regarding the testing of these. Consequently, managing the documentations will be a big project with many actors involved, which will require the establishment of a new process within the organisation.

In projects where many actors are involved, Grossi and Gidnum (2003) implies the importance of dividing the activities into subtasks in order to simplify the work and obtain an efficient way of working. Accordingly, every software developer needs to be responsible for documentation of their own DTC's and can therefore be 'task-based responsible'. Each one of the developers will be responsible for establishing documentation regarding their DTC's and making sure that all necessary information is included. It is especially important that the information regarding these is clear and correct since any misunderstanding or lack of information will result in

questions from CARB, as stated in the regulations, which will need to be clarified and thereby affect the projects time estimations. By including all the necessary information from the start, questions can be avoided and the process will move on smoothly. Moreover, by doing it right the first time, it will simplify the process for the upcoming years and thereby increase the efficiency. Dividing a big project, a document package in this case, into subdocuments simplifies the way of working and as Grossi & Gidnum (2003) explains, it is a great foundation to meet the deadline of a project and to avoid misunderstanding.

According to the senior lead engineer and the senior engineer, it is crucial to include the software developers in the documentation management since they are the ones with the knowledge regarding the DTC's and the testing of these. Although it must be taken into consideration that this is the first time the developers establish documents and since there are several hundreds of DTC's many developers will be involved, and it is vital to support them with the documentation part. A great suggestion would be to introduce workshops for the developers in order to ensure the understanding of conducting the documents and instead of supporting the software developers individually, the workshops result in resource savings as well as engagement within the group. Selznick (2003) supports this reason and underlines the importance of working and cooperating within groups in order to meet the aim of a project.

5.4 The management of the DTC's

As mentioned earlier, the software developers are responsible for their own fault codes and have knowledge about the functionality of the software and how it can be tested in the testing cell. For the Euro VI process, a list containing the DTC's and information regarding this is forwarded to the OBD group upon a request which causes waste irritations and uncertainties. The object leader expresses that the responsibility of delivering the DTC-list should be on the software developers. It is clear that a poor understanding of the responsibility distributed for the current OBD process is something that might affect the new process and due to the complexity of the new process, it is crucial for the actors involved in the project to be well-understood of where the responsibilities lies.

For the US project it is vital to achieve a great coordination between the departments involved and distribute the information and knowledge to the actors involved and therefore a solid documentation containing detailed information about the fault codes and the testing of these. When studying coordination theory, Malone and Crowston (1994) explain the importance of coordination actors in between. Before an actor can perform a task, he must ensure that his action does not affect other actors' activities. This is relevant in this case since a delayed DTC-list affect the activities for the OBD group and therefore this must be coordinated in a good way and the responsibility distribution has to be more clarified and the accountability must be ensured. Additionally, according to Gross and Gidnum (2003), the software developer would be 'causally responsible' if other activities are postponed due to delayed DTC-list. It is of a great advantage for an organisation to integrate the different dimensions within the organisational responsibility theory in order to clarify the responsibility across departments and individuals

within it. The lead engineer confirms that the distribution of responsibility is a big challenge and has to be considered once again for being able to keep the time schedule for the US project.

When certifying an engine according to the regulations of Euro VI, the authority chooses a certain amount of fault codes to be tested. The software developers that are responsible for these fault codes have to attend the witness test and demonstrate the performance of their fault codes. However, for the US project, every single fault code will have to be tested and therefore Scania's current process of each developer testing their own fault codes will be quite inefficient, instead the focus of the software developers should be on the development of the particular software. This will result in the involvement of many software developers in the US project since a considerable amount of fault codes have to be tested in cell. According to Crowston (1997), an activity that requires a specific kind of skill to be performed is a typical coordination problem that can significantly reduce the flexibility of the distribution of tasks. This is a big challenge that Scania must take into consideration since flexibility within an organisation is a vital factor to ensure. According to the senior engineer, only those fault codes that the authority chooses are examined for Euro VI. This means that many fault codes have never been tested and since all fault codes must be certified for the US project, this lack of knowledge regarding the testing of fault codes might jeopardize the time schedule of the certification activities as well as the deadline for the project. Therefore, it is of high importance to increase the flexibility of the distribution of tasks and assign an employee to be responsible for the testing of the fault codes. In order to ensure great results, the testing engineer must be provided detailed information and documentation about the performance and testing fault codes from the software developers. Assigning this task to a testing engineer can be favourable in many ways, since it will result in resource savings. Moreover, the software developers will understand the importance of conducting detailed documentation about the fault codes for another actor to comprehend and thereby simplify the documentation process for CARB.

5.5 The management of time

A big challenging factor that may come with the US project is the stricter requirements from CARB regarding running changes and the implementation of them into the hardware. An important factor that relate to this challenge is the different activities that have to be done for each model year and when studying the legislation, it appears that activities for model year 1 will overlap with the activities for model year 2. This is a comprehensive change in the regulatory for Scania and according to Greatz (2000), such changes requires strong leadership in order to implement a new process accordingly. First of all, the activity regarding documentation, testing and certification will have to be conducted each model year. This way of working is not familiar to Scania when it comes to Euro VI certification. A successful movement has to be built on a solid plan of how the new process will be obtained and what kind of necessary activities are required to occur in order for an organisation to establish a robust process that all actors involved comprehend. Bullock and Batten (1985) emphasize that planning the change thoroughly is vital to succeed.

However, it is known that manufacturers are developing their software continuously and therefore it is quite common to release software updates during a product's model year. This has been the case when it comes to Euro VI classified engines, where Scania implements the updates directly since there is no need for an approval from the authority. For the US regulation on the other hand, every change or update during a model year needs to be approved by the authorities. Since CARB must approve these so-called running changes, the manufacturer will have to submit the entire documentation package once again but this time with the changes included. This requires added recourses and extra workload, which will affect the time management since in the meantime the company has to conduct documents for the next year's model as well as performing other required testing activities for the current model year. Consequently, flexibility, distribution of tasks and responsibility are very important when it comes to the US project to avoid delays which the respondents underlined. From a comparison of the two legislations, it is clear that an optimal solution for a company to reduce the workload is to start reducing the amount of software updates during a particular model year and instead make the application for these changes when applying for a certification for the upcoming model year. Otherwise the company will have to conduct a documentation package twice which is waste of resources as long as the documentation is not automatically generated which is not the case at the current time.

Additionally, the manufacturer can obtain an approval from an authority despite deficiencies in the application. An authority certifying according to Euro VI regulation allows deficiencies with a period of one year. Similar to Euro VI, the manufacturer has to apply for an approval each year if deficiencies exist when certifying for CARB. According to these two regulations, the deficiency period can be extended upon a request from the manufacturer if the time for fixing the deficiencies is expected to be longer than the allowance period for the deficiency. However, the main difference appearing when studying these two regulations is that CARB requires an application for the deficiencies each year and a fee has to be paid for all the deficiencies at each application. Therefore, it is of high importance that the manufacturer avoids deficiencies already from the start since it might result in high expenses and the manufacturer might face difficulties managing the time schedule for fixing them. Also, since this is the first US project for Scania, a realistic time schedule is crucial and knowledge about the regulations and its importance must be distributed to all the actors involved.

6 DISCUSSION

This chapter presents further discussion regarding the challenges that companies will face with the movement followed by some concluding remarks. Furthermore, the study and its validity and contribution are discussed.

6.1 Results discussion

Due to the fact that the process for Euro VI and the process for CARB will operate simultaneously, it is important to avoid coordination problems in the form of dependencies between an actor and an activity for keeping a good level of flexibility within the organisation. These dependencies can be avoided by distributing knowledge about the tasks and the performance of these to the actors involved in the early phase. Otherwise, the actors will be limited to one process which in the long run might jeopardize the flexibility of the task distribution. This lack of flexibility could also result in unnecessary costs for the company since there will be a need to hire actors with knowledge regarding the specific process instead of assigning tasks to the actors within the company working on the other process. However, there will still be a need for recruiting additional actors since this new market entry will result in increased demand. Although, ensuring task flexibility can give the possibility of distributing the tasks among already existing actors in cases of high workload.

It is also important to consider dependencies that can develop between the departments involved in the OBD certification process and in order for the project to proceed smoothly, it is important to obtain a great cooperation between the departments. Poor communication within an organisation deteriorates the cooperation between the departments as well as the actors involved. Therefore, for ensuring a successful process for CARB, there should be focus on the distribution of responsibility, tasks and information. In other words, it is crucial to keep a focus on the changes that this new process will result in and not solely on the implementation of it. For example, the distribution of responsibility will differ for the process of CARB compared to Euro VI. There will be uncertainties regarding where the responsibility for a certain task lies and who has responsibility for what. This is an organisational change that the new process will bring which need to be addressed at the earliest state of the project and actions must be taken accordingly.

As opposed to the process of Euro VI, where there is no need for an approval in the case of implementing new updates to the software, the process of CARB requires approval by the authorities before implementation. At the current process, no approval is needed for changes in the software and therefore, software updates occur continually. Updating a software results in great competitiveness for a company but when entering the US market, a decision regarding the number of updates has to be made. Continuously software updates gives the customer the best performance possible but it will also result in higher workload for the company. Due to the fact that the CARB process requires yearly certification of the engines, the workload for this is much higher than the current process since several activities for the next model year have to occur during a current model year. Therefore, the best alternative for a company that want to

reduce the workload is to reduce software updates during a year and instead implement them when applying for certification for the next model year. A relevant question to ask is: Can the same amount of software updates be done for a CARB classified engine compared to a Euro VI classified engine?

These two processes have different requirements regarding the documentation management. For CARB, all DTC's must be documented in detail. At the current process, such documentation has never been performed. Moreover, the software developers will, unlike the current process, be involved in the creation of documents. This means that the software developers must be well aware of the document setup and content that CARB requires. This is a new way of working for the software developers and therefore uncertainties may appear regarding the establishment of the document package. Since there will be many software developers involved in the process with no earlier experience of conducting this type of documents, it is safe to say that there will be a need for templates to follow and support meetings to ensure that the documents conducted comply with the legislation.

However, the document package is a big issue that has been addressed by Scania and a solution for this is still not found. CARB requires the certification documentation to be established in a predetermined way with a specific structure. This information must be distributed to all actors involved in the documentation management. It is vital for the actors to understand what CARB requires as it reduces the reviewing work at the end since reviewing a gigantic document package is time consuming and the probability of delivering a flawless document package the first time might not be very high. CARB reviews the documentation package submitted by the manufacturer very thoroughly and all uncertainties are forwarded as questions to the manufacturer and these questions must be answered within one week. If CARB is not satisfied with the answers, follow-up questions will take place. As understood, this can be time consuming and since the questions must be answered within one week, other activities might be shifted in time which results in consequences. The first-time application will certainly result in unknown rounds of questions and therefore a manufacturer should take this into consideration. A great suggestion would be to automatically generate documentation which requires an implementation of a document management system. Generating the documentation automatically would reduce the time working with documents considerably. Also, the workload during one model year will also be reduced since software updates require changes in documentation and if the documents are generated automatically, the changes would be inserted in the system and a whole documentation package can be obtained automatically. This can be revolutionizing when certifying for CARB where documentation is a central part of the project.

When it comes to the DTC's, for the current process only a selection of DTC's has been tested and certified during a witness test. This means that there are several hundreds of fault codes that have never been tested before and can therefore contain unknown deficiencies that will be noticed when certifying for CARB. Also, the time required for testing these fault codes is unknown which might jeopardize the time schedule for project. The best way to go through with the CARB certification smoothly could be to start testing additional number of fault codes when certifying for other markets at the current process. By doing so, the testing engineer

would obtain a good knowledge about these fault codes which will simplify the testing period for CARB.

6.2 Justification and evaluation

This study has provided knowledge in a research gap regarding organisational change as a result of change to a regulation. Since this study is complement to the gap in the existing research, the manufacturers can use this study when entering the US market and can take advantage of the outcomes of this study. Not least, this study can be as a great support for the manufacturers when interpreting the legislation and which organisational changes that need to be taken into consideration. Further on, since this study is based on a case study, the outcome of this study will be of a great value for the case company since this research can work as a complement to the ongoing US project. The research questions comply with what the case company expects as a result from this study and the analysis of this study gives a valid outcome built on an interaction of the empirical study and the theoretical framework. Additionally, the scope of the study was thoroughly discussed with the case study company and since the purpose of this study is fulfilled, the outcome will certainly benefit the company. However, this study is not aimed for the society in general but rather for the heavy-duty manufacturers, not only in Sweden but internationally.

The validity and reliability as well as ethical consideration have characterized this entire study, from the execution of the interviews to reviewing the theoretical literature and the analyse work. Using one case company might be seen as a weak way of gaining generalized results. However, since this study is built on the legislation from CARB and Euro VI and what organisational challenges the movement from Euro VI to CARB will bring, the case study company was used as a supportive source these findings. Therefore, this study can certainly be generalized and utilized by many manufacturers.

7 CONCLUSIONS

The following chapter presents the answer to the research question and thereby fulfils the purpose of this study. Along with the conclusions, suggestions for further studies are also presented.

7.1 Identified challenges regarding the OBD certification process

The purpose of this study was to identify the challenges regarding the OBD certification process that may come with the move from Euro VI to CARB for a manufacturing company and how these challenges affect the organisation. The purpose has been fulfilled by answering the research question "What type of challenges arise for a manufacturing company when developing an OBD certification process according to the requirements from CARB compared to Euro VI, and how do these challenges affect the organisation?".

This study concludes that the movement from Euro VI certified engines to engines certified according to the requirements from CARB will result in comprehensive changes for a company's OBD process itself as well as organisational changes within the company. Such organisational challenges include distribution of responsibility, comprehensive coordination difficulties as well as the development of new working processes.

It is clear that compared to the current OBD process for Euro VI, the OBD certification process for CARB needs to be integrated into the entire CARB project and therefore the implementation of the new process will be widespread across the organisation and many actors will be affected and have responsibilities. The new process will involve more actors and departments in comparison to the current process and it is therefore crucial for all involved parts to be certain of their responsibilities and roles in this new process.

Furthermore, this move will also result in the development of new processes for the ways of working. The process for the DTC's, running changes and the documentation management are big changes that will require the development of new processes and new ways of working. With the development of new processes and designing tasks, coordination problems and dependencies can develop, which can, if not considered, affect the company in a negative way. The problem of coordination and dependencies can be tackled by having them in mind when designing the tasks and breaking them down into activities and assigning them to actors. Furthermore, promoting good communication in between actors and departments can be a good tool for avoiding misunderstandings and developing a great cooperation departments in between as well as between actors.

Moreover, compared to the current OBD process, the new process will increase the workload for the company. The reason for this is the yearly application for certification required by CARB as well as the fact that all running changes must be approved before implementation which requires additional resources. It is clear that this new process will require more resources than the current one, however, by increasing the knowledge and flexibility among the actors, less resources will be needed and actors can work on both processes simultaneously.

In conclusion, it is as important to consider the effects of the changes that this movement will bring on the company and the actors within, as it is with the implementation of the process itself. Hence, this study can act as a guidance for companies that are going through the same change.

7.2 Suggestions for further work

The management, leadership and way of working within a company can differ greatly. Consequently, these factors can have an impact on the current processes within a company which might lead to a lack of generalisation and applicability of this study on other manufacture companies with different circumstances. Since this study is based on one case study at a specific company, it would be highly interesting for further research to perform this study with more than one case study at several companies in order to address whether the results can be generalized or not.

There are many parts of an engine that need to be certified and approved before production and therefore it would be interesting to conduct research on the certification process for other parts of the engine or the entire engine and not delimit the study to the OBD system only. Studying the certification process for the entire engine requires an interpretation and understanding of the entire regulation as well as the involvement of many more actors. This could result in other organisational changes and other approaches when establishing a new process than what have been addressed in this study.

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APPENDIX 1: INTERVIEW GUIDE

1. How are you currently involved in the OBD certification process?
    a. What are your responsibilities?
2. How does the current OBD certification process for Euro VI look like?
    a. Are there any challenges with the current process?
3. How will the OBD certification process for CARB differ compared to the current process for Euro VI?
    a. What will be the main differences between these two processes?
4. What type of challenges to you see for the move from Euro VI to CARB?
    a. How will these challenges affect the company?
    b. How can the company handle these challenges?
5. What is the best way of distributing the responsibility within the certification process?
6. How is the OBD certification process integrated with the rest of the project?
7. How will the documentation management differ for the process of CARB?
    a. What is the best way to handle the documentation of the fault codes (DTC's)?
8. How will the yearly certification activities affect the company?
9. Can you make an estimation of the time it will take for the certification activities?
    a. What are important factors to consider when it comes to the time frame of the activities?
10. What are the challenges when it comes to the testing of the fault codes (DTC's)?
    a. What is the best process for the testing of the DTC's?
    b. Who should be responsible for the testing?

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