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# Thesis:
# Explaining the role of dieselgate in the rise of Electric Vehicles

*Author:*
Maurits Terwindt (4026381)

*Committee:*
Prof. Dr. R.R. Negenborn (chair)
Dr. W.W.A. Beelaerts van Blokland
Dr. J.A. Annema

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**Abstract**

This thesis looks into the link between the Volkswagen emission scandal, or dieselgate, and the strong rise of electric vehicles in the years following that event. In order to investigate this, a framework is build that describes the process of an innovation (the electric vehicle), taking over from an incumbent technology (fossil fuel cars), in measurable factors. This framework combines several theories on these subjects, including innovation diffusion, standard battles, disruptive innovation and radical innovation. The addition of manners to measure the underlying factors is one of the new aspects this thesis brings to both science and society. Through the application of the framework in case study concerning the automotive industry, it was concluded that dieselgate has indeed influenced the rise of electric vehicles, both directly and indirectly through Company Strategy, the reputation of a company, the opinion of consumers on technology, and government regulations and incentives.

**Keywords:** Dieselgate, Electric Vehicles, Standard Battle, Innovation Diffusion, 3C-model

# Contents

# 1 Introduction

Although electric passenger vehicles have been around since the start of the $20^{th}$ century, the rest of that century has been dominated by usage of vehicles with internal combustion engines, also known as ICE vehicles. Due to globalisation, governmental regulations, technological advancements and customer preferences, the car industry is experiencing rapid changes. Concerns regarding climate changes, air pollution and fossil fuel depletion call for more sustainable transport, which requires the adoption of electric vehicles, or EV's (Van de Kaa et al., 2017; Schulze et al., 2015; Wittmann, 2017; Sick et al., 2016). As a result, a second wave of EV's can be seen, starting in the second decade of the $21^{st}$ century. Strong increases in sales can be seen since the second half of that decade (Pelegov and Pontes, 2018; Berkeley et al., 2017).

Around that same time (in September 2015) it became public that Volkswagen had been cheating on their diesel emission tests, a scandal which became known as 'dieselgate'. Although regulations surrounding the emission-levels of passenger vehicles had been around since before then, and several car manufacturers were already developing EV's, Wittmann (2017) suggests that dieselgate might have been a tipping point, in which the industry started to focus on the development of EV's, rather than focusing on the production of cleaner ICE vehicles (Berkeley et al., 2017; Sick et al., 2016). Support for this suggestion can be seen in various car manufacturers stating, shortly after dieselgate came out, that they will start to focus on EV's, rather than ICE vehicles, in the near future. For instance, Audi (a subsidiary of Volkswagen) announced in April 2016 that it will stop with the development of ICE vehicles in 2025. Volkswagen followed suit in September 2017, stating that were working on a full conversion of the powertrain to fully electric. In December 2017, Toyota announced that in 2025, every one of their models should be available as a hybrid or fully electric (Wittmann, 2017; Siemssen, 2018; Reid, 2018). Secondly, the past decade has seen the fast rise of an automotive company that solely produces EV's, namely Tesla. In 2017, the market value of Tesla, surpassed that of industry-giant Ford, a company that had been around for 100 years longer (Siemssen, 2018). Tesla is new and small in comparison to the rest of the industry, but when looking at EV car sales and market capitalisation, it is the absolute market leader. Additionally, Tesla has been credited as being the company that showed that EV's were feasible, when other market leaders thought the technology was at least years away (Pelegov and Pontes, 2018; Siemssen, 2018).

EV's are as of yet a small portion of the total passenger car market, accounting for only 4.2% in 2020. However, significant growth was seen in the second half of the past decade, going from half a million sold in 2015, to 3.2 million sold in 2020 and this trend is very likely to continue, making it very likely that EV's will in the near future overtake ICE vehicles as the dominant format for passenger cars. Given the fact that these developments started to develop strongly after it became known that Volkswagen was cheating on their emission tests, the question arises whether that event has contributed to the rise of EV's, and if so: how?

## 1.1 Research statement and questions

Both the causes and effects of dieselgate, as well as the rise of EV's are well researched through literature. But attention to the fact that EV's really took off after the event, is something that seems to be missing from literature. Since dieselgate caused fossil fuels to become more scrutinised int he public opinion, and in the eyes of various governments, it stands to reason that dieselgate might have had something to do with the fast rise of these types of vehicles.

It seems unlikely that dieselgate has exclusively caused the shift, as a lot of companies were already producing EV's before dieselgate, public opinion regarding climate change had been growing for some time, and governmental regulations concerning air pollution and emissions had been tightening over the years. As such, it is unlikely that dieselgate is an actual separate driver in the process of this change. But what it might have done, is magnify or accelerate the influence of other drivers (for instance: make the influence of brand reputation or public opinion even stronger). In other words, dieselgate might have been a catalyst in the rise of EV's, both in terms of increasing sales, as well as in terms of the industry switching towards them.

This influence has not yet been described in literature. As such, this thesis aims to analyse the factors that have driven the strong rise of EV's and subsequently determine which of these factors have been influenced by dieselgate (and if so: in what way). As such, the main research question in this research is defined as follows:

> MQ: What has been the role of dieselgate in the strong rise of EV's?

In order to answer this main question, several steps need to be taken, which are formulated as sub questions, or research questions. These will now be discussed. First and foremost, it is important to see in what manner the automotive industry has changed over the past decade (the decade of the second wave of EV's), in order to see what changes exactly happened, when they happened and if they were important. In this context, attention will

be paid to dieselgate, and changes or developments relevant to the rise of EV's. Based on that, the perspectives from which to analyse the changes can be determined. As such, the first research question is formulated as follows:

> RQ1: Which relevant changes can be observed in the automotive industry over the past decade?

After creating an overview describing important changes in the automotive industry, the next step is to find a framework which allows to put these changes into perspective. Put shortly: the factors that have driven these changes need to be defined, so as to see which of them are influenced by dieselgate. In order to do so, a framework is needed that describes the process of an innovation (which the EV is), taking over from an incumbent technology (ICE-vehicles), in clear factors, whose influence can be determined (either qualitatively or quantitatively). As it turns out however, no framework from literature provides these exact purposes. As such, this knowledge gap needs to be filled be by creating a new one, using insights from literature. In order for this thesis to fill this literature gap, and to prevent bias by creating a framework that specifically looks for influences of dieselgate, a generic framework is required. Note that 'measurable' does not exclusively refer to assigning a numerical value. It can also be done by assigning a score based on qualitative considerations. This requirement is formulated into the second research question:

> RQ2: What framework can be used to analyse the process of an innovation taking over from an incumbent technology, in terms of measurable factors?

Using this generic framework, the process of EV's taking over from the incumbent technology can be analysed, and the factors can be investigated as to whether they have been influenced by dieselgate, by using the insights gained form RQ1. This last research question is formulated as follows:

> RQ3: What factors from the framework are likely to have been influenced by dieselgate, and how?

## 1.2 Relevance and Contributions

This thesis contributes to literature and society in several ways. First, it contributes to the literature on the effects of dieselgate, and literature related to the rise of EV's, by clearly linking the two and positive understanding on how the one has influenced the other. This was a very clear knowledge gap from literature. This thesis looks into what factors have driven EV uptake from an organisational perspective, which is an thinly researched aspect of EV research, as most research focuses only on uptake amongst consumers. Another scientific contribution of this thesis are the results regarding the influences of dieselgate. First of all, the aftermath of dieselgate is described very fragmented in literature. This thesis compiles existing knowledge regarding dieselgate and presents a clear overview, without only focusing on one specific aspect, as existing literature does. Secondly, this thesis then takes this aftermath, and proceeds to find out whether it has had an influence on an industry-wide change (i.e. : the switch towards EV's). The findings therefore, contribute to science by providing insights into the effects that a mayor disruptive event might have on an that industry. This is of course, determined for dieselgate specifically, but the research might provide a basis for research into other disruptive events and their effects on various industries.

Secondly the thesis develops a framework that was missing from literature, and in doing so has several contributions. Since the framework is designed to be generic, it can be used further in science and practice. The framework can for instance, be used to analyse other innovation versus incumbent technology scenario's and provide more insight this process. As it combines insights from various theories, like standard innovation and innovation diffusion, and attaches a way to measure an influence to the factors these frameworks are built on, it can be contributes to, and can be used in further research into, these theories. The same goes for research regarding disruptive and radical innovation. Lastly, this research contributes to literature surrounding partial financial performance indicators (like the 3C-model), by demonstrating that they can be applied to quantitatively analyse the influence of factors that are normally analysed qualitatively in literature. Since the generic framework describes the process at hand from an organisational perspective, it can be used by companies and investors to gain more understanding regarding these topics as well. Here, the fact that the framework takes many factors into account, while making clear how these influence the process, can be useful. It allows companies and investors to determine how they perform in each of the factors, leading to insights on whether their innovation is likely to be successful, or that their incumbent technology might be under threat. For instance, if a new technology is introduced, an incumbent company can use the framework to see whether that might constitute a threat by examining their own performances in each factor, and compare them to the company of the new technology. Conversely, it can be used by company introducing a new innovation, to analyse what aspects of the process they need to pay attention to.

## 1.3 Research overview

This structure of the research is seen in Figure 1. This structure will now be discussed, after which an overview of the report will be outlined. The research begins with an literature review on the relevant developments in the automotive industry (namely dieselgate and the rise of EV's), in order to answer research question 1. This literature review also looks into frameworks that can be used to analyse innovation from different perspectives, and several ways to measure the influences the different aspects of such a process might have in order to answer part of research question 2. These findings are summarised into two matrices, from which the knowledge gaps that lead to research questions 1 and 2 follow more clearly. Next, in order to fully answer research question 2, the factors of the frameworks are analysed and clustered into new factors that form the basis for the new framework. This new framework is then designed, verified through expert interviews and subsequently updated. The resulting version of the framework is validated through a theory-testing case study, in order to test it. Once verified and validated, the second research question is answered. Then, using the framework, and the insights of the first research question, a theory-testing case study is done, which determines the influences of dieselgate on the rise of EV's. The results are then compared with results from the interviews and discussed, leading to a well-rounded answer to the main questions.

The report is structured as follows. The methodology on the literature research, the interviews and the case studies is found in section 2. The literature research and knowledge gaps are discussed in section 3. The analyses on what frameworks to sue and subsequent new factors are found in section 4. Using these, a new framework is designed, verified and updated in section 5. This framework is then validated and tested in section 6. The framework is then applied in a second case study in section 7. The results thereof and a discussion leading to an answer are found in section 8. The conclusion, a discussion on the framework and recommendations are found in section 9.

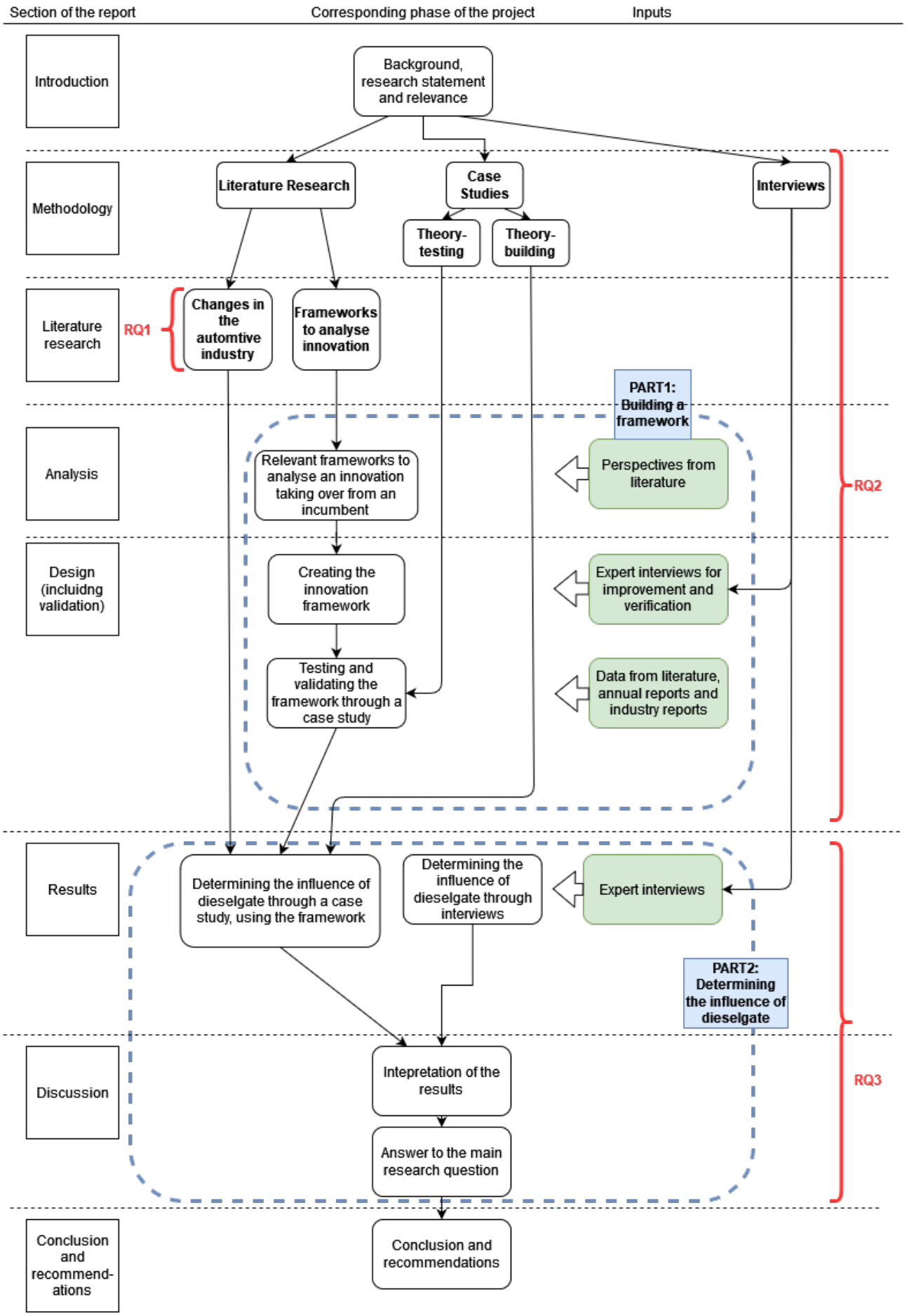


Figure 1: Outline of the research

# 2 Methodology

This section contains an overview of the methods used in this thesis, alongside a substantiation as to why certain choices were made. The processes will be discussed thoroughly, so as to make the work a reproducible as possible. In this thesis, the main question is whether dieselgate in some manner influenced the rise of EV's. In order to investigate this, first it was determined exactly happened in the industry in the past decade, when sales rose sharply and most companies switched (research question 1). As it turns out, EV's are considered an innovation, which means that in order to analyse the developments, a framework is needed which can be used to analyse the rise of an innovation. As such, the second research question looks into finding or creating a framework that can be used to analyse the rise of an innovation. Since no framework fitted the specific needs of this thesis, a new framework was build that analysed the strong growth of EV's, in several clear underlying factors, both qualitative and quantitative. This framework is subsequently tested through several interviews (verification: is it the right model?), and a theory-testing case study (validation: does the model work as intended?). The last question is which of those factors might have been influenced by dieselgate (research question 3). This is investigated through a theory-building case study. The results are discussed using literature and insights from the interviews, as interviewees are also asked what factors think have been influenced by dieselgate. These findings lead to a complete and well-balanced answer.

## 2.1 Literature review

In order to answer the first research questions and to find potential frameworks for the second research question, literature research was conducted. This method is chosen because a lot of research has already been done on both the automotive industry, and frameworks that explain the phenomena of an innovation, or new technology, taking over from an incumbent technology. As such, looking into previous research provides insight into which aspects and developments are important when analysing the automotive industry and innovations, and what kind of frameworks have been used to research innovations.

The literature review paid attention to the causes and effects of dieselgate, papers that discussed the rise of EV's, and papers that discussed frameworks that can be used to explain the rise of innovations. In order to find literature regarding these subjects, Google Scholar was used, as this is an extensive database with accurate search options, convenient result display and easy citing tools. In Google Scholar, a set of search terms were used, which are visible in Appendix A.

With these search terms a variety of papers containing information on dieselgate were found. In order to decide whether a paper was useful, first a selection was made based on the title, then on the abstract, then the introduction and then on discussion/conclusion sections. A paper was deemed as relevant for this thesis, and subsequently read entirely, if any mention of the causes and effects of dieselgate were made. The same procedure was on papers found regarding the rise of EV's. These were deemed suitable if mention was made regarding factors that caused EV's (mainly BEV's and PHEV's, although several papers on FCEV's were also found to be useful) to become more popular, or ICE-vehicles to become less popular. Aside from that, dieselgate-papers were checked for any factors that might have influenced the rise of EV's, and papers on EV's were checked for any connection or mention of dieselgate. As it turns out, very little papers discuss or link both concepts, which alongside suggestions for further research into dieselgate (such as in Beelaerts van Blokland et al. (2019)), prompted the first knowledge gap and the main question in this thesis. More on this in section 3. In order to put this thesis into context, and to provide data on specific important aspects mentioned in the papers, data on the automotive industry, such as sales or the market share of EV's, were obtained for the period of 2010-2020, alongside statements regarding automotive companies switching over to EV's, using annual reports (either directly, or through websites accumulating data from annual reports), news articles, and reports from industry insiders or consultancy firms. Several titles of these kind of reports were also found through the literature review, such as ZSW-BW.de (2020).

Many papers regarding the rise of innovations, or the competition between two technologies were found. In order to decide whether a paper was useful, first a selection was made based on the title, then on the abstract, then the introduction and then on discussion/conclusion sections. A paper was deemed as relevant for this thesis, and subsequently read entirely, if it provided a framework (usually consisting of several factors) which explained how a new kind of technology or innovation started, penetrated the market, or rose to become either a serious threat to an incumbent technology or even the new standard. It became clear rather quickly that most of these papers only provided qualitative statements on how to analyse innovation, and as such, papers were also searched that provided information on how to quantitatively analyse these kinds of developments. Some of the papers on the analysis of innovation were about innovations or technology in a more general sense, or connected to a specific industry. As will be explained later, the framework concerns technological innovations on a grand scale, and as such, papers connected to a specific industry were deemed suitable if they concerned large,

technological and (highly) competitive industries. Several of these paper were already about the automotive industry, but as will be explained later, this did not make it more suitable then others which also qualified, as a generic framework was needed. As it turns out, no generic framework that described the process of an innovation taking over from an incumbent technology (the core process of this thesis), in terms of measurable (qualitative or quantitative) factors, which is the second literature gap of this thesis. More on this in section 3. Aside from directly usable information, many of these papers also contained mention of other papers which could be interesting for this thesis, based on the above listed criteria. Several of the papers used have been found in this manner, like Van den Hoed (2007) and Cowan and Hultén (1996). The papers that were deemed relevant for this thesis, are discussed in section 3. As can be seen in Appendix A, a lot of search terms were used. A lot of these returned non-relevant papers, based on titles and abstracts. At some point it also started to return very few new papers, signalling saturation. At this point, the search for new papers was stopped. The findings from the literature research, together with matrices summarising their contents, and the subsequent emerging knowledge gaps, can be found in section 3.

In regards to research question 2, only part of this question is answered through literature research, another part is answered through verification using interviews, and validation using a case study. As it turned out, no framework suited the exact needs of this thesis, so one was constructed, and subsequently tested through a case study, the procedure of which is explained below. On the basis of the literature in frameworks, an analysis is made of which of the frameworks found are actually suitable in this thesis and how. No framework suited the exact thesis, so the selected frameworks were analysed in order to see how they might contribute to a new framework. This procedure is described in section 4. This analysis formed the basis for the design of the framework that, while being designed to be generic, fitted the needs of this thesis. The steps pertaining to the design of the framework are described in section 5. In order to verify the first iteration of the framework that was made to answer research question 2, interviews were conducted. Based on the input and subsequent extra research, a second iteration of the framework was build, which was then again verified through an interview, and validated through a theory-testing case study, where it was tested to see if it indeed did what is what designed for. When found to be verified and validated, the framework was applied in a theory-building case study, in order to answer research question 3. The procedure behind the interviews is now discussed, followed by the procedures on the case studies.

## 2.2 Interviews

To verify the framework that was constructed through the findings of the literature review (research question 2), and to gain insights on possible influences of dieselgate, several interviews were conducted with experts (referred to as 'interviewees' from here on). These interviewees were found through the papers from the literature research, searching the internet, and by asking previous interviewees on recommendations (snowballing method). A complete table of interviewees, alongside a short description of their role, how they were found and the date of the interview, is included in Appendix B. This appendix also contains the transcripts of the interviews.

Interviews were chosen because this research utilises a framework that did not exist before. As such, the framework needed a way to be checked. Aside from that, the influence of dieselgate (or any disruptive event) was not researched before, in terms of its influence on the uptake of an innovation, i.e. EV's. For these reasons, insights from people knowledgeable in the subject were required, and gathered through semi-structured interviews (Kallio et al., 2016; Wilson, 2013). Semi-structured interviews are used when some knowledge or issues on a certain a topic have already been found (through literature research, for instance), but further details are needed. This research requires systemic information on several topics from each interviewee, while also requiring the possibility to explore the emergence of new topics or insights. The semi-structured interview leads to both of these types of responses. Further strengths include the possibility to discover previously unknown (or missed) issues, clarifying complex information through probes, providing a mechanism to prevent straying to far from the topic, and broad comparisons between the outcomes of the interviews. Most of the weaknesses of this type of interview are related to using different interviewers, but since this research was conducted by one researcher, those are not relevant. There is one relevant weakness, namely the fact the interviewer might guide the interviewees into a particular answer, which needs to be watched for (Wilson, 2013). All interview questions were open, so that the interviewee could give in-depth answers and new insights, which led to better results for this research. The questions used in the interviews can be seen in Appendix C. The interviewees were sent a short document explaining the framework ahead of the interview (one interviewee was interviewed twice, he received an updated version), so they had a chance to study it beforehand. This allowed for a more effective interview, as the interviewee already had some knowledge beforehand and could directly ask for clarification.

As stated, the interviewees were asked to give their opinion on the framework, and what factors they feel are influenced by dieselgate. Regarding interviewees, it was logical to start with Interviewee A and Interviewee B, as

both have designed frameworks that are featured in the framework of this thesis, making them strong candidates to be interviewed regarding this framework, as their insights could be (and were) used to strengthen it. The interviewees were asked whether they had recommendations for others to interview. This led to Interviewee C.

In order to help the researcher to thoroughly analyse the data, and for the purposes of transparency, all interviews were recorded and transcribed. Transcription was be done by hand, because the researcher could then immediately extract useful information. Apart from that, transcription by hand is the most thorough: certain cues or non-verbal communication can be missed it automated software is used. Lastly, this kind of software is never really fool proof, which will likely lead to errors. Aside from recording and transcribing, the researcher also took notes during the interview. This was to remind himself of questions that arose, and for interesting points that came up and he wanted to discuss later on in the interview.

The data from the interviews was transformed into results through a qualitative content analysis. In the qualitative content analysis of an interview, both during and after transcription, the researcher looks for answers, statements and other remarks that stand out in regards to the questions, and other statements by the interviewee. According to LeCompte (2000), qualitative content analysis consists of 5 steps. The first step is 'tidying up', which means neatly cataloguing and filing the data. After that, in step 2, items are found. Items are the pieces of information that can be coded, counted or assembled into results. Items are found by the researcher by looking at frequency (certain pieces of information occur numerous times), omission (a suspected piece of information is missing), or declaration (a piece of information is clearly stated). In step 3, items are related to each other either trough semantic relationships (item A is related to item B), or through the creation of taxonomies (items share common characteristics). In step 4, patterns are found by looking into how taxonomies can be grouped together in meaningful ways. This might be through similarities, co-occurrences, sequences, hypotheses or triangulation. In the final step, these patterns are build into structures that together, provide an answer to the problem that was being researched. Using semi-structured interviews and qualitative content analysis, both direct answers to the questions (and hypotheses) can be found, but it also allows for the emergence of new results, through data from spontaneous remarks and insights. The interview process is visualised in Figure 2.

Due to the use of interviews, this research is classified as 'human research'. This means that it is subject the guidelines of the TU Delft Human Research Committee. Therefore, the interviewees were asked to fill out the TU Delft Informed Consent Form. As is good practice, the interviews were recorded and transcribed, and the interviewees were presented with the transcript and an overview of the main take-aways from the interview. Approval to use/publish these findings was asked as well. See `https://www.tudelft.nl/over-tu-delft/strategie/integriteitsbeleid/human-research-ethics/` for more information on Human Research Ethics and the Informed Consent Form.

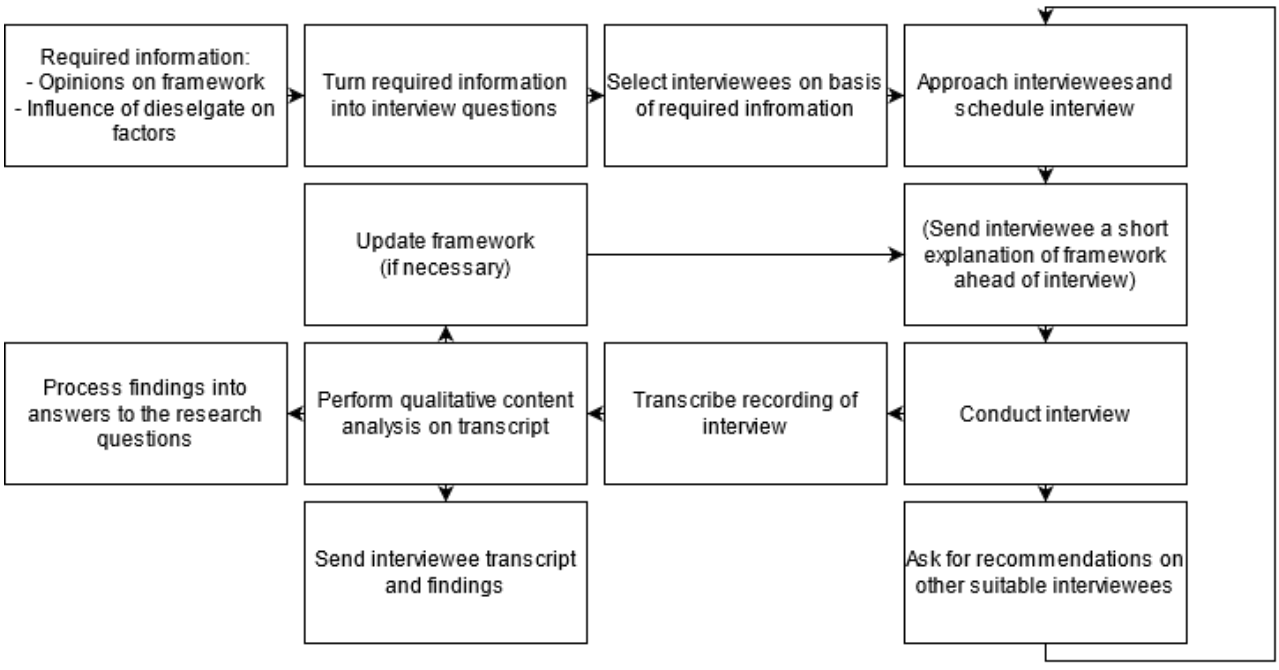


Figure 2: The process of the interviews.

## 2.3 Case studies

For the case studies, the methods described in Dul and Hak (2007) are used. In this book, a case study is defined as 'a study in which (a) one case (single case study) or a small number of cases (comparative case study) in their real life context are selected, and (b) scores obtained from these cases are analysed in a qualitative manner'. With 'a qualitative manner' it is meant that these scores are interpreted by their meaning rather then using statistical interpretations. Dul and Hak (2007) define 3 types of research in which case studies may be used: practice-oriented, theory-testing and theory-building. By 'theory' the authors mean a set of statements regarding the relations between concepts. In this thesis, the latter two are used: a theory-testing case study is preformed to validate the framework (thereby finalising the answer to research question 2), and a theory-building case study, in order to determine the influence of dieselgate on the rise of EV's (thereby answering research question 3). The procedures behind both types are discussed in this section, but first some definitions from Dul and Hak (2007) are explained, as these feature often throughout this section:

- **The object of study:** defined as the stable characteristic in the study. In the framework, the object of study is the process of an innovation taking over from an incumbent.
- **Domain:** The larger context that the object of study belongs to. This could for instance be a specific industry, when looking at a certain technology as the object of study.
- **Concept:** these are the variable characteristics of the object of study. In this thesis, these are the factors of the framework (independent concepts), and the success/failure of a technology (concept B). Also known as 'variables'.
- **Proposition:** this is the formulation of a causal relation between concepts. These can be one of four condition, or relations:
  - the sufficient condition ('if there is A, then there will be B')
  - the necessary condition ('B exists only when A is present')
  - the deterministic relation ('if A is higher, then B is higher')
  - the probabilistic relation ('if A is higher, then it is likely that B is higher'
- **Measurements:** this is the way in which an independent concept is expressed, in order to determine its relation to the dependent concept. Note that 'measuring' does not strictly refer to a process of numerical scoring, but refers to any process of determining the influence a concept has on another concept. As such, it can also be done by attaching a qualitative score. For instance, an independent concept can be favourable or unfavourable. The proposition than might be (with a sufficient condition): a favourable A leads to the presence of B (and an unfavourable A to the absence of B).

### 2.3.1 A theory-testing case study

The developed framework needs to be tested before it can be applied to the actual case study, in which the influence of dieselgate is determined, by looking at EV's (innovation) rising at the expense of the ICE-vehicles (incumbent technology). Since developing the framework specifically for that case would likely lead to bias, and the fact that there is a knowledge gap surrounding frameworks describing the process of an innovation taking over from an incumbent in both qualitative and quantitative terms, a generic framework is developed.

This was also important, because this allowed the framework to be tested prior to applying it, by looking whether it also works for another situation in which such a process (innovation versus an incumbent) occurs. This is done through a theory-testing case study. The theory here is that the framework indeed correctly describes the success of the innovation, as a result of the various factors. In more specific terms, the question than becomes, if each of the factors correctly describes its contribution to the success of the innovation. When this is then expressed in the terms of Dul and Hak (2007), each of the factors become the independent concepts (concept A) and the success of the innovation becomes the dependent concept (concept B). Note that success of the innovation is expressed as either successful or unsuccessful. See Figure 3.

Lastly, it is important to note that on the basis of one case study, it is not possible to state with absolute certainty that the theory (namely, that the factors - and thus the framework - all work as intended) is correct for every case. In order to be able to state this with more certainty, more theory-testing case studies must be done. However, for the purposes of this thesis, one case study suffices to assume that the framework works as intended and can be used for the theory-building case study.

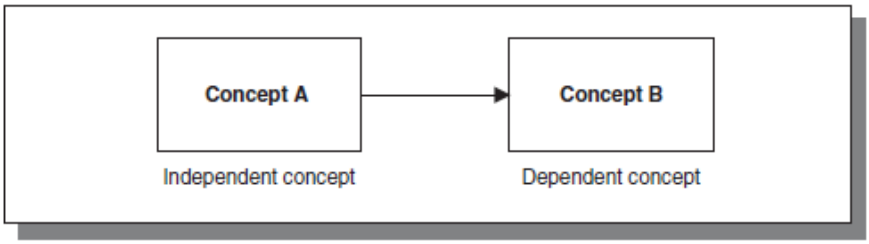


Figure 3: Independent concept and dependent concept (Dul and Hak, 2007)

The theory is, that each of these concepts A, lead to concept B. In other words, each concept A leads to concept B (each factor plays a role in the success/failure of a technology). The proposition then becomes: if there is A (for instance: a favourable market), then there is B (a successful innovation). As such, the proposition for set of concepts is the sufficient condition.

Each concept A has its own measurement, which are defined through various insights from the literature. For instance, when looking at the market conditions, this might be favourable (low competition, existence of niche markets), unfavourable (high competition, no niche markets), or neutral (neither, or a balance between the aspects that make up this measurement). The measurements for each concept are discussed in the section 6.

### 2.3.2 A theory-building case study

In a theory-building case study, the process is reversed, but similar nonetheless. In the theory-testing case study, all the concepts and their relations (propositions) were known, and the goal was to test if these propositions were indeed correct. In the theory-building case, the concepts are known, but their relations are not, and the goal is to define new propositions between them, on the basis of observations. See Figure 4.

In this case study, the independent concepts (factors from the framework) and the dependent concept (success/failure for the technologies) remain the same. In the theory-testing case study, it was proven that they work as intended (i.e.: have the relation that is expected of them), so now the question is whether that is also the case when applying them to the rise of EV's. In other words, the goal of the theory-building case study is to formulate new propositions on the basis of observations. By observing whether different relations occur between the concepts, new propositions are formulated, which ultimately lead to the formulation of a theory surrounding the influence of dieselgate through the factors of the framework.

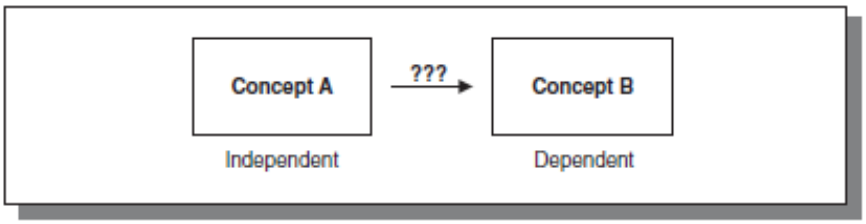


Figure 4: Independent concept and dependent concept, with an unknown proposition (Dul and Hak, 2007)

# 3 Literature review: Dieselgate, the rise of EV's, and innovation

This thesis looks at the second wave of EV's, which started in 2010. EV sales have been growing fast in the last few years of that decade. The main purpose of this thesis is first to find out what underlying factors have caused this growth, and subsequently determine which (if any) of these factors have been influenced by dieselgate. For the first step, it needs to be known what developments have actually happened. The second step is then to determine what frameworks can be used to analyse these developments.

The review starts of with a section on recent developments in the automotive industry. It begins with a section on dieselgate, analysing its causes and effects. This is followed by a section on recent developments, related to EV's. It shows increasing sales and market share, the background of which is discussed through various papers from literature. The first section is concluded by a matrix summarising the findings, and establishing the first research gap, namely that there are no papers that describe a complete picture of the possible influences that dieselgate might have had on the rise of EV's.

The second part reviews literature on innovation. In this section, several framework and perspectives are discussed and analysed for their applicability to the research statement of this thesis. The objective of this section is to decide what framework(s) will be useful for the research, or what aspects are important when multiple frameworks are grouped or incorporated. This section too, is concluded with a matrix summarising the findings. As it turns out, there exists a second knowledge gap, which this thesis will fill, namely the fact that there is no framework that describes the process of an innovation taking over from an incumbent technology, in terms of measurable factors.

## 3.1 Development and changes in the automotive industry

The first step in order to determine what the influence of dieselgate has been, and whether it has driven the rise of EV's, is to determine what developments and changes can be observed in the automotive industry. The most obvious development has been the fact that between 2010 and 2020, the amount of EV's sold has risen from a 10000 in one year, to 3.2 million in one year. This section starts with a description of dieselgate from literature, both in terms of causes and effects. Starting with dieselgate has two reasons: it is a central theme in this thesis, and in the section discussing literature regarding the rise of EV's, attention will be paid to the question if dieselgate is considered. As such, it is important that the reader has knowledge about dieselgate.

Following the section on dieselgate, relevant changes in the automotive industry are discussed. First, the two main observations are discussed, namely the strong rise of EV-sales, and statements regarding industry leaders phasing out ICE development in favour of EV development. This is followed by a literature review on papers explaining the rise of EV's, in which attention is paid to the possible influence of dieselgate. The section concludes with a matrix that summarises the findings from the papers, while stating the knowledge gaps that each paper has. These gaps are then reformulated into the first knowledge gap that this thesis, aims to fill, namely that the influence of dieselgate on the current rise of EV's has not been adequately researched.

### 3.1.1 Dieselgate: what happened?

In September 2015, the news broke that the Volkswagen Group had been using illegal software in their diesel cars to manipulate emission test results. This scandal became known to the public as 'dieselgate'. The fallout for Volkswagen Group was immense: the company had to pay a total of €30 billion in fines and settlements, and two Volkswagen employees were sentenced to prison (Dworaczek et al., 2020; Matussek, 2021).

So what happened? Volkswagen introduced the diesel-powered Golf to the European and US market in the mid 1970's, and the model became a success. In the late 1980's, Volkswagen successfully introduced direct injection technology in their Audi models, which led to better engine performance and reduced fuel consumption. These successes led Volkswagen to become the dominant force in the passenger diesel market in Europe. In the late 1990's, several other car companies (Fiat, BMW, Mercedes-Benz) started using a new diesel technology, called Common Rail, or CR. Volkswagen developed its own new technology: the *Pumpe-Düse*, or PD. The PD offered more power and consumed less fuel than the CR, but produced a much higher NOx emissions, which among other problems, cause respiratory problems and cancer. In fact, NOx emissions are deemed to be the biggest environmental risk to health in Europe by the World Health Organisation. (Mujkic and Klingner, 2019; Milionis et al., 2019). EU nations at the time had been incorporating NOx limitations in the EURO norms since 1992, with the introduction of the EURO 1 in 1992. They had been more concerned with CO2 emissions however, and had only been seriously reducing NOx limitations since EURO 3 in 2001. US regulations had focused on NOx a lot longer already, and thus were a lot stricter. Volkswagen's PD technology could not comply with even the minimal 2009 Euro V norms (and later, the even stricter EURO VI norm of 2014), let alone the US norms (Milionis et al., 2019; Mujkic and Klingner, 2019).

Volkswagen's long term goal since the 1990's was to become the world's largest car manufacturer, which required capturing a large share of the US car market. In order to do so, in the mid/late 2000's it started to introduce many vehicles to the US market, using their 2.0-litre EA189 engine, which relied on the PD technology. In spite of Volkswagen's 'clean diesel' claims, these engines could not meet the US Environment Protection Agency (EPA) standards, without using SCR technology, a filtering technology that reduces NOx emissions. Adding this technology would add several thousand dollars to the price of the car, and Volkswagen feared that this would led to pricing themselves out of the US market (Mujkic and Klingner, 2019).

In 2005, a solution was offered by a Volkswagen technical expert, which was approved by top-level management. Software was installed which altered the way in which the Engine Control Unit (ECU) functioned: the car would recognise when it was being tested (different air pressure, no steering, rear wheels not spinning), and would alter the performance of the car accordingly. It would change the ration between air and fuel being injected into the engine, thereby lowering power and thus reducing NOx emissions. After the test, the ECU would return to the regular settings. Such software is commonly known a a 'defeat device'. The reason for installing it was twofold. On the one hand, it was the only way that Volkswagen would be able to sell its diesel cars on the US market, while buying time to catch up with it competitors using CR technology. On the other hand, by marketing 'clean diesel', they could actually attract a new segment of the market, namely the consumer that was environmentally conscious, but also wanted a car with good performance. As to why this decision was approved by Volkswagen top-level management, research indicates that Volkswagen had 'unethical corporate leadership', a 'lack of accountability', and a 'culture of ruthless management in which engineers could not admit defeat' (Mujkic and Klingner, 2019; Nunes and Park, 2016; Bovens, 2016).

The first signs of the fraud were discovered in 2014, when a group of students from the West Virginia University (supported by the International Council for Clean Transportation, or ICCT), started testing 'clean diesel' claims by conducting pollution tests on the road (instead of a testing environment, for which the defeat device was designed). In these tests, they noticed that the Volkswagen Jetta TDI (which was equipped with an EA189 engine), emitted up to 40 times more NOx then what was reported in tests, and what was the norm. They presented their findings at a conference in San Diego in 2014, after which the California Air Resources Board (CARB) gave them access to their own test facilities to conduct more research. After this, the students and the ICCT turned over their results to the CARB and the EPA, who certified them and confronted Volkswagen. At first Volkswagen denied the charges, but after CARB kept pressing, the company agreed to recall 482.000 Volkswagen models in December 2014. The CARB however, suspected that this recall was an attempt to hide the defeat devices, and met on 20 August 2015 to discuss this. Here, Volkswagen representatives admitted having used defeat devices, and on 3 September 2015, Volkswagen executives confirmed this. EPA officially announced on 18 September 2015, that Volkswagen had knowingly cheated tests results. Volkswagen CEO Martin Winterkorn was forced to resign, but claimed having not known about the fraud, despite whistle blowers claiming the opposite. He was replaced by Matthis Mueller, who came from Porsche. Volkswagen agreed to buy back 500.000 Volkswagen models with the EA189 engine, and was hit with fines and settlements for a total of €30 billion. US engineer James Liang, who developed the software, and German Volkswagen executive Oliver Schmidt were sentenced to prison. Becoming known publicly as 'dieselgate', the Volkswagen emission scandal was the largest and most costly fraud in automotive industry history (Mujkic and Klingner, 2019; Nunes and Park, 2016; Bovens, 2016; Dworaczek et al., 2020).

Not surprisingly for a scandal of this scale, dieselgate's effects stretch far wider than only to perpetrator Volkswagen. Many studies have been conducted into the effects on various economies, the public and influence on other companies (known as the inertial or spill-over effect). Several of these effects will now be discussed in more detail, as these form the bases for the possible influence of dieselgate on the rise of EV's.

First and foremost, the public opinion on several topics has shifted. Logically, the public opinion on Volkswagen became more negative. The company had engaged in illegal activities, covered it up, and subsequently lied about it, which caused a lot of negative publicity, a loss of trust of its consumers and its legitimacy (Mujkic and Klingner, 2019; Dworaczek et al., 2020). This negative attitude towards Volkswagen also reflected in its finances: in the 3 days following the announcement, its stock prices dropped by 20%, the largest drop in history. In the last 2 months of 2015, Volkswagen sales had dropped by 25%, indicating a change in consumer behaviour, or rather: the negative consequences a company has to deal with when the public no longer views them as legitimate (Cârstea, 2016; Dworaczek et al., 2020). Interestingly however, despite consumers saying that they were upset with Volkswagen, the company did become the largest car manufacturer in 2016 (Mujkic and Klingner, 2019). Although here it must be noted that Volkswagen, of course, was already a huge company. Global sales dropped from 10.4 tot 9.9 million, still putting them at the very top (Dworaczek et al., 2020)

In spite of this, dieselgate raised the public's doubts on the environmental impact of cars, traditional ways of propulsion and the environmental viability of diesel engines in general (Nunes and Park, 2016; Cârstea, 2016). Especially American consumers became less confident in the trustworthiness of the automotive industry

(Cârstea, 2016). Diesel was already unpopular as a fuel in US (as showcased through strict regulations by the EPA), and dieselgate made it even less popular. According to The Economist (2016): 'The damage done by Volkswagen's cynical and ethically challenged behaviour could well prove fatal to the future of the diesel technology in the USA'. In January 2016, 222 diesel powered passenger cars and light trucks were sold, as compared to 4.500 in January 2015: a 95% drop (Eisenstein, 2016). In Germany, the feeling of distrust amongst the public as a result of dieselgate, led to dropping sales of new diesel vehicles: from 48.0% of all new vehicles sold in 2015, to 33.3% in 2018 (Baumgärtner and Letmathe, 2020).

Baumgärtner and Letmathe (2020) suggest that due to dieselgate, and due to distrust of diesel vehicles in general, the past few years have seen an increase in regulations surrounding diesel cars. In Berlin, Hamburg and Stuttgart, vehicles not complying with emission standards were banned in 2018. Similar regulations can be seen in the rest of Europe. Starting from 2021, diesel vehicles are prohibited in Bristol, and large cities as Madrid and London are issuing low-emission zones. These types of regulations are mainly present in the EU, as diesel cars have a high market share in Europe, whilst they are much less popular in the US (Baumgärtner and Letmathe, 2020). Next to that, Dieselgate has caused the EU to accelerate initiatives or to take new actions regarding the testing of vehicle emissions, in order to prevent a similar event from occurring again. Some of the accelerated legislative changes in the EU vehicle emission system are granting the Commission to power to review national bodies tasked with testing, test vehicles themselves, and to penalise perpetrators. Aside from that, testing will no longer only be in laboratory conditions (which the software from the VW cars picked up upon), but also on the road. These real-driving emissions tests (or RDE's) are now also meant to measure NOx-emissions (Milionis et al., 2019).

As stated before, dieselgate caused Volkswagen stock prices and sales to drop. In the 3 weeks after the scandal became public, the company's market capitalisation even dropped by 45% (Baumgärtner and Letmathe, 2020). Aside from that, the company has had to pay €30 billion in fines and settlements (Dworaczek et al., 2020). But beyond that, dieselgate had other severe economic impacts as well, to the economic position of Germany, to the labour market, and to other (automotive) companies (Bovens, 2016; Cârstea, 2016; Baumgärtner and Letmathe, 2020). This influence on other companies or organisations (both in the same, as well as in other industries) who weren't part of the initial event, is known as the 'inertial effect' (Nunes and Park, 2016), the 'contagion effect' (Bouzzine and Lueg, 2020) or the 'spillover-effect' (Dworaczek et al., 2020). The term 'inertial effect' is used in the paper by Nunes and Park (2016), who demonstrate that dieselgate caused stock prices to drop of several American companies, both directly in the automotive industry, and in the supplier industry of the automotive industry. Through this inertial effect, these companies depreciated for a total of $6.44 billion. The majority of the damages were found in companies that were possible targets for mergers or acquisitions with Volkswagen. Aside from this direct stock price drop, dieselgate also strongly affected supplier companies who bet on diesel breaking through in the American market, and thus bet on supplying companies that manufacture diesel vehicles. These supplier companies also saw their businesses threatened by the sudden drop in popularity of diesel vehicles. This goes for both companies directly doing business with Volkswagen, as for companies who worked with other car manufactures. (Cârstea, 2016; Nunes and Park, 2016).

According to Dworaczek et al. (2020), who refers to this phenomenon as the 'spillover-effect', this also happened in Europe, where dieselgate resulted in severe financial damage to material suppliers, business customers and other car manufacturers, even competitors of Volkswagen. Daimler and BMW, being other large German car manufacturers, suffered financial losses (mostly due to stock price drops), even though only Volkswagen was investigated (Jacobs and Singhal, 2020). Bouzzine and Lueg (2020), who call the phenomenon the 'contagion effect', attribute this to 'guilt by association', even though there was no indication that either of these companies was involved in similar practices at the time. However, shareholders feared that due to the event, inspections would be held at other automotive companies, and that similar practices would be found. This led them to withdraw from these companies. As such, the state that the impact of dieselgate was 'far worse for Volkswagen's peers than for Volkswagen itself'. Same as in the US, European supplier companies saw sales drop and their stock devalue as a result of dieselgate. Even the 'Made in Germany' label, which for a very long time stood for high quality, was discredited due to the scandal (Bouzzine and Lueg, 2020; Dworaczek et al., 2020).

The drop in popularity of diesel powered vehicles amongst the public has already been discussed, but since the dieselgate scandal affected a lot more companies than only perpetrator Volkswagen, it is not surprising that in these companies too, the popularity waned. This caused several companies to re-evaluate their business practices and start to focus on new technologies. Even heralded as 'The death of the Internal Combustion Engine' by The Economist (2017), dieselgate has had and will have long term effects on the automotive industry. Where Japanese companies had already bet on hybrid cars, European car makers (particularly Volkswagen, of course) had bet on diesel. As a result of dieselgate, this strategy had to be revised. At the same time, Europeans started to pay more attention to the health risks associated with NOx (Mujkic and Klingner, 2019).

Although the author strongly suggests that other forms of internal combustion engines, such as the 'lean

burn compression ignition technology' might be a better alternative than electric vehicles, Boretti (2017) states that dieselgate has had an serious impact on the future development of power trains. According to him, the scandal and in particular, the US settlements, have accelerated to the adoption of battery electric vehicles. In the US, Volkswagen had to pay approximately $14.7 billion. $10 billion of this is to buy back the cars with the defeat devices, $2.7 billion is to establish an environmental thrust, and the last $2 billion is to finance electric car infrastructure. This last portion of course, is very interesting as it clearly indicates a link between dieselgate and EV's. The main idea of that part of the settlement is 'to promote non-polluting cars (zero emissions vehicles or ZEV's), over and above any amount Volkswagen previously planned to spend on such technology'. As such, these settlements have forced Volkswagen the re-evaluate their strategy and further development of diesel-engines and to start looking at EV's. Apparently Volkswagen had already foreseen that such actions might be taken against them (or perhaps as an act of damage-mitigation), because while these settlements stem from 2017, the company had already started to promote cars with a smaller impact on the environment, like EV's or gasoline powered vehicles, on the American market in 2016 (Cârstea, 2016). Since the scandal also affected other car manufactures, and the settlement is mainly focused on establishing the infrastructure, it stands to reason that this will also influence the view of other car manufacturers on traditional power trains, vis à vis EV's (Boretti, 2017; EPA.gov, 2017).

The paper by Beelaerts van Blokland et al. (2019) looks at how performance of automotive companies was affected by the 2008 crisis, by using the metrics from the 3C-model (discussed in more detail later). For further research, this paper suggests measuring what the effect of dieselgate was on the performance metrics. This suggestion, alongside the identified gap (see Table 3) were the main reasons to investigate dieselgate. While this thesis applies the 3C-model in a different manner (by looking at competing technologies, instead of the maturity of companies), it does determine the 3C-metrics before and after dieselgate and describes the changes, thereby taking on (part of) the suggestion of Beelaerts van Blokland et al. (2019).

### 3.1.2 The rise of EV's, and the switch of the industry

In order to analyse developments regarding EV's, some demarcation is in order. The second wave of EV's started in the second decade of the $21^{st}$ century, and dieselgate happened in halfway through that decade Pelegov and Pontes (2018). As such, this thesis considers the period of 2010-2020. Secondly, as will become clear, many automotive companies are moving away from traditional ICE vehicles, and towards various kinds of EV's. As of 2020, these vehicles only make up a very small part of total car sales, but the number is growing, and more importantly: growing significantly faster than ICE vehicle sales. EV's come in two main variants: plugin vehicles and fuel cell electric vehicles (FCEV's). Plugin vehicles consist of two main variants: plugin hybrid electric vehicles (PHEV) and battery electric Vehicle (BEV). In this thesis, only plugin vehicles (BEV and PHEV) are considered, as fuel cell electric vehicles are a relatively insignificant portion of the market for the past decade, and according to Van de Kaa et al. (2017) BEV's are, in regards to the standard battle, superior in every metric when compared to FCEV's. Therefore, PHEV's and BEV's are very likely to become the standard in EV's. As such, when this thesis discusses EV's, it refers only to BEV's and PHEV's.

First off, to give some context to this thesis, two main observations regarding EV's are discussed, namely the very significant growth in sales in the last decade, and the observation that every large automotive company has stated that, in one way or another, they will phase out ICE development in favour of EV's somewhere in the next decade. These two observations are now discussed, after which several papers are discussed which attempt to explain the rise of EV's. Figure 5 shows the development of the BEV and PHEV market. The left vertical axis shows total sales numbers, while the right vertical axis shows market share. Significant growth in these numbers can be seen in the second half of the decade. Only 10000 EV's were sold in 2010, while more than a million were sold in 2017, more than 2 million in 2018 and 2019, and more than 3 million in 2020.

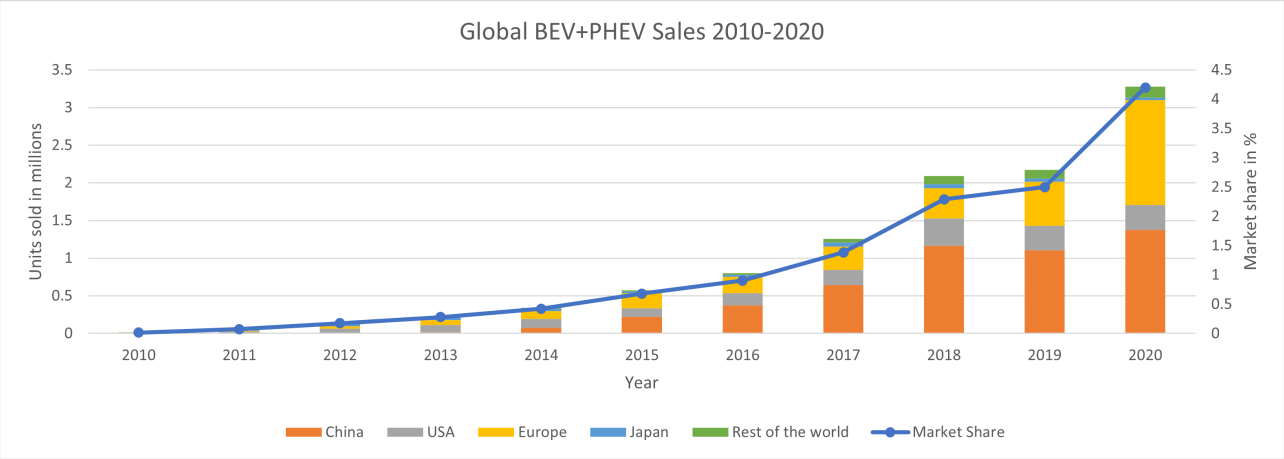


Figure 5: Global BEV and PHEV sales and market share for the period 2010-2020 (ZSW-BW.de, 2020)

Cumulatively, these sales amount to 10.9 million BEV's and PHEV's sold (ZSW-BW.de, 2020). When looking at the companies behind these figures, it is important to note that the Top 10 of EV-sellers is not the same as the Top 10 automotive companies, when measured by total sales or market capitalisation (although some are in both). This is interesting, as it indicates that this market is dominated by different players than before. For instance, Toyota, the number 2 automotive manufacturer in the world when looking at yearly revenues, is not even in the EV top 10, while smaller and newer companies like Tesla and BYD top the list. As such, different mechanics are at play, as the market is shifting and the large household names are no longer the key players. The top 10 of companies behind these numbers are visible in Table 1. Note that several of these companies represent not just one brand, but a whole group. For instance, Volkswagen also includes Audi, Skoda and Seat.

Table 1: Top 10 PHEV and BEV sellers (cumulative)

| # | **Company** | **BEV's and PHEV's sold** | **Share of total[%]** |
|---|---|---|---|
| 1 | Tesla | 1384500 | 12.82 |
| 2 | BYD | 916400 | 8.49 |
| 3 | Volkswagen | 778300 | 7.21 |
| 4 | BMW | 603200 | 5.59 |
| 5 | SAIC | 569100 | 5.27 |
| 6 | Nissan | 531300 | 4.92 |
| 7 | BAIC | 509600 | 4.72 |
| 8 | Hyundai | 378200 | 3.50 |
| 9 | Geely | 356200 | 3.30 |
| 10 | Renault | 346600 | 3.21 |

A second important observation regarding the automotive industry, is the fact that several car-companies that historically focused on manufacturing ICE-vehicles, announced in recent years that they will phase out their ICE-development and instead start focusing on the development of EV's. Audi (a subsidiary of Volkswagen) announced in April 2016 that it will stop with the development of ICE vehicles in 2025. Volkswagen (the brand) followed suit in September 2017, stating that were working on a full conversion of their powertrain to fully electric. In December 2017, Toyota announced that in 2025, every one of their models should be available either as a hybrid or as fully electric option (Wittmann, 2017; Siemssen, 2018; Reid, 2018). A lists of the top automotive companies and their announcements can be seen in Table 2. Note that since this observation is about traditional ICE-manufacturers, this table takes revenue in 2020 as its base. This gives an accurate overview of the top of the industry, and thus clearly illustrates that this switch is happening.

This is a very interesting development, as a lot of these companies initially resisted the development of EV's, instead focusing on improving the efficiency or emission-behaviour ICE-vehicles, because the switch to EV's would involve large overhauls of their production lines and require large investments in Research and Development. This phenomenon is referred to as 'sailing ship', 'path dependency', or 'incumbents curse' (Sick et al., 2016; Hardman et al., 2013; Dijk et al., 2016; Van den Hoed, 2007). As could be seen in subsubsection 3.1.1, this phenomenon occurred at Volkswagen: they had bet on the EA189 engine and it would be to costly to develop a new engine or to upgrade this one with the filtering technology, and thus they decided to cheat. At some point

in time however, these automotive companies decided to switch over, in spite of always having developed ICE vehicles (and thus experiencing path dependency). Since this switch clearly illustrates changes in the industry, it is an important aspect of the rise of EV's.

Table 2: Top car companies by revenue (2020), along with their announcements to switch towards EV's

| # | **Group** | **Revenue (in mil. $)** | **Brands** | **Year and nature of switch** |
|---|---|---|---|---|
| 1 | Volkswagen | 282,760 | Volkswagen, Audi, Seat, Skoda, others | 2016 (Audi): Stop the development of ICE vehicles in 2025<br>2017 (VW): Start working on converting powertrain to fully electric |
| 2 | Toyota Motor | 275,288 | Toyota, Daihatsu, Lexus, others | 2017: All mainstream vehicles available as a hybrid or fully electric in 2025 |
| 3 | Daimler | 193,346 | Mercedes-Benz, Smart | 2020 (Mercedes-Benz): By 2022, the entire Mercedes-Benz product range is set to be electrified |
| 4 | Ford Motor | 155,900 | Ford, Lincoln | 2021: Every European Ford will be semi-electric in five years, and 100% EV by 2030 |
| 5 | Honda Motor | 137,332 | Honda, Acura | 2019: All mainstream vehicles electrified by 2022 |
| 6 | General Motors | 137,237 | Chevrolet, Cadillac, others | 2021: Phase out combustion engines, and be all-electric by 2035 |
| 7 | SAIC Motor | 122,071 | Maxus, MG, others | 2020: Announces plans to take over from Tesla as largest EV manufacturer<br>2020: China to phase out ICE vehicle production by 2035 |
| 8 | BMW | 116,638 | BMW, Mini, Rolls-Royce | 2020: Announces 10-year sustainability plan, which includes selling more then 7 million EV's by 2030. |
| 9 | Nissan Motor | 90,863 | Nissan, Renault, Infinity, Datsun | 2018 (Nissan): Phase out diesel and push EV-models<br>2020 (Renault): Phase out diesel and focus on electrifying range of vehicles. |
| 10 | Hyundai Motor | 90,740 | Hyundai, Kia, others | 2021: Immediate 50% reduction of ICE vehicle options, in favour of EV development. Full electrification by 2040 |

The rise of EV's is widely researched, and papers offer many different perspectives on this rise. This section now continues with an overview of papers that attempt to explain the factors driving this rise. The main findings from these papers are discussed, while paying attention to any mention of the possible influence of dieselgate. At the end of this section, a matrix is presented that summarises the findings. This matrix also contains the gaps that both the papers on the rise of EV's and the papers on dieselgate leave. This gap (a lack of in-depth research into the possible influence of dieselgate) serves as the basis for the main question of this thesis.

Concerns regarding climate changes, air pollution and fossil fuel depletion are often named as reasons for the adoption of EV's (Pelegov and Pontes, 2018; Van de Kaa et al., 2017; Schulze et al., 2015; Wittmann, 2017; Sick et al., 2016). More specifically, government mandates and incentives to combat these problems, and changing customer requirements as a result of them, have strongly contributed to the rise of EV's. Pelegov and Pontes (2018) states that there are 3 main drives for governmental support for EV's: ecology, politics and

economics. The first factor concerns the fact that the world is becoming more aware of the negative effects of fuel-based transportation, in terms of pollution as a result of the acquisition of fossil-fuel (such as oil-spills), and climate change. The authors name the zero-emission mandate by the CARB as a turning point for the new EV era. They also state that dieselgate confirms the importance of EV adoption, because it demonstrates a gap between official and real-world emissions of ICE vehicles. They do not state however, whether dieselgate has influenced this rise. Regarding politics, the authors refer to events such as the 1970's energy crisis, and wars over fossil-fuel security. Regarding economics, they state that governmental support for EV's in China has strengthened its global position, while at the same time promoting battery production. As a result of governmental concerns regarding the environment, and its subsequent support for EV's, new regulations and incentives arose. According to Schulze et al. (2015), these new regulations lead to significant turbulence in the mature automotive industry, as they place increasing demands on automotive manufacturers. The main reason for this is the 'complex socio-political agenda' that desires less oil dependency, and is concerned about climate change and air pollution. These changes, along with globalisation and technological advancements have created a situation in the industry in which companies look into new manners of innovating. Wittmann (2017) also mentions this pressure, and contributes it to changes in societal requirements and customer preferences, as a result of climate change, growing urbanisation and technological developments. According to the author, mainly the climate change concerns have cause a strong societal and political push. The pressure caused by societal requirements and customer needs, create a sandwich position for the automotive sector, causing them to put low-emission and zero-emission vehicles on their agendas. Wittmann (2017) is one of the few authors to name dieselgate as an possible influence in the rise of EV's stating that it 'seems to be a turning point' for the automotive industry to turn away from combustion engines, and towards EV's. Sick et al. (2016) state that concerns regarding climate change, specifically through regulations concerning low carbon emission and a rise in societal demand for sustainability, force the automotive industry to look into innovations in either conventional propulsion technologies, or into alternatives such as EV's. They observe however, that due to previously mentioned 'path dependency', that traditional automotive manufacturers are not making this switch, and that EV's are likely to only receive a very minor market share in the coming decades. While 4 years later the EV indeed only had a market share of 4.2%, it can be observed that these traditional automotive companies all did make this switch in fact. While first received and published in 2016, the paper makes no mention of dieselgate which happened a few months prior (when the paper was being written). This is likely due to the fact that the authors used data on patents leading up to 2012 as their data. Depending on when the paper was written and finalised, it could have at least mentioned dieselgate in its discussion, despite the consequences being fairly unknown at that point. At any rate, the fact that the industry is now switching en masse, suggests that dieselgate might have influenced this switch. Berkeley et al. (2017) state that concerns regarding the environment and energy security, have created a favourable 'push' for car manufacturers. This is explained through efforts by various governments to reduce oil dependency, carbon emissions and air pollution. These efforts consists of policies to stimulate the design, manufacturing and adoption of various new propulsion methods for cars, most importantly BEV's. They particularly mention the efforts of the Norwegian government, whose consumer incentives have put Norway's EV's sales at the very top of Europe: in 2015, 17.1% of all car sales in Norway were BEV's. In comparison, in the number 2, France, only 0.9% of all sales were BEV's. Aside from consumer incentives, the Norwegian government has also invested a lot in the charging infrastructure. Internationally, the authors state that environmental and economic pressures have led to governments worldwide to invest $13 - 16 billion in policies and incentives to stimulate the market and ensure cost competitiveness between 2008 and 2014. Roughly half of that has gone into Research and Development to stimulate innovation, the rest mainly in investments in charging infrastructure, and tax breaks, grants or discounts on the purchasing of EV's. These amounts vary per country, with car producing countries investing more in Research and Developments, the rest more in the latter 2 categories. Another form of governmental influence on EV's can be seen in Denmark, where ICE vehicles are heavily penalised through taxing. In the Netherlands, local municipalities are investing in charging infrastructures, but at the same time switching their won vehicles to EV's in order to increase visibility and encourage EV adoption. (Berkeley et al., 2017) state that the favourable 'push' that these incentives caused have in fact led to serious commitment from these companies, but that due to several barriers, the market penetration remains low. These barriers consist of economic barriers (high up-front prices, and concerns over re-sale value), consumer barriers (concerns over technical superiority and low visibility), and technological barriers (concerns over range and charging times). However, the authors state that many of these concerns (such as those regarding battery range) are declining in strength. For the other concerns, the argue that the right policy is key (as can be seen in Norway). Therefore, they propose policies targeting the supply-side, more investments in charging infrastructure and R&D, financial incentives and raising consumer awareness. In spite of these concerns, worldwide EV-sales went from 1.26 million in 2017 (the year Berkeley et al. (2017) was written), to 3.2 million in 2020. This indicates that these barriers are beginning to be overcome, likely

through the implementation of these policies. The paper by Berkeley et al. (2017) is one of the few papers that describes a link between EV-uptake and dieselgate, stating that it has contributed to growing concerns over climate change and air pollution, which they describe as one of the 'levers' in EV adoption. They do not describe any other influences that dieselgate may have had, however.

This next section focuses on literature regarding the industry-side of the debate. As could be seen in Table 2, nearly all automotive manufacturers are starting to produce EV's. In the past however, most car manufacturers rather focused on developing cleaner ICE technologies, as the switch to EV's would require serious investment, and due to sunk costs these companies were dependent on the ICE path. Most of these companies also had very little faith in EV's, believing that the required technologies were years away. Early adopters of the EV-development also faced disappointing sales, which led to less enthusiasm from the rest of the industry (Berkeley et al., 2017; Bailey, 2015; Siemssen, 2018; Schulze et al., 2015). But this lack of interest changed, as the successes regarding EV's of a few companies proved that it could be feasible after all. One company whose influence is widely mentioned in literature as a driving factor for companies switching to EV's, is Tesla. The success of Tesla has played a major role in creating a favourable environment for EV's, both through showing that the technology is feasible, as well as proving that there is demand for EV's. While in 2009 GM and Toyota thought that lithium-ion technology was 10 years away, Tesla suddenly proved its feasibility. According to GM vice-chairman Lutz, Tesla 'was the crowbar that opened up the logjam' (Siemssen, 2018; Wittmann, 2017). Tesla's successes are illustrated through the strong rise of the company as a serious player. In 2017, the market value of Tesla surpassed that of industry-giant Ford, a company that had been around for 100 years longer (Siemssen, 2018). Tesla is new and small in comparison to the rest of the industry, but when looking at EV car segment, it is the number one for the decade (see Table 1). Tesla's proof that EV's can be feasible, led the industry to take it serious very quickly. BMW skipped the 2016 Paris Motor Show to discuss the threat Tesla posed, and to revise their own EV strategy. According to Wittmann (2017), Tesla is 'a pioneer and a gamechanger' and a driver of the trends towards the societal requirements and customer needs being on the agenda of the automotive industry. In their paper regarding the question whether hydrogen fuel cells or (lithium-ion) batteries will become the industry-standard as power source for EV's, Van de Kaa et al. (2017) state that Toyota and Tesla seem to be the companies that have the most influence in this 'standard battle'. Tesla's influence is clear, as their success is clearly one of the drivers of the industry towards EV's. The statement about Toyota is remarkable however, as Toyota is not in the top 10 for the decade, nor is it in the top 10 sellers for 2020. It is unclear why the authors felt that way in 2017, as Toyota wasn't one of the big EV seller at that time either. This does suggest however, that a company does not need to be a top-seller in order to be influential. Regarding EV's, Toyota is very well-known for introducing the Prius, one of the first PHEV's on the market. As such, they were one of the first players on the market as well, and while its influence is not was well expressed a that of Tesla in literature, given the influence an early success can have, it is likely that Toyota also has contributed to companies switching over. Aside from the influence that successful newcomers had on the industry, there are several other drivers according to the literature. Schulze et al. (2015) mention globalisation, which has led to both a strong increase in demands, as well as competition from new firms. Another driver for the industry towards EV's are technological advances in other sectors, as battery technology and other technologies required for EV's are now more developed and offered by more companies (Schulze et al., 2015; Wittmann, 2017).

In conclusion, the main effects of dieselgate were a change in public opinion regarding diesel-powered vehicles, financial damages both to Volkswagen and surrounding companies, and steps into the direction of alternative propulsion, both by Volkswagen as well as other companies. For Volkswagen, it also meant a change of CEO, to which the larger focus on EV's might be attributed. Regarding the EV market, the main takeaways from this section are the fact that EV-sales are rising rapidly in the past few years, and that many (non-EV) companies have decided to phase out ICE-vehicles in favour of EV's. Literature research indicates that several of these companies were inspired by the successes of early EV-sellers (like Tesla), and that the market is strongly stimulated by government mandates and incentives, and the changing public opinion as a result of climate change, air pollution and energy security.

The contents of the papers in this first section of the literature review are summarised in Table 3. This matrix displays the gaps that each paper leaves open. When looking at the total picture, a few things become clear. First off, there are very few papers that discuss both the factors that have led to the rise of EV's, as well as the causes and effects of dieselgate. Moreover, the papers that do mention both either only suggest a vague link, or only name one aspect, such as a loss of trust in diesel, stricter regulations (although these are not always clearly linked to either of the concepts), or financial incentives funded through the fines and settlements of Volkswagen. From these statements, it becomes clear that there are various influences, but no paper comprehensively discusses all of these influences completely. As such, a knowledge gap exists around a complete assessment of the influence of dieselgate on the rise of EV's. This knowledge gap is the main cause for this research, and constitutes the main research question.

Table 3: A matrix depicting various concepts relevant to this study, and the presence or absence in literature.

| **Paper** | **Content** | **Factors describing EV rise** | **Dieselgate: causes and/ or effects** | **Gap** |
|---|---|---|---|---|
| Baumgärtner and Letmathe (*Transportation Research Part D*, 2020) | External costs of dieselgate | No | Yes | Mentions stricter regulation as result of dieselgate, but nothing about influence on EV adoption |
| Dworaczek et al. (*Management Studies*, 2020) | Financial damage of dieselgate | No | Yes | EV's not mentioned |
| Mujkic and Klingner (*Public Integrity*, 2019) | Bad leadership caused dieselgate | No | Yes | EV's not mentioned |
| Beelaerts van Blokland et al. (*International Journal of Six Sigma*, 2019) | The Stability Value Leverage Maturity Model | No | Yes | Suggests investigating changes in company performance as a result of dieselgate |
| Pelegov and Pontes (*Batteries*, 2018) | Review of EV market | Yes | Yes | No direct link |
| Siemssen (*Copenhagen Business School (thesis)*, 2018) | Disruptiveness of Tesla and EV's | Yes | Yes | Only mentions decline in fuel popularity as result of dieselgate. No other influences. |
| Boretti (*SAE Technical Paper*, 2018) | Future of combustion engines after dieselgate | Yes | Yes | Only covers the EV incentives funded by the fines of VW. No other influences |
| Van de Kaa et al. (*Energies*, 2017) | Standard battle: BEV's and PHEV's | Yes | No | Dieselgate not mentioned |
| Wittman (*Phantom Ex Machina*, 2017) | Trends in the automotive industry | Yes | Yes | Little attention for influence of dieselgate. Only suggests that it 'seems' to be a turning point. |
| Berkeley et al. (*Transportation research Part A*, 2017) | Drivers and barriers in EV take up | Yes | Yes | Only states that dieselgate 'may have' influenced concerns regarding climate and pollution. No other influences |
| Carstea (*Romanian Economic and Business Review*, 2016) | Influence of dieselgate on the labor market | No | Yes | Mentions loss of trust in diesel as a result of dieselgate, but no statements about influence on EV adoption |
| Bovens (*Midwest Studies in Philosophy*, 2016) | The ethics of dieselgate | No | Yes | States that stricter regulations encourage EV's, but no statement about influence of dieselgate on those regulations |
| Nunes and Park (*Journal of Global Responsibility*, 2016) | The cost of dieselgate | No | Yes | Mentions loss of trust in diesel as a result of dieselgate, but no statements about influence on EV adoption |
| Sick et al. (*Journal of Cleaner Production*, 2016) | Influence of path dependence on the rise of EV's | Yes | No | Dieselgate not mentioned |
| Schulze et al. (*Industrial and corporate change*, 2015) | Changed innovation in car industry | Yes | No | Dieselgate not mentioned |

## 3.2 Analysing an innovation taking over from an incumbent technology

In order to determine what factors have caused these developments, the next step is to find one or multiple frameworks which underlying factors can explain industry and market changes. Due to the relative advantages over ICE-vehicles, the EV is often considered to be an innovation (Hardman et al., 2013; Van de Kaa et al., 2017; Van den Hoed, 2007). As such, several of these frameworks are related to different innovation theories. These frameworks consist of factors that explain why and how an innovation penetrates a market, and how it causes disruption to the existing structure of incumbents. The following section of the literature review looks at frameworks that can explain this process. As it will turn out, no framework exists that can fully explain this process in terms of driving factors and quantifiable metrics. As such, a framework needs to be developed for this purpose, which will be done in section 4. In the following section various frameworks are analysed for their usefulness in building this framework. As this framework is missing from literature as a whole (discussed at the end of this section), a generic framework needs to be developed in order to analyse the process of an innovation taking over from an incumbent. In other words: the framework will not only be applicable to the process of the EV taking over from the ICE vehicle, but to any (disruptive, radical) high-tech innovation taking over from an incumbent technology. This both contributes to literature in a more broad perspective, and allows the framework to be tested on a case that is not related to the question at hand. This prevents bias and allows the framework to be used in other studies as well. However, since the main question of thus thesis is about the automotive industry and dieselgate, some remarks regarding the usefulness of each framework for that subject are added in this review section, by way of early exploration for the main question. In addition, some concepts are illustrated through the use of examples related to the EV, because a few of the papers that are used are about the automotive industry. These are deemed useful in the context of this thesis, which is why they were kept. However, it must be very clear that any remarks, examples or usage of papers related to EV's only serve as useful illustrations or as early exploration, and do not play a decisive role in the analysis of what frameworks are useful for the design of the framework. This will become more clear in the next sections, where the frameworks and factors are analysed and used, and where these hooks or examples are not featured.

The purpose of this section is to provide a literature review of various frameworks that describe the process of an innovation taking over from an incumbent technology. As it turns out, there are many frameworks that describe such a process, but all seem to focus on specific subjects, or on specific aspects of such a process. As such, these frameworks are all discussed now, together with their shortcomings. In section 4, an analysis is made of which frameworks are useful and why.

### 3.2.1 Standard Battle

First and foremost, the perspective of the standard battle is considered, as the battle between 2 technologies is a central theme in this research. A standard battle refers to the phenomenon of two (or more) technologies competing for dominance (Van de Kaa et al., 2011). Given the fact that this thesis looks at the rise of one technology at the cost of another, the factors that decide the winner in a standard battle are a logical first place to start when looking for a framework that can explain this process in several clear, discrete factors.

In Van de Kaa et al. (2011), an extensive literature study is performed, leading to 29 factors that decide the winner of a standard battle. As stated, the winner is the technology (or format, in that paper) that has become the dominant one. Here, it becomes clear that the framework that is designed for this thesis needs to be a generic one, instead of one tailored specifically to the EV/ICE vehicle battle: that battle is far from won, as EV's at this point only have 4.2% market share. So if the framework were to be tailored exactly for that battle, it would not be possible to test whether the framework actually works. Therefore, a more generic framework is desirable, which can be tested through a case study that looks at a battle that is already decided (see section 2).

Van de Kaa et al. (2011) present the reader with a framework of 29 factors that lead to dominance. These factors can be to explain the outcomes of standard battles both in the present and in the past. Since this thesis aims to find out what is causing an innovation to win over an incumbent technology, these factors are of great value to this research. The authors divide them into 2 categories:

1. Factors that can be influenced by the firm, called 'firm-level factors'. This category holds 4 groups of factors: characteristics of the format supporter, characteristics of the format, format support strategy, and other stakeholders.
2. Factors that are given in specific industries and can hardly be influenced by individual firms, called 'environmental factors'. This category holds 1 group of factors called 'market characteristics'.

But as it turns out, not all factors are relevant for every battle. In fact, in Van de Kaa et al. (2017), only 11 factors were found to be relevant to the standard battle between BEV's and FCEV's. These 11 factors were

found to be relevant if they were mentioned in secondary sources. Unfortunately, the paper does not mention what secondary sources were used. This makes it hard to replicate the procedure for other battles.

The factors from Van de Kaa et al. (2011) form a more general framework, that applies to every standard battle, both current and past. As such, they cover a lot of aspects, many of which might not be relevant for every standard battle. This is illustrated by only 11 factors being relevant to the standard battle regarding BEV/FCEV. That means that different factors are relevant for each battle, and as such, for the purposes of the framework, it is better to include all the factors as described in Van de Kaa et al. (2017). For example, while both subjects are seemingly similar, it is very well possible that the factors for the BEV/FCEV battle might not be relevant for the EV/ICE vehicle battle, as there are larger differences between the types of cars then in the BEV/FCEV standard battle (emissions, for instance). More on this in section 4.

Unfortunately, the author does not specify exactly how it was determined whether a factor was relevant (only mentions that it must be present in secondary sources, but does not mention what secondary sources), so the procedure might not be repeatable. The selection does however illustrate which ones are relevant for a standard battle pertaining to types of cars (although there is a large difference, more on this in section 4), and could therefore serve as inspiration. The factors are therefore included in this section, and the links with the ICE/EV case are briefly discussed, to give an impression on how to utilise these factors. Again, this will not be a deciding factor for the final framework, but this discussion is included as a link to the main question of this thesis.

The 11 factors are:

1. Financial strength (firm-level: characteristics of the format supporter)
2. Brand reputation and credibility (firm-level: characteristics of the format supporter)
3. Learning orientation (firm-level: characteristics of the format supporter)
4. Technological superiority (firm-level: characteristics of the format)
5. Compatibility (firm-level: characteristics of the format)
6. Complementary goods (firm-level: characteristics of the format)
7. Pricing strategy (firm-level: format support strategy)
8. Marketing communications (firm-level: format support strategy)
9. Commitment (firm-level: format support strategy)
10. Regulator (firm-level: other stakeholders)
11. Network of stakeholders (firm-level: other stakeholders)

Some observations regarding the applicability of these factors to the ICE/EV standard battle can be made at this point, by way of a link to the main question. Financial strength is dependent on the companies presenting the formats. An interesting case then, is Tesla: although it already exists for 18 years, and its market capitalisation tops the automotive industry, it has only began to turn profits in 2020. This is indicative of its financial strength to bring a new format to the battle. Brand credibility can be linked to reputations of companies (for instance, Volkswagen after dieselgate). Technological superiority could refer to EV's being better for the environment, being silent, or accelerating faster. Compatibility might be a concern, as a new fuelling (or charging) infrastructure is needed, and since the range is often limited this might cause different riving behaviour. This is also connected to complementary goods (charging points). Pricing strategy and marketing depend on the brands: Tesla's cars are expensive, but there are also cheaper EV's on the market. Again, more or other factors might be relevant to the ICE/EV battle, but the previous illustrates the manner in which these factors could be applied to a standard battle.

Another paper dealing with standard battles is Suarez (2004), on which the work from Van de Kaa et al. (2011) was based. In this paper, the author defines 8 factors that determine the outcome of a standard battle, divided into firm-level factors and environmental factors. These 8 form the basis for the 29 of Van de Kaa et al. (2011), who uses the same distinction, as can be seen above. These factors, divided into their 2 categories are:

- Firm-level factors
    1. Firm's technological superiority
    2. Firm's complementary assets and credibility
    3. Firm's installed base
    4. Firm's strategic manoeuvring
- Environmental Factors
    1. Regulation
    2. Network effects and switching costs
    3. Regime of appropriability
    4. Characteristics of the technological field

What really makes Suarez (2004) a valuable paper however, is that it divides the process of a standard battle up into 5 phases. To add to this, the author describes what factors apply to each phase, and how strongly. These 5 phases will now be discussed, alongside the factors relevant for each phase. See Figure 6.

Phase 1 is known as the 'R&D Build Up'. This phase determines what the technological field will look like. Usually the groups doing R&D into a new technology are incumbents, several newcomers, and institutions such as universities. Different approach to the problem at hand are developed, and competition or collaboration are established. In this phase, the factors 'Credibility/Complementary Assets', 'Regime of Appropriability', and 'Characteristics of the technological field' are important.

Phase 2 is referred to as 'Technical Feasibility'. This phase commences when one of the actors develops a working prototype (illustrating technical feasibility) of the new technology. This creates new dynamics in the field, as all the other actors need to re-evaluate the status of their own research and development, and their strategies on how they will fight the upcoming standard battle (for instance: if they will fight it alone, or form an alliance). Important factors in this phase are 'Technological superiority', and 'Regulation'.

Phase 3 is called 'Creating the market'. This phase is started when the first commercial product is launched. It changes the focus of the field from technological factors towards market factors, causing technological differences between alternatives to become less important. The phase is mainly important for the first mover, as he establishes reputation and an early influence over resources. The actors also start to establish user bases. In this phase the factor 'Strategic Manoeuvring' is important.

Phase 4 is the 'Decisive Battle'. This is where actual dominance is achieved for a technology. The installed user base is growing and this has an effect on customers. There even is empirical evidence that shows that the benefits of a technology are only observed after a critical mass of customers has been achieved. The customers from phase 3 are often called 'enthusiasts' or 'visionaries' but the mainstream market consumers (a significantly larger group) make up the customers for phase 4. They are more conservative and less impressed by technological performance. Instead, they go for products made by trustworthy firms. Factors important in this phase are therefore: 'Credibility/Complementary Assets'. 'Installed base', and 'Network effects and Switching costs'.

Lastly, Phase 5 is known as 'Post-Dominance'. As the name implies, in this phase dominance has been achieved by one format. The large user base, network effects and switching costs defend the standard against potential challengers. Competition often comes from within: a challenger offering the same standard. This phase can last very long, often until a new dominance cycle is started (which may have various reasons, such as climate change). As discussed, factors important in this phase are 'Installed base', and 'Network effects and Switching costs'.

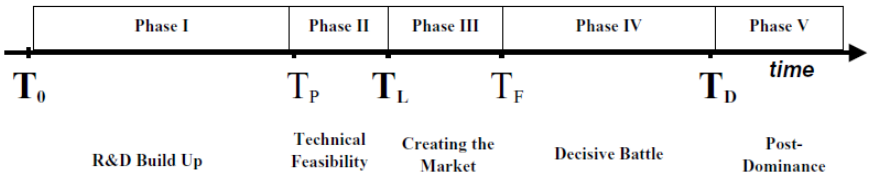


Figure 6: The 5 phases of a standard battle (Suarez, 2004)

### 3.2.2 Innovation Diffusion

A framework is sought that describes an innovation taking over from an incumbent technology. This more generic framing of the process at hand, allows the usage of several innovation theories. One of those is the theory of innovation diffusion by Rogers (2003), who defines diffusion as: 'the process by which an innovation is communicated through certain channels over time among the members of a social system.' This principle is illustrated by two curves: the first curve indicates the percentage of people accepting the innovation over time. This curve is then divided in 5 parts, corresponding to the time of adoption of the innovation by the members of that group: innovators (early in time, very low percentage), early adopters (later in time but still early, somewhat larger percentage), early majority (medium in time, large percentage), late majority (late in time, large percentage), and laggards (latest in time, small percentage). These groups and the corresponding percentages are are based upon a normal distribution (Oldenburg and Glanz, 2008). Cumulatively, the percentages make up the second curve, or S-curve, which stops at 100% when the innovation is fully diffused (adopted by the members of the social system). The point of 100% diffusion marks the end of the x-axis, which denotes time. These two curves can be seen in Figure 7. The diffusion per group is illustrated in blue, the S-curve is in yellow.

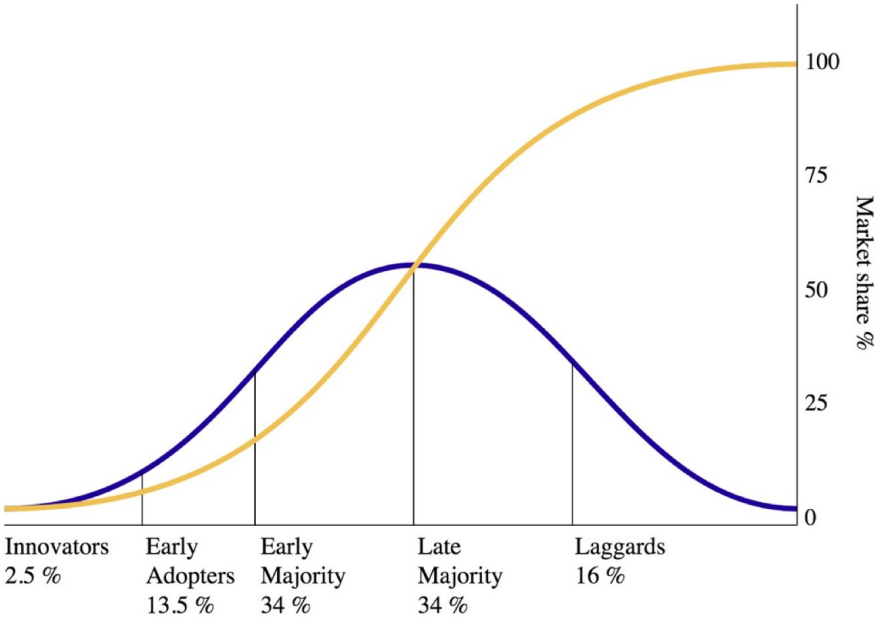


Figure 7: The two curves of innovation diffusion (Dans, 2016)

The framework for this thesis looks at how an innovation takes over from an incumbent technology. This can be re-framed as how an innovation gains market share (at the cost of the incumbent technology), or diffuses. This makes the innovation diffusion theory a strong addition, as it provides a quantifiable measure, namely the market share, to show how far along the takeover (or diffusion) is. According to Oldenburg and Glanz (2008), there are three groups of variables that explain whether an innovation diffuses successfully or not, and if so, at what rate. These are:

1. Characteristics of the innovation (relative advantage, compatibility, complexity, possibility to try it out, and the visibility of its benefits).
2. Characteristics of adopters (learning style, meaning of the innovation, and concerns in the pre-adoption stage, early use and when use is established).
3. Features of the setting or environmental context (geographical settings, societal culture, political conditions, and globalisation and uniformity)

The framework of innovation diffusion and the 3 factors as described by Oldenburg and Glanz (2008) provide a strong framework to quantify the state of adoption of an innovation in various perspectives. Several of the listed factors are reminiscent of the factors described in other frameworks, which makes innovation diffusion a strong framework to base the thesis-specific framework on. For instance, as can be seen later, the combination of the theory of innovation diffusion, and the framework by Dijk et al. (2016) regarding being the first (or second) movers of a disruptive innovation, can provide valuable insights regarding the starting phase of an innovation.

### 3.2.3 Disruptive Innovation

Another perspective to analyse the rise of an innovation is that of the Disruptive Innovation. This refers to 'a process whereby a smaller company with fewer resources is able to successfully challenge established incumbent businesses' (Christensen et al., 2013). The author hereby notes that a smaller firm becomes disruptive when offering an innovation while incumbents focus on improving their products. While this section is about a more generic framework, an interesting hook to the EV/dieselgate case can be made here. The phenomenon in which incumbents focus on improving their technology instead of switching to a different technology, was widely the case in the car industry in the past decade. An important example is of course dieselgate: Volkswagen had bet on improving their diesel technology, but it turned out that that technology was not able to comply with the regulation. Instead of switching over to a new technology, they claimed to have 'improved' their technology, while in reality they were cheating (see subsubsection 3.1.1). Switching to a new (innovative) technology from a companies' current technology is costly. The phenomenon in which costs (such as new production lines or R&D) prohibit a company in switching to a new (possibly better) technology has several names, like 'path dependency' or 'incumbent's curse' and is discussed later in this section (Hardman et al., 2013; Sick et al., 2016).

The definition of a disruptive innovation by Christensen et al. (2013) serves well in order to briefly introduce the concept, but is not very useful when classifying an innovation as 'disruptive', and is thus not very suitable for this thesis. Luckily, Hardman et al. (2013) describe a useful framework for this exact purpose. They propose 3 characteristics that are very common in most disruptive innovations, and state that an innovation needs to fulfil a minimum of 2 of these characteristics in order to be regarded as 'disruptive'. These three common characteristics are:

1. Disruptive to Market Leaders: The manufactures of the disruptive technology are different companies to those producing the incumbent technologies.
2. Disruptive to End Users: The different characteristics of disruptive technologies mean they are disruptive to end users, changing the way in which the technologies are used.
3. Disruptive to Infrastructure: The disruptive technology requires different infrastructure than the incumbent technology.

Using the above criteria, it is possible to classify whether an innovation is disruptive, and whether the factors pertaining to disruptive innovation can be used to explain its rise. As a hook to the EV/dieselgate case, one can see that the EV as a whole, is indeed a disruptive innovation, as it is both disruptive to end users (new manner of powering, and thus fuelling, a vehicle, cleaner, more silent, etc.) and disruptive to the infrastructure (charging points are a major indication of this). Depending on what company made the EV, one could also say that the EV is disruptive to market leaders. Tesla's EV's were a good example of this, but around the time of their introduction there was also the very popular Nissan Leaf, which was made by market leader Nissan, and thus did not fit the first criterion. Since several market leaders started making their own EV's around the start and first half of the decade, in general, the EV did not fit the first criteria. But since it does fit the other two criteria, it is indeed a 'disruptive innovation.'

The criteria from Hardman et al. (2013) have 3 applications: determining if an existing technology was a successful disruptive technology upon market entry, determining if a technology that is in the process penetrating the market will be disruptive to the current market, and predicting whether a new or innovative technology will be a candidate disruptive technology when it enters the market. Based on the multiple applications and the clear distinct factors in it, the framework by Hardman et al. (2013) is of value for this thesis.

Here too, exists an interesting link with the EV/dieselgate case. Tesla as a company, is sometimes called disruptive. Although their EV's were certainly a disruptive innovation (and several researchers cite Tesla's success as a cause for many companies to start producing their own EV's, see subsection 3.1), not everybody agrees on Tesla as a company being disruptive. As will be discussed in the next section, the market in which a disruptive company places its product (foothold) is a defining characteristic of being disruptive. According to Hardman et al. (2013), Tesla placing their EV's in the high-end market, which was interesting to incumbents, made them less disruptive as a company. For the purpose of the analysis in this thesis, the EV is treated as a 'disruptive innovation' in which Tesla has played a large role in developing and introducing.

Regarding the entry-position in the market (or foothold), Christensen et al. (2013) states that disruptive innovations start in either low end footholds or new market footholds. The low end foothold refers to a market of less demanding customers, as opposed to the high-end customers that incumbents mostly focus on (think: better preforming or better looking cars). The new market foothold refers to disruptors creating a market were none was before. According to Hardman et al. (2013), most of the early EV's (such as the Nissan Leaf and the Peugeot iOn) were aimed at the mass market. Regarding Tesla's market foothold, there is discussion. Tesla offered both its first two models in the high-end market instead of a new market or a low-end market, according to Hardman et al. (2013); Christensen et al. (2013). Dijk et al. (2016) on the other hand, argue that Tesla has found 'a limited, luxury niche market and found customers who are willing to pay a premium for an electric sports car', implying that they did indeed entered in a new market foothold.

Hardman et al. (2013) also refer to the market footholds aspects of disruptive innovations, referring mostly to the first of their 3 criteria, being disruptive to market leaders. The authors remark that one of the reasons that disruptive innovations don't always fit all three criteria, is because sometimes market leaders also come up with disruptive innovations (which therefore, do not fit criterion 1). These do however disrupt component supply chain, infrastructure and end-users. The Nissan Leaf and Peugeot iOn are examples. Regarding Tesla's EV's, Hardman et al. (2013) state that they are more disruptive to the existing automotive industry, then previous examples of EV's produced by market leaders. Being 'more disruptive' is an interesting notion in Hardman et al. (2013), who also criticise the original disruptive innovation theory for not including the 'level of disruption'. The authors express 'the level as disruption' as the number of criteria that an innovation fulfils: 3 out of 3 is the highest level, and 1 or 0 out of 3 means no disruption at all. This is in line with their statement that Tesla's EV's are more disruptive then Nissan's EV's: Tesla meets all 3 criteria, while Nissan only fulfils 2.

Lastly, Hardman et al. (2013) mentions the importance of the existence of niche markets for technologies that are disruptive, innovative and/or radical.

Dijk et al. (2016) highlight another aspect of the role of the market in disruptive innovation theory, which is very useful in this thesis: namely being (one of the) first companies on the market with a new technology. They state that disruptive innovation can provide a significant competitive advantage to the company introducing it, but there is also competitive advantage in being a quick mover or a quick follower. These advantages might be generous profit margins and a monopoly-like status. But there are disadvantages as well: the cost of developing the market and product might be too much to bear for one company (especially if it is a new company). According to Dijk et al. (2016), being a second mover carries advantages as well, namely 'free-rider effects' in the form of imitation and savings on Research and Development, and being able to learn about the successes and failures of the initial users. Regarding full-electric vehicles, Dijk et al. (2016) find that it's usually new entrants that are the first movers regarding disruptive innovation, rather than the incumbents (Tesla being an obvious example of this). As stated earlier, the framework by Dijk et al. (2016) and in particular, the advantages and disadvantages the first (and second) movers of a disruptive innovation encounter, have some common themes with the theory of diffusion innovation.

The paper by Dijk et al. (2016) provides interesting additions to the original disruptive innovation theory, regarding the market in which a disruptive technology enters. They offer critique on the original disruptive innovation theory, stating that it does not assess the phenomenon of a disruptive innovation, through gaining market share, possibly leading to a new market regime. In their paper, Dijk et al. (2016) define a useful framework consisting of 6 factors that define whether a disruptive technology will successfully penetrate the market. These are:

1. The reframing of consumer perspectives
2. Changes in the social connotation of product technologies
3. Firms experiencing or expecting higher financial returns with the new technology compared to the established technology
4. Technology spilling-over from other sectors which compensates the scale and learning gap of the niche with respect to the regime
5. Resource scarcity driving up cost and weakening the price/ performance advantage of the established technology
6. Regulation providing the niche technology with relative benefits over the established technology

The authors then proceed to test the case of the full-electric vehicle (FEV) against these factors. The conclude that the FEV (BEV and FCEV), which they call a disruptive niche, are not likely to replace ICE-vehicles, as they suffer too much from competition from more efficient ICE vehicles and PHEV's. This is interesting, as the situation at the end of the decade has shown that automotive companies are phasing out ICE-development in favour of EV's, and sales of BEV's and PHEV's are roughly comparable. This ties in nicely with the standard battle theory: Dijk et al. (2016) state that EV's will not win over ICE, while the current evidence points to the contrary. This means that either the framework is wrong, or the situation has changed. It seems likely that the latter is the case: between 2015 (the year in which the paper was written) and 2020, many things have happened pertaining to their 6 factors (like dieselgate). The authors advise for further research in their paper, by testing their 6 factors for cases in which the disruptive niche is growing more significantly. This is now the case with the EV market, and this thesis aims to find out why that happened. The paper by Dijk et al. (2016) is regarded as a strong addition to the frameworks considered in this thesis. As mentioned, the framework by Dijk et al. (2016) also seems to hold some common grounds with the innovation diffusion theory, as it deals with companies bringing a new product to the social system, which then starts the process of diffusing amongst its members. These commonalities are a strong starting point on determining how these frameworks might be combined in order to create a strong framework for the questions in this thesis.

A second aspect, aside from the market foothold, described by Christensen et al. (2013) is the fact that disruptive innovations are usually do not reach mainstream customers until the innovation's quality catches up to the mainstream's standards. This is emphasised by Hardman et al. (2013), who mentions that a disruptive innovation's quality is often worse than the incumbent technology at first. This is a phenomenon that has been going on with EV's. While the sales are indeed increasing, the vast majority of car sales are still ICE vehicles. Reasons found for the mainstream being hesitant to switch over to EV's are high costs, concerns regarding battery range, lack of vehicle choice and lack of charging infrastructure (Berkeley et al., 2017).

In addition to 3 criteria useful to determine when an innovation is disruptive, Hardman et al. (2013) describe 7 characteristics that historically successful disruptive innovations share: if a new disruptive innovation has these characteristics, it is likely that it will become successful. This is useful for the purposes in this thesis, because it looks at successful innovations, and this framework allows to explain or interpret that success using

these 7 characteristics. Hardman et al. (2013) then test these 7 characteristics against battery electric vehicles and fuel cell electric vehicles. The authors find that find that both face the same challenges as defined in the characteristics. The paper is from 2013, a time where both technologies were far less developed, and in which the authors state that the introduction of BEV's is proving difficult when compared to other many other successful disruptive technologies. Given that time has passed and the situation regarding BEV's has significantly improved, it might prove interesting to apply these 7 characteristics to the current state of EV's and assess what has changed and why. The 7 characteristics of successful disruptive technologies as defined by Hardman et al. (2013) are:

1. The threat of the new technology is not often recognised by existing market leaders.
2. Disruptive technologies are initially more expensive than the incumbent technologies.
3. The quality of the disruptive technology initially is often worse than the quality of the technologies they seek to replace.
4. The technologies have some form of 'added value' to the consumer.
5. The disruptive technologies will fill niches markets first here they spread to other niches, the meso-level and eventually reach the macro level of the market.
6. The incumbent technology is never wiped out alltogether, it in turn becomes the technology for niche market applications.
7. Socio-technical systems are ever evolving.

With these characteristics known, a hook can be made with the main question of this thesis, namely to analyse how the success of the EV can be explained from a disruptive innovation viewpoint. Market leaders (save for a few) did indeed not recognise the threat of EV's at first, but are now all switching towards them. The Tesla Roadster and Model S were indeed expensive, but the Nissan Leaf was not. While 'quality being worse' might be a bit strong, the EV faces many challenges when compared to ICE-vehicles, regarding range, ability to charge, and a lack of vehicle choice (Berkeley et al., 2017). As such, one may find that they indeed have, in some aspects, a worse quality than ICE-vehicles. Added value may be obtained from the fact that these vehicles are cleaner than ICE-vehicles, and signal to the world that the owner cares about the environment, or about the newest technologies. Point 5 is hard to elaborate on, but when looking at innovation diffusion, one might say that regarding customers, EV's are still in the niche market (or have just entered meso). It's hard to say if the incumbent technology will never be wiped out, but automotive companies are phasing it out, so they will eventually no longer be produced for the mainstream. Thus, when looking from a company perspective, it seems that at some point the new technology (EV) will completely replace the incumbent (ICE-vehicles). Lastly, Point 7 refers to a system in which the innovation becomes the incumbent, and is eventually also replaced by a new innovation, which then becomes incumbent, and so on. While this might not play a role in this thesis as EV's are just coming up, this perspective might be interestingfor further research.

One important take-away from papers regarding disruptive innovations, is that most papers mention the phenomenon of incumbents resisting to switch over to a new technology, and instead keep working on improving the current one. Switching to a new (innovative) technology from a companies' current technology is costly. The phenomenon in which costs (of new production lines, or RD expenses) prohibit a company in switching to a new (possibly better) technology has several names, like 'sailing ship effect', 'the incumbents curse', 'familiarity trap', 'path dependency' (Van den Hoed, 2007; Hardman et al., 2013; Sick et al., 2016; Dijk et al., 2016). In this thesis, the term 'path dependency' is used.

Dijk et al. (2016) provides a few insights on the causes of path dependency. He states that individual automotive manufacturers have tried to avoid costly and risky technological innovation, which at an industry level has emerged as a tendency to avoid regime disruption. Instead, focus goes out to reproduction or reorganisation, which is done in part by incorporating elements of disruptive niches into the regime. This pattern is the result of incumbents firms who find the innovation (in Dijk et al. (2016): full-electric vehicles), too risky too bet on. Other factors contributing to path dependency are the fact that the processes behind resource allocation are not aligned to the new technology, and favouring past routines, prior knowledge and proven technologies.

Path dependency was widely the case in the car industry in the past decade. As mentioned before, it was also one of the causes of dieselgate, as Volkswagen bet on improving their internal combustion system and it turned out that it would not comply to regulations. A lot of the earlier papers also regard path dependency as a reason why EV's would probably not succeed in disrupting the ICE-vehicle industry or market (incumbents would not switch). It is also very likely an important factor in the reasons why incumbents have started to produce EV's so late. Eventually however, many automotive companies have gone of the path, and started focusing on EV's. The fact that they chose to step of the path they were dependent upon, is illustrative for this switch. One of the possible uses of the framework in the EV/dieselgate case is to explain what has caused those

companies to decide to pay the high costs in order to enter the EV-market. In a generic sense, the framework can also be used to analyse other industries in which this switch can be observed.

A second phenomenon that is related to the status quo preventing a switch toward a new, disruptive technology, is the phenomenon of 'lock-in' (Hardman et al., 2013). Lock-in means that the society (as opposed to a company, in the case of path dependency) is locked on to one specific deeply entrenched technology. It has three causes: increasing economics of scale of incumbent technologies, learning difficulties (changing to new technology reduces efficiency, because users are unfamiliar with it), and the network effect (a system being dependant on a high number of users). Cowan and Hultén (1996) suggests 6 ways of escaping lock-in. Since this process is now going on in the domain of this thesis (EV's slowly causing the world to break free from the lock-in with ICE-vehicles), and the fact that lock-in is an important factor in any industry where an innovation takes over from an incumbent (signalling a break away from the lock-in) these 6 ways might be a useful addition to the frameworks considered in this thesis. They are:

1. The existing technology reaches a state of crisis.
2. Regulation has an impact on the industry.
3. The occurrence of a technological or cost breakthrough with the new technologies.
4. Changes in tastes that favour the new technology.
5. The presence of niche markets
6. The new technology receives support from the scientific community

Aside from its general applicability, this framework seems applicable to the dieselgate/EV case for a number of reasons. For starters, one might indeed say that the existing technology has reached a state of crisis, which was illustrated by dieselgate: Volkswagen bet on improving their ICE engines because of path dependency, but could not get them to comply with the regulations, and instead cheated. This illustrates that (at least in the case of Volkswagen), the current technology is not suitable for current regulations. This is tied to the second point, which covers both 'regulation that supports a disruptive technology or regulation that makes incumbent technology less favourable'. The former of those two can also be seen in numerous incentives for usage of EV's. Technological breakthrough is very wide, but can be related to the improvement of EV-batteries. Cost breakthrough is of course, dependent on the company. Regarding point 4, Hardman et al. (2013) states that the rise of environmental awareness amongst the public can lead to less demand of ICE vehicles and more demand for EV's. Over the years leading to the end of the decade, this became very much the case. Hardman et al. (2013) also states that the presence of niche markets is important, as it allows the disruptive technology to enter in a smaller, less demanding market, before it aims to take on the locked-in incumbent technology on the mass-market. Whether EV's were a niche market remains a discussion, but the fact of the matter is that they are now on the mass market. Lastly, EV's receive support from the scientific community, although concerns exist regarding the sources of electricity (Sick et al., 2016; Wittmann, 2017).

The concept of a new disruptive technology causing the social system to break free from an entrenched incumbent technology, has a not inconsiderable degree of commonality with the concept of the standard battle as described by Van de Kaa et al. (2017). As such, the possibilities to combine these frameworks was further investigated, as this combination of frameworks strengthened the thesis-specific framework. A large degree of commonality can also be observed with the 6 factors of Dijk et al. (2016). For instance, cost breakthrough and experiencing higher financial returns, changes in taste/scientific support and changes in social connotation/reframing of consumer perspectives, and both cover regulation. Using these overlapping points to combine these frameworks provides a strong addition to this thesis, as such a joined framework could explain the process of breaking the regime of a locked-in technology, through the successful market penetration of a disruptive technology.

Disruptive innovation theory is an interesting addition to the thesis-specific framework, and also can be of use for the practical applications of this research. According to Hardman et al. (2013), knowing whether a newly introduced innovation is disruptive, allows developers of the innovation to adapt their market entry strategy accordingly, and existing market leaders how to respond to it (by knowing whether it will disrupt the status quo or not). Although discussed in more detail in section 4, several frameworks regarding disruptive innovation stand out. The 7 factors of Hardman et al. (2013) provide useful insight into how a disruptive innovation becomes successful (and thus challenges the incumbent technology). A strong addition to this, are the 6 factors described by Dijk et al. (2016), which describe the start of this process: namely factors deciding successful market entry of a disruptive innovation. The factors from these frameworks can be combined with factors from Van de Kaa et al. (2017) (factors deciding the winner of standard battle), and Oldenburg and Glanz (2008) (factors deciding a successful innovation diffusion, and the rate thereof). Combining these frameworks

provides more insight into what factors are at play at a certain phase of a disruptive innovation. The insights regarding path dependency and lock-in also play a role in the main question of this thesis, as they are closely related to traditional ICE-vehicles manufacturers switching to EV's. As stated, a more thorough analysis on the usefulness of each framework can be found in section 4, and the actual combining of the frameworks can be found in section 5.

### 3.2.4 Radical Innovation

Aside from being disruptive (in which a new company on a market challenges incumbent companies with their innovation), an innovation can also be classified as 'radical'. Various definitions of 'radical innovation' exist. According to Leifer et al. (2001), 'a radical innovation is a product, process, or service with either unprecedented performance features or familiar features that offer significant improvements in performance or cost that transform existing markets or create new ones'. In Van den Hoed (2007), a radical innovation is defined as a technology that builds on a different set of engineering and scientific principles that replaces the incumbent technology, and alters the current knowledge and procedures of the industry. Dul and Hak (2007) define it as innovation where both the technology and the market are new, and customer requirements are unknown. Lastly, Hopp et al. (2018) define radical innovation as the creation of new knowledge and bringing completely new ideas or products to the market. As such, they state that research on radical innovation often looks at organisational structures. In short, an innovation is radical when it is a completely new product, that alters the way the industry and the market work. As such, the notion that replaces the incumbent technology is by definition radical, as it is a completely different technology that sets a new standard.

An innovation can therefore, be disruptive and radical at the same time. Take for instance, the EV. At the start of the second wave, EV's were offered by incumbents (Nissan), and by newcomers (Tesla) making them disruptive. What can now be seen, is that the EV (which is in many ways a very different technology than ICE vehicles) is gaining market share, and that many companies are switching towards producing them. In other words: the industry and the market are being changed by a new product, thus making the EV a radial innovation as well. This duality allows to usage of theory surrounding radical innovation frameworks for the purpose of analysing the rise of an innovation as well. This is a strong addition to the innovation takeover framework, as a new technology that replaces an incumbent technology is by definition a radical innovation (it changes the market and the industry). As such, factors explain the way these types of innovation breakthrough or gain market share are a valuable addition for this analysis.

When also incorporating the perspective of radical innovation, one framework stands out being of great value in this research: that of Van den Hoed (2007). In this paper, the author describes five factors that can explain the adoption of a radical innovation. This paper also contains several hooks to the EV/dieselgate case central in this thesis. The author starts by describing the need for a sustainable radical innovation in order to replace ICE-vehicles, but states that a switch to BEV's is too radical and costly and can thus not be expected. He then proceeds to apply his framework to FCEV's. The paper was written well before the second wave of EV's, and currently automotive companies are indeed making the switch towards BEV's (and PHEV's), while FCEV's are not very popular. Add to that, according to Van de Kaa et al. (2017) BEV's are the superior technology in comparison to FCEV's and thus will become the winner of the standard battle regarding those two. As such, re-evaluating and then incorporating the framework by Van den Hoed (2007) is a strong addition to his research, as it allows to pinpoint what factors did indeed go well for BEV's (and PHEV's), and less well for FCEV's. Aside from interesting points regarding the EV market that this paper brings, the factors described in the paper are also very useful in the generic framework, as they explain how radical innovation emerges.

Similar to the considerations regarding the markets in the section on disruptive innovation, Van den Hoed (2007) notes that an returning phenomenon in innovation literature is the fact that incumbent firms have difficulty in dealing with radical technologies, and that in a large number of cases the incumbent firms are no longer the market leaders after a radical technology has replaced the incumbent technology. Of course, EV's haven't completely replaced ICE vehicles yet (although it seems to be going that way), but it can already be observed that Tesla - a company introducing a radical innovation - is now a new market leader. This can at least be seen as a sign on the wall of apparent change. According to Van den Hoed (2007), this difficulty in dealing with radical innovation stems from the resistance in leading firms to invest in them, due to being dependent on resources that are already invested in fixed assets, incorrect evaluations of the market, and a tendency to keep building upon (or even cannibalising) their own established technology. Instead, the author states that small entrepreneurs or outsiders are the more likely candidates for adopting radical technologies, rather than incumbent firms. These companies are less entrenched, have less to lose, no established interests and use their positions to slowly but gradually enter the market. For established firms, the opposite is often true. Van den Hoed (2007) refers to established firms have problems in dealing with radical innovation as 'the incumbent's curse'. This phenomenon has already been discussed earlier in this thesis, as 'path dependency' in the section

on disruptive innovation.

However, radical innovation does happen within incumbents in an industry. A clear example can be seen for the EV market, in which the adoption was picked up early by incumbents like Nissan and BMW, and is now rapidly being picked up by the rest of the industry, The framework by Van den Hoed (2007) can therefore be of great value, because the author defines five factors, that provide insight into when and why radical innovation within incumbents is more likely. Be aware that the author notes that these are 'potential change factors' and that the combination of these is important. Seeing as to how these factors can provide explanations as to how an industry is turning around by an innovation (the exact process which the framework is about), these factors are of use to this thesis. The five change factors that may explain the emergence of radical technological change, as defined by Van den Hoed (2007) are:

1. New entrants
2. External shocks or crises
3. Performance of the new technology
4. Market changes
5. Industry competition.

This is a rather general list for the automotive industry, and not specifically of FCEV's, as the author only starts his analysis of FCEV's after this list. This means that this list is applicable to other types of innovations or industries as well, meaning that it is very useful for the innovation takeover framework. It also means that it can be applied specifically to the EV case central in this thesis, and that possible hooks with the dieselgate/EV case can be stated. The influence of the successes of Tesla on other companies starting their own EV development, can refer to both 'new entrants' and 'performance of the new technology'. The mention of 'external shocks and crises' warrants again investigation of the influence of dieselgate. The author names 9/11 and the Zero Emission Vehicle regulation established by the California Air Resources Board (CARB) in 1990, as two external shocks that have been of influence on EV's for the time when the paper was written. Regarding the CARB regulations, many recent regulations (such as the New Green Deal) might have had similar effects. In addition, dieselgate was a response by Volkswagen not being able to comply with those very same CARB regulations (see also subsubsection 3.1.1). Regarding 9/11, the author notes that although it did indeed created a push for more independence from Middle-Eastern oil countries, several other initiatives for alternative fuel vehicles were already being investigated as well. The event just heightened the sense of urgency. This too, is an interesting observation, as there might have been cases that have 'heightened the urgency' of EV-development or adoption in recent times as well. One of them might be dieselgate. Market changes refers to, amongst other things, changing public opinion causing more demand for EV's, and less demand for ICE vehicles. These quick but obvious links between the framework and the case make it a strong framework to incorporate in this research. It also shows common insights with the framework by Hardman et al. (2013), explaining successful disruptive innovation, and Dijk et al. (2016) explaining successful market penetration of disruptive innovation. Combinations of these frameworks provide insights into differences and commonalities between radical innovation and disruptive innovation. As such, incorporating the insights into radical innovation by Van den Hoed (2007) into this thesis is a valuable addition. The author notes that his paper 'explores the way in which radical innovations that offer qualitatively better performance in terms of sustainability, may or may not come to pass within a large, established industry that is not usually associated with such dramatic changes.' The paper is from 2007, and one might say that these dramatic changes are happening now and have happened during the past decade. As such, it is a good idea to incorporate this perspective, by looking how its factors have developed since the paper was written. Especially since the paper predicted that FCEV's would win the standard battle, while the winner turned out to be BEV's (Van de Kaa et al., 2017). Furthermore, it is also of benefit to the practical applications of this research, as the study into radical innovation is of interest to multiple parties: incumbents need to study it for competitive reasons, and because these innovations have an effect on their current knowledge base and competencies (Van den Hoed, 2007).

### 3.2.5 3C-Model

The previously mentioned frameworks all describe drivers of various stages or aspects of the innovation versus incumbent technology process in term of qualitative factors. Since the process is regarded over time, an interesting way to measure the influence of a factor, is to determine how it changes over time. A logical way to do this, is by using quantitative data to express a factor, and analyse how it changes over time, and if any trend disruptions can be seen, which might be related to important aspects of the process. With the exception of the innovation diffusion, none of the frameworks contain quantifiable metrics that can be used to analyse the process, and even innovation diffusion only offers one specific metric (namely the market share). In order to

gain understanding of how the innovation takeover process goes, and how certain factors contribute, a framework is needed that works with quantifiable metrics which are expressed over a time series. In order to do so, the 3C-model by Beelaerts van Blokland and Santema (2006) is considered as an addition to the framework. It was originally designed for the analysis of co-innovation in high-tech industry, making it suitable to apply in a framework that considers technological innovative processes. And given that the current developments regarding technology and innovations in the automotive industry, that industry has started to behave like an high-tech industry, making the framework also suitable specifically for the EV/dieselgate case (Wittmann, 2017; Beelaerts van Blokland et al., 2019).

The 3C-model is developed to express the degree to which a company can leverage its value, when co-innovating. Co-innovation refers to the process where a company involves companies from its value chain into the process of innovating. This new innovation has value (as creating value is the main goal of a company), and the 3C model describes the ability of the company to have a part of the value of the innovation being created by the other involved companies. In doing so, the required investments and risks are spread amongst (leveraged to) to all companies involved. This ability is expressed in three dimensions, that all describe aspects of a company: Configuration (the formation of partnerships or a network of stakeholders, as well as the ability to leverage assets and resources on the supply chain), Continuation (the extent to which the company is able to create value for the customer), and Conception (the unique technology or process a company possesses or can create). These dimensions are operationalised into so-called 'partly financial performance indicators': Turnover per capita, Profit per capita and RD-expenses per capita, respectively. In these metrics, 'capita' refers to the number of employees. By expressing these financial aspects on a 'per capita' basis, the 3C-model allows to compare companies to one another (benchmarking). As can be seen, in contrast to many of the previously discussed frameworks, the dimensions of the 3C-model as are based in financial/numerical data, and are thus quantitative rather than qualitative like the rest. This allows them to be used to measure certain aspects of the innovation versus incumbent technology process over time, which leads to interesting insights. The 3C's of the model are now discussed, alongside how they are useful for the framework. Note that while this section has an elaborate section on the RD/C, the final framework incorporates all 3C's. The more elaborate substation on the RD/C is included to demonstrate what kind of inferences can be made using these metrics. The other two metrics are used, and similar inferences are made when using the framework in the case studies.

First off, the RD/C dimension (conception) is of interest for analysing innovations, as this indicates the focus on innovation within a company, when applying the 3C-model on an organisational level (Beelaerts van Blokland et al., 2008a). In order to demonstrate how the RD/C dimension could be useful, the Research and Development expenditures, and the number of employees of the top 10 PHEV and BEV sellers of the past decade (see also: Table 1), have been researched. This has been done specifically for this thesis. As such, these data do not stem from a paper or a book, but were accumulated from annual reports of each respective company. The results are visible in Figure 8. Amounts are in dollars, and the average exchange rate has been researched for each individual year. Note that some of the data is incomplete: before 2014, the annual reports for SAIC Motor only included the number of employees of the holding company and not of subsidiaries, which gave an askew number. BAIC went public in 2014, so no annual reports exist from before then. In the annual report of 2015, BAIC does not differentiate between capital and R&D expenditures. Hyundai does not report its number of employees, so secondary sources needed to be used. Several annual reports could not be found: Hyundai (2010-2013), SAIC Motor (2020), BYD (2020) and Nissan (2019 and 2020).

The first observation is the high spike for Tesla at the start of the decade (2010 and 2011). Since Tesla introduced the Model S in 2012, this seems to fit the theory that the introduction of an innovative new product (as the Model S certainly was in that time) goes paired with a high RD/C. After that, Tesla returns to a more average RD/C rate. Smaller spikes are visible for Tesla around 2015 (introduction of the Model X), and for for BMW in 2013 (introduction of the i3). These spikes, paired with the introductions of new innovative EV's, might therefore be indicative of these companies being innovators, or at least early adaptors. As was discussed earlier, these companies could be referred to as 'disruptors' for these reasons. Another important aspect to note about this is the fact that Tesla's early success have been of great influence on the EV market, as it proved feasibility, causing many companies to also switch towards EV's. Making these kind of events visible through the RD/C dimension, makes a strong addition to the framework. Secondly, it stands out that the average RD/C for the 2 Chinese companies (SAIC Motor and BYD) lies a lot lower than the other companies. This might be an indication of a non-innovative company culture. Consequently, these companies are likely not innovators, and more likely early or late majority, or laggards. These companies are likely to wait until a technology is invented and proven by another company, and then buy it to use in their own models. An alternative explanation might be the way in which R&D is reported. The entirety of BYD is an electronics company, rather than a car company. As such, not much expenditure might be reported for the R&D of car batteries at BYD Auto, as those are the core business of BYD Company (the parent company). Lastly, it is interesting to see that there is

hardly any difference in the RD/C rate for Volkswagen before and after dieselgate. Even in the years after the settlements (2017), there is very little disturbance. According to the yearly reports, Volkswagen kept on hiring and the RD expenditures only went down a little bit before going up again. It is possible that they saw the need to innovate, and therefore made sure that there would be enough money for Research and Development, in spite of all the fines and settlements. Keep in mind that these figures apply to the Volkswagen Group (which includes, amongst others, Audi, Seat and Skoda) rather than the brand Volkswagen. It is possible that these dimensions do differ for the individual brands.

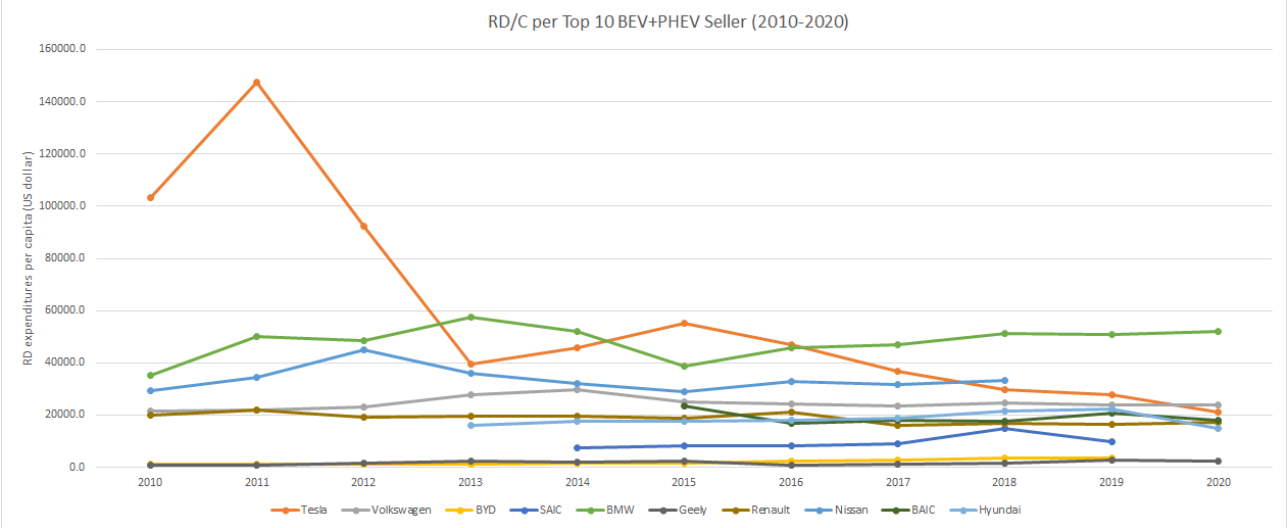


Figure 8: R&D expenditures per capita for the top BEV + PHEV sellers of the decade 2010-2020

Configuration, which is operationalised as Turnover per capita, or T/C, is of interest for the innovation framework, as on an organisational level, it denotes the ability of a company to leverage its value on it supply chain (Beelaerts van Blokland et al., 2008a). This means that it leverages its own assets and resources against those of other companies in the value chain, in order to create a greater value from those assets and resources, by placing a part of the burden with her companies. In other words, this dimension describes the ability and strength to form partnerships, or a network of stakeholders. This is interesting from an innovation perspective, as a company rarely works alone. incorporating this dimension into the framework, provides insights into how a company bringing a successful innovation to the market involves other companies in that process. This gives insights into the importance of such partnerships. For example, if one or more companies that were very successful in bringing an innovation to the market all had a high T/C, that could indicate that it is important for such a success to involve the other companies in the value chain in that process. As such, this dimension also bears resemblance to several (qualitative) drivers from other frameworks that were previously discussed. Examples of this are Suarez (2004), in which the firm's assets and credibility are named as a driver in the standard battle theory, and Dijk et al. (2016) who names 'technology spilling over from other sectors' as a driver in whether a disruptive technology will successfully penetrate the market.

Lastly, continuation, which is expressed as the profit per capita or, P/C, is of use for the innovation takeover framework. As stated, on an organisational level, this dimension expresses the ability of a company to create value for a customer, meaning that the customer will purchase tat company's product which thereby continues to exist (Beelaerts van Blokland et al., 2008a). The link here with an innovation replacing an incumbent technology is obvious. The company that creates the product that the customer wants, is the company that continues to exist. Thus, if the company creates an innovation that has value for the customer, that innovation gets bought and profits (and thus profit per capita) go up. Therefore, this dimension is useful in the framework, by incorporating it to quantify whether the innovation is indeed adopted by the customer. Links to the previously discussed (quantitative) frameworks are seen in, amongst others, Hardman et al. (2013), who state that successful disruptive innovation have 'added value' for a customer, and (Dijk et al., 2016) who names 'the reframing of customer preferences' as a factor dictating whether a disruptive technology will successful penetrate the market. As can be seen, the P/C dimension is closely related to customer factors from the previous frameworks, and thus can be used to quantify the influences of those factors.

Aside from using the dimensions from the 3C-model separately, there are also applications in which they are used combined. This is done in Beelaerts van Blokland et al. (2019). Here, the authors developed 2 rankings

using the dimensions from the 3C-model, and combined those into what they named 'the stability-value leverage maturity model'. The two rankings are the relative ranking, which denotes stability and the absolute ranking which denotes the capability to leverage value. The relative ranking, or Average Value-Leverage (AVL) denotes stability and is calculated as the average of the 3 correlations between RD/C, T/C and P/C. The scores for this dimension go on the x-axis of the grid. The absolute ranking is achieved by looking at the best and worst performances within each dimension, comparing each company to those extremes, and then summing each score for each company. This ranking denotes the capability to leverage value and goes on the y-axis. The two rankings form a grid (referred to as a matrix in the paper), on which the position of a company determines both the stability of that company, and its ability to leverage its value. Based on these positions, the authors than can make inferences regarding certain aspects of the company, like being vulnerable to disruptions, the likelihood to be taken over, or being industry leaders. As mentioned, the authors look at changes in automotive company performance as a result of the 2008 crisis, in terms of the dimensions of the 3C-model. For further research, they suggest looking at these changes as a result of dieselgate as well. When using the dimensions from the 3C-model in conjunction with the qualitative factors from the previously mentioned frameworks, it could be interesting to include the stability-value leverage maturity model as well, as the data is already there. In doing so, the framework could gain an extra dimension, as it allows using stability and the ability to leverage value as possible explanations in the innovation takeover process, especially when looking on an organisational level. This could, for instance, lead to inferences about stable companies being better in bringing industry-changing innovations to the market, or to generate more value from innovations. It could also lead to inferences regarding what happens when companies are not able to keep up or embrace a market shift. Less stable or mature companies might not be able to spend as much as is needed on R&D in order to keep up with the market shift and as a result could go bankrupt or need to be sold to survive, This can be seen in the automotive industry at the moment, because Opel did not possess the required technology for EV's, and as a result they were sold to PSA, who did and as such could keep the company alive.

A model based upon the 3C-model, named the value time curve, is found in Beelaerts van Blokland et al. (2008a) and Beelaerts van Blokland et al. (2008b). The value time curve is originally developed for co-innovation, which refers to the process of involving partners on the supply chain in the innovation process (rather than doing it alone), and looks at the value of a specific product of a company over time (rather than a whole technology). The value time curve can be seen in Figure 9. It has time on the x-axis, and the value of the innovation in the y-axis. As can be seen, the curve has a rather unusual shape, with a negative value first. This shape is inspired by the product life cycle, and can be explained as the innovation not generating profit first, but rather costing money (in the form of investments). This negative part is called the new product development phase, starts at t=0 and ends when the break-even point for that product is achieved (when the earnings equal the investment). After that, the value grows until it stabilises or starts to decline. The value time curve has two coefficient which are useful in determining developments regarding the value, namely the directional coefficient (which is the first derivative of the value time curve, i.e.: a first degree trendline of the curve), and the growth coefficient (which is the second derivative, i.e.: the slope of said trendline). For a successful product, the directional coefficient is positive in the early value-generating phase, and positive or equal to zero (indicating stability) in the maturity phase. The growth coefficient is the slope of the directional coefficient. Therefore a higher growth coefficient, indicates successful development of the value.

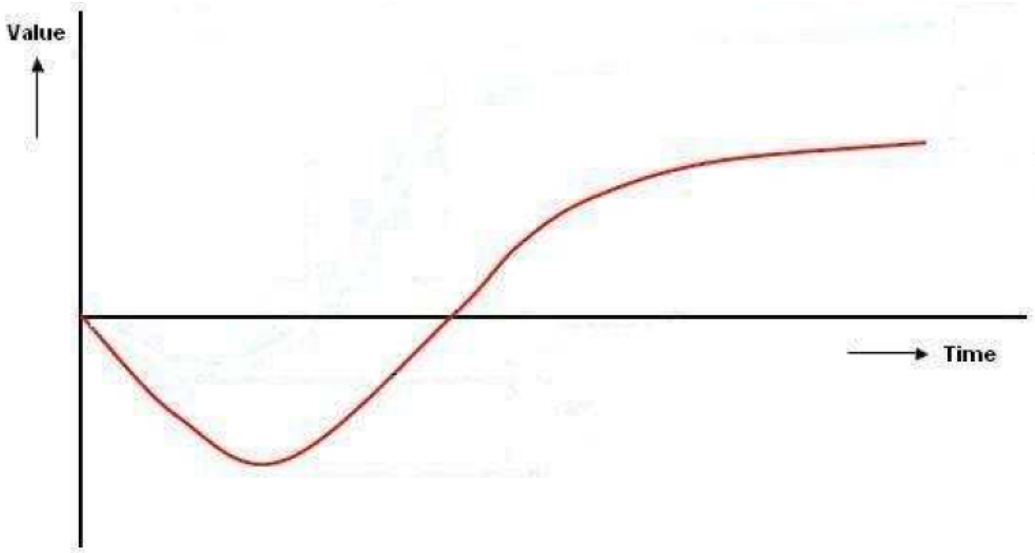


Figure 9: The value time curve (Beelaerts van Blokland et al., 2008b)

As stated, the value time curve is closely related to the 3C-model, and is based on the same dimensions (configuration, conception and continuation). However, in the value time curve model, these dimensions are applied on the product level rather than the organisational level (as was the case with the classic 3C-model). As such, they are operationalised in a different manner. Continuation, determining whether the product delivers better value for the customer, is expressed as an increase in market share (or $\Delta$MS). Conception in this sense refers to how much of the total investment is done by the firm itself. By leveraging more of the investment to partners, a company can achieve break even faster. On the product level, conception is expressed as the total investment divided by the investment of the firm. This is called the Investment Multiplier (IMP). Lastly, configuration on the product level expresses how much of the production is leveraged to partners, as this reduces the complexity of the supply chain. This is determined as the total production value, divided by the firm's own production value. This is called the Production Multiplier (PMP). A more complex representation of the value time curve can be seen in Figure 10. Here, the value time curves of two products are displayed, together with the aforementioned metrics.

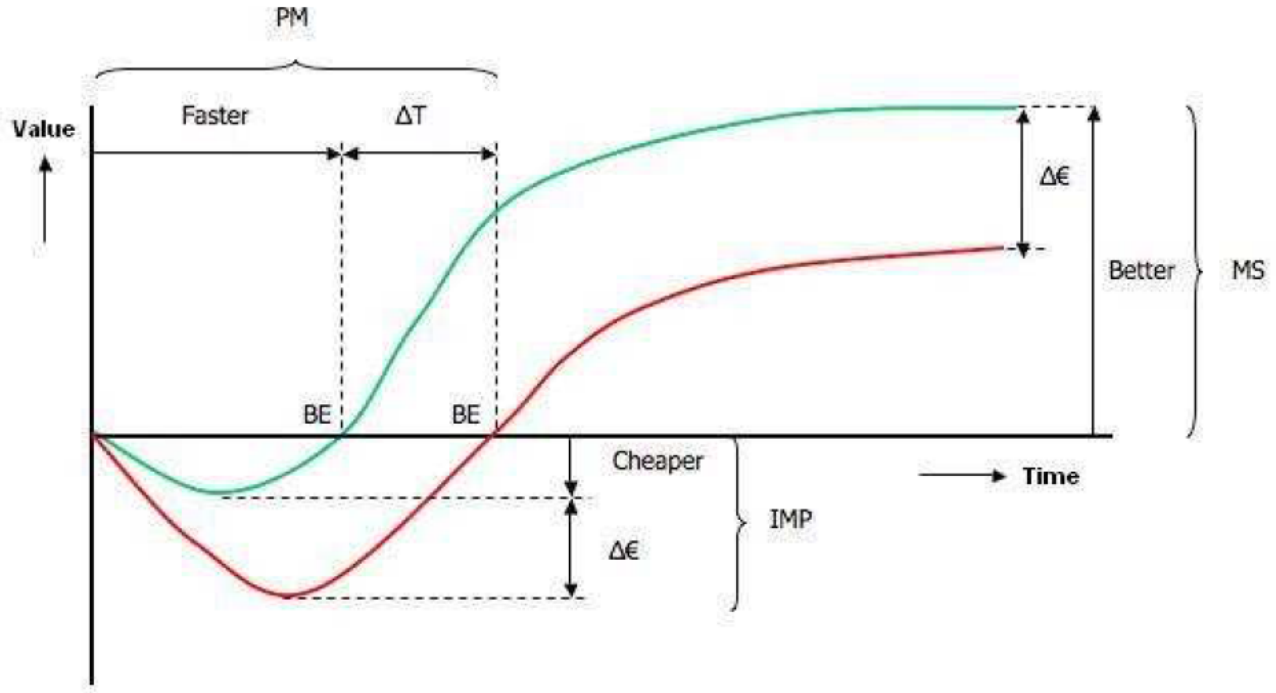


Figure 10: The VTC for two products, with the metrics displayed (Beelaerts van Blokland et al., 2008b)

In conclusion, there are many frameworks that can be used to analyse (parts of) the process of an innovation taking over from an incumbent technology. The concepts of the papers found in this section are summarised in Table 4. As can be seen, there are is no single framework however, that satisfies the exact needs for this thesis, namely one that describes the process for both the innovation and the incumbent technology, while at the same time provide a way to determine the influence of each factor (either quantitatively or qualitatively). Through the literature, it is possible to formulate several qualitative ways to measure them, by piecing several frameworks together (which is indeed done later), but especially measuring them quantitatively is interesting, as this is not featured anywhere in the literature pertaining to these factors. Literature on measuring in a quantitative matter (for instance, the 3C-model) are not related directly to the innovation versus the incumbent battle, and innovation diffusion theory does not consider the incumbent technology, nor does it provide ways to measure the influence of the driving factors.

In short, the lack of a framework that describes the process of an innovation taking over from an incumbent technology in measurable (either qualitatively or quantitatively), is defined as is the second knowledge gap of this thesis. In order to create such a framework, the next section (section 4) will discuss the factors from each frameworks on the applicability in such a framework. On the basis of that analysis, a framework suitable filling this gap is created in section 5. The framework is verified through interviews, and validated through a theory-testing case study. This testing is done using an unrelated case, as using the main one would lead to bias. Once verified and validated, the framework is then used in a theory-building case study in order to answer the main question of this thesis. As stated before, while there are many hooks in this section made to the EV/dieselgate, these are not leading and the framework will be built as a generic framework for technology industries, in order to fill both the knowledge gap, as well as being able to be tested on a case study not related to the thesis (in order to prevent bias).

Table 4: A matrix depicting various concepts relevant to this study, and the presence or absence in literature.

| **Paper** | **Content** | **Qualit. factors** | **Quantit. factors** | **Gap** |
|---|---|---|---|---|
| Beelaerts van Blokland et al. (*International Journal of Six Sigma*, 2019) | The Stability Value Leverage Maturity Model | No | Yes | No connection to the innovation/incumbent process, or the driving factors |
| Van de Kaa et al. (*Energies*, 2017) | Factors of a standard battle (specific) | Yes | No | No manner of measuring the state of the battle, or the drivers |
| Dijk et al. (*Technological Forecasting and Social Change*, 2016) | Successful market penetration by a disruptive technology | Yes | No | Only considers the innovation, not the battle with the incumbent technology. No manner of measuring. |
| Hardman et al. (*International Journal of Hydrogen Energy*, 2013) | Characteristics of successful disruptive technologies | Yes | No | Only considers the innovation, not the battle with the incumbent technology. No manner of measuring. |
| Van de Kaa et al. (*Technological Forecasting and Social Change*, 2011) | Factors of a standard battle (general) | Yes | No | No manner of measuring the state of the battle, or the drivers |
| Oldenburg and Glanz (*Health behavior and health education*, 2008) | Innovation diffusion | Yes | Yes | Only considers the innovation, not the battle with the incumbent technology. |
| Beelaerts van Blokland et al. (*TU Delft*, 2008) | Usage of 3C-model metrics on an organisational level | No | Yes | No connection to the innovation/incumbent process, or the driving factors |
| Beelaerts van Blokland et al. (*Journal of business market management*, 2008) | The Value Time Curve | No | Yes | No connection to the innovation/incumbent process, or the driving factors |
| Van den Hoed (*Journal of Cleaner Production*, 2007) | Emergence of radical innovation within incumbents | Yes | No | Only considers the innovation, not the battle with the incumbent technology. No manner of measuring. |
| Beelaerts van Blokland and Santema (*Proceedings of the 22nd IMP Conference*, 2006) | 3C-model | No | Yes | No connection to the innovation/incumbent process, or the driving factors |
| Suarez (*Research Policy*, 2004) | Phases of a standard battle | Yes | No | No manner of measuring the state of the battle, or the drivers |
| Cowan and Hultén (*Technological Forecasting and Social Change*, 1996) | Escaping lock-in | Yes | No | No manner of measuring the state of lock-in, or the drivers of the escape |

# 4 Analysis: Useful frameworks, and how to combine them

In section 3, several frameworks were found that could be useful to analyse the process of an innovation taking over from an incumbent technology. It turned out however, that there is no single framework that concerns both the innovation and the incumbent technology, and explains that process through factors (qualitative and quantitative), whose type of influence could be measured. As stated before, a generic framework is required, in order to fully grasp the complexity of the process (rather than testing for one specific influence), and to prevent bias. Designing a generic framework also fills the discovered knowledge gap and allows it to be independently test on a different case study, in order to see if it works as intended before it is applied to the main research question of this thesis. In the previous section, when researching various frameworks, several hooks and examples related to the EV/dieselgate were made, by way of early exploration into the main topic of this thesis. As it was stated however, these do not play a deciding role in whether a framework was suitable, which will become clear in this section, where no such hooks and specific examples are present.

The next step in order to answer research question 2, is to build such a framework. This is first done by analysing each framework, and determining how they can fit in a combined framework that fits that need. These steps are executed in this section. First, a short recap is given of the various frameworks, then a selection is made of (parts of) frameworks suitable for this thesis. Then, is it analysed how these framework may be combined, by determining which of their factors show overlap, and grouping them in so-called clusters, which make up the factors of thesis-specific framework. Subsequently, for each of these new factors, a method to measure their influence is determined. Several will be measured quantitative, in which the way of measuring is called a 'metric', and several will be measured qualitatively, for which the measurement is called a 'criterion'. These new factors are then used in the section 5, in which the new framework is designed.

## 4.1 Analysing existing frameworks

In the previous section, a variety of perspectives was researched and analysed. From these perspectives, several frameworks that describe parts of the innovation versus an incumbent technology process emerged that prove useful for this thesis. These will now be listed, with their applications, after which their applicability will be analysed. Note that the frameworks related to the 3C-model will be discussed later, as those are used to measure several of the other frameworks, and do not describe factors of the process at hand.

1. Van de Kaa et al. (2011): general factors deciding the winner of a a standard battle.
2. Van de Kaa et al. (2017): specific factors relevant for the FCEV versus BEV standard battle.
3. Suarez (2004): the phases of a standard battle
4. Oldenburg and Glanz (2008): factors deciding if a new innovation will successfully diffuse.
5. Hardman et al. (2013): factors classifying whether an innovation is disruptive, and characteristics of historically successful disruptive innovations.
6. Dijk et al. (2016): factors defining the successful market penetration a disruptive technology.
7. Cowan and Hultén (1996): ways to successful escape a lock-in.
8. Van den Hoed (2007): factors explaining the emergence of radical innovation within incumbent companies.

Throughout the previous section pertaining to the found perspectives, some ideas have already been voiced upon possible combinations in order to create a new framework. Put shortly: A framework is needed that explains the process of an innovation taking over from an incumbent technology, while providing a way to measure their influence when comparing the technologies. This framework ideally consists of a handful of discrete factors which provide information on how that factor has influenced the process. As such, first the suitable frameworks are selected, after which their factors are analysed on their resemblance, which leads to clusters of factors, which in turn form the factors of the new framework.

The framework of Van de Kaa et al. (2011) is deemed rather essential to this thesis, because the process at hand is a standard battle (a new technology competing with an incumbent technology for market dominance). Apart from that, this framework is very elaborate: it holds 29 different factors, divided in 5 distinct groups. These groups describe general categories, and as such, provide a strong basis to determine the clusters for the new framework. For these reasons, the new factors and the new framework take the standard battle perspective as its starting point. The next framework dealing with the standard battle, the one by Van de Kaa et al. (2017), is deemed not useful for this research, as is pertains to a specific standard battle, namely that of FCEV's versus BEV's. The new framework needs to be generic, so incorporating elements of a specific battle is not logical. Apart from that, this battle contains 2 innovations competing for dominance, while the framework looks at an innovation versus an incumbent technology (it is possible to look at 2 innovations using the framework, but there needs to be an incumbent technology present in the battle as well). For these reasons the framework by

Van de Kaa et al. (2017) does not fit well within the new framework. The framework by Suarez (2004) also concerns the standard battle. This framework divides the standard battle up in several phases, and because this provides more insight in the process, this framework is deemed useful. Additionally, the framework by Van de Kaa et al. (2011) is based upon this work, and it used similar groupings of factors. Van de Kaa et al. (2011) is more recent, contains more research into the topic and as a result contains more factors and more extensive groupings. Therefore, the factors by Van de Kaa et al. (2011) will be used as a base, but the fact that it is based on Suarez (2004) makes for a good connection between the two. For these reasons, the framework from Suarez (2004) is incorporated. As was described in section 3, there is no framework that considers both the innovation and the incumbent technology, while at the same time providing ways of determining the factors their influence. At the end of this section, when the new factors are developed, the ways of determining this will be discussed, but the framework of Suarez (2004) plays a role in this, as it allows to look at how certain factors might have changed over time, and as such can be used to give a balanced score where necessary. Additionally, dividing up the process into discrete phases, allows for more in-depth analysis of a certain phase. There is however, one gap that the framework leaves open. The framework starts immediately with the R&D build-up phase, while not addressing how an innovation goes into the R&D phase. In other words, the grounds for starting with R&D are not included. In the value-time curve (Figure 9), this can be seen at $t = 0$, where the investment first goes down. In other words: something at $t = 0$ initiates this process, and this is not accounted for in the framework by Suarez (2004). This lack of a phase where there are grounds for starting R&D was also addressed in one of the interviews, where the interviewee mentioned that innovations start as either a 'chance' or a 'necessity' to do something new, kicking of the R&D phase. As such, a phase before the R&D phase is included, which is called 'Opportunity'. In line with the numbering of Suarez (2004), this phase is numbered as 0. More on this in the section on the design of the framework, section 5.

The framework by Oldenburg and Glanz (2008) is also deemed essential for this research, as this framework expresses the rise of an innovation through a rise in market share. This is expressed through the s-curve, seen in Figure 7. The usage of market share and the s-curve introduce a strong way to express the success of an innovation, and the rate thereof into the framework, because it quantitatively expresses the state of the take-over by the incumbent, and introduces a way to expresses the way in which this is going when used in conjunction with the coefficient form the value-time curve (more on that later in this section). Since the framework looks at the rise of an innovation at the expense of an incumbent technology, the market share of an innovation is the direct inverse of the market share of an incumbent technology. As such, one of the additions to the existing literature on this topic, is including a second s-curve, which describes the market share of the incumbent technology, in order to clearly display the state of the standard battle. Additionally, the paper by Oldenburg and Glanz (2008) provide several factors that describe the rise of an innovation, and bear resemblance with the ones from the previous frameworks, allowing them to be neatly incorporated. The theory of innovation diffusion also divides up the various groups of adopters of an innovation, into when they adopted it. These will not be incorporated directly into the framework, as certain thresholds of amounts of adopters do not correspond well with the phases of Suarez (2004), distorting the framework. Since these phases are strongly related the standard battle which the framework is based upon, these take priority. These groups are however, taken into account where relevant, when determining the influence certain factors or interpreting results.

Hardman et al. (2013) provides 2 frameworks: one for determining if an innovation can be called 'disruptive' and one describing common characteristics of historically successful disruptive innovations. The first one is useful for this thesis, but not directly as a part of the new framework. Instead, it is used a qualifier for the usage of the framework: if the innovation that is being analysed, was indeed disruptive, then the framework can be applied. The second framework by Hardman et al. (2013) is a very useful addition to the new framework, as it lists factors that historically successful disruptive innovations share. Given that the innovation under analysis is disruptive (established through the first framework), the second framework provides a very clear list of factors that can be used to analyse the driving factors of that success. Additionally, these factors bear strong resemblance to the factors from the previous frameworks. Therefore, they can be neatly incorporated, thereby providing more in-depth information on what factors drive the success of an innovation. As such, the second framework by Hardman et al. (2013) is strong addition to the new framework.

The framework provided by Dijk et al. (2016) is also regarded as a very strong addition to the framework. This framework defines several factors that define whether a disruptive innovation successfully will penetrate the market. The framework looks at a standard battle, and partially expresses the state of that battle through a rise of the market share of the innovation. The framework by Dijk et al. (2016) provides an interesting perspective to this, namely the factors that have contributed to the very start of that rise. Additionally, the factors by Dijk et al. (2016) are reminiscent of prior considered factors, meaning that they can be incorporated well. Therefore, this is a very strong framework to incorporate into the new framework.

Cowan and Hultén (1996) describe several factors that cause the world to escape a lock-in. Since a lock-in is

a barrier for the innovation to break through, looking into what lowers or ends that barrier (and subsequently allowing the rise of an innovation), this is a strong framework to incorporate. This allows the researcher to analyse the role of an innovation or the incumbent technology in this process.

The framework by Van den Hoed (2007) is a strong addition to the new framework, as it provides a second approach to analysing innovations, namely that of the radical innovation. When an innovation is radical, it changes the entire industry and market. When looking at the framework, this is what is indeed the process that is being described: the incumbent technology is taken-over by the innovation, thereby changing the industry and the market, in favour of the innovation. As such, incorporating a framework that looks at radical innovation is important. The framework of Van den Hoed (2007) can be used to explain when (and why) radical innovation within incumbent companies is more likely. This is an interesting addition to the framework, as it balances out the newcomer-perspective. Aside from that, these factors also bear strong resemblance to the prior mentioned factors, which allows for neat incorporation.

The frameworks discussed above, provide various factors that influence the process of an innovation taking over from an incumbent technology, and several manners as to how to express this process. As mentioned in section 3 and more specifically in Table 4, the frameworks by concerning the 3C-model are not directly related to this process. They do provide however, very valuable aspects, that can be used to express the direction the market share of either technology is heading in, and to determine the type of influence that certain factors might have. The next step now however, is to determine how the innovation/incumbent technology frameworks fit together, by looking at commonalities in their factors. This is done in the next section, after which the framework surrounding the 3C-model will be analysed for their application to provide information on the various aspects of the framework.

## 4.2 New factors and how to measure them

With suitable frameworks selected, the next step is to look into how they may be related or have overlap, as a first step into creating a framework those describes the process of an innovation taking over from an incumbent technology. In previous section, some mention was already made of multiple frameworks having factors that are similar or show overlap. As such, the essence of this step was to identify clusters of factors within all frameworks which refer to the same things, yet have different names, and group them together under a common name. This provided a lot more insight into the relevant factors, as it greatly reduced the number of factors while keeping the aspects of the process they refer to. The process of clustering is done as follows.

First, an empty matrix was constructed with only the names of the selected frameworks on the top row. Then, framework by framework, the underlying factors were placed in the cells. Each time a new framework was added, attention was paid to the meaning of each factor and if a that factor (or something closely related) was already present in another column. If so, similar factors from different frameworks were placed on the same row. In this manner, each row began to correspond to a theme that factors from different frameworks shared. Through the overlap between the factors, the groundwork for combining the frameworks was laid.

For example: 2 factors from different frameworks might both be about the characteristics of the technology, while having different names. If a factor did not correspond to an already existing row, a new row was added. If many factors in a row seemed to correspond to the same sub-category of a row, the row was split and a new theme was conceived and named. This process started off with the framework by Van de Kaa et al. (2011), as that contained 5 large clusters. After that, the frameworks were added one by one, and new groupings became clear. Through this process, several broad groupings were found. In order to fine tune these groupings, the next step was to divide the categories from Van de Kaa et al. (2011) up in their 29 underlying sub-categories, and place them in the correct rows, or add new rows where necessary. After this, the factors from the other frameworks were checked once more, to see if they were still in the right row, or needed to be moved to a newly emerged category.

The last step was to clearly name these groupings, hereby paying attention that the name represents the underlying factors as accurately as possible. The resulting clusters of factors, now known as the new factors, are listed below. The entire matrix these clusters are based upon can be found in in Appendix D. The new factors that have emerged from these clusters are listed in the left-most column. The process of turning these factors in to a framework is described in section 5.

- Company Strategy and Finances
- Adopters/ Consumers
- Other firms
- Characteristics of the technology
- State and image of the company

- Government
- Characteristics of the Market
- Environmental factors

To be able to accurately use these factors into a framework, and to use them when analysing a case study, it is important to understand what each new factor represents and how it is determined what kind of influence it has on either the technology or the innovation. This last step involves connecting the new factors to a way of measuring or scoring them. This is where the 3C-model, and the value-time curve come into play, as these are used to operationalise 3 of the factors, namely 'Company Strategy and Finances', 'Adopters/ Consumers' and 'Other firms'. Therefore, these frameworks are now first discussed.

The 3C-model, as seen in Beelaerts van Blokland and Santema (2006) and Beelaerts van Blokland et al. (2008a), introduces three metrics to be used on a company level, namely the Conception, the Configuration and the Continuation. These are all operationalised by expressing a certain financial key-indicator on a per-capita basis, allowing them to be used for benchmarking various companies. Since the framework looks at an organisational level and this allows them to be compared, and the fact that certain new factors bear a resemblance to the 3C's, these per-capita metrics are used to operationalise these 3. The manner of doing so, will be discussed in the section on the relevant factor.

As can be seen in section 3, the value-time curve (VTC) looks at a product-level. The curve in Figure 10 is constructed through aspects of a specific product by a specific company, namely the break-even time, information on how much of the production and value are leveraged, and a difference in market share. While the market share is used in the framework in order to determine the success of an innovation, this is different as it looks at the market share innovation as a whole, rather than a specific product. Since this is the case, there is no data on the other aspects, and as such the value-time curve as is, is not a part of the framework. However, as was already discussed in the section on the phases by Suarez (2004), the process of a product (or an entire technology, in the case of this framework) does not just start out of nowhere. In the VTC this can be seen at t = 0, when the curve starts to develop. The fact that the curve starts, signals that there was a reason for it to do so. In other words: there was a reason for a company to start investing in a product. This is not addressed in Suarez (2004), as those phases start right already in the R&D phase. As such, an additional phase is added, named phase 0, named Opportunity' in which there is a sort of 'big bang', kicking of the process.

The paper by Beelaerts van Blokland et al. (2008a) does present another aspect of the value-time curve, that is of very high value to the framework, when used in conjunction with the metrics from the 3C-model, and the market shares of the technologies that are analysed: the directional and the growth coefficients. Since the 3C-metrics are based on financial and employment data over time, it is possible to plot them for the period under analysis. Then, using the directional coefficient, it is possible to analyse whether they move in a positive direction, indicating an increase of a factor, and to look at the rate of growth. In short, using these coefficients, it is possible to make statements regarding the influence of a factor. For instance, if a company has a positive directional coefficient for RD/C, the factor the RD/C is connected to ('Company Strategy and Finances'), has a positive influence on that company and the technology it represents, signalling success for that company and technology. When looking at specific periods within the period under analysis (for instance, before and after a certain event), one can compare the directional and growth factors before and after, and make inferences about the influence of such an event. The coefficients from the VTC are also used for the market shares of the innovation and the incumbent technology, in order to demonstrate that a technology is successful (positive directional coefficient), or unsuccessful (negative directional coefficient). The use of these coefficients can be seen in the case studies, in section 6 and section 7.

The last model regarding the 3C-model that was discussed in section 3, namely the Stability Value Leverage Maturity Model by Beelaerts van Blokland et al. (2019), is not used as is in this thesis, because it did not fit the model or the factors. However, the authors suggest looking at changes in company performance (in of the 3C-model) as a result of dieselgate. While not applying them into the Stability Value Leverage Maturity Model, this thesis does look at the 3C's, and how they changed before and after dieselgate, thereby providing information regarding this suggestion.

Not all influences of factors are measured in the quantitative manners described above. Note that in line with Dul and Hak (2007), 'measuring' does not strictly refer to a process of numerical scoring, but refers to any process of determining the influence a concept has on another concept. As such, it can also be done by attaching a qualitative score. The remaining 5 are measured using a qualitative criterion specific to that factor. This was chosen either because no suitable numerical was found, or the fact that a factor is to complex and extensive to describe a numerical measure. These qualitative measurements could be for example, 'favourable' (signalling a positive influence), 'unfavourable' (signalling a negative influence), or 'neutral' (which may also leads to a negative influence, more on that per factor). The score of a factor is then based on qualitative information

regarding that company, or the technology it represents. This information comes from literature, reports and news articles regarding the specific company. As these scores refer specifically to the aspects of each factor, they are discussed directly when describing the relevant factor. The factors whose influence is quantitatively measured (and their measures, also known as 'metrics') are discussed first, followed by the factors that are qualitatively measured factors (and their measurements, also known as 'criteria').

**Company Strategy and Finances**
This factor concerns anything related to the financial and strategical decisions of a company, both for the innovating as well as the incumbent party. It also concerns internal company culture (learning, approach towards being dominant in the market, etc.), and the focus/commitment to innovations. It also involves its ability to claim resources for its own. Since the RD/C dimension refers to both strategy (as it signifies a focus on innovation), as well as finance (as it concerns the expenditures), the influence of this factor is measured through that metric. As discussed previously, a positively developing RD/C (indicated by a positive directional coefficient) indicates a positive influence of this factor, while a negatively developing one signals a negative influence.

**Adopters/ Consumers**
This factor concerns the manner in which the technology is regarded by the consumers. The adopters are described through aspects such as: characteristics of the adopters, customer preferences, (changes in) the social connotations of a technology, the added value for a consumer, and the bandwagon effect. It also involves a company's ability to convince the adopters of the value of its technology, through pricing strategy, marketing communications (PR or commercials, for example), the timing of the product's entry on the market, and the distribution strategy. Another aspect in this factor are 'network externalities', which describe the effect of the value of a product to a consumer increasing when the number of people adopting the product grows. This factor's influence is also determined through on of the 3C-metrics, namely continuation. On an organisational level, this metric denotes a company's ability to create value for the customer. As this factor clearly entails the customer, its influence is measured through the profit per capita, or P/C. As discussed previously, a positively developing P/C (indicated by a positive directional coefficient) indicates a positive influence of this factor, while a negatively developing one signals a negative influence.

**Other firms**
This factor refers to all influences that other firms, or the relations between other firms, have on a company. As such, this factor consists mainly of aspects related to the suppliers of the industry, and the network of stakeholders related to the incumbent technology or the innovation. This is the third factor operationalised through one of the 3C's, namely the configuration, as that denotes the strengths of partnerships, and leverage to the value-chain. As this factor clearly concerns the relation a company has to its value chain, it is measured through the turnover per capita, or the T/C. A positively developing T/C (indicated by a positive directional coefficient) indicates a positive influence of this factor, while a negatively developing one signals a negative influence.

**Characteristics of the technology**
This factor refers to any inherent characteristics of the technology under analysis that determine its success or failure. This includes, for instance, performance, quality, price, switching costs, complementary goods, flexibility, and compatibility with existing structures. This is the first factor who's influence is determined qualitatively. The technology's characteristics are compared to the standard in the market, and therefore scored as better, same or worse. Better characteristics (signalled, for instance, through better quality, better price, or higher flexibility) receives a positive score, indicating a positive influence of this factor. Logically the inverse is also true, meaning that worse characteristics lead to a negative influence of this factor. In section 3 the importance of innovating was stressed multiple times. This does not always mean a radical innovation is needed which changes the whole industry, but could also refer to continuously improving an existing technology in order to keep it up to date. A technology that is on par with the standard of the market is regarded as 'same', which means that it has no discernible qualities making it stand out. As this means a lack of innovation (improvement, in this sense), a company that puts out technology that has the 'same' characteristics receives a negative influence from this factor.

**State and image of the company**
Aspects of this factor are related to the state and image of a company. The state refers to the company reaching a state of crisis, or operational supremacy. Through the 'image', this factor also includes the manner in which the company is perceived by parties such as environmental organisations, politicians, and the public. It also

refers to how the company is perceived by shareholders or investors. In other words, this factor describes the reputation of a company. As both state and image influence how well regarded and present the company is, they are united in this one factor. This factor's influence is also measured quantitatively, and is scored as 'positive', 'neutral' and 'negative'. A company with a positive state and image (signalled, for instance, through practices beneficial to the environment or society, or being perceived as a company that delivers top of the line work) receives a positive score, indicating a positive influence of this factor. Logically the inverse is also true, meaning that a negative state and image lead to a negative influence of this factor. A company who's state and image are regarded as neutral, does nothing to discern it from the rest of the industry or market, which in the long term leads to failure. As such, a 'neutral' score also leads to a negative influence.

**Government**
This factor refers to all aspect related to various governments, such as regulation, or the general attitude of regulators that might make either technology more or less attractive. It also refers to antitrust laws (which mainly concern fair competition). This could refer to both regulation or regulators' attitude pertaining to the manufacturer (laws pertaining to a certain technology or its production, tax breaks, research funding, fines, loans, bail-outs), and the consumer (financial incentives, or regulation pertaining to the infrastructure surrounding a technology, like governmental investments, or regulation barring usage of technology in certain areas). The influence of this factor is qualitatively scored, and operationalised as 'rewarding', 'neutral' and 'penalising'. Positive influence of this factor is signalled by rewarding regulation, which includes tax breaks, funding, loans, bail-outs or governmental investments that make the technology more attractive. Negative influence of this factor, penalising regulation, is signalled by fines, or laws that discourage production or usage of a certain technology. In section 3, it became clear that an active positive regulation or attitude of regulators is required to make or keep a technology successful. As such, a neutral score for this factor also means a negative influence.

**Characteristics of the Market**
Characteristics of the market concerns all aspects that have to do with the market in which the companies of either technology operate. As such, it concerns changes to the market, the existence of niche markets, and the pattern in which a new technology enters the market (often first niche, then meso, then macro, but this may vary). It also refers to uncertainty in the market (through a number of causes), which could create a favourable environment for one standard (or new technology) to become the dominant one, the level of competition and the rate of change. As such, this factor is operationalised as 'favourable', 'unfavourable' or 'neutral'. A positive influence of this factor, a favourable market environment, is signalled for example, by the existence of a niche market, which allows easy entry or less competition, or compatibility with the externalities of the market (such as supporting services which allow easy entry). A negative influence, an unfavourable market, is signalled by the opposite: lots of competition, no niche markets, and low compatibility with the externalities of the market. A neutral market signals low interest and low value-generation for company, and since that leads to failure in the long term, also signals a negative influence of this factor.

**Environmental influences**
This factor concerns the environment in which the company operates. This factor concerns aspects that do not fall in the other categories, as well as the aspects that describe the ecosystem (environment) in which the innovation and the incumbent technology exist. It refers, for example, to the geographical location for a company, which may mean access to supporting companies and technologies, or access to good personnel. It also contains the influence of socio-technological systems, which mainly refers to the relation between people or society, and technology. It is operationalised through a 'favourable, neutral or 'unfavourable' score. This factor has a positive influence, if the environment is favourable, which may be signalled through a geographical location that may lead to access to supporting companies/technology and personnel, or the connection between the people and the technology developing positively. A negative influence, an unfavourable environment, is signalled through a location with little access to supporting technologies/companies and personnel, or society moving away from the technology. A neutral environment, signalled by medium access, or no relevant connection between the technology and the society, leads to little value-generation in the long term (as other companies and society are always in motion), also leads to failure in the long time, and therefore also signals a negative influence of this factor.

With the new factors and ways to measure their influence, either quantitatively or qualitatively, the required framework can be build. This is done in the next chapter, by determining the overall the process, and seeing how each factor exerts influence. 2 iterations of the framework are described, the first one which was verified and updated through expert interviews, and the second one in which the feedback, further research and clearer purposes are incorporated.

# 5 Design: An innovation takeover framework

With the new factors and ways of measuring their influence on the process, a new framework can be build which describes the generic process of an innovation taking over from an incumbent (which is operationalised as an increase, respectively a decrease, in market share). As stated, several useful frameworks have been found, but none of them capture all aspects, while proving a way to measure the influence of each factor. As such, a new framework is needed. Common factors have been found in several frameworks, and have been grouped into clusters in the previous sections. With these factors, and ways to measure their influence (both quantitatively and qualitatively) a new framework is designed. The process behind this is described in this section. First, the purposes of the framework are discussed, after which the framework is designed. This is done in 2 iterations. The first iteration of the framework was verified through interviews, which led to more insights. Subsequently, more research was done and the proposes of the framework were defined more clearly, leading to several alterations. These iterations are discussed separately.

## 5.1 Purposes and requirements of the framework

The final framework describes the process of a new innovation successful penetrating the market, and replacing the incumbent technology as the dominant one. This process is driven through several factors, which are all included in the framework. These factors can be measured in order to determine their type of influence on the process. The framework is built to be used on an organisational level, meaning that the innovation and the incumbent technology are represented by companies, as those drive the process. various aspects of each company and their technology are analysed through the factors, using the measures. The final framework can used for two purposes. These are now both briefly discussed.

The first purpose of the framework is to answer the main question of this thesis. Namely, to determine whether (and if so: how) dieselgate has had an influence on the rise of EV's. As can be seen through he various factors and frameworks, the rise of an innovation is a complex process, consisting of many influences. As became clear through the literature on dieselgate, the event has had an influence on various aspects of the automotive industry, many of which are captured in the factors of the framework. As such, it is likely that dieselgate in itself was not a separate factor, but has influenced the uptake of EV's through the defined factors. As such, dieselgate's influence in these factors needs to be determined, in order to understand its role in the process (if any). Designing the framework to specifically look for this influence leads to bias however, because considerations regarding the usefulness of frameworks might be influenced when they tend to display explanations for dieselgate. This might lead to factors being missed, or only applicable to the dieselgate case, which influences the outcome of the research. As such, a generic framework is needed, which can then first be tested independently, and then applied to determine the influence of dieselgate.

The generic framework is verified through experts interviews, updated as a results thereof and subsequently tested and validated through a case study, which looks at the process of an innovation taking over from an incumbent technology, in a domain (in this case, an industry) other than the automotive industry. When it is determined that the framework indeed performs like it should, it is applied for the case of the automotive industry, in order to see how dieselgate had an influence through the various factors of the framework. Initially, the plan was to test this completely through interviews, by formulating hypotheses on the basis of literature, asking experts what factors they thought were influenced, and thereby confirming or rejecting the hypotheses. Since the interviews were done semi-structured, emergence of new insights on influences could also emerge. It was decided however, that the results of this thesis would be a lot more extensive, if the factors in the framework would be made measurable and applied through a case study, in which, through these measures, possible influences of dieselgate could be determined. The first iteration of this framework was designed completely for interviews, while the second one accounted for measurability and the usage on a case study. The factors of the framework were kept constant however, which meant that the results of interviews were still representative. This made for an extensive analysis of the possible influence of dieselgate, as it was now determined through 2 distinct processes. The case study in which the influence of dieselgate is researched, can be seen in section 7. The results of the case study and insights from the interviews are discussed in section 8.

Apart from its purpose of answering the research, the framework also serves a wider purpose, as it became clear from the literature research that no framework like it previously existed. Since it is designed to be generic, it can be used further in science and practice. The framework can for instance be used to analyse other innovation versus incumbent scenario's and provide more insight this process. As it combines insights form various theories, like standard innovation and innovation diffusion, and attaches a way to measure an influence to the factors these frameworks are built on, it can be used in further research into these theories. The same goes for research regarding disruptive and radical innovation.

Since the generic framework describes the process at hand from an organisational perspective, it can be used by companies to gain more understanding regarding these topics as well. Here, the fact that the framework takes many factors into account, while making clear how these influence the process, can be useful. It allows companies to determine how they perform in each of the factors, leading to insights on whether their innovation is likely to be successful, or that their incumbent technology might be under threat. For instance, if a new technology is introduced, an incumbent company can use the framework to see whether that might constitute a threat by examining their own performances in each factor, and compare them to the the company of the new technology. Conversely, it can be used by company introducing a new innovation, to analyse what aspects of the process they need to pay attention to. While the framework alone might not be enough ground to overhaul a strategy, it might expose aspects where a company underperforms and needs to pay more attention to.

## 5.2 The first iteration of the framework

The first step of building the framework, was to determine what the process of an innovation being researched, being developed, entering the market and rising in market share looked like. To do so, the various steps of the process were constructed by looking at the selected frameworks, and what step or steps they described. While there was no separate phase for when the idea to look into a new innovation was conceived (phase 0, in the final framework), the step of an innovation starting was already added, as this presented a logical first step of the flow diagram. Then phases were added. Note that originally, the framework only consisted of 2 phases, the starting phase and the growing phase, which were divided by the point where the innovation successful penetrates the market on a bigger scale. This distinction was initially based upon the threshold between 'early adopters' and 'early majority', from the innovation diffusion theory, although at that point, no clear metrics on defining this exact point were determined. The 6 phases of the final framework were added in the second iteration, as the paper by Suarez (2004), and more research into a separate 'Opportunity' phase were the result of the first verification round.

Defining the steps of the framework was done as follows. Since the innovation diffusion framework provided a useful way to express the rise of an innovation (namely as increasing market share over time), that framework was taken as a base for the design. However, several frameworks look at specific steps or phases, so a flowchart was constructed describing these various steps. The flowchart started of with a logical starting point, which was simply defined as 'Innovation or new technology'. The next step in the flowchart are the companies introducing that innovation. The framework by Van den Hoed (2007) describes what makes the emergence of radical innovation within incumbent companies more likely, and as such, 'Incumbent start with innovation' was added as a step. The frameworks by Hardman et al. (2013) and Dijk et al. (2016) concern disruptive innovation, and while this is not always true, this type of innovation is often introduced by newcomers. As such, the step 'Newcomers start with innovation was also added. However, per the framework of Hardman et al. (2013), a disruptive innovation can also be introduced by incumbent companies (see the qualification of the EV as being disruptive on 2 of the 3 points, in section 3). As the framework by Dijk et al. (2016) provides information on how such innovations successfully penetrate the market, that frameworks was also attached to the first phase, the starting phase, which included both types of companies introducing an innovation.

As successful market penetration was regarded as the point where the 'early majority' started to adopt the innovation, this marked the second phase: the growing phase. As this is the phase in which the standard battle begins, the framework by Van de Kaa et al. (2011) was connected to the entire phase. Several of the steps are also based upon this framework. In the growing phase, the first step 'Innovation is successful' was added to signal successful market penetration, based upon the perspectives form the frameworks by Van de Kaa et al. (2011) and Hardman et al. (2013). Hardman et al. (2013) also describes the fact that a lock-in with the incumbent technology might prevent an innovation from rising. Based on this notion and the framework by Cowan and Hultén (1996) which provides ways into escaping this, the next step 'lock-in ends' was added. At this point, the standard battle begins to near its conclusion. As an innovation rises in popularity, while the incumbent technology's popularity starts to decline, it becomes clear what direction the market is heading in. At this point, firms may abandon their path dependency and start with the new innovation (or don't, and decline further, although this is not made explicit in the first iteration of the framework), signalling the start of the new regime. As such, based on the framework regarding the standard battle by Van de Kaa et al. (2011), the steps 'Firms abandon path dependency and start with the innovation' and 'New regime established/ Standard battle won by innovation' were added.

With the steps and phases of the process defined, the next step of designing the framework was incorporating the factors. In section 4, it was established that many of the selected frameworks have factors, that although they have different names, describe the same influences. As such, these factors were grouped into clusters, which refer to an overarching theme. These clusters are the new factors, and as such are the ones that were attached

to the framework. This was done as follows. Keep in mind that for the second iteration, several factors have received updated names, as to better describe what aspects they are referring to. These updated names are the ones that are used in section 4. As this section pertains to the first iteration, several of the previous names are used. This is avoided as much as possible, but where relevant, it is indicated. As described previously, the steps and phases were formulated using the frameworks. As such, these frameworks were connected to the design, in the place(s) they applied to, expressed as a label containing the context of framework and is author. This label was then changed to the factors that framework contained, but written in the terms of the new factors. For instance, the framework by Cowan and Hultén (1996) contained the factor 'existence of niche markets', which was grouped into 'Characteristics of the market'. As such, 'Characteristics of the market' instead of 'existence of niche markets' was inserted as one of the factors on the label that described the framework Cowan and Hultén (1996). This procedure resulted into labels containing lists of the new factors, attached to specific places in the new framework.

The next step was then, to remove factors that are already present in higher-level frameworks. For instance, the framework of Oldenburg and Glanz (2008) applies to the entire process. As such, the factors from that framework are excluded from the frameworks that lie on a lower-level. An example is the factor 'Adopters and marketing' (later renamed into Adopters/ Consumers), which is also present in several other frameworks. As the influence of that factor is already exerted by the overarching framework, it is not listed separately in the labels of the other frameworks. This leaves a cleaned up framework. The framework by Hardman et al. (2013) disappears from the framework, as the factors from that framework are all present in higher level frameworks. This does not mean that the framework is not relevant: as can be seen in Appendix A, the factors from that framework were important in the creation of the clusters. It is not gone in the framework, it is simply absorbed by higher level frameworks. The remaining factors in the labels, are split up into a separate labels per factor, in order to clearly show the various factors influencing the process.

Initially, the 3C-model was intended to be used differently in this framework, and to only use the RD/C metric as that expressed a focus on innovation. The idea was to attach the factor as a sub-factor to the factor 'Company Strategy and Finances', as it denoted an important aspect of strategy, as well as containing a financial aspect. The other factors did not have any measurements, but this one did, as could be seen in section 3. The idea was to indeed express the RD/C of a company, and to use this in conjunction with what experts said about that factor to reach a balanced conclusion to the influence of 'Company Strategy and Finances'. As this sub-factor could be numerically measured, it was included in the framework as a red label, rather than blue, the colour used for all other factors that did not have the ability to be measured. The idea to make a factor measurable was eventually incorporated in the second iteration, in which the RD/C metric was used to operationalise the entire factor. However, in the first iteration, it was still present as a sub-factor. The final first iteration of the framework can be seen in Figure 11.

In order to be verified, the framework was then presented to several experts, which - alongside their ideas regarding dieselgate's influence - were interviewed about their opinions of it. Ahead of the interview, they were sent a document containing the first iteration of the framework, alongside short explanations regarding each factor. This was done so they could study it in advance, and prepare their remarks. The explanation document and the interview questions can be found in Appendix B. This section goes on to discuss the results from the interviews regarding the framework. After that, the second iteration is discussed.

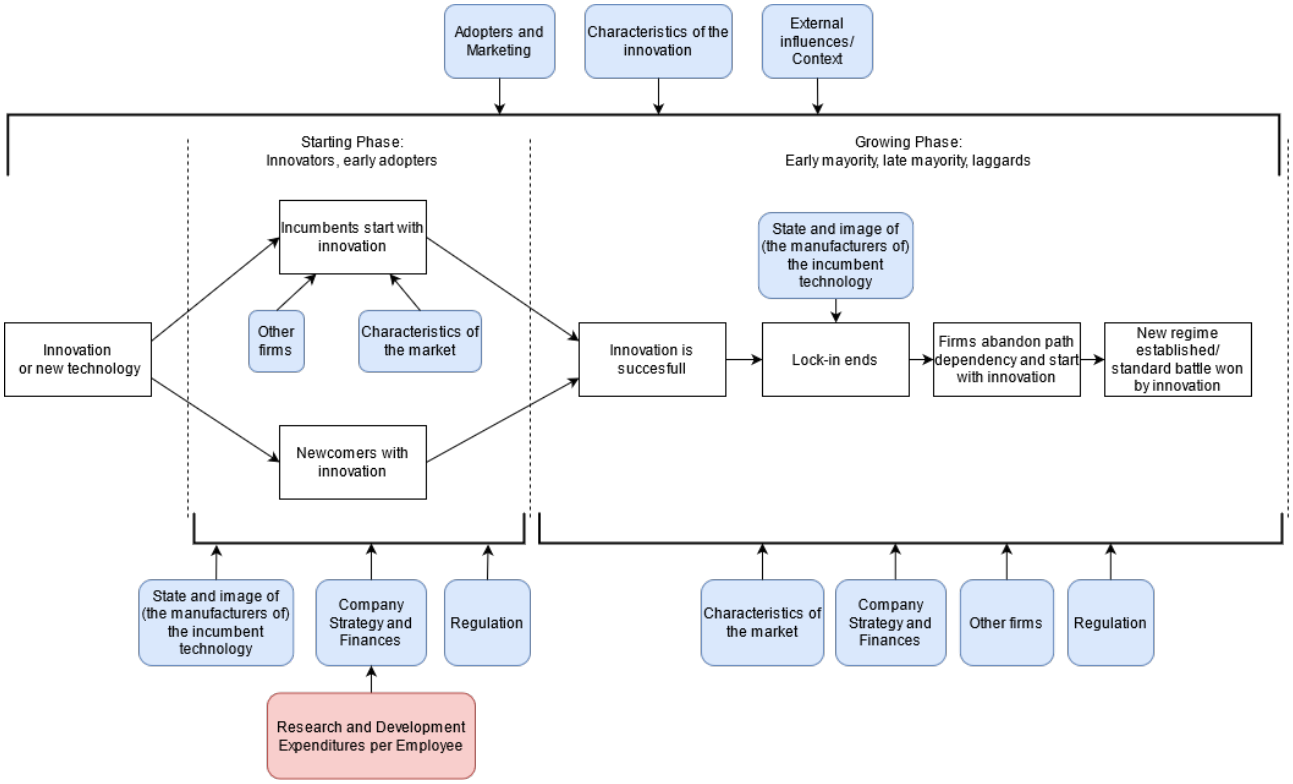


Figure 11: The first iteration of the framework.

### 5.2.1 Verification and feedback

Verification and improvement of the framework were done through expert interviews. In these interviews, the interviewees were shown the framework, and explained how these factors influenced the process (they also received this information beforehand, but logically some clarification was needed). Keep in mind that even though the framework was designed to be generic (as could be seen in the previous sections), at the time of the interviews, the focus was solely on using it to determine the influence of dieselgate, so the questions and answers tend to be more tailored towards that. The interviewees were asked if they felt that this framework accurately described the process of the automotive industry moving towards EV's, and if they felt that the factors accurately describe the drivers influencing that process. Through their responses, many insights were gained. The feedback on the framework and the factors are first discussed. Then, adjustments that have led to the formulation of the second iteration are discussed .

In general, all respondents indicated that they thought that the framework as presented in Figure 11 was right. They found that it correctly displayed the process of a innovation coming up, and taking over from an incumbent technology. They all also offered feedback or remarks in order to improve the framework. These remarks will now be grouped into several categories on the basis of their contents, after which it is discussed whether or not they will be incorporated into the framework.

**Phases and steps**

In 2 of the interviews, the phases that are used in the framework were discussed, while in the third one, mainly the steps were discussed. Interviewee A recommended looking into the work of Suarez (2004). The work by Suarez (2004) is discussed in more detail in section 3, but shortly put, the paper describes the phases of a dominance battle between two standards. Since this process is at the very core of the framework, these phases are a strong inclusion into the model. Furthermore, Suarez (2004) also describes several factors that are of influence on each of these phases. These phases were not new to this research however, as the work by Van de Kaa et al. (2011) was based upon them. The phases described by Suarez (2004) are: R&D build up, Technical feasibility, Creating the market, Decisive Battle, and Post-dominance. More information on each phase can be found in section 3.

Interviewee B spoke about the importance of a phase before what is known as the 'starting phase' in the framework. He said that it could framed as 'fertile soil'. This means that an innovation or new technology never comes out of nowhere ('It won't be there without an incumbent or new company'). There has to be a cause for

a company to start looking into new technologies, which is either a necessity or a chance. Necessities can be the result of regulations (for instance: in 10 years, a car can't emit more than some amount of emissions. That causes car manufacturers to innovate so they can comply). Chances might come from expectations amongst the players of an industry: where do we expect the market to go in 10 years? These expectations then cause a period in which (some) companies start up new R&D-activities. This is an important phase of the framework, because nothing has been sold yet, but a company still needs to decide whether it wants to start investing in this new technology, based on expectations as to where the market is heading. In regards to the current framework, this proposed R&D phase would then correspond purely to the innovators (those who actually invent the new technology).

Interviewee C had some feedback regarding one of the steps of the process, namely 'The innovation is successful'. He inquired about the way in which 'successful' is defined in this step, as it has multiple dimensions, not all of which are prerequisite for the 'Growing phase' to commence. In his opinion, an innovation is indeed successful if the market picks up on it. But he also remarked that until very recently, Tesla has been reporting large financial losses (and it is unclear whether EV's turn profits for other car manufacturers), so the question is when something is financially successful. He adds to that, that EV's at the moment are not as good for the environment as they ought to be (due to unclean sources for the required electricity, and the practices surrounding the resource-gathering). EV's might even be detrimental to the environment. This could, in turn lead to diminishing returns for FCEV, which he believes might be a better option for the problems at hand. So in that regard, he also states that EV's are not very successful (yet). The step 'The innovation is successful' was not meant to signal commercial or technological breakthroughs with regard to the innovation, but rather signify that the innovators and early adopters had shown that the innovation could be potentially successful (in the long term), causing the rest of the industry to join in, causing the user base to grow. It was therefore proposed to use 'the innovation was proven', but this was contested by Interviewee C, who stated that that specific step happens earlier (namely when a working prototype is developed). A second point of feedback, related to the definition of 'successful', was some ambiguity regarding the step 'Lock-in ends', as it wasn't clear that it concerned the lock-in of the old technology, rather than the new one. When this was cleared up, Interviewee C agreed that a commercially and technologically successful innovation could indeed end a lock-in (but keep in mind that an innovation can lead to another lock-in of its own). Here, technologically successful does not only refer to a proven concept, but also to the emergence of complementary technologies (like charging points for EV's). Lastly, Interviewee C found the usage of 'firms' in the step 'Firms abandon path dependency and start with innovation' a bit odd, as there were already firms that produced the innovation in the Starting Phase. From this, it becomes apparent that it is not clear what firms are referred to in this step. In short: these are not the firms that invent the technology or quickly realise its potential, but the firms that would rather wait and see how the technology and the market develop before they join in, or only join in because they no longer have a choice (because of regulations, for instance).

**Factors**

Feedback on the factors of the framework can be divided into two parts; what factors are in the framework and where, and feedback on what a factor represents (or how it is defined). Especially the latter part came up often in the interviews, which is not surprising as the interviewees were only presented with very short definitions, and were unaware of what factors were clustered underneath the terms they were presented with. In most cases however, they agreed on the definitions after some explanation. The cases in which they still felt something was not right or incomplete, are discussed in this section. In general, the interviewees felt that the factors indeed influenced the parts of the process that they were connected to. Some feedback was offered on how to improve this however. In line with his recommendation to incorporate the phases of Suarez (2004) into the framework, Interviewee A discussed the factor 'Reputation' as an example. This factor is not featured directly in the thesis-framework, instead being clustered into 'State and Image of a company'. Interviewee A agreed on the name and that reputation should be a part of it, but stated that if the phases of Suarez (2004) were to be used, the location of this factor (and several others) might change.

A second piece of feedback regarding the locations of the factors and their influence, came from Interviewee C, who remarked that next to 'Regulation', there is also the 'Regulator', which refers to governments (European, National and Regional). Regulators can also prescribe subsidies and fiscal benefits, both for citizens wanting to drive EV's, and companies producing them (for example, this also applies to other cases). These incentives can influence decisions by both these parties, and therefore are related to 'Adopters and Marketing, as well as 'Company Strategy and Finances'. Interviewee C agreed that several factors, like 'Regulation' or 'Company Strategy and Finances', were included several times, as their influence on the process might be different regarding the part of the process that is being analysed. He did remark however, that he felt that 'State and Image' did not only apply to 'Lock-in ends' but to the entire Growing phase. Simply put, the reason for this is that if the

image of incumbents decreased, it would allow a new technology and new manufacturers to grow. He illustrated this by stating that the recent profits by Tesla indicated that the process had now entered the 'Growing phase'.

As indicated, it was no surprise that some feedback was offered upon the definitions used in the factors of the framework. The interviewees all had had little time to study the document that was send ahead due to their busy schedules. As a result, each interview started with a short explanation and the framework was put on the screen, but this was hardly enough to understand each factor. Luckily, they all understood the factors to some degree, or asked about them if they didn't. This section contains remarks regrading factors of which the interviewees felt that the definition was not correct, required more elaboration or should be defined differently. At first, Interviewee A suggested to rename 'Company Strategy and Finances', to 'Characteristics of the Firm' (as it is called in his own work), because he was under the impression that it included 'reputation' but did not reflect it. It was explained however that 'Reputation' is included in 'State and Image'. Interviewee B also offered some feedback on this factor, stating that an interesting aspect is how one defines company strategy. This is not directly reflected in the definition, but is incorporated in the underlying explanation. Lastly, Interviewee C remarked that he was somewhat surprised by the way 'Research and Development per Employee' was incorporated in the framework, stating that he would expect the arrow to flow the other way, as he felt that strategy influences the amount of money that is spend on R&D.

## 5.3 The second iteration of the framework

As a result of the feedback gathered from the interviews, more research was done, many of which is already incorporated in section 3. The biggest change as a result of the interviews, was the inclusion of the phases of the framework by Suarez (2004). The 'starting phase' and the 'growing phase' were expended into the 5 phases form that paper: R&D build up, Technical feasibility, Creating the market, Decisive Battle, and Post-dominance. As was discussed in section 4, and indicated by Interviewee B, there also needed to be a phase that describes the reason to start looking into an innovation. This was included in the framework as phase 0: 'Opportunity'. Several of the steps were also redefined, in accordance with the interviews, the new phases, and further research. Additionally, as was discussed previously, the groups of adopters from the innovation diffusion theory were taken out of the framework, as they did not correspond well with the phases, thereby distorting the framework.

Several points of feedback also related to the factors, either the way they were defined, or the way they way they related to the framework. While incorporating the feedback, and looking into operationalising the factors, several names were redefined, as they no longer accurately reflected a factor, or weren't practical. 'State and image of the manufacturers of the incumbent technology' for instance, was renamed into 'State and image of the company'. This also applied to 'Characteristics of the innovation, which was renamed into 'Characteristics of the technology'. 'Adopters and marketing' was renamed into 'Adopters/ Consumers', 'Regulation' was renamed in 'Government' and 'External influences/ Context/ was renamed into 'Environmental influences' to better reflect the contents of the factor.

However, while updating the framework, exploring the ways to operationalise the factors, and exploring the way to conduct case studies, several shortcomings were discovered. The inclusion of the new phases led to a distorted relation to the factors, as several factors applied to specific steps, other to specific phases, and yet others to the entire period under analysis. This turned out to be very unpractical when applying it. To solve this, the factors were moved to the bottom of the framework. This 'phases-framework' is seen in Figure 12.

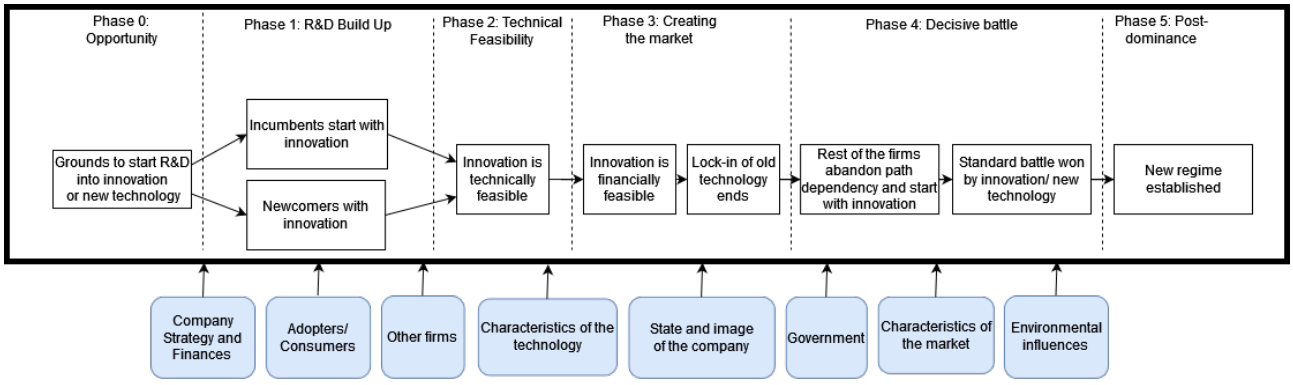


Figure 12: The 'phases-framework'

But while the feedback and the inclusion of more research made the framework reflect the steps of the process in a more accurate way, when exploring the ways to apply the framework on a case study, it became very clear that

the above framework was still not entirely practical. For one, the framework contained no way to express the state of the battle (or the diffusion of the innovation), in a comprehensive way, namely via an s-curve. Secondly, when analysing an innovation taking over from an incumbent technology, the incumbent technology needs to be considered as well. As was discussed in section 4, the original innovation diffusion theory only considers the s-curve of an innovation. But since this framework considers the battle with an incumbent technology, it makes sense to add a second one, for the incumbent technology, to more accurately express the state of the battle. As such, two s-curves were placed inside the framework, in the place of the phases and steps. In doing so, the framework still represents the right process, but now expressed in a much more logical and practical way.

With a more practical representation of the battle, the factors are now applied to the entire period under analysis and are scored as such. In order to better express the fact that all factors contribute to the entire process, the representation is changed: the market shares are now placed in the middle of the model, with the factors and their types of influences placed around the centre. The framework from Figure 12 still plays a role in applying the framework however. Where necessary, the new phases and steps are used to determine a balanced score for the relevant factors. But in order for the framework to be practically applicable, as will be seen in section 6, the factors no longer refer to specific steps or phases (as their influence on those provided very little information), but to the s-curves of both technologies (because through these, an actual rise or decline can be seen). This allows to framework to be used in case studies, as it now much more accurately reflect the relevant aspects of the process, namely a way to represent the incumbent technology rising in market share, and the incumbent technology declining in market share. Additionally, since the framework now no longer hinges on each of the phases, it can be used to analyse the process even for cases in which the battle is far from over, and even analyse specific periods within the period under analyses.

Most importantly, this framework fills the knowledge gap from section 3 much better, as it considers both the incumbent technology and the innovation, while at the same time providing a variety of distinct factors, whose influence can be measured, either qualitatively or quantitatively. This new, more practical framework, can be seen in Figure 13. Since this model more clearly expresses the influence of each factor on the success or failure of a technology, it is also renamed into the 'Successful innovation, Failing Incumbent Technology', or the SIFIT-model. The next step is to test whether this framework is indeed generic and works as intended, by testing it on an a case not related to the main question of this thesis (namely the smartphone industry). This is done in the next section.

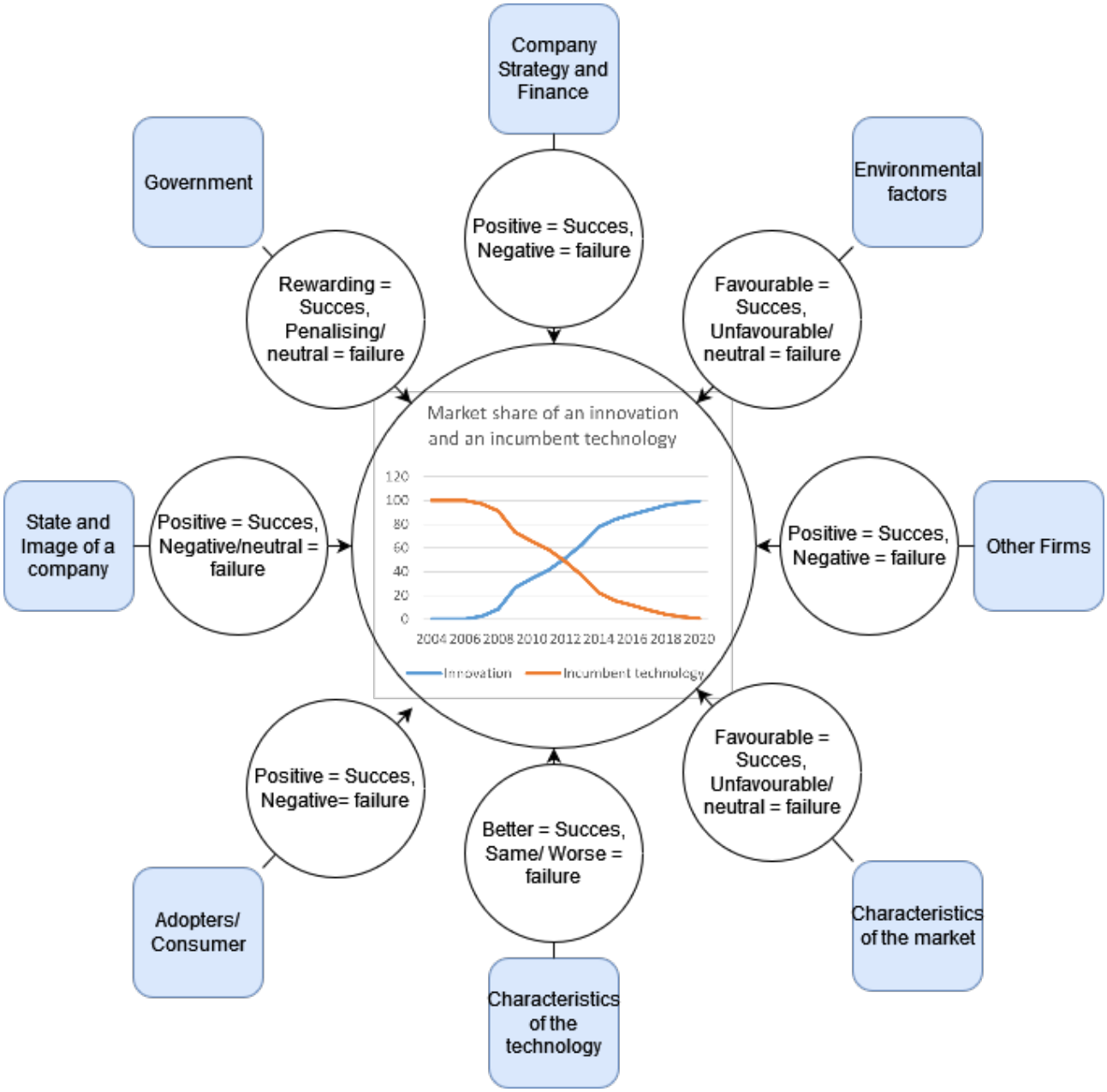


Figure 13: The second iteration of the framework, which fills the knowledge gap surrounding frameworks and can be used in a practical manner to analyse the process. This model is known as the 'Successful innovation, Failing Incumbent Technology', or the SIFIT-model

# 6 Case study 1: Testing the framework

The framework designed in the previous section describes the process of an innovation rising in usage (or adoption), at the expense of an incumbent technology. The innovation is likely to take over the incumbent technology at some point (winning the standard battle). The framework is built to look at an organisational level and therefore allows one to see what factors have driven this innovation to take over, by looking at aspects of companies that represent either technology. As such, the framework could be of practical use to companies as well, either through providing insights into the relevant factors for their own innovation to take over the industry, or through providing insights into when an innovation is promising and they should start with it as well. First however, the framework needs to be validated, i.e.: tested if it works like it should. This is done through a theory-testing case study, the procedure of which is described in section 2. Short recap: the case study revolves around 8 independent concepts (the factors) and their influence on the dependent concept (success or failure of a technology). Each one is tested independently on an a case unrelated to the main question, to prevent bias and, to validate whether the propositions (relations between concepts) are indeed correct. For each factor, it is defined in section 4 what kind of influence it has, but these are repeated per factor in this section as well for clarity. In the SIFIT-model (Figure 13) the types of influences which are now tested through the propositions, are expressed on each of the inward lines connecting the factors to the centre. If each factor indeed influences the success/failure in the correct way, the framework is validated and ready to be used in the second case study. Bear in mind that it is not possible to, on the basis of one case study, state with absolute certainty that the framework will work correctly for every case. It is here however assumed, for the sake of the thesis, that if the framework proves to work for the test case, it can be used for the main case as well. As can be surmised from the procedure above, this case study mainly uses the market share variant of the framework (the SIFIT-model) to deduce the influences of the factors on the market shares of both technologies. The phases-framework (Figure 12) also plays a role however. First off, as mentioned, the innovation is fully diffused, meaning that the final phase of the process is reached. Data is available for the entire process, meaning that this case study considers all phases of the process, which is also what makes it a very suitable test case. Secondly, wherever relevant, the phases of the framework are also mentioned when scoring various factors, in order to achieve a more informed score. This also makes the case indicative of how the phases-framework can be applied. Next to that, it lays the groundwork for the scope of case study 2 in which, as will be discussed further in section 7 and section 8, only phase 3 is considered. Demonstrating how the framework works when all phases are considered, leads to more understanding of why certain aspects of the second case are different.

## 6.1 The case of the smartphone

The case to be analysed using the framework is that of the rise of the smartphone industry, which will be analysed using the companies Apple and Nokia. Nokia had been the dominant company in mobile phones for most of the late 80's and the 90's, yet its sales started to wane in the early 2000's. After the iPhone was launched in 2007, and Google's Android platform became available in 2008 for other devices, Nokia more or less collapsed. Its mobile division was bought by Microsoft for a fraction of what it once was worth. The case study will focus on where Nokia went wrong, and where Apple went right. As it turns out, Nokia did not recognise the threat of the new innovation (the modern smartphone) in time, instead clinging to implementing their own inferior platform on their products.

This case is illustrative for a practical application of the framework: it shows to complete process of an innovation taking over from an incumbent technology, by looking at how each factor influenced that process. The characteristics of this case are very beneficial for testing, as the innovation is fully diffused (99.3% of all smartphones in 2020 were what is here defined as a 'modern smartphone'), and thus the standard battle is clearly won (the 'old smartphone' is hardly used anymore, and its largest producer sold of its mobile phone division). Aside from that, it involves a high tech industry (the framework was made for technology, signified by the large focus on R&D), a radical innovation (the 'modern smartphone' was a new concept, and completely changed the industry and the market). Aside from that, the modern smartphone is a disruptive innovation, as it was disruptive to market leaders because it was introduced by a new company on the smartphone market, disruptive to end-users, because it completely changed the role the mobile phone played in people's life, and disruptive to infrastructure as it introduced the concepts of apps and having access to the internet all the time (i.e.: 3 out of 3 points form Hardman et al. (2013)).

The case also bears similarities to the case of the automotive industry (case study 2), as that industry is can be regarded as high-tech as well (Wittmann, 2017; Beelaerts van Blokland et al., 2019). Aside from that, similarities between the cases can be seen: a company (Volkswagen/Nokia) clung to a technology which was no longer sustainable, and as a result, failed (although, as opposed to Nokia, Volkswagen managed to survive that failure), while a newcomer in the market (Tesla/Apple) focused on an innovation (internet-capable

smartphones/EV's), and as a result grew to become the dominant force. An important difference however, is the lack of a large scandal. However, for the purposes of demonstrating the applicability of the framework, that is no problem. This is because the framework has been designed as a generic framework for the analysis of an innovation taking over from an incumbent technology. As a result of this generic design (which fills a knowledge gap, and allows testing without bias), dieselgate (or any disruptive event, for that matter) is not a separate factor, and is hypothesised to be an accelerating influence on the other factors. As such, the framework describes a very general process, which can (as will be proven through this case study) be applied to a wide variety of cases. The influence of a disruptive event can be incorporated as an accelerating effect on other factors, or left out alltogether , as it has no direct influence. First, a short profile of both companies will be given, after which, using the framework, the process of the innovation taking over from the incumbent technology will be discussed.

Nokia was founded in 1865 as a wood pulp mill in Finland. Over the years, through many joint ventures and take-overs, it became a very diverse company, producing paper products, chemicals, aluminium and various electronic products. In the 60's it branched out into telecommunications, producing radio-equipment. In the 70's it began to produce components for telephone switchboards. In the early 80's it started producing telephones, and Nokia was largely responsible for the development of the Global System for Mobile Communication, or GSM. Throughout the 80's and 90's, Nokia put a stop to its diverse portfolio, and started to focus mainly on mobile phones. It produced many mobile telephones in that time, and in 2002, launched the first telephone with a built-in camera. This phone, the Nokia 7650, also ran Nokia's operating system Symbian, and is regarded as the world's first smartphone. Throughout the 2000's, Nokia continued on developing smartphones running Symbian, but the phones became less popular, both due to designs as well as the lacking capabilities of Symbian. In the 2010's Nokia started developing touchscreen phones, and switched to another operating system called MeeGo. MeeGo came to late and was still not as good as iOS and Android, leading to dire financial straits at Nokia. The mobile division of Nokia was eventually sold to Microsoft in 2013, and the company (which now specialises in satellites and wireless technology) never became a dominant force on the smartphone-market again after that (Borhanuddin and Iqbal, 2016; Sulphey, 2019). Nokia-brand phones still exist, but are now produced by Microsoft and run on Android.

Apple was founded in 1976 as Apple Computers Inc. by Steve Jobs, Steve Wozniak and Ronald Payne. It started with selling the Apple I, a motherboard designed for computer hobbyists. The Apple II followed in 1977, and by 1980's, Apple had a staff developing computers. It launched the Apple III to compete with industry giants Microsoft and IBM. The Apple Lisa was the first computer with a Guided User Interface (GUI) for the public in 1983. The Macintosh, the first computer that didn't require programming by the user, was first sold to the public in 1984. Throughout the 80's and 90's Apple sold several personal computers, to varying success, with the successful iMac personal computer in 1998. From 1993 to 1997, Apple also sold the Newton, a Personal Digital Assistant (or PDA), a device reminiscent of modern day smartphones. They stopped selling it, after the return of Steve Jobs, who had been fired a few years earlier. In 2001, Apple launched the iPod, a highly successful MP3-player. In 2003, this was followed up with the iTunes tore, a platform selling music for the iPod. The first iPhone, which used iOS was launched, in 2007. It was a revolutionary device, and is the first model in what has been called 'the second coming of the smartphone'. The iPhone was the first phone to combine mobile devices and the internet, which would prove to be an innovation that would revolutionise the mobile phone industry. Applications for the iPhone and later generations for the iPod were sold via the App store, which was launched in 2008. The ability to install third-party software on the devices, would prove to be an important feature that determined the success of this second coming. Over the following years, Apple would continue to sell highly successful mobile devices such as follow-ups to the iPhone, the iPad and smartwatches. In the meantime they also continued to sell highly successful personal computers and laptops. Today, Apple is the highest valued electronics company in the world. The iPhone is one of the bestselling mobile phones, and iOS is one of the dominant forces in mobile device operating systems. iOS's main (and only real) competitor is Google's Android Operating System, but Google licences this to other smartphone manufactures, while producing very little phones themselves. For this reason, Android will be mentioned a few times in this case study (as are used to expresses the MS of the innovation), but since the case is mainly about smartphone manufacturers, Google is not an integral part of the study (Stanko, 2015; Morrissey, 2010; Sulphey, 2019).

## 6.2 Determining the independent concept

As stated, each of the factors are what is referred to as 'concepts' in Dul and Hak (2007). The proposition then becomes, that each of these concepts individually contribute to whether a technology has success or not: If there is concept A (a certain factor), there will be Concept B (success or failure of a technology). In this case, the innovation is the 'modern smartphone', which mainly refers to smartphones with internet-capabilities and access to every app on the market. More practically expressed, since apps are only made for the App

store (iOS), and the Play Store (Android), this means any model running iOS or Android (these 2 together made up 99.3% of all smartphones in 2020, indicating (nearly) full diffusion). The incumbent technology is the 'old smartphone', which did not have those features, (or more practically, any model that does not run iOS or Android). The independent concept, or concept B, in this case, is success for the innovation (and conversely, failure for the incumbent), which is determined as follows.

The procedure for determining success is based on the coefficients the value time curve (VTC), see section 4. There is a directional coefficient to determine the direction the value of a specific product is heading in, and a growth coefficient which determines at what rate. In this case, no specific product is analysed through these coefficients, but an entire technology, by looking at market share.

This is done as follows. The market shares for both technologies are plotted and a trendline (the directional coefficient) is added, which is either positive of negative, and has a slope (the growth coefficient). When the directional coefficient is positive, the value is heading in a positive direction, indicating success. A negative slope indicates failure. The market shares over time, alongside their trendlines, can be seen in Figure 14. Note that while this graph goes up to 2020, the actual case study looks at the period 2004-2013. This graph goes to 2020 to demonstrate that the modern smartphone eventually becomes (nearly) fully diffused.

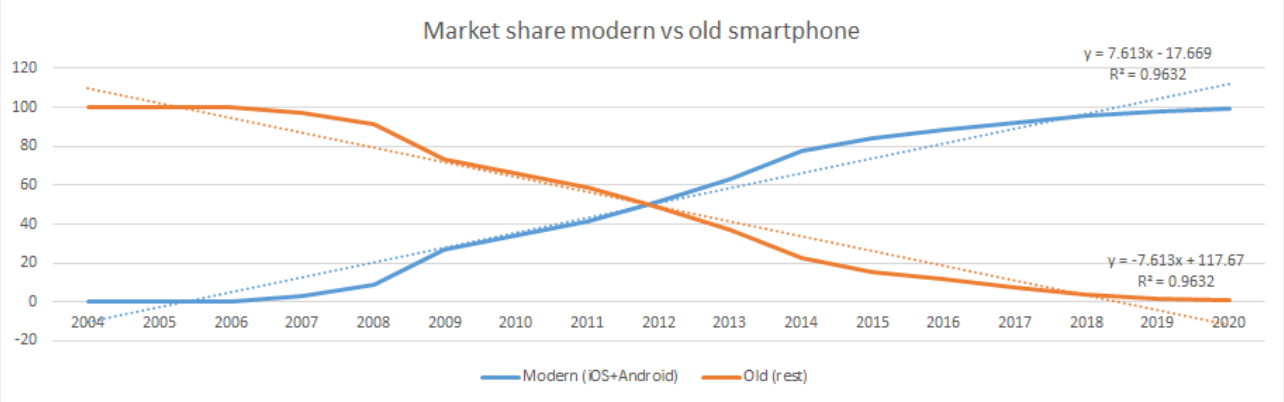


Figure 14: Development of the market shares of the modern smartphone (the innovation), and the old smartphone (the incumbent technology), 2004-2020

The results regarding the coefficients can be seen in Table 5. As can be seen, the modern smartphone has a positive directional coefficient, indicating success. The directional coefficient for the old smartphone is negative, indicating that the old technology is failing in the smartphone market. This is also very clear when looking at the values, as in 2020 the modern smartphone had a market share of 99.3% indicating nearly full diffusion.

Table 5: The coefficients of both technologies' market shares

| **Case** | **Directional coefficient** | **Growth coefficient** | **$R^2$** | **Success?** |
|---|---|---|---|---|
| Modern Smartphone (innovation) | 7.613x - 17.669 | 7.613 | 0.9632 | Yes |
| Old smartphone (incumbent technology) | -7.613x + 117.67 | -7.613 | 0.9632 | No |

## 6.3 Applying the framework

As the framework is designed on an organisational level, the success or failure of each technology is investigated through companies representing either technology, as they are the ones responsible for the market share. These companies are ideally the market leaders for either technology (as they contribute the most), or companies that have a specific reason to be included in the case. For each company, the factors of the framework are then analysed, in order to see how they contribute - through the company - to the success of an innovation.

The companies that are investigated are Nokia, since that company was the market leader for the 'old smartphone', and Apple, due to the fact that they introduced the modern smartphone and them being market leader for a few years after introducing it. The period under investigation starts in 2004, when the development of the first model of the innovation (the iPhone, the first model to run iOS) began, and ends in 2013, when Nokia's mobile division was sold to Microsoft. In this case, when referring to the technology of Nokia, all of

its phones running SymbianOS (their first smartphone OS) are meant, and not specific models. It also means Nokia's phones running Meego, Nokia's second smartphone OS, but to a much lesser degree as it was introduced in 2010, still had inferior capabilities, and never achieved more than a 0.04% market share. When referring to the technology of Apple, all of its phones running various versions of iOS are meant, and not specific iPhone models (save for the very first one, but that one will be analysed as the first of the new technology, rather than as a specific product).

### 6.3.1 Company Strategy and Finances

This factor is operationalised by RD/C, per the 3C-model. To determine whether it has contributed, the directional coefficient of the RD/C is researched. The propositions here are:

*1A. A RD/C with a positive directional coefficient leads to success.*
*1B. A RD/C with a negative directional coefficient leads to failure.*

The results can be seen in Table 6. As can be seen, the factor is indeed of influence. The positive directional coefficient (Apple) is linked to success of a technology, while the negative directional coefficient (Nokia) is linked to failure technology. As such, the propositions, are correct, and this factor works as intended.

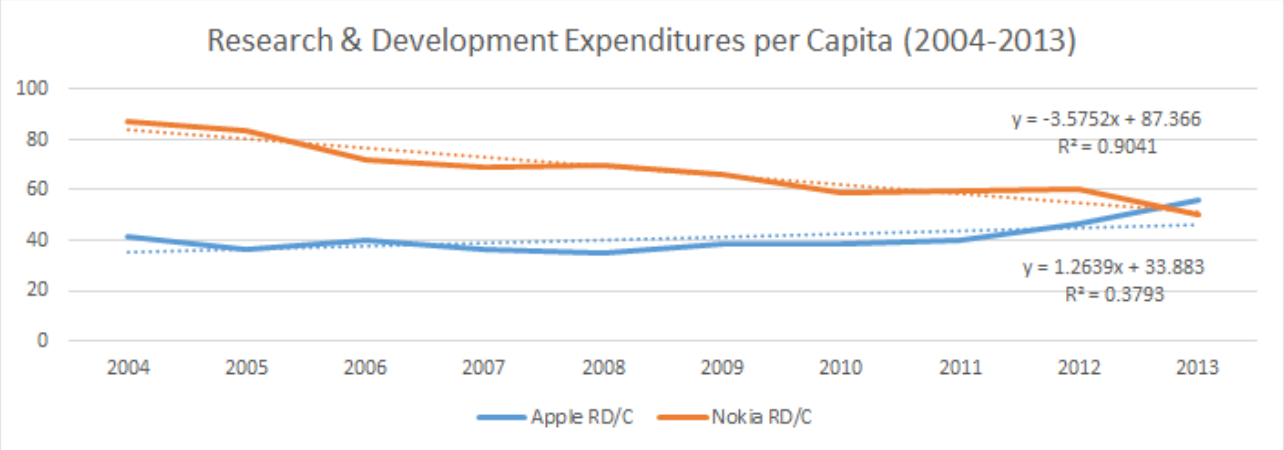


Figure 15: RD/C for both cases, alongside their trendline

Table 6: The coefficients of each company's RD/C

| Case | Directional coefficient | Growth coefficient | $R^2$ | Success? | Factor works as intended? |
|---|---|---|---|---|---|
| Apple | 1.2639x + 33.883 | 1.2639 | 0.3793 | Yes | Yes |
| Nokia | -3.5752x + 87.366 | -3.5752 | 0.9041 | No | Yes |

### 6.3.2 Adopters/ Consumers

This factor is operationalised by P/C, per the 3C-model. To determine whether it has contributed, the directional coefficient of the P/C is researched. The propositions here are:

*2A. A P/C with a positive directional coefficient leads to success.*
*2B. A P/C with a negative directional coefficient leads to failure.*

The results can be seen in Table 7. As can be seen, the factor is indeed of influence. The positive directional coefficient (Apple) is linked to success of a technology, while the negative directional coefficient (Nokia) is linked to failure technology. As such, the propositions, are correct, and this factor works as intended.

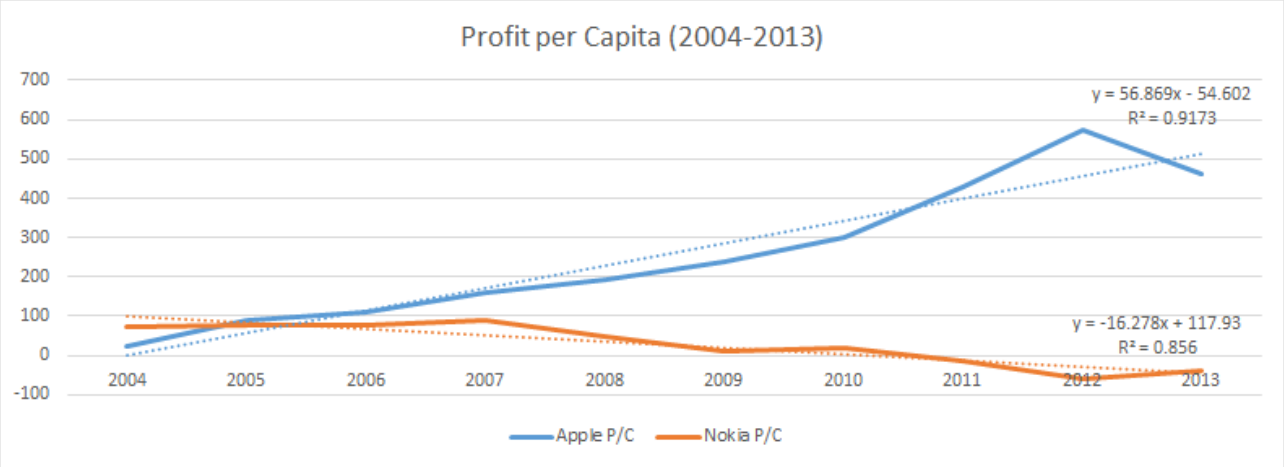


Figure 16: P/C for both cases, alongside their trendline

Table 7: The coefficients of each company's P/C

| Case | Directional coefficient | Growth coefficient | $R^2$ | Success? | Factor works as intended? |
|---|---|---|---|---|---|
| Apple | 56.869x + 54.602 | 56.869 | 0.9173 | Yes | Yes |
| Nokia | -16.278x + 117.93 | -16.278 | 0.856 | No | Yes |

### 6.3.3 Other firms

This factor is operationalised by T/C, per the 3C-model. To determine whether it has contributed, the directional coefficient of the T/C is researched. The propositions here are:

*3A. A T/C with a positive directional coefficient leads to success.*
*3B. A T/C with a negative directional coefficient leads to failure.*

The results can be seen in Table 8. The positive directional coefficient (Apple) is linked to success of a technology, while the negative directional coefficient (Nokia) is linked to failure technology. As such, the propositions, are correct, and this factor works as intended.

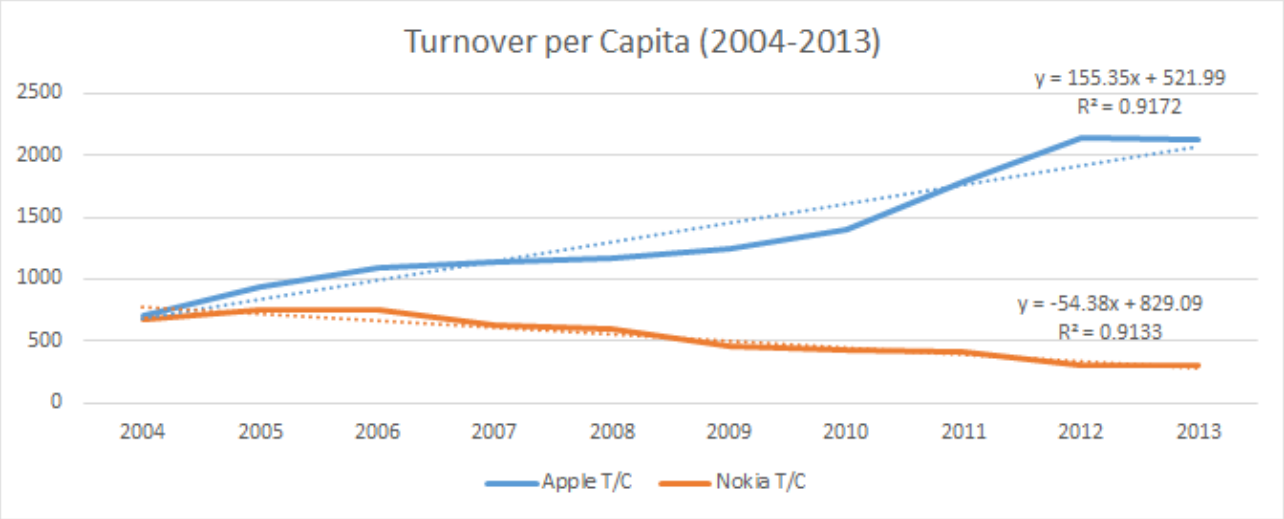


Figure 17: T/C for both cases, alongside their trendline

Table 8: The coefficients of each company's T/C

| Case | Directional coefficient | Growth coefficient | $R^2$ | Success? | Factor works as intended? |
|---|---|---|---|---|---|
| Apple | 155.35x + 521.99 | 155.35 | 0.9172 | Yes | Yes |
| Nokia | -54.38x + 829.09 | -54.38 | 0.9133 | No | Yes |

### 6.3.4 Characteristics of the technology

The factor 'Characteristics of the technology', is operationalised through the question of whether a company's technology is better, the same or worse than standard in the market (see section 4). The propositions here are:

*4A. Better characteristics lead to success.*
*4B. Worse or the same characteristics lead to failure.*

While Nokia was, at the time the of the iPhone launch, the market leader in the incumbent segment (the 'old smartphone'), their technology was not per se the best in the market. Many other, smaller companies were introducing new types of phones, like so-called clam-shells, and smartphones with touchscreens (a technology Nokia shelved). They were however, also not per se worse than the standard in the market (good camera's, high market share). As such, Nokia's technology is regarded as being the same as the market standard. Apple's technology was a lot better than the standard (access to apps and the internet, new capabilities and usage of recent or new technology). These results are summarised in Table 9. The influence of this factor is defined through the fact that having a better technology leads to success, while having a technology that is non-discernible form the market standard leads to failure (as one must strive for continuous improvement), see section 4. As this is indeed the case, the propositions are found to be true, and as such, the factor works as intended.

Table 9: The characteristics of each company's technology, compared to the standard in the market

| Case | Characteristics | Success? | Factor works as intended? |
|---|---|---|---|
| Apple | Better | Yes | Yes |
| Nokia | Same | No | Yes |

### 6.3.5 State and image of the company

The factor 'State and image of the company', is operationalised through the question of whether a company's reputation and its strength can be regarded as positive, neutral or negative, when compared to the rest of the industry or market (see section 4). The propositions here are:

*5A. A positive state and image lead to success.*
*5B. A negative or neutral state and image lead to failure.*

Since Apple was at the time the of the iPhone launch, already a very innovative and well-known company (showcased through successes the iPod and the iTunes store), they receive a 'positive' score. In order to score Nokia, the framework with the phases also comes into play, as it is needed to reach a balanced score. Nokia was a market leader at first (early phases from the framework), but after the launch of the iPhone (mid-phases from the framework), sales dwindled and Nokia quickly became a lesser known company. Due to bad management, who did not recognise the importance of innovating, the company was not very inventive, putting out non-value generating items, focusing on the wrong aspects (like better cameras) and shelving innovative ideas that worked for competitors (such as touchscreens). In the late phases, the company became even less known. As such, looking at the progression over the various phases, Nokia receives a 'negative' score.

Table 10: The state and image of the company

| Case | State and Image | Success? | Factor works as intended? |
|---|---|---|---|
| Apple | Positive | Yes | Yes |
| Nokia | Negative | No | Yes |

### 6.3.6 Government

The factor 'Government' is operationalised through the question of whether regulation, and the general attitude of regulators are rewarding, neutral or penalising for each technology. The score 'rewarding' is given for example, if there are financial incentives (for both the company, and the adopters). 'Penalising' could refer to regulation that tries to reduce usage of an undesirable technology (for example, in the case of fossil fuels (in any sector): higher taxes for polluting fuels, or emission-free zones). See section 4 for further elaboration. The propositions here are:

*6A. Rewarding regulation leads to success.*
*6B. Negative or neutral regulation leads to failure.*

Since the smartphone isn't really a device any government discourages or encourages the usage of (in contrast to vehicle that pollute or contribute to climate change, for instance), there are not many incentives, tax breaks or penalties involved in this case. But what can be said, is that Apple developed the iPhone with US government funding, through research grants on, amongst others, touchscreen displays and its internet capabilities. Since in this manner, the government contributed to the development of an innovation, Apple scores 'rewarding' on this factor (Marx, 2017). By contrast, when Nokia was in financial need, the Finnish government did not help them out. Due to the fact that this is not really penalising, and the fact that this only started to occur in the later phases of the framework, Nokia for this receives a score of 'neutral' (Wohlson, 2012).

Table 11: Government

| Case | Government | Success? | Factor works as intended? |
|---|---|---|---|
| Apple | Rewarding | Yes | Yes |
| Nokia | Neutral | No | Yes |

### 6.3.7 Characteristics of the Market

The 'Characteristics of the market' are operationalised as favourable, neutral or unfavourable for either technology. This is elaborated upon further in section 4. The propositions here are:

*7A. Favourable market characteristics lead to success.*
*7B. Unfavourable or neutral market characteristics lead to failure.*

At the time of the release, Apple's iPhone had a lot of competitors. There were a lot of other smartphones on the market, amongst which Nokia was one. However, the iPhone looked very different. It had no buttons, and was not a so-called clam-shell, a popular model at that time. It was also widely hyped prior to its arrival amongst tech-geeks, fans of Apple and design-enthusiasts. As such, the iPhone, being an innovation, was able to operate in a niche-market, which is usually beneficial for an innovation. Since in this case, it was as it allowed Apple to open up a new type of market, which would become the main market in the years after the iPhone's release, Apple gets a 'positive' score (Mickalowski et al., 2008). Nokia on the other hand, had to play on that new market (of the modern smartphone) as well, while not offering a product that was wanted in that market. In addition, US carriers used a different network-system then EU carriers, which required Nokia to alter their designs in order to operate on that market. They hardly did that, giving themselves a disadvantage and effectively denying themselves entry to the US market (O'Brien, 2009). All the while, Apple designed their phones they could be used in Europe, allowing them to operate in an essential market for Nokia. For these reasons, Nokia gets a 'negative score'.

Table 12: The characteristics of the market for both technologies

| Case | Market | Success? | Factor works as intended? |
|---|---|---|---|
| Apple | Favourable | Yes | Yes |
| Nokia | Unfavourable | No | Yes |

### 6.3.8 Environmental influences

The factor 'Environmental influences' is operationalised as favourable, neutral or unfavourable. This is elaborated upon further in section 4. The propositions here are:

*8A. Favourable environmental factors lead to success.*
*8B. Unfavourable or neutral environmental factors lead to failure.*

For this factor, mainly the geographical position and the relation between technology and society play a role. Apple is positioned in California, and more specifically, in Silicon Valley. This gives them a very close proximity of an area where many innovations are created, which Apple can and does, profit of. In addition to that, it gives them access to top of the line personnel. Meanwhile, Nokia is headquartered in Finland, a small country.

In addition to that, the Finnish language is not widely spoken, creating a barrier, which means that it has less access to the world's leading engineers and developers. A second and important aspect looks at the socio-technological evolution, or the relation between society and technology. Following the launch of the modern smartphone, it rapidly grew in usage. This created a network effect: the more people start to use a technology, the more the network surrounding it grows. This means that people started using apps for all types of services, began using the internet (3G/4G) via their phone more, and this caused everyday tasks and social interactions to rely more on the capabilities of the smartphone. Since Apple's technology was at the centre of this socio-technological evolution, they greatly benefited from it. Nokia's technology on the other hand, did not have such capabilities (very little to no apps, inferior internet capabilities) and as such, suffered from this development. For these reasons, Apple receives a 'favourable' score, an Nokia a 'unfavourable' score.

Table 13: Environmental Influences

| **Case** | **Environment** | **Success?** | **Factor works as intended?** |
|---|---|---|---|
| Apple | Favourable | Yes | Yes |
| Nokia | Unfavourable | No | Yes |

## 6.4 Results

The findings from the various tested propositions described above, are summarised in Table 14. As it can be seen, for each of the factors, it has been proven that they indeed have contributed to the success (or conversely, failure) of either technology in the way they were intended to. Since the framework has been build up from a lot of frameworks from literature, the factors cover a wide variety of factors that each influence this process. In other words: it is unlikely that a mayor contributing factor has been missed, and that these factors are indeed the factors that describe the process. Given this, and the fact that these factors are now indeed proven to work in the intended manner, it can assumed that for the purposes of this thesis that the framework is validated and tested, and thus ready to be used for the second case study, in which it will be used to determine the influence of dieselgate through each of these factors.

Table 14: The 8 factors, and whether they have been proven in each case

| **Factor** | **Apple case** | **Nokia case** | **Propositions confirmed?** |
|---|---|---|---|
| Company Strategy and Finances | Positive leads to success | Negative leads to failure | Yes |
| Adopters/ Consumers | Positive leads to success | Negative leads to failure | Yes |
| Other firms | Positive leads to success | Negative leads to failure | Yes |
| Characteristics of the technology | Better leads to success | Same leads to failure | Yes |
| State and image of the company | Positive leads to success | Negative leads to failure | Yes |
| Government | Rewarding leads to success | Neutral leads to failure | Yes |
| Characteristics of the Market | Favourable leads to success | Unfavourable leads to failure | Yes |
| Environmental influences | Favourable leads to success | Unfavourable leads to failure | Yes |

With all propositions confirmed, the theory that the framework works as intended is confirmed. As stated, the framework looks at the market shares of the innovation and the incumbent technology, and determines the influences of each factor by looking at how they influence the process through companies that represent both technologies. As such, success for the innovator, becomes success for the innovation (and failure for the incumbent company becomes failure for the incumbent technology). This is displayed in Figure 18.

This is a filled-in version of the SIFIT-model (Figure 13). In the original model, the relations were placed on each the lines connecting the factor to the centre. These relations (propositions) are now all tested and proven in this case study and in order to show the results, the outcomes for each analysis of the case study are filled in in the places of the propositions, and the success of the innovation/failure of the incumbent technology are placed in the centre. This filled-in version of the SIFIT-model is the general outcome of the framework when used in a case study. Therefore, this model is also used in displaying the outcomes of the dieselgate case, with the addition of the influences of dieselgate. The model for the dieselgate case is displayed in section 8.

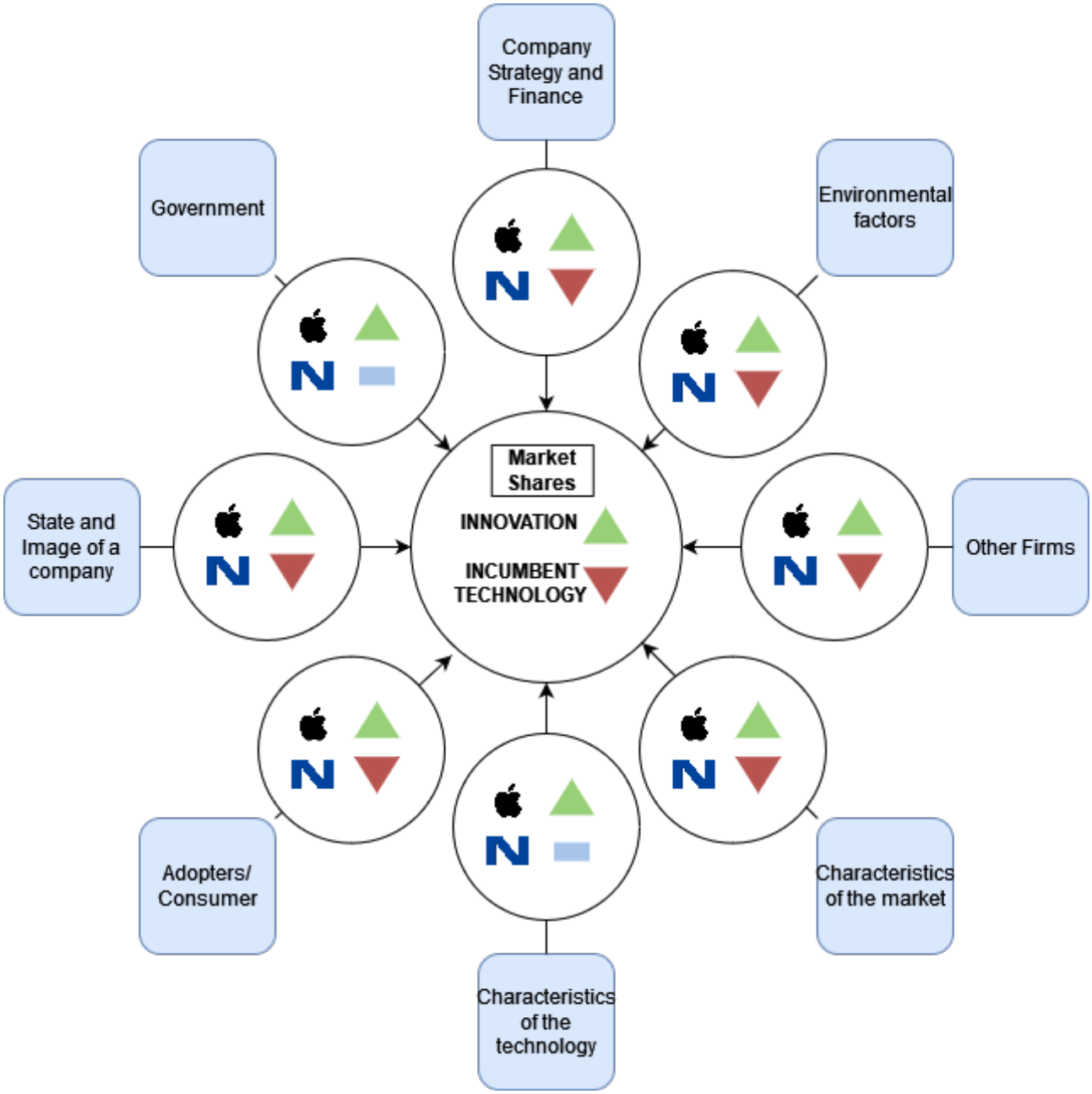


Figure 18: The filled-in SIFIT-model for the smartphone case, displaying how each factor, through the studied companies, influences the rise or decline of the market shares of each technology. Green arrows indicate positive influences and developments, red arrows indicate negative influences and developments, and blue stripes indicate neutral influences and developments.

# 7 Case study 2: Determining the influence of dieselgate

Now that the framework has been validated and tested, it can be used to analyse the influence of dieselgate on the rise of EV's. This is done through a theory-building case study. The procedure for this is slightly different, as are the cases. The main differences are as follows.

First off, the innovation is far from diffused, meaning that the process is not complete: the innovation has not taken over from the incumbent yet, but it is going that way, based on literature and trend analysis, discussed below. As such, in contrast to the previous case study, not the entire process is analysed, as only the first few phases as described in the 'phases-framework' (Figure 12) have passed or are in progress. This framework, based on the phases of Suarez (2004), but with an added phase 0, (which describes the opportunity to start with an innovation), is now used to express the scope of this case. When looking at the phases of that framework, the innovation of this case (the EV) is in phase 3 of the framework, called 'Creating the market'. This based on the fact that that phase is characterised with the first commercial products being launched, a user base is established and starts growing. The phase ends and transitions into phase 4 ('Decisive battle'), when the innovation becomes mainstream and the decisive battle is coming to a conclusion, that is, when the market shares start nearing each other. Given the fact that the innovation was only diffused for 4.2% in 2020, and the fact that the period is characterised with various companies bringing out their own EV's and user starting to pick up, the standard battle is clearly in phase 3. This phase started before the period under analysis, since Tesla proved the feasibility by introducing the Tesla Roadster, its first model, in 2008. By doing so, they proved the feasibility of EV's, as can be seen by statements from GM in 2009 Siemssen (2018), and therefore, the second phase ended around that time. As such, the entire period under analysis is phase 3. This has some implications for this case study. As the entire period under analysis is one single phase, and the focus is mainly on determining whether changes can be observed in the factors after dieselgate, the framework which uses the market shares to express the state of the battle (the SIFIT-model) is used as the main one in this case study. This analysis looks at the influence of dieselgate, which came to light in 2015, and as such the time-period for this case is divided into 2 periods, namely pre- and post-dieselgate. Since this is returns more information than using the phases-framework while only considering one phase, the phases-framework is mainly used for the above described scope. Insights regarding that phase, however, will be used in section 8 when interpreting certain outcomes.

Secondly, and contrary to the previous case study, there is no company that fully represents the incumbent technology. In this case, several automotive companies are studied and, as was discussed in section 3, all automotive companies are stepping away from the incumbent technology (ICE vehicles) and are switching over to the innovation (EV's). As such, any company that would be worth it to analyse (i.e.: market leaders in the incumbent segment) also represent the innovation to some degree. This makes analyses somewhat difficult, but given the low percentage that EV's make up of each company's total amount of passenger cars produced, 2 non-EV incumbent market leaders are assumed to only represent the incumbent technology. Where relevant, their EV-activities are discussed as a part of what is observed. These procedures are discussed below.

Lastly, this case study is a theory-building one, for which the main procedures are discussed in section 2. First of, it is important to note that due to the way the framework is build, and on the basis of the literature, dieselgate is hypothesised to not be a separate factor, but influences the process through the factors of the framework. As such, the influence of dieselgate is determined through the factors of the framework. Instead of testing whether a pre-defined relation between two concepts holds true (as was done in case study 1), here the relation (as indicated on each of the inward lines of the SIFIT-model) comes from the observations. This is done in various steps. First, for each factor, the outcomes pre- and post-dieselgate are investigated. Then, it is determined whether the outcomes have changed and if so, in what direction. Note that an outcome can stay the same between the eras, but still have gotten better or worse (for instance, something could have gotten more positive, or a growth coefficient may have changed for the better). The observed relations, and how they changed between the eras are then filled in the SIFIT-model. If change has indeed been determined for a factor (as it turns out, this is the case for all of them), conditions are analysed to determine whether this is indeed attributable to dieselgate. On the basis thereof, new propositions are formulated and insights are gained into what factors' influences have indeed been altered as a result of dieselgate. These influences are then displayed in relation to the filled-in SIFIT-model containing the observed relations. This following section focuses on using the framework to determine change, while the interpretation and subsequent results are discussed in section 8.

This case study looks at the automotive industry. The framework is designed for a high-tech industry, and this industry certainly behaves like one, meaning that the framework can be applied in that regard (Beelaerts van Blokland et al., 2019). Secondly, the framework can be applied, because the innovation here, the EV, is both disruptive (scoring 3 out of 3 points on the scale of Hardman et al. (2013)), and radical, as signalled by the fact that the entire market and industry are changing as a result of this new idea. The cases in this study, are

Volkswagen, BMW and Tesla. Tesla fully represents the innovation, as it has only ever produced the innovation, has been highly influential in introducing it, and has always been a market leader for the innovation.

The representatives for the incumbent technology are a bit more tricky in this case, as there are no (large) companies that only still produce the incumbent technology. Every large automotive company has been producing EV's for some time. However, while Volkswagen was indeed a market leader in the EV-segment in 2020, EV's only made up 4.5% of their total amount of produced passenger cars in that year. This was only 0.87% in 2019. The same goes for BMW, albeit a bit more: 8.2% in 2020, 4.8% in 2019. Due to these low percentages, and since both companies are market leaders in the non-EV market as well, they can still be regarded as proponents of the incumbent technology and as such are the representatives of the incumbent technology in this case study. Apart from that, Volkswagen was logically included because it caused dieselgate, and BMW was included because it is a comparable company, but did not resort to cheating to reach or remain at the top. Daimler (the company behind Mercedes-Benz) would also have been an option, and it might appear to be more akin to Volkswagen when looking at Table 2, but a lot of that revenue is made up by their trucks and busses division, which BMW does not have, making it a better company for comparison to Volkswagen.

Note that in the following sections, when referring to Volkswagen and BMW, the complete groups are meant, not just the specific brands. This is done in order to have complete and correct data on market shares, finances and employment. Also, in line with the rest of the thesis, by EV's only BEV's and PHEV's are meant, as FCEV's are such a small part of this market that they are assumed to be inconsequential, and are counted as 'non-EV's'.

## 7.1 Defining concept B (success for the innovation)

The framework defines the dependent concept, or concept B, as the success of an innovation (and since this is at the expense of an incumbent technology, the failure of an incumbent technology by extension). Whether the innovation has success, is determined through the directional coefficient of the market share. The market shares and the trendlines used to determine the directional coefficient can be seen in Figure 19. In this case, the innovation is far from fully diffused, but it can be observed that the innovation has positive directional coefficient for the period under analysis, indicating success. The findings are summarised in Table 15.

Aside from the coefficients that the framework uses, some other statements can be made to demonstrate the fact that EV's are likely to overtake non-EV's in the long term. Between 2010 and 2020, EV sales rose by 33000% (from roughly 10000 in 2010, to 3.24 million in 2020), while non-EV sales rose by only 7%. Secondly, as was demonstrated in Table 2, every large automotive company has issued statements regarding them phasing out non-EV's and focusing on EV's instead. So while the standard battle is far from over, and the innovation is far from fully diffused, it can be assumed that they will win and largely diffuse in the long term.

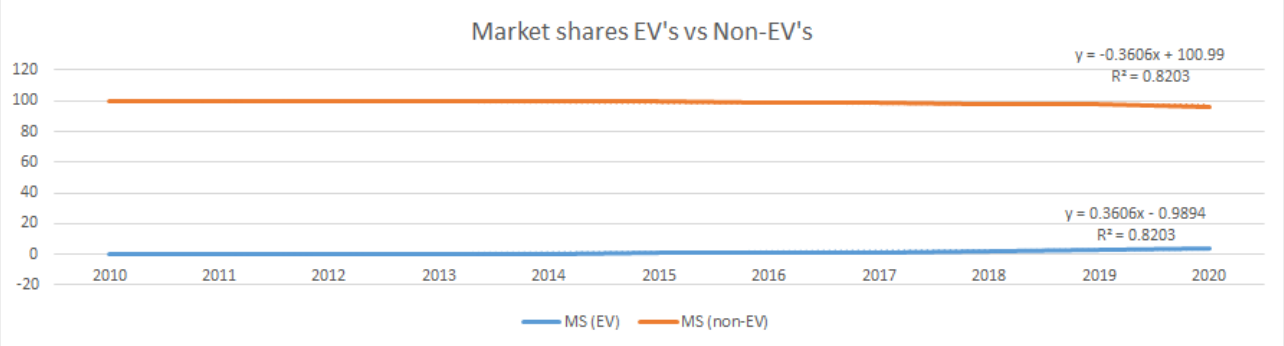


Figure 19: Development of the market shares of EV's (the innovation), and non-EV's (the incumbent technology), 2010-2020

Table 15: The coefficients of both technologies' market shares

| Case | Directional coefficient | Growth coefficient | $R^2$ | Success? |
|---|---|---|---|---|
| EV | 0.3606x - 0.9894 | 0.3606 | 0.8203 | Yes |
| Non-EV | -0.3606X + 100.99 | -0.3606 | 0.8203 | No |

In order to demonstrate that dieselgate might have influenced the fast rise of EV's, the directional and growth coefficients of market shares for EV's and non- EV's are also for the pre- and post-dieselgate era. This can bee seen in Figure 20 and Figure 21. The findings regarding the coefficients are summarised in Table 16.

As can be seen, the growth coefficient becomes quite a bit larger after dieselgate, indicating higher rate of success for the innovation. Due to the many factors that demonstrate the complexity of the process, it is unlikely that the entirety of this rise can be attributed to dieselgate. Neither is it likely that dieselgate was a direct factor like the ones in the framework, and it is therefore hypothesised that dieselgate has influenced the other factors, which will now be investigated through the framework.

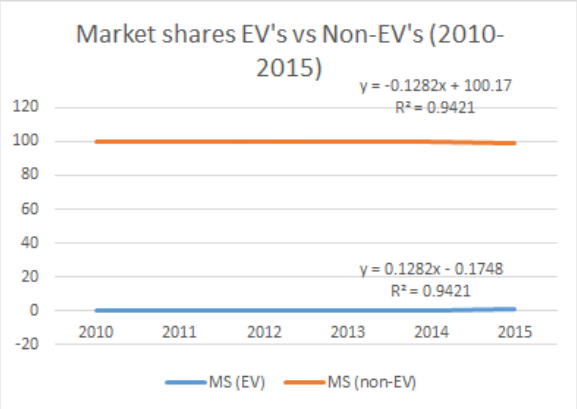


Figure 20: Market shares for both technologies, pre-dieselgate

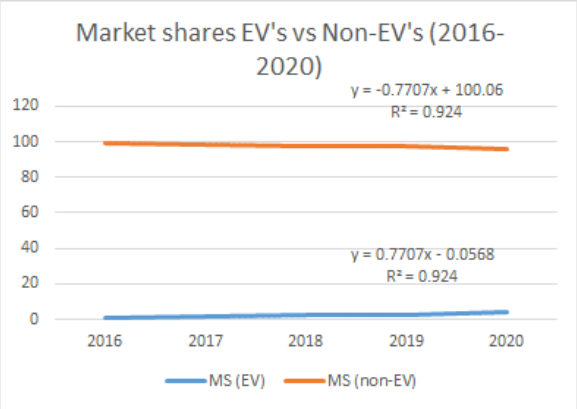


Figure 21: Market shares for both technologies, post-dieselgate

Table 16: The growth coefficient of both technologies' market shares

| **Case** | **Directional coefficient** | **Growth coefficient** | **$R^2$** | **Success?** |
|---|---|---|---|---|
| EV (pre-dieselgate) | 0.1282x - 0.1748 | 0.1282 | 0.9421 | Yes |
| EV (post-dieselgate) | 0.7707x - 0.0568 | 0.7707 | 0.924 | Yes |
| Non-EV (pre-dieselgate) | -0.1282x + 100.17 | -0.1282 | 0.9421 | No |
| Non-EV (post-dieselgate) | -0.7707x + 100.06 | -0.7707 | 0.924 | No |

## 7.2 Applying the framework

With the cases representing the types of technologies in this case study established, and the success of the innovation determined, the framework can be applied. The object is now, to determine on the basis of the observations, what relations exist between the concepts, and what proposition follows from that relation. The first 3 analyses (quantitatively measured factors) first consider the whole period under analyses, and then for the pre- and post-dieselgate era as well, in order to gain a complete understanding of any changes, by looking at any trend disruptions. The remaining 5 analyses (qualitatively measured factors) directly look at the pre- and post-dieselgate era, as an analysis regarding the entire period would take the same aspects into consideration and is therefore redundant. Also note that due to the way in which the companies are operationalised, the 3 quantitative measures also take into account the EV-activities of the companies that represent the incumbent technology In other words: it is not possible for these metrics to differentiate between EV or non-EV data, as these refer to the R&D-expenditures, profits, turnover and number of employees for the entire group, rather than the RD, P, T and C that apply specifically to the non-EV activities. This is accounted for in interpretations. For the qualitatively measured factors this is possible, so when scoring those, only the non-EV's of Volkswagen and BMW are considered.

The goal of this case study, is to determine whether a factors' influence has changed for either technology, between the pre- and the post-dieselgate era. If this is the case, that does not automatically mean that it is a direct result of dieselgate, which is why these changes will be interpreted. It is also possible that a factors' influence has not changed, but that dieselgate did have an influence. For instance, making a negative score even

more negative, or that a negative score pre-dieselgate was the result of other factors that a negative score in the post-dieselgate era. This too, is considered in the interpretations.

### 7.2.1 Company Strategy and Finance

This factor is operationalised by RD/C, per the 3C-model. In the framework, a positive directional coefficient indicates success for either technology, while a negative coefficient indicates failure. The RD/C for the 3 cases can be seen in Figure 22, and the findings are summarised in Table 17.

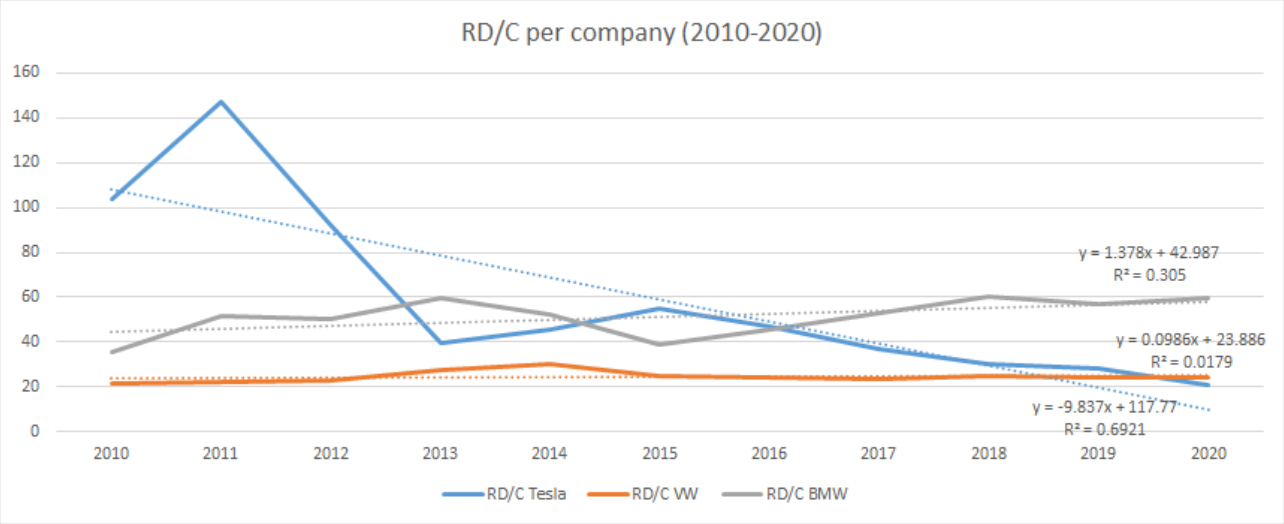


Figure 22: RD/C for each case, alongside their trendline (2010-2020)

Table 17: The coefficients of each company's RD/C

| Case | Directional coefficient | Growth coefficient | $R^2$ | Technology |
|---|---|---|---|---|
| Tesla | -9.837x + 117.77 | -9.837 | 0.6921 | Innovation |
| VW | 0.0986x + 23.886 | 0.0986 | 0.0179 | Incumbent |
| BMW | 1.378x + 42.987 | 1.378 | 0.305 | Incumbent |

Right of the bat, some interesting observations can be made here. First of all, Tesla, the company representing the innovation, shows a negatively developing RD/C, while VW and BMW, who represent the incumbent technology, show positive directional coefficients. It should be noted however, that growth coefficients of both are very low, and that due to the low R-squared, not a whole lot is explained by these coefficients. Possible explanations for these observations are given in section 8.

Looking directly at the values of the RD/C, something else that might be of interest can be observed. The RD/C shows peaks in the years before, and in the year a new EV (the innovation) is introduced: the Model S (Tesla) came out in 2012, the Model X (Tesla) came out in 2015, the i3 (BMW) came out in 2013, the e-UP! (VW) came out in 2013, and the e-Golf (VW) came out in 2014. While this is not of interest for determining the influence of dieselgate for this factor, this observation could be of use to distil other possible insights form the framework. More in this in section 8.

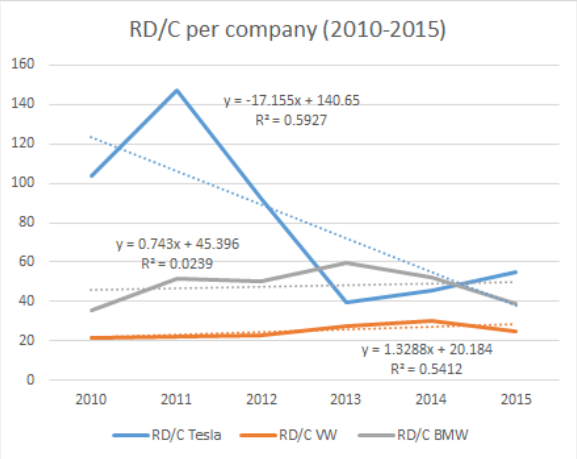


Figure 23: RD/C for each case, pre-dieselgate

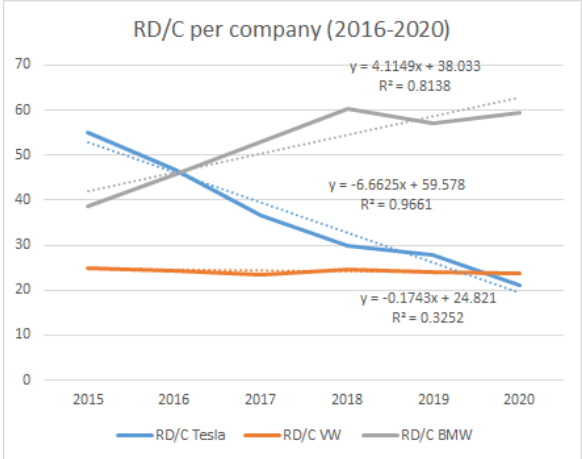


Figure 24: RD/C for each case, post-dieselgate

Table 18: The coefficients of the RD/C for each case, pre- and post dieselgate

| **Case** | **Directional coefficient** | **Growth coefficient** | **$R^2$** | **Technology** |
|---|---|---|---|---|
| Tesla (pre-dieselgate) | -17.155x + 140.65 | -17.155 | 0.5927 | Innovation |
| Tesla (post-dieselgate) | -6.6625x + 59.578 | -6.6625 | 0.9661 | Innovation |
| VW (pre-dieselgate) | 1.3288x + 20.184 | 1.3288 | 0.5412 | Incumbent |
| VW (post-dieselgate) | -0.1743x + 24.821 | -0.1743 | 0.3252 | Incumbent |
| BMW (pre-dieselgate) | 0.743x + 45.396 | 0.743 | 0.0239 | Incumbent |
| BMW (post-dieselgate) | 4.1149x + 38.033 | 4.1149 | 0.3252 | Incumbent |

Tesla shows a less strong negative growth coefficient post-dieselgate, still signalling a negatively developing RD/C, but at a slower rate. A negatively developing RD/C for VW can be seen in the post-dieselgate era, albeit at a very low growth rate. BMW has a positively developing RD/C both pre- and post-dieselgate, which even grows more strongly post-dieselgate although it must be noted that pre-dieselgate, the rate was very low, as was the R-squared. Therefore, care must be taken in interpreting these results.

### 7.2.2 Adopters/ Consumers

This factor is operationalised by P/C, per the 3C-model. In the framework, a positive directional coefficient indicates success for either technology, while a negative coefficient indicates failure. The P/C for the 3 cases can be seen in Figure 25, and the findings are summarised in Table 19.

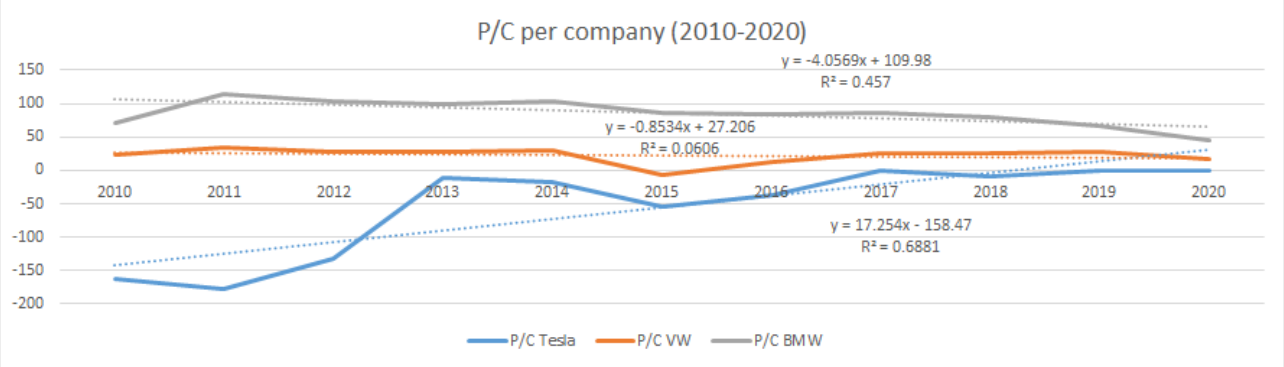


Figure 25: P/C for each case, alongside their trendline (2010-2020)

Table 19: The coefficients of each company's P/C

| Case | Directional coefficient | Growth coefficient | $R^2$ | Technology |
|---|---|---|---|---|
| Tesla | 17.254x - 158.47 | 17.254 | 0.6881 | Innovation |
| VW | -0.8534x + 27.206 | -0.8534 | 0.0606 | Incumbent |
| BMW | -4.0569x + 109.98 | -4.0569 | 0.457 | Incumbent |

It can be observed that the P/C develops in line with expectations. It develops positively for the innovation, while developing negatively for the incumbent technology. Care must be taken however, when interpreting these results for Volkswagen, as it shows a very low R-squared. Looking at the values themselves, a dip can be seen in the P/C for Volkswagen in 2015. This is interesting, but note that for the other brands, dips can be observed as well.

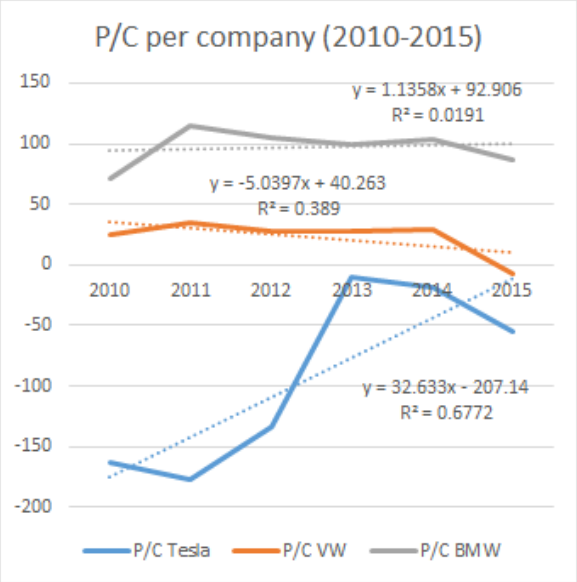


Figure 26: P/C for each case, pre-dieselgate

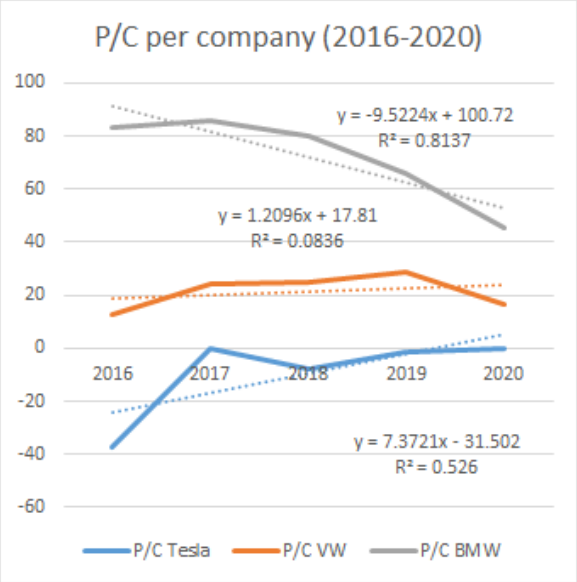


Figure 27: P/C for each case, post-dieselgate

Table 20: The coefficients of the P/C for each case, pre- and post dieselgate

| **Case** | **Directional coefficient** | **Growth coefficient** | **$R^2$** | **Technology** |
|---|---|---|---|---|
| Tesla (pre-dieselgate) | 32.633x - 207.14 | 32.633 | 0.6772 | Innovation |
| Tesla (post-dieselgate) | 7.3721x - 31.502 | 7.3721 | 0.526 | Innovation |
| VW (pre-dieselgate) | -5.0397x + 40.263 | -5.0397 | 0.5412 | Incumbent |
| VW (post-dieselgate) | 1.2096x + 17.81 | 1.2096 | 0.0836 | Incumbent |
| BMW (pre-dieselgate) | 1.1358x + 92.906 | 1.1358 | 0.0191 | Incumbent |
| BMW (post-dieselgate) | -9.5224x + 100.72 | -9.5224 | 0.8137 | Incumbent |

Tesla's P/C develops positively in the pre- and post-dieselgate era, but a lower growth coefficient can be observed. VW goes from a negative coefficient, to a positive coefficient, which is interesting. BMW's P/C steeply drops after dieselgate, which is also interesting. Note however, that pre-dieselgate BMW shows a very low R-squared, as does post-dieselgate VW. Therefore, some care must be taken when interpreting these outcomes.

### 7.2.3 Other firms

This factor is operationalised by T/C, per the 3C-model. In the framework, a positive directional coefficient indicates success for either technology, while a negative coefficient indicates failure. The T/C for the 3 cases can be seen in Figure 28, and the findings are summarised in Table 21.

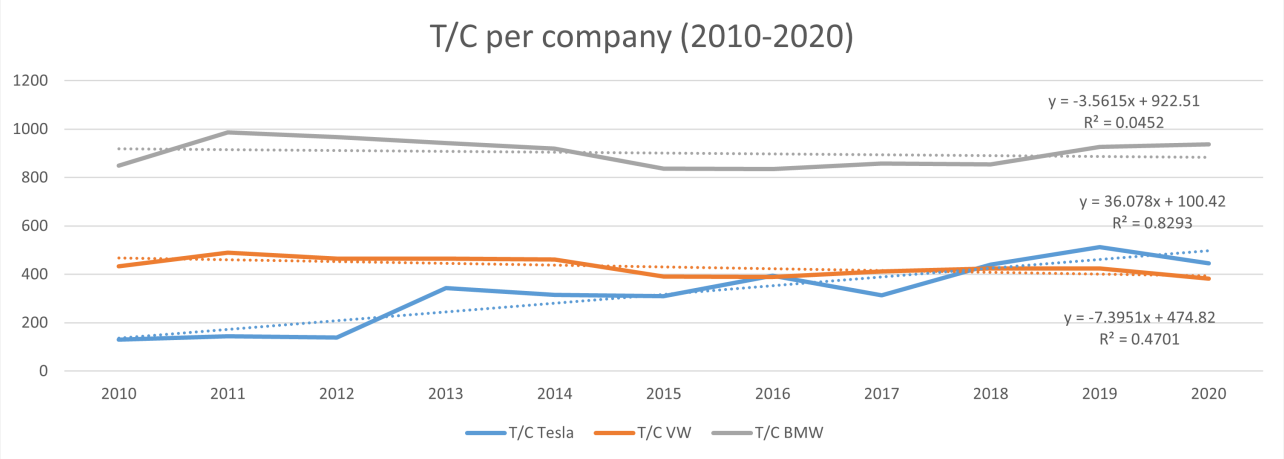


Figure 28: T/C for each case, alongside their trendline (2010-2020)

Table 21: The coefficients of each company's T/C

| Case | Directional coefficient | Growth coefficient | $R^2$ | Technology |
|---|---|---|---|---|
| Tesla | 36.078x + 100.42 | 36.078 | 0.8293 | Innovation |
| VW | -7.3951x + 474.82 | -7.3951 | 0.4701 | Incumbent |
| BMW | -3.5615x + 922.51 | -3.5615 | 0.0452 | Incumbent |

Tesla, the innovation, shows a positively developing T/C, which is to be expected. Conversely, the representatives of the incumbent technology both show negatively developing T/C, which is also to be expected. Note however, that the R-squared for BMW is very low, meaning that care must be taken when interpreting this outcome.

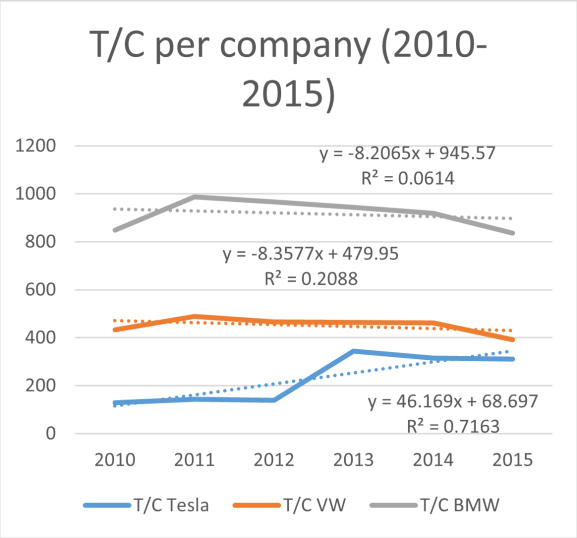


Figure 29: T/C for each case, pre-dieselgate

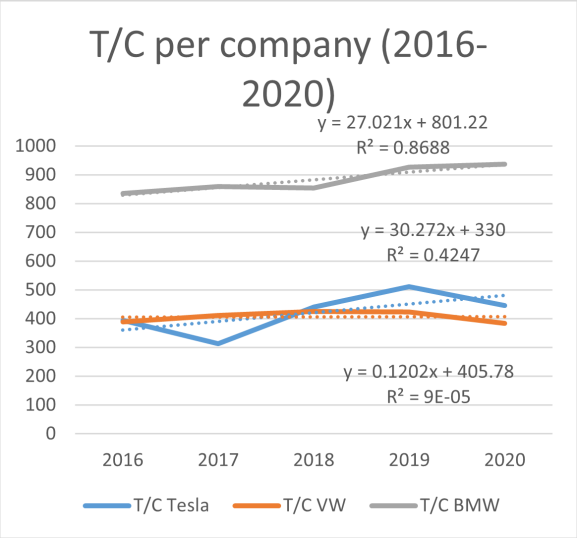


Figure 30: T/C for each case, post-dieselgate

Table 22: The coefficients of the T/C for each case, pre- and post dieselgate

| **Case** | **Directional coefficient** | **Growth coefficient** | **$R^2$** | **Technology** |
|---|---|---|---|---|
| Tesla (pre-dieselgate) | 46.169x + 68.697 | 46.169 | 0.7163 | Innovation |
| Tesla (post-dieselgate) | 30.272x + 330 | 30.272 | 0.4247 | Innovation |
| VW (pre-dieselgate) | -8.3577x + 479.95 | -8.53577 | 0.2088 | Incumbent |
| VW (post-dieselgate) | 0.1202x + 405.78 | 0.1202 | 0.0001 | Incumbent |
| BMW (pre-dieselgate) | -8.2065x + 945.57 | -8.2065 | 0.0614 | Incumbent |
| BMW (post-dieselgate) | 27.021x + 801.22 | 27.021 | 0.8688 | Incumbent |

In both eras, Tesla shows a positively developing T/C, although the growth coefficient reduces. VW shows, interestingly, a switch from a negatively developing T/C to a positively, developing T/C. The R-squared for the post-dieselgate era, is very low however, signalling that these outcomes might not represent a lot of information. BMW also goes from negative to positive, and shows a very strong growth coefficient in the post-dieselgate era, which is interesting. For BMW, the pre-dieselgate T/C might not give a lot of information, as the R-squared is very low there.

### 7.2.4 Characteristics of the technology

The factor 'Characteristics of the technology', is operationalised through the question of whether a company's technology is better, the same or worse than standard in the market. This includes, for instance, performance, quality, price, switching costs, complementary goods, flexibility, and compatibility with existing structures.

Pre-dieselgate, Tesla's technology was a lot cleaner than the rest of the market. However, the technology was new, so not a lot of charging infrastructure was available. The reliability of their technology also wasn't up to date, with problems mainly related to the life-expectancy of the battery packs (Noland, 2015). Since the problems existed with other EV's at the time, and did not exist within non-EV's, Tesla receives a 'neutral' score pre-dieselgate, balanced between the clean technology (better) and the problems of a new technology (worse). Post-dieselgate, Tesla's technology receives a 'better' score. The technology is still cleaner than the rest of the market, and the technology is more mature which leads to a lot of problems being solved. In addition to way more charging infrastructure in general, Tesla constructed its own infrastructure, making the innovation perform even better (Wittmann, 2017).

Volkswagen's technology obviously preformed bad pre-dieselgate, even though this was not known by the public at the time. It was however, known by the company since 2005, and they had been cheating ever since. Therefore, a 'worse' score is received. Post-dieselgate, while - at least apparently - complying with the rules set for emissions, the technology is still responsible for many forms of air pollution and greenhouse gasses, and has become more scrutinised. Additionally, with EV's on the rise, the standard in the market becomes cleaner. When regarding the non-EV's produced by VW, the technology is still worse (Bovens, 2016).

BMW was not involved in any mayor scandals, but still produces a polluting technology. However, the company seems to comply with the rules, and is known to produce very highly reliable and well performing cars. The only drawback is that the cars are somewhat expensive when compared to the rest of the market. Through the balance of polluting technology, but high performance and quality (at a cost), BMW receives a 'neutral' score pre-dieselgate. Post-dieselgate, many of these considerations remain the same, but since the technology has become more scrutinised, BMW receives a negative score (Amaldoss and Jain, 2015; Rayappa et al., 2015).

Table 23: The characteristics of each company's technology, pre- and post-dieselgate

| **Case** | **Characteristics** | **Technology** |
|---|---|---|
| Tesla (pre-dieselgate) | Neutral | Innovation |
| Tesla (post-dieselgate) | Better | Innovation |
| VW (pre-dieselgate) | Worse | Incumbent |
| VW (post-dieselgate) | Worse | Incumbent |
| BMW (pre-dieselgate) | Neutral | Incumbent |
| BMW (post-dieselgate) | Worse | Incumbent |

### 7.2.5 State and image of the company

The factor 'State and image of the company', is operationalised through the question of whether a company's reputation and strength can be regarded as positive, neutral or negative (see section 4). The state refers, for instance, to operational supremacy, or to the ability to deal with shocks and crises. Through the 'image', this factor also includes the manner in which a company is perceived by parties such as environmental organisations, politicians, investors and the public.

Tesla and its technology have generally always been regarded as innovative. As such, many loans and investments were granted to the company. This innovative reputation is also strongly displayed by the fact that Tesla is regarded as the company that showed the world that BEV's are feasible technology. A part of the company's image is also represented by its charismatic and pioneering founder and CEO, Elon Musk. More recently, the company is also closely related to the exploits of another company of Musk, SpaceX, who actually launched a Tesla into space. The technology is regarded as more reliable, and Tesla's cars even have become somewhat of a status symbol. Therefore, the brand's image was already regarded as positive in the pre-dieselgate era, but it certainly is regarded as positive in the post-dieselgate era. As for the state, signalled here by being able to deal with shocks and crises, Tesla also scores positive as it was virtually unaffected by dieselgate, and even if so, not in a negative way, as their technology was not the one under fire. Being shock-resistant, signalling a strong state, contributes even more to the positive influence of this factor (Siemssen, 2018; Lambert, 2015).

Pre-dieselgate, Volkswagen was seen as a reliable brand, with a lot of different options, and several iconic cars, such as the Beetle. The technology was known to be polluting, and concerns regarding that were rising. As such, Volkswagen receives a 'neutral' score pre-dieselgate. Post-dieselgate, Volkswagen receives a 'negative' score as they were the ones who caused dieselgate and even tried to cover it up. As a result, the company took a mayor hit on several aspects as a result of it, mainly with the public and with shareholders. While the company has been recovering, signalling a somewhat strong state, the damaged reputation here outweighs that, so a negative score is given (Bouzzine and Lueg, 2020; Cârstea, 2016; Dworaczek et al., 2020).

Pre-dieselgate, BMW was seen as a high quality brand, very reliable and top of the line in technological aspects and performance. Being a luxury brand, their cars are also somewhat regarded as a status symbol. The technology was known to be polluting, and concerns regarding that were rising. Due to these considerations, a neutral score is given. Post-dieselgate, BMW is one of the companies that is said in literature to suffer a lot from the inertial effect of dieselgate, through a form of 'guilty by association', making the company seen as less reputable and strong with the public and shareholders. As such, their image suffered, and declining financial figures signal a somewhat weaker state in the second half of the decade. These factors lead to a negative score (Bouzzine and Lueg, 2020; Dworaczek et al., 2020; Amaldoss and Jain, 2015; Rayappa et al., 2015).

Table 24: The state and image of each company, pre- and post-dieselgate

| **Case** | **State and image** | **Technology** |
|---|---|---|
| Tesla (pre-dieselgate) | Positive | Innovation |
| Tesla (post-dieselgate) | Positive | Innovation |
| VW (pre-dieselgate) | Neutral | Incumbent |
| VW (post-dieselgate) | Negative | Incumbent |
| BMW (pre-dieselgate) | Positive | Incumbent |
| BMW (post-dieselgate) | Negative | Incumbent |

### 7.2.6 Government

The factor 'Government', is operationalised through the question of whether regulation, and the general attitude of regulators are rewarding, neutral or penalising for each technology. This factor refers to any regulation, or the general attitude of regulators that might make either technology more or less attractive. This could refer to both regulation or regulators' attitude pertaining to the manufacturer (laws pertaining to a certain technology or its production, tax breaks, research funding, fines, loans, bail-outs), and the consumer (financial incentives, or regulation pertaining to the infrastructure surrounding a technology, like governmental investments, or regulation barring usage of technology in certain areas).

Pre-dieselgate, Tesla suffered a lot of financial trouble, which lead them to having to take out enormous loans. Fortunately, the US government granted part of these loans, signalling a very positive attitude of the regulators regarding the company and the technology. In addition, many countries grant tax breaks and other financial incentives for the usage of EV's, and invest in infrastructure. Many of these incentives continued after dieselgate or even increased. Tesla finally started to turn profits, reducing the need for loans, but still received several in the early years of the second half. As such, Tesla gets a 'rewarding' score for both eras (Wise and Witesman, 2019; Wittmann, 2017).

Pre-dieselgate, even though it looked like they complied, VW was actually cheating on emission-tests, as they had no way to pass them otherwise, or risk pricing themselves out of the US-market. As such, regulation prior to the scandal coming out, regulation was already working against VW. This is backed up by ever rising limits for various types of emissions, that specifically target fossil fuel cars (EURO 1 to 6, for instance). As such, regulation was 'penalising' already for VW. This got even worse after dieselgate came out, as the company was had to pay fines and settlements to the tune of approximately $30 billion. Additionally, post-dieselgate regulations regarding fossil fuel cars became even harsher, with low- and zero-emission zones being a clear example. As such, post-dieselgate, VW receives a penalising score as well (Baumgärtner and Letmathe, 2020; Bouzzine and Lueg, 2020; Cârstea, 2016; Boretti, 2017).

While BMW has not been scrutinised as much as VW, since they were complying with the regulations, these regulations are penalising for them as well, as the earlier mentioned EURO-norms for instance, set higher limits with every update, meaning that due to regulation constant action is required. So, pre-dieselgate, regulation was already penalising for BMW. Post-dieselgate, regulations regarding fossil fuel, such as low- and zero-emission zones, became even stricter meaning that BMW is also penalised by regulation in the post-dieselgate era (Cârstea, 2016; Boretti, 2017; Baumgärtner and Letmathe, 2020; Bouzzine and Lueg, 2020).

Table 25: Government, pre- and post-dieselgate

| **Case** | **Government** | **Technology** |
|---|---|---|
| Tesla (pre-dieselgate) | Rewarding | Innovation |
| Tesla (post-dieselgate) | Rewarding | Innovation |
| VW (pre-dieselgate) | Penalising | Incumbent |
| VW (post-dieselgate) | Penalising | Incumbent |
| BMW (pre-dieselgate) | Penalising | Incumbent |
| BMW (post-dieselgate) | Penalising | Incumbent |

### 7.2.7 Characteristics of the market

The 'Characteristics of the market' are operationalised as favourable, neutral or unfavourable for either technology. This is elaborated upon further in section 4. Characteristics of the market concerns all aspects that have to do with the market in which the companies of either technology operate. As such, it concerns changes to the market, the existence of niche markets, and the pattern in which a new technology enters the market. It also refers to uncertainty in the market (through a number of causes), which could create a favourable environment for one standard (or new technology) to become the dominant one, the rate of change and the level of competition.

Tesla introduced its first mass market EV, the Model S, in 2013 in the high segment. Thereby competing directly with VW's Phaeton and BMW's 7-series. By competing in the high segment, the competition was lower as there were not a lot of models in that segment, so a completely new one was fresh breath of air. When looking at the EV-market at the time, the competition was even lower. Effectively, Tesla could operate in a niche-market (the EV-market) with a high end model, creating a form of niche market for itself. As such, pre-dieselgate, the characteristics of the market were favourable for Tesla. Post-dieselgate however, a lot of companies introduced EV's many of which were directly competing with Tesla's middle segment car, the Model 3, which in that segment is quite expensive. As such, the market characteristics are more neutral for Tesla (Wittmann, 2017; Thomas and Maine, 2019).

VW was been, and still is, present in nearly every segment, especially through the many brands it has under its umbrella. As the EV-market was still underdeveloped in the pre-dieselgate era, VW faced little competition form that segment. Market characteristics also concern uncertainty and rate of change, and pre-dieselgate, there was little of both: EV's were rising but not at rates that it would instil uncertainty, and due to the low amount of companies offering EV's, the rate of change wasn't high. As such, the market was favourable for VW's non-EV's. Post-dieselgate, that changed. VW is still present in every market segment, but the market became a lot less certain, as now it started to look like it might move towards EV's. As such, VW's non-EV's face a lot more competition (partially through various models by Tesla which compete directly with high-profit models of VW), and indeed, many people were making the switch to EV's, as signalled by the fast rising market shares. As such, for VW's non-EV's, market characteristics became unfavourable (Kieckhäfer et al., 2017; Wanitschke and Hoffmann, 2020; Meckling and Nahm, 2019).

BMW mostly operates in the higher segment, and as such faced little competition in the pre-dieselgate era, save of course for newcomer Tesla. For BMW too, there was little uncertainty, or rate of change, leading to favourable market conditions for the company. Post-dieselgate, the still face little competition, but more than before. Additionally, they too face market uncertainty for their non-EV's, as the market is starting to head towards them. A lot of cars in their segment are now also offered as EV's (amongst them, models by Tesla), indicating a higher rate of change. As such, the market conditions have turned unfavourable for them too (Kieckhäfer et al., 2017; Wanitschke and Hoffmann, 2020; Meckling and Nahm, 2019).

Table 26: Characteristics of the market, pre- and post-dieselgate

| **Case** | **Characteristics** | **Technology** |
|---|---|---|
| Tesla (pre-dieselgate) | Favourable | Innovation |
| Tesla (post-dieselgate) | Neutral | Innovation |
| VW (pre-dieselgate) | Favourable | Incumbent |
| VW (post-dieselgate) | Unfavourable | Incumbent |
| BMW (pre-dieselgate) | Favourable | Incumbent |
| BMW (post-dieselgate) | Unfavourable | Incumbent |

### 7.2.8 Environmental influences

The factor 'Environmental influences' is operationalised as favourable, neutral or unfavourable. This factor concerns aspects that do not fall in the other categories, or aspects that describe the ecosystem (or environment) in which the innovation and the incumbent technology exist (i.e.: aspects of the industry not described through the other factors). It refers, for example, to the geographical location for a company, which may mean access to supporting companies and technologies, or access to good personnel. It also contains the influence of socio-technological systems, which mainly refers to the link between people or society, and its relation to technology.

Tesla is located right in Silicon valley, giving them access to a lot of complementary technology, and top of the line personnel. But what's more, Tesla was even in its early years a company that integrated many of people's everyday life into the usage of their car (digitisation), through the big panel at the centre of their dashboard. It also allows online updating the software of the car. As such, Tesla very early on understand that the way people interacted with technology, even in their car, was changing and made sure their cars were equipped for that. As such, Tesla gets a favourable score, pre-dieselgate. After dieselgate, Tesla retains this score, as society moving even faster towards more integrated technologies in - amongst other things - cars, creating an even more favourable environment to operate in for Tesla (Wittmann, 2017).

Volkswagen is located in Germany, which is widely known as car company, signalled by the large amount of brands hailing from it. As such, they too, have access to a lot of technology and access to top of the line personnel. While less inclined to make the link between technology and society, that played a lesser role in the pre-dieselgate era, as such, VW gets a positive score. Post-dieselgate, in the second half of the decade, as signalled by the rise of EV's but also through many other societal indicators, society started to be more sustainability-focused and as such, require more sustainable cars. As such, VW receives a negative score for the post-dieselgate era (Wittmann, 2017; Nunes and Park, 2016; Dworaczek et al., 2020).

Like, VW, BMW is headquartered in Germany, and as such also has an ideal geographical location. Likewise, because the first half of the decade focused less the link between technology and people, BMW also receives a positive score. Post-dieselgate, BMW also had to deal with the fact that society as a whole is becoming more sustainability-oriented and as such starting to require cars that are more sustainable, which their non-EV's are not. As such, this became an unfavourable environment (Wittmann, 2017; Nunes and Park, 2016; Dworaczek et al., 2020). .

Table 27: Environmental influences, pre- and post-dieselgate

| **Case** | **Environment** | **Technology** |
|---|---|---|
| Tesla (pre-dieselgate) | Favourable | Innovation |
| Tesla (post-dieselgate) | Favourable | Innovation |
| VW (pre-dieselgate) | Neutral | Incumbent |
| VW (post-dieselgate) | Unfavourable | Incumbent |
| BMW (pre-dieselgate) | Neutral | Incumbent |
| BMW (post-dieselgate) | Unfavourable | Incumbent |

## 7.3 Outcomes

The outcomes from the analyses are summarised in Table 28. As can be seen, it is indicated if a factor has changed between the pre- and post-dieselgate era. Positive changes are indicated by 'better', while negative changes are indicated by 'worse'. It is possible that while a factor did not change enough to warrant a higher or lower score, there was still change observable. This is indicated then indicated by the prefix 'slightly'. In the case of the 3 quantitatively determined factors, this was given if the growth coefficient showed improvement, while still holding the same directional coefficient. In the qualitatively determined factors, this was given if conditions were already positive, but became even more positive in the post-dieselgate era (or conversely, more negative).

Table 28: The 8 factors, and whether a change was observed between pre- and post-dieselgate

| | **Innovation** | **Incumbent** | |
|---|---|---|---|
| **Factor** | **Tesla** | **VW** | **BMW** |
| Company Strategy and Finances | Slightly better | Worse | Slightly better |
| Adopters/ Consumers | Slightly worse | Better | Slightly Worse |
| Other firms | Slightly worse | Better | Better |
| Characteristics of the technology | Better | Slightly worse | Worse |
| State and image of the company | Slightly better | Worse | Worse |
| Government | Slightly better | Slightly worse | Unchanged |
| Characteristics of the Market | Worse | Worse | Worse |
| Environmental influences | Slightly better | Worse | Worse |

These findings are more clearly displayed in relation to the success/failure of each technology in the filled-in SIFIT-model for this case, Figure 31. Like in the base model, the influence each factor has on the success/failure is expressed on the lines connecting the factors to the centre. Here, however, the influences of both eras are represented, in order to see how each influence changed between them. In order to display an influence that changed between the eras but not enough to warrant a different score (indicated by a 'slightly' in Table 28), two arrows are used to indicate a slight change in influence. For instance, the State and image of Tesla became 'slightly better' between the two eras, but remained positive overall, so Tesla goes from one green arrow to 2 green arrows. The centre represents the development in market share for each entire technology. Here too, 2 arrows are used to indicate the development.

As can be seen, many factors changed in ways that can't be interpreted right of the bat. The influences of each factor on the market shares, indicate different relations than in case study 1. This is - in part - likely attributable to the fact that in case study 1, all phases of the phases-framework (Figure 12) were considered, while in case study 2, only phase 3 is considered. Aside from that, even if factors changed between the eras, it is a complex industry and a complex process, and as such, a lot of context is needed to interpret these results. All of the changes seen in the model do not speak for themselves, and are merely a reason to investigate the factor further. This is now done in the next chapter, in which the influence of dieselgate per factor will be investigated. This section then discussed the outcomes form the interviews, and a comparison is made between the outcomes. The section concludes with a discussion on the results, which leads into an answer on the main question of this research.

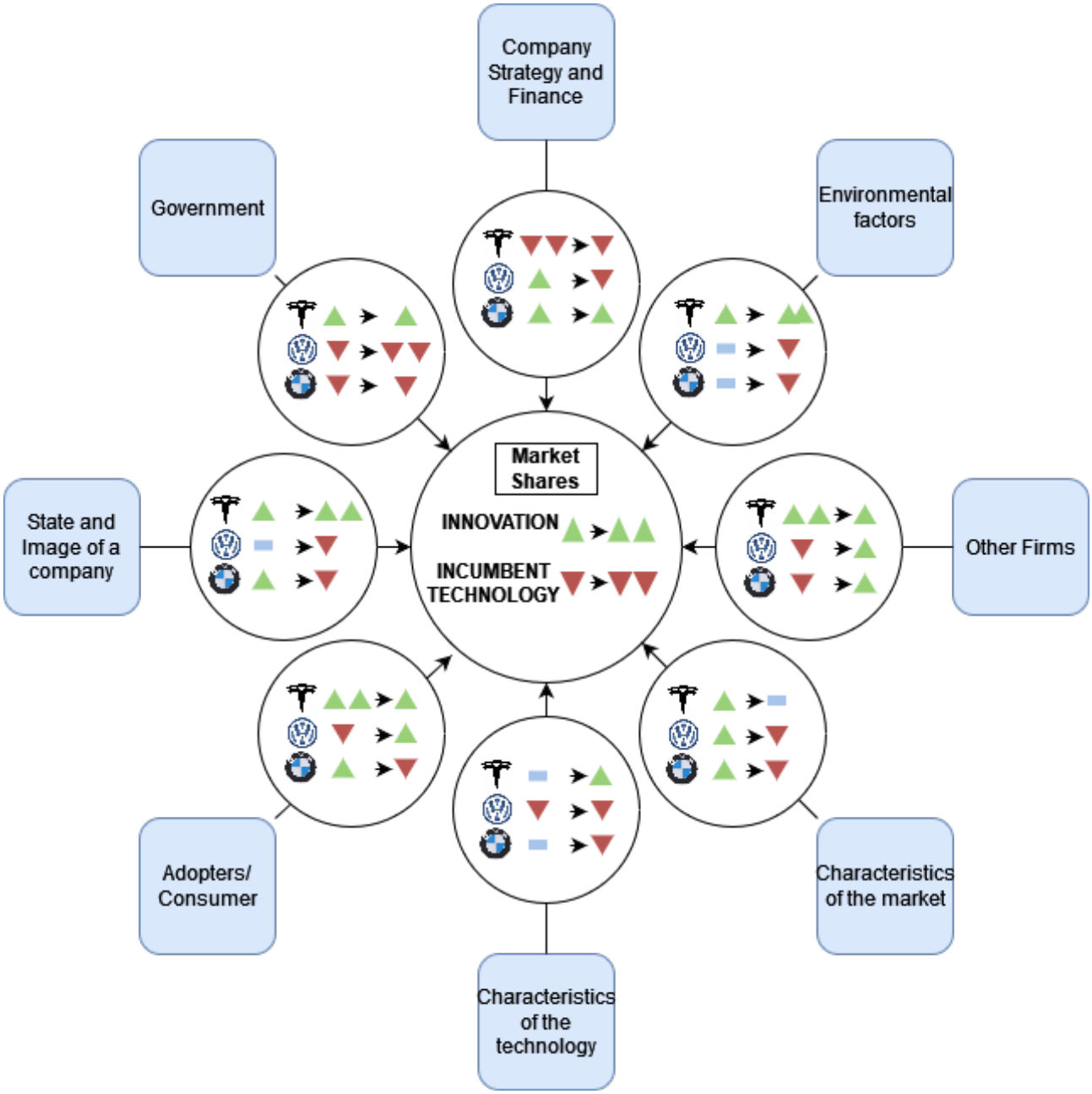


Figure 31: SIFIT-model for the automotive case. Each inward line contains the outcomes of the case study for the pre- and post-dieselgate eras. One green (or red) arrow going to two, indicates a slightly better score, while still being positive (and vice versa for two arrows going to one, indicating a slightly worse score, while still being positive)

# 8 Results and discussion

This section contains the results from the second case study. As could be seen in the SIFIT-model, each factor's influence changed between the pre- and post-dieselgate eras. In this section, it is analysed whether these changes can be attributed to dieselgate. The results of this analyses are presented as propositions regarding dieselgate's influence. Per factor, these concern both an influence on the rise of EV's, as well as the decline of non-EV's. This is followed by a preliminary conclusion, in which the results that were found to have indeed by to be influenced are singled out, and updated into a single proposition per factor, as the decline of the incumbent technology implies the rise of the innovation. These preliminary propositions are then discussed on the basis of insights from literature, and relevant insights form the interviews (as the interviewees were also asked what factors they thought to be affected by dieselgate). In this section, all propositions are confirmed, and updated with insights regarding underlying relations. The final propositions form the answer to the main question of this thesis, which was *'What has been the role of dieselgate in the strong rise of EV's?'*.

## 8.1 Results from Case Study 2

As can be seen in Table 28 and in the filled-in SIFIT-model (Figure 31), a lot of factors have changed between the pre- and post-dieselgate era, for all companies under analysis. These changes however, can't be directly attributed to dieselgate, as many other aspects are at play as well, and a lot changed in the past decade. Additionally, in several cases concerning the quantitatively determined factors, the R-squared was very low, meaning that not a lot of info is given by the trendline in itself. As such, the outcomes from the analyses of Case Study 2, mainly serve as indicators for what factors to look at (because if there would have been absolutely no change, dieselgate wasn't likely to have played a role either). As can be seen, every factor has experienced some degree of change. As such, every factors' outcomes need to be examined more closely. In doing so, the observations and outcomes are interpreted per factor, and a statement is made regarding the possible influence of dieselgate through that factor, on the rise of EV's.

### 8.1.1 Company Strategy and Finances

First off, when regarding the entire period under analysis, the RD/C shows some unexpected behaviour, as the companies representing the incumbent technology show a positive directional coefficient here, while the innovation company shows a negative directional coefficient. It must be noted however, that Volkswagen a very low R-squared, but still, this is a ground for further investigation. These behaviours could have a couple of reasons. First off, some assumptions were made regarding the incumbent technology, that the quantitative metrics do not account for, namely that these companies do not purely produce the incumbent technology, they also started working on the innovation. This requires R&D spending, which could explain the positive directional coefficient. These companies also continue to produce the incumbent technology, and their sales of non-EV's continue to increase. Unlike the case of Nokia, the incumbent technology remains popular, and thus it makes sense to keep investing in this. This is also tied to the switches announced in Table 2, most companies do not cease non-EV production immediately, but will do so in a couple of years. As such, R&D budget still goes to the incumbent technology. This is also tied to the fact that the innovation is far from fully diffused. As for Tesla, the negatively developing coefficient can possibly be attributed to the fact that the innovation is in phase 3 of the phases of the standard battle, which were describe by Suarez (2004), and incorporated into the phases-framework. Since only a part of the entire process is analysed, and that part is one single phase (namely phase 3) it is possible that this development is the result of starting with a new innovation. Tesla started in 2003 as a company intending to develop purely EV's (phase 0). In doing so, they started their research (phase 1), and the first model which also proved feasibility to the rest of the industry was delivered in 2008 (phase 2). The Model S, which came out in 2012, is their first model aimed at mass market and their user base is growing, signalling that the innovation is currently in phase 3. Tesla was a new company, and one of the first companies to introduce EV's (and by far the most influential, signalling the quality of their innovation), which could explain the enormous R&D spending Tesla had at the start of the decade (when phase 3 just began). After the technology was developed, it required less R&D spending as they now had the bulk of the technology. And since they had developed the technology early in the decade, it is possible that started to focus less on innovation, shifting their strategy and instead started investing that money in other ways, like expanding the company. This is also signalled by the fact that between 2010 and 2020 Tesla's R&D expenditures have strongly increased (1500%), but their amount of employees has increased a lot more (7770%). These numbers have remained a lot more stable for the other companies (VW: 90% and 70%, BMW: 110% and 30%), which can be tied to the fact that Tesla is a very new company, while the others are more established. Tying these considerations to the phases-framework, it is possible that when entering phase 3, these large expenditures are needed, and while

the innovation develops towards phase 4, the interest shift towards being stable for when the decisive battle begins. In short, it is likely that the early phases of a new innovation, when introduced by a new company, show different coefficients then what was found in case study 1, especially when only one phase is analysed. There, the innovation was introduced by Apple, which was already an established company, while Tesla is both introducing a new technology, and establishing itself as a company. Lastly, it could also be tied to the fact that Tesla had to borrow a lot of money, and suffered great losses for a lot of years. This could have led to prioritising R&D spending at the beginning, in order to get a working model, and then starting to focus on other aspects of the company, such as scaling up production (going from phase 2 to phase 3). As mentioned in section 7, an interesting takeaway from these graphs, without looking at the trends, is the fact that R&D spending in all companies goes up in the years before, on in the year itself, that a new innovative model is released. Combined with the fact that the incumbents also produce the innovation, this might also explain the unexpected observations regarding these coefficients.

As for the possible influence of dieselgate on either technology, it is likely that this is high. Volkswagen got a negatively developing RD/C, which might be attributed to the financial repercussions that the company suffered as a result of the scandal, which were approximately $30 billion. This is likely to have brought a shift in their strategy, as that money could have been spend on R&D and Volkswagen could have been a lot more innovative in the second half of the decade, continuing their positive trend from the start of the decade (and showing a trend which is more akin to BMW). While it is hard to state things with absolute certainty pre-dieselgate, BMW shows a strongly developing positive RD/C in the second half, indicating a strategy with a strong focus on innovation. It is possible that this money is spend on their non-EV's, but since these numbers also include EV's, and that technology is a lot newer within the company, it is likely that the bulk of that money is going towards EV-development. Tesla's negatively developing RD/C started to become more stable (lower growth coefficient) in the second half, and it like it was explained above, it is likely that this is the result of expanding the company. This is likely the result of more demand for EV', as a result of dieselgate. So while the company became 'less innovative' over the decade, and as such may have had a negative influence for this factor when purely looking at the data, Tesla is doing pretty well all in all, just spending its money into becoming a stronger company. All in all, it seems very likely that dieselgate has both impacted the decline of non-EV's and the rise of EV's through the factor 'Company Strategy and Finances'. As such, the propositions for regarding the influence of dieselgate are:

> *1A. Through the factor 'Company Strategy and Finances', dieselgate has had an influence on the rise of EV's*
> *1B. Through the factor 'Company Strategy and Finances', dieselgate has had an influence on the decline of non-EV's*

### 8.1.2 Adopters/ Consumers

The coefficients are in line with expectations, but some observations stand out. Again, care must be taken with interpreting the coefficients, as the R-squared for VW is very low. That said, VW and BMW show negative directional coefficients, indicating that the incumbent technology is indeed leading to less P/C (since it is still the bulk of their technology), signalling a loss in popularity. This might be attributable to dieselgate, as that has caused diesel (and fossil-fuel in general) to become less popular, which may lead to declining sales (at least for VW, this was indeed found through literature to be the case, and for BMW as well, possibly through the inertial effect). Tesla only started making profits in 2020, while suffering losses for the rest of decade. These losses, and the subsequent P/C, show a positive directional coefficient however, indicating that the losses became less over time, which in turn indicates more sales. In other words, the EV became more adopted, and thus more profitable. This is in line with what is to be expected of a successful innovation in phase 3, as it indicates that the user base is indeed growing. Secondly, looking purely at the values, a dip can be seen for VW in 2015, the year of dieselgate. VW made a loss that year, possibly through the reservation of funds for the financial repercussions. Aside from that, sales for the last quarter of that year were extremely low. Interestingly however, a year later they were making profit again. Still, it is very likely that this dip is attributable to dieselgate. While still making losses in 2013, Tesla shows a large spike for 2013, the year after the Model S was introduced in the US, and the year in which it was introduced in the rest of the world. A second spike can be seen in 2017, the year that the Model 3 was introduced. Tesla also shows a dip in 2015. This is interesting, as Tesla was in no way involved with dieselgate. The Model X was introduced in that year, it is possible that that model was less popular than the others (it is an SUV, rather than the sedans Tesla normally produces, which might be related). BMW also shows a dip in 2015, although this was a dip in profits rather than losses. The P/C continues to decline after that. This might possibly be attributable to the inertial effect, signalling an influence of dieselgate.

When looking at the pre- and post-dieselgate eras, changes can be observed. While pre-dieselgate the R-squared is very low, so not much can be said about that, post-dieselgate coefficients turned negatively for BMW. This signals a lack of ability to create value for the customer, meaning that their products are less in demand. Bear in mind that this metric also includes EV's, but since non-EV's are the bulk of their output, this indicates a decline in demand for them. Through the inertial effect, and decline in fossil fuel trust, this may very well be attributable to dieselgate. Interestingly, VW shows a negative coefficient in the first half of the decade, but this is likely to them reserving funds for the expected fallout, since the scandal came to light in 2015. Post-dieselgate a positive directional coefficient can be seen, but this with a very low R-squared so this is not saying much. Considering the dip in P/C in 2015, and no real indication of recovery post, it is very likely that dieselgate has had an influence on the decline for non-EV's through the factor 'Adopters/ Consumers'. Regarding the innovation, the metric keeps developing positively, but the growth coefficient reduces post-dieselgate. This could be attributable to the fact that there are more companies producing EV's in the second half of the decade, meaning that consumers have more choice. What is even more likely, is that Tesla invested more of their profits into paying back their loans. Lastly, Tesla's profits increased quite a bit (or rather, their losses declined), to a positive profit in 2020, but as stated before, the employee base rose enormously, which may distort this metric a bit. All in all however, the P/C keeps developing positively, to a positive score in the end of the second half. This signals continuing interest by consumers in the innovation, which is likely attributable to an increases interest in EV's, post-dieselgate. As such, it is also likely that dieselgate has influenced the rise of EV's through the factor 'Adopters/ Consumers'. The propositions regarding this factor therefore become:

*2A. Through the factor 'Adopters/ Consumers', dieselgate has had an influence on the rise of EV's*
*2B. Through the factor 'Adopters/ Consumers', dieselgate has had an influence on the decline of non-EV's*

### 8.1.3 Other firms

When regarding the entire period under analysis, the T/C behaves as expected, although it must be stated that not much can be said about BMW due to a very low R-squared. Interestingly, when regarding the absolute values, BMW lies a lot higher than the other however, indicating a strong interaction with the other firms. Tesla rises, which is interesting, due to the company being known to be vertically integrated rather then horizontally, meaning that many parts of is value chain are incorporated in the company (this may also explain why Tesla generally scores the lowest for a large part of the decade). VW develops negatively, indicating a lower positive influence from its interaction with other firms.

It seems rather easy to attribute this to the inertial effect as a result of dieselgate, as papers on that subject stated many companies in VW's (and BMW's) value chain also suffered as a result of dieselgate. Looking at the pre- and post-dieselgate metrics however, this seems not to be the case. Both companies show a strong, and similar, negatively developing T/C pre-dieselgate, but positively developing coefficients post-dieselgate. Although it must be said that VW has such a low R-squared for this period, that the trendline explains very little. Still, looking at the values, it remains rather constant, indicating very little change post-dieselgate. BMW however, shows an extremely positively developing T/C post dieselgate, indicating that its value chain suffered very little as a result of dieselgate. As such, it is unlikely that dieselgate has influenced this factor's influence on the decline of non-EV's. As for Tesla, the T/C develops positively in both eras but shows a lower growth coefficient post-dieselgate. Again, Tesla is vertically integrated, rather than horizontally, as is the norm in the automotive industry. So the parts of its value chain that are affected by this metric, induce a positive influence. Post-dieselgate this declines a little however, which might signal a higher degree of integration. Even so, there is very little to connect this to dieselgate, as this company's value chain was very unlikely to be affected by it, which makes it unlikely that this decline is attributable to it. The propositions regarding this factor therefore are:

*3A. Through the factor 'Other firms', dieselgate has not had an influence on the rise of EV's*
*3B. Through the factor 'Other firms', dieselgate has not had an influence on the decline of non-EV's*

### 8.1.4 Characteristics of the technology

As can be seen in Table 23, the characteristics of Tesla's technology became better in the second half of the decade, due to the technology becoming more mature and Tesla's efforts to create its own charging infrastructure. These developments however, seem to be the results of Tesla's own efforts, and little indication exist that these efforts are the result of dieselgate. It is much more likely that the company has had the time to improve the technology, and did so as a result of the ambitions to become a large and reliable company, delivering a high quality and highly performing technology. As such, an influence here seems unlikely.

As for the incumbent technology, the main point is that the technology is becoming more scrutinised. That is, while the technology itself is not getting worse, the standard in the market is raising to more sustainable modes of transportation. However, an influence through this factor seems unlikely, because not a lot can be said with absolute certainty in regard to the causes of the market becoming more sustainable (as this is also attributable to non-dieselgate related concerns over climate and air-pollution) and there is little evidence that technology itself has become worse as a result of dieselgate. Therefore, the propositions are:

*4A. Through the factor 'Characteristics of the technology', dieselgate has not had an influence on the rise of EV's*
*4B. Through the factor 'Characteristics of the technology', dieselgate has not had an influence on the decline of non-EV's*

### 8.1.5 State and image of the company

State and image for the incumbent parties obviously changed a lot as a result of dieselgate. VW was of course responsible, leading to damage in reputation, and having to deal with the massive consequences for this event. As was discussed in section 7, they did manage to restore the state of the company, but there is evidence that it did lead to reputational damage to the company. The same can be said for BMW, who wasn't even part of the scandal. Their reputation got tarnished through the inertial effect of the event, and post-dieselgate financial figures show a dip. As such, it can be stated that dieselgate has influenced the decline of non-EV's through this factor.

For Tesla, these influences are harder to determine, as the company was not related to the scandal, and as such no inertial effects. Post-dieselgate, its state and image grew stronger, but there seems to be very little evidence that this is directly attributable to dieselgate, and not to other factors, like the exploits of the company's CEO, the fact that the brand put out new models, and has become a lot more well known. There also seems to be no evidence that people were buying more Tesla's as a direct result of dieselgate, therefore it is unlikely that the rising success of the company was attributable to dieselgate. Thus, regarding this factor, the propositions are:

*5A. Through the factor 'State and image of the company', dieselgate has not had an influence on the rise of EV's*
*5B. Through the factor 'State and image of the company', dieselgate has had an influence on the decline of non-EV's*

### 8.1.6 Government

While between the two eras the influence of the factor 'government' stayed roughly the same for all companies, there is ample evidence that this factor's influence on the process was indeed influenced by dieselgate. Most obviously, this is signalled by the fact that VW got enormous fines, which signals the fact that the government takes violations of this nature very seriously. Moreover, there has been evidence in literature that testing procedures have been revised as a result of dieselgate, meaning that the technology is under a lot of scrutiny. There is also the suggestion in literature, that a lot of regulations regarding low- and zero-emission zones have been the result of dieselgate. As such, the incumbent technology, fossil fuelled cars, has certainly been negatively influenced as a result of the event.

As for the innovation, it is harder to determine if post-dieselgate government influences were the direct result of dieselgate. Concerns regarding climate change have been on the agenda for quite some time in a lot of countries, and as a result many tax breaks and financial incentives have been given to cleaner cars. Moreover, the loans that Tesla received form the US government were granted well before dieselgate, and as such there is no evidence that the event has influenced any of that. Given the fact that most incentives regarding EV's were already in place prior to dieselgate, and that there is no evidence that any new mandates are the direct result of it, it is unlikely that the influence of the factor 'government' on the rise of EV's, was influenced by dieselgate.

*6A. Through the factor 'Government', dieselgate has not had an influence on the rise of EV's*
*6B. Through the factor 'Government', dieselgate has had an influence on the decline of non-EV's*

### 8.1.7 Characteristics of the market

While the market characteristics have indeed changed between the two eras, each company has found less favourable conditions than prior to the event. Tesla found a market that was neutral, as the uncertainty and the rate of change or in it advantage, but since other companies also have seen this, many companies are

switching (and newcomers are entering) leading to more competition. So while certainly not unfavourable, the market is less favourable then before dieselgate. It is however, hard to determine whether this has been a direct result of dieselgate, or rather an effect of other reasons to start producing EV's (which may have even been Tesla's own doing, by demonstrating their feasibility). As such, it is unlikely that this is a direct result of the influence of dieselgate.

As for the incumbents, the market turned unfavourable, but here too, there is little evidence to attribute this directly to dieselgate. The high rate of change and the uncertainty regarding what way it is going, can also be just as likely an effect of other concerns regarding climate change and air pollution. Due to this lack of a direct link between the factor and an influence of dieselgate, it is unlikely that the event has influenced the decline of non-EV's through this factor. As such, the propositions are:

*7A. Through the factor 'Characteristics of the market', dieselgate has not had an influence on the rise of EV's*
*7B. Through the factor 'Characteristics of the market, dieselgate has not had an influence on the decline of non-EV's*

### 8.1.8 Environmental influences

Between the two eras the geographical locations of all companies remained the same, and even if not, this is not likely influenced by dieselgate. As such, a possible influences of this factor has to come from the socio-technological systems: the way people interact with technology. Tesla's score remained favourable, as they very well recognise the growing link between society and integrated technologies. This is however, not very likely influenced by dieselgate, as it in the case of Tesla concerns very little fuel-related aspects, but rather more of the connectivity of people, and the fact that Tesla had been walking this path already before dieselgate. Society has of course become more sustainability-oriented, which positively influences the EV, but this can also be attributable to other concerns related to climate change and air pollution. As for the companies behind the incumbent technology, their influence of this factor became unfavourable, coming from neutral. But again, there is no evidence that society became more sustainability oriented as a direct result for dieselgate. So while the environment in which the incumbent technology operates indeed became less favourable, no direct link could be found. The propositions therefore become:

*8A. Through the factor 'Environmental influences', dieselgate has not had an influence on the rise of EV's*
*8B. Through the factor 'Environmental influences', dieselgate has not had an influence on the decline of non-EV's*

## 8.2 Preliminary conclusion regarding the propositions

Following the case study, 8 propositions have been formulated regarding the influence of dieselgate on the rise of EV's, and the decline of non-EV's, as per Dul and Hak (2007). These are all formulated in a proposition A, regarding the EV, and proposition B, regarding the non-EV's. It can be seen that several factors were found to have influenced both, while several only influenced either the EV or the non-EV. However, in a standard battle, the rise of the one means the decline of the other. As such, when a proposition A states that no influence was found, but proposition B does, this still means that dieselgate has influenced the process through that factor. Therefore, the propositions can be reformulated to describe the influence more clearly. Additionally, not all factors were found to have been influenced by dieselgate. The preliminary concluding propositions of the case study are therefore:

1. *Dieselgate has influenced the rise of EV's, through 'Company Strategy and Finances'*
2. *Dieselgate has influenced the rise of EV's, through 'Adopters/ Consumers'*
3. *Dieselgate has influenced the rise of EV's, through 'State and image of the company'*
4. *Dieselgate has influenced the rise of EV's, through 'Government'*

These reformulated propositions give a clear overview of the results of the case study, and thus regarding the influence of dieselgate on the rise of EV's. The influences of dieselgate are also displayed in relation the filled-in SIFIT-model for this case, in Figure 32. As can be seen in this preliminary model, there have indeed been multiple influences. These results will now be discussed on the basis of findings from literature. Additionally, the interviews did not only serve to verify the framework. Interviewees were also asked through what factors they thought dieselgate had influenced the process. Given the fact that they were presented the first iteration of the framework, their remarks might be about previous definitions of the factors, but they all thoroughly substantiated these remarks, and as such these insights of the interviews present an interesting addition to the results. Therefore, these remarks are taken into regard into the discussion.

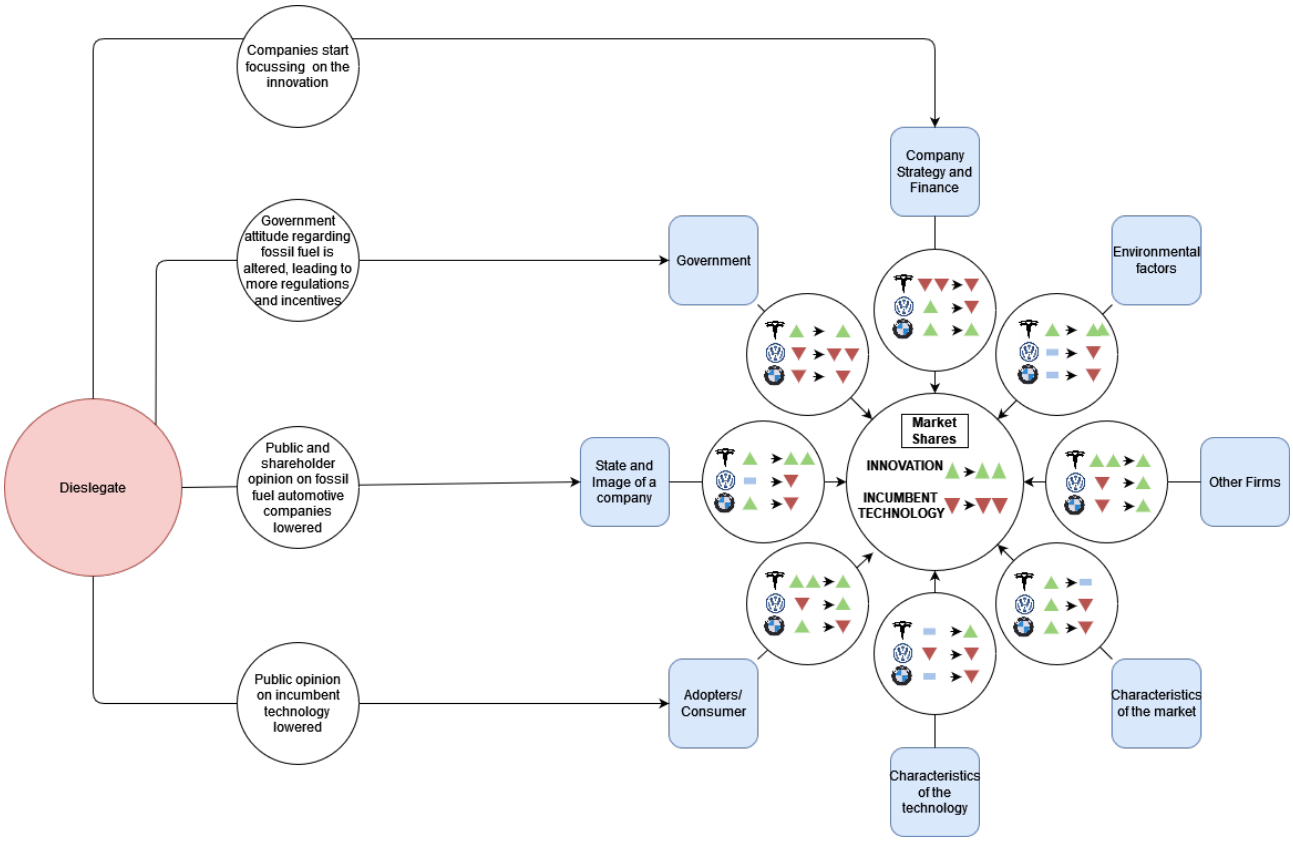


Figure 32: The SIFIT model of the automotive case (right), with the influences of dieselgate (on the basis of the propositions) added on the left side.

## 8.3 Discussion

Through the case study, dieselgate was found to have influenced the rise of EV's through 4 factors. These influenced are now discussed on the basis of literature and remarks from the interviews, on a per factor basis. As it will turn out, the propositions that followed from the case study are all confirmed, and some are updated because through the literature and interviews, several underlying relations were found. These underlying relations are incorporated into the propositions, leading to definitive results (in the form of propositions) regarding the influence of dieselgate on the rise of EV's. Note that in each proposition, only dieselgate's direct and indirect influences on that factor are stated. Any influences that a factor has on another factor, are incorporated into the proposition of the affected factor. For 'Adopters/ Consumers' has an indirect effect on 'Company Strategy and Finances'. That influence is described in the propositions regarding 'Company Strategy and Finances' and not in the proposition regarding 'Adopters/ Consumers'.

The first factor that was found to have been influenced by dieselgate, was 'Company Strategy and Finances'. Dieselgate was found to have led to large financial damages, both at Volkswagen (leading to less focus on innovation, as that money could have been spend on Research and Development), as well as other companies, through the so-called inertial effect. These effects were found to be beneficial for the innovation, as it opened up more interest for the EV. In the interviews, this was confirmed and more insights were gained regarding dieselgate's influence on this factor. Interviewee B stated that the event caused a shift in company strategy for a lot of companies, mainly towards the plans of phasing out fossil fuel (see Table 2). Specifically, he stated that dieselgate caused Volkswagen to focus more on EV's (this new course can also be tied to the new CEO). Interviewee C provided more context as to how this works. He stated that the automotive industry used to be cherished in some countries, and that it was regarded as very innovative. But with dieselgate, that got screwed up, both with the public and with politicians. Things like that reach the board rooms, and causes the board to consider new experiments, and bet on EV's. He also stated that there is trend visible amongst investors, in which they are more likely to bet on companies looking into more sustainable solutions (i.e.: innovating companies). This is interesting, as it shows that company strategy is not only influenced directly by dieselgate, but also through other factors. The event caused public opinion, the attitude of various governments and the attitude of shareholders to shift. Through these shifting attitudes, it seems very likely that more companies have adjusted their strategies towards more focus on EV's, and aspect that is also seen in the fact that every mayor company has made an announcement for the near future in this regard. The shifting opinions of the public, governments and shareholders was also found in section 3, specifically in the papers by Nunes and Park (2016); Bouzzine and Lueg (2020); Dworaczek et al. (2020); Cârstea (2016); Baumgärtner and Letmathe (2020). These effects are also described in other factors that were found to be influenced, indicating several underlying relations between the factors. These factors are described more thoroughly in the upcoming paragraphs, but their relations are stated here already, to indicate their specific relations to the factor 'Company Strategy and Finances'. A shift in public opinion on fossil fuel causing more demand for EV's and less demand for non-EV's (which in turn influences Company strategy) was found to be dieselgate's influence through the factor 'Adopters/ Consumers'. A shift in the public and the shareholders opinions on a certain company, was found to be dieselgate's influence on the factor 'State and image of the company'. And a shift of various governments' attitude, leading to more regulations, was found to be dieselgate's influence on the factor 'Government'. A more comprehensible overview of these underlying relations, can be seen in Figure 33. On the basis of these considerations, proposition 1 from the preliminary conclusions is confirmed, and more information is added regarding its relations to other influenced factors. The updated and definitive proposition regarding this factor therefore becomes:

> *1. Dieselgate has influenced the rise of EV's, through 'Company Strategy and Finances', both directly, as well as indirectly through the factors 'Adopters/ Consumers', 'State and image of the company' and 'Government'.*

Regarding Adopters/ Consumers, the case study led to the conclusion that this factor was very likely to be affected through dieselgate, as could be seen in dips in the P/C around the time of dieselgate for VW and BMW, negatively developing profit per capita for BMW, and a stagnated one for VW, post-dieselgate. From the interviews and literature, more insight was gained to explain these developments. It followed that public opinion also turned sour in relation to the incumbent technology as a whole as a result of dieselgate, and this reflected into less demand for non-EV's, and thus, more demand for EV's (Mujkic and Klingner, 2019; Nunes and Park, 2016; Baumgärtner and Letmathe, 2020; Cârstea, 2016). 'Adopters/ Consumers' takes this public opinion in consideration by looking at how demand of the technology develops a result of dieselgate. Apart from confirming the lowered public opinion on the incumbent technology, the interviews turned up some insights regarding how, through this factor, dieselgate has also influenced 'Company Strategy'. This public opinion being lowered causes it to create more demand for EV's and less demand for non-EV's. This is noticed by companies, leading them to revise their strategy. This effect was described above. As such 'Adopters/ Consumers' has

and underlying influence on the factor to Company Strategy and Finances'. However, the factor 'Adopters/ Consumers' itself, is also indirectly influenced by another factor, namely 'Government'. Dieselgate led to a shift in government attitude, leading to more regulations (this is described more thoroughly below). These regulations cause EV's to be more attractive, and non-EV's to become less attractive for consumers, which causes the Adopters/ Consumers to become even more interested in EV's. This, in turn, also strengthens the influence of this factor on 'Company Strategy and Finances'. These influences can be seen more clearly in Figure 33. Given the confirmations through literature and the interviews, it can be stated that there was a direct influence of dieselgate on the factor 'Adopters and Consumers' through shifting public opinion, as well as an indirect influence through regulations (the factor 'Government'), proposition 2 from the preliminary conclusion can be updated into a definitive statement regarding dieselgate's influence:

> *2. Dieselgate has influenced the rise of EV's, through 'Adopters/ Consumers', both directly, as well as indirectly through the factor 'Government'.*

Through the case study, the factor 'State and image of a company' was found to be affected by dieselgate. Logically, reputational damages for Volkswagen followed, and this too, spilled-over to other companies through the inertial-effect. These reputational damages both refer to the public's opinion on a company, as well as that of the shareholders, and are found in several papers, most notably Mujkic and Klingner (2019); Dworaczek et al. (2020); Mujkic and Klingner (2019); Baumgärtner and Letmathe (2020); Bouzzine and Lueg (2020). Through the state, this factor also refers to the ability of a company to handle such a shock, and as it turned out in the case study, companies like BMW did preform less well after dieselgate, indicating a weakened state. Tesla's state and image were found to be slightly better after dieselgate, but this was hard to attribute specifically to dieselgate. However, through the fact that companies associated with the incumbent technology were found to be affected by this, it can be stated that this has certainly had an influence in making these companies weakened and less well regarded, both with the public and shareholders, thus having an direct influence on the rise of EV's. The influence of this factor was also confirmed in the interviews and additional insights regarding relations between the influenced factor were described. In several interviews the fact that the public opinion on multiple companies producing diesel technology had been lowered was mentioned, leading to less demand for models from these companies. One interviewee stated that part of the public might still buy Volkswagen, for instance, but only an EV. This in turn, forces these companies to start looking at the innovation. As such, not only has dieselgate had an effect on the factor State and Image, but through that factor also an effect on company strategy. This was discussed in more detail in the section on 'Company Strategy and Finances'. The factor 'State and image of the company' not only influences another factor, but is also influenced by another factor, namely 'Government'. Obviously, there were the huge fines for Volkswagen that disrupted its state, and demonstrated stark government response to these kind of practices, which lowered diesel producing companies' images even more. But what's even more interesting, and follows from Bouzzine and Lueg (2020), was that the governmental investigations into Volkswagen (which on its own led to shareholders and investors withdrawing), led to the expectation that these investigations would also look into other (German) diesel producing companies, and that similar practices would be discovered. This led to shareholders and investors withdrawing from companies like BWM and Daimler as well. Thus, through the governments' stark actions and investigations, the state and image of companies producing the incumbent technology lowered even further. As such, the preliminary proposition regarding 'State and Image of the company' is confirmed and can be updated into a more definitive statement regarding dieselgate's influence:

> *3. Dieselgate has influenced the rise of EV's, through 'State and Image of the company', both directly, as well as indirectly through the factor 'Government'.*

Lastly, the influence of dieselgate on the 'factor' Government was also found through the case study. Aside from the fines that Volkswagen suffered, there is mention in several papers, that the event had led to more regulations on testing, and more mandates that make EV's a more attractive option, for instance through so-called low- and zero-emission zones, which ban fossil-fuel cars (Wittmann, 2017; Bouzzine and Lueg, 2020; Baumgärtner and Letmathe, 2020). These effects of dieselgate also came forth from the interviews. Interviewee A stated that it had influenced the ways various emissions are reported. Interviewee B stated that dieselgate must have led to changes in testing regulation as well. Additionally, he and interviewee C both found that (an increase of) zones in cities limiting certain vehicles are a result of the event as well. Interviewee B also stated that dieselgate has weakened the power of lobbyists and car companies on the negotiation table surrounding regulation. In other words: regulation on the automotive industry is usually fought over hard by these parties, but dieselgate has led to their power declining, as regulators can refer to the scandal when pushing their mandates. Lastly, he remarked that it had also influenced the position of European Commission regarding this matter, as they

were expected to enact harsh punishment, by environmental organisations and European citizens. Interviewee C stated that dieselgate caused companies producing the incumbent technology to be seen as less favourable, both with the public and the politicians, and through those politicians found that the whole industry was forced to start looking into EV's. He also stated that (expected) changes in regulation as a result of dieselgate, might cause newcomers to enter the market as they now see chances (niche markets for environmentally conscious people, or people who buy EV's because they expect regulations to change), and for incumbent companies to feel threatened by these changes as they might not be able to sell to certain markets anymore. From these considerations, the influence of the factor Government' on the other factors become more clear. As was discussed in the previous paragraphs, more regulations make EV's more attractive for customers ('Adopters/ Consumers'), make certain companies to become less popular ('State and Image of the company'), and force companies to focus more on EV's ('Company Strategy and Finances'). These influences are incorporated in the propositions regarding those factors. There were no suggestions found in literature or in the statements of the interviewees found that any of the other factors had any influence on the factor 'Government', so this proposition needs no update. It is however, clearly confirmed that this factor was influenced by dieselgate. The proposition remains:

*4. Dieselgate has influenced the rise of EV's, through 'Government'.*

As can be seen, the propositions from the case study are all confirmed through the literature and statements from the interviews. Additionally, and this was not found explicitly through the case study, a lot of underlying relations between these factors were found. These are incorporated into the propositions, and are displayed in relation to the SIFIT-model in Figure 33, in order to show the relations more clearly. These underlying relations demonstrate that both the transition towards EV's, as well as the influence that dieselgate has on that process and the industry, are complex. However, through the case study it was proven that there was indeed an influence, and through what factors, and from literature and interviews more insights regarding that influence were described. An interesting last note on this discussion, is the fact that these underlying relations could also be true in reverse. In other words, consumers could buy more EV's which leads to a company's strategy being more focused on EV's, but it stands to reason that when a company focuses more on EV's, this might also lead to more demand for them amongst consumers, i.e.: there could be feedback loops. This is not researched specifically, but could be a very interesting recommendation for further research, as it leads to more understanding, both on how dieselgate has influenced the process, as well as more understanding of how the factors influence each other in general.

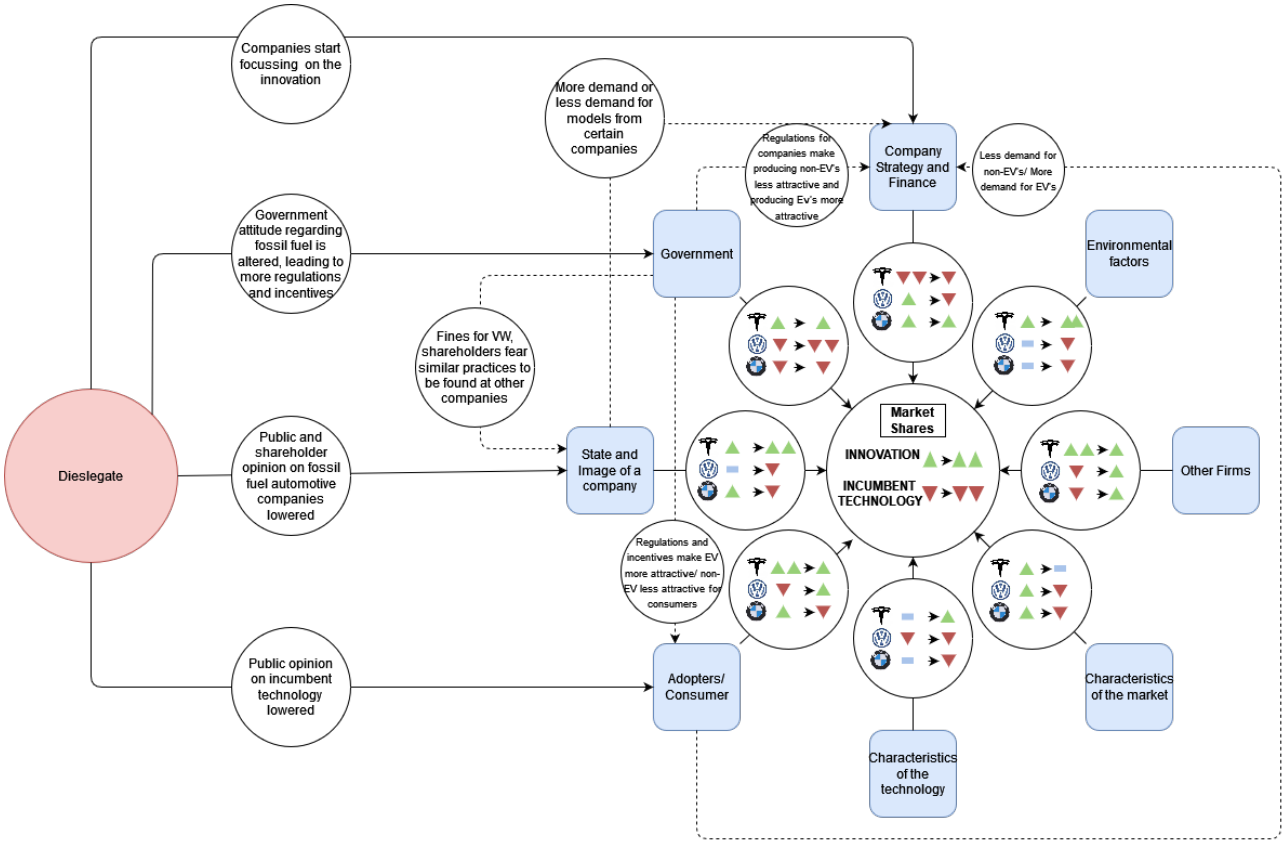


Figure 33: The SIFIT-model of the automotive case, with the direct influences of dieselgate added in solid lines, and the indirect influences - as described in the discussion - added as dashed lines.

# 9 Conclusion, discussion on the framework and recommendations

## 9.1 Conclusion

This thesis looked into the influence dieselgate had on the strong rise of EV's in the past decade. Dieselgate was caused by bad management at Volkswagen. The company recognised that with their current technology, they would not be able to competitively price themselves in the US market, as emissions were to high and adding technology to resolve that, would make the price of their vehicles to high. Instead of focusing themselves on improving their technology or coming up with a new innovation to counter this problem, it was decided that software would be installed that recognised when a vehicle was being tested, and subsequently alter engine conditions to emit as much as 40 times less NOx.

When they were caught in 2015, the resulting scandal had far-reaching consequences, many of which related to altered views on how cars were propelled. The following years saw a strong increase in alternatively propelled cars, most prominently, electric vehicles or EV's. This thesis set out to determine whether part of this strong increase was attributable to dieselgate. In order to do so, a framework was developed, that described the process of an innovation (the EV) taking over from an incumbent technology (fossil fuel vehicles), in terms of 8 factors whose influence on the process could all be measured qualitatively or quantitatively. This framework was then applied in a case study, to find out how the process was affected by dieselgate (the event was not a separate factor, but hypothesised to be an influence on the factors of the framework). The resulting propositions were then confirmed and augmented using literature and statements from interviews. The resulting propositions, that answer the main question, namely *'What has been the role of dieselgate in the strong rise of EV's?'*, are:

> *1. Dieselgate has influenced the rise of EV's, through 'Company Strategy and Finances', both directly, as well as indirectly through the factors 'Adopters/ Consumers', 'State and image of the company' and 'Government'.*
> *2. Dieselgate has influenced the rise of EV's, through 'Adopters/ Consumers', both directly, as well as indirectly through the factor 'Government'.*
> *3. Dieselgate has influenced the rise of EV's, through 'State and Image of the company', both directly, as well as indirectly through the factor 'Government'.*
> *4. Dieselgate has influenced the rise of EV's, through 'Government'.*

In conclusion, these propositions describe through what factors dieselgate has directly and indirectly influenced the rise of EV's. The event caused more automotive companies to move away from fossil fuel vehicles and to start looking into EV's. This led to statements of every mayor company to declare this intent. This switch is strengthened by the fact that consumers show more demand for EV's, the fact that these fossil fuel automotive companies' their images were tarnished by the event (not only Volkswagen, but others too, through the inertial effect), and the fact that more regulations make the production of fossil fuel vehicles less attractive (proposition 1). The event led to consumers' opinion on fossil fuel vehicles to be lowered leading to the previously mentioned lower demand, while at the same time, regulations resulting from the event made EV's more attractive to consumers (proposition 2). As mentioned, Dieselgate caused the opinion on fossil fuel automotive companies to be lowered, which in turn led them to look into EV's to restore that image, both with the public, as well as shareholders. The tarnished image was strengthened by the fact that Volkswagen got huge fines, and the fact that shareholders expected that similar practices would be found in other companies, leading them to withdraw (proposition 3). Lastly, as discussed prior, dieselgate led to many new regulations on testing and incentives to make EV's more attractive (low- and zero-emission zones). These regulations and incentives, in turn led to increased demand for EV's, less demand for fossil-fuel vehicles, lack of trust from shareholders, and making the production of EV's more attractive (and fossil fuel vehicles less attractive) for automotive companies (proposition 4).

## 9.2 Discussion on the framework

Now, the framework that was at the centre of this research, the SIFIT-model, is discussed. This is done in the same order the framework was created: first by its theoretical background, then by its construction, then by its verification and validation, and finally by its usage. As became clear through the literature research, there was no framework that suited the exact needs of this thesis' main question, namely one that clearly expresses the process of an innovation replacing an incumbent technology, while providing ways to measure the type of influence the driving factors have. As such, one had to be constructed, by seeing how certain aspects of frameworks that did exist, could fit together. To that end, four mayor theories pertaining to innovation and new technologies have been used, namely the standard battle, the innovation diffusion theory, disruptive innovation and radical innovation. For each one, several papers were examined, and frameworks were found that described how an innovation would be successful in the market. On these grounds, the theoretical background of the framework is deemed solid. The research is extensive, and takes many different theories into consideration, and therefore it is likely that all relevant aspects for the process have been researched and incorporated. Additionally, research was done in methods of measuring several aspects of this process, and on the basis of this, a strong and clear research gap was defined, which made the requirements and purposes of the new framework very clear.

The first step in constructing the new framework was to determine the factors it would consist of. This was done by looking at the various factors from the theoretical background and determining how they would fit together. Due to the fact that many perspectives and factors were taken into consideration, it is very likely that the resulting clusters describe every relevant aspect of the process, and it is very unlikely that any major influences have been missed. For each of these clusters, a method of determining its influence was determined. Some of these followed directly from the research, like the ones measured through the 3C-model, while others were determined through analysing the literature. As followed from the literature gap, very few of the researched papers provided ways of actual measuring, so qualitative scores were defined through statements from different papers regarding what separates a successful technology from an unsuccessful one. While the actual qualitative scores are the researcher's own contribution to literature, their background comes from prior research, and are therefore deemed to be solid. Piecing the various steps of the process together in a logical sequence was done on the researcher's own insights, but due to several overarching frameworks providing a strong basis (innovation diffusion and the standard battle), and the fact that the steps themselves followed from literature, the resulting sequence is very likely to contain all relevant steps. In addition, this process is described transparently and thoroughly, which allows it to be checked for consistency and if relevant, a good point to start further research on the framework. The first iteration of the framework was thereafter verified through expert interviews, in which all interviewees expressed that they felt the framework indeed described the process well. Naturally, the interviews led to some points of improvement, which were incorporated, strengthening the framework. On the basis thereof, the design of the second iteration of the framework began. While incorporating the feedback, the practical usage of the framework was explored as well. Eventually, this led to the creation of two versions of the framework, on that is more suitable for a more theoretical approach (the 'phases-framework'), and one that it is also suitable for practical application (the SIFIT-model). Both versions still consider the same process, but express it in different ways. The factors of the framework were applied to the entire process. For practical reasons, this was deemed necessary, but for a purely theoretical approach, they may be connected to the phases again to provide more insights. This thesis manly considers the SIFIT-model, so this is not done in this thesis. The application of each factor to the entirety of the framework is deemed to be correct, as most factors already applied to the entire process already. When analysing a specific phase for a theoretical viewpoint, this will become clear as well. Additionally, the ways the factors are operationalised for practical use, can also be used for the theoretical approach as they can provide insights into each factors' influence on a specific phase as well. As can be seen, the second iteration of the framework takes some liberties, but this was done transparently and every consideration is substantiated. In the end, the SIFIT-model more accurately fills the knowledge gap and allows the framework to be validated using a real life case study, making the final iteration a very strong one.

The framework was validated using a case study that was unrelated to the main question of the thesis, as it needed to be generic, and therefore applicable to all types of cases with the right conditions (a standard battle in a high-tech industry, with a disruptive, radical innovation), in order to prevent bias. In the case study, a fully diffused innovation was considered, and the factors were each tested on the question if each factors' influence affected the process in the intended way. This was indeed the case, and therefore the framework was deemed to be usable to answer the main question. It should be noted however, that on the basis of one case study, a theory (in this case: the factors indeed influence the process correctly), can't be confirmed with absolute certainty. This means that in order for the framework to become even more valid, more testing with other case studies is required. The testing case study proved to be satisfactory however, and since this indicated a certain required degree of validity, for the purposes of this thesis the framework was deemed to be usable.

The second iteration of the framework was also verified through an expert interview, namely a second

interview with Interviewee C. He was asked to specifically pay attention to the way the factors were measured. This led to several points of feedback, some of which are already incorporated. Certain points of feedback weren't incorporated for various reasons, and may be taken into consideration for further research. The feedback from this interview is now discussed. Interviewee C felt that using the RD/C mostly denoted the focus on innovation, rather than strategy. He found that it might be better to rename this factor as such, and formulate a different factor that would consider the finances, or leave that out alltogether, as he found that money is more of a result of the innovation being successful, rather than a cause. While this might be worth looking into, it was decided to leave this factor as is, because R&D spending are a large part of strategy, as innovation is very important for the existence of any company. Additionally, this measurement was found to be very suitable on the basis of the various works regarding the 3C-model, and these considerations were not presented to the interviewee, leading to a potential misunderstanding of their theoretical background. The same could be said for the feedback on the 'Adopters/Consumers' measurement, which the interviewee felt should be represented by market share. The whole point of the framework however, is to show that market share is driven through various factors (rather than being a driver), and the fact that the 'Adopters/ Consumers' factor was operationalised through the P/C metric, came from the fact that this metric describes a company's ability to create value for the customer, and that is exactly what this factor describes. Lastly regarding the 3C-metrics, similar critique was offered on using the T/C to determine influences of other firms. He found that it describes the factor on a product level, rather than a company level and found that the metric said nothing about the other companies. He would also rather see the influence of competition measured through this factor. The factor however, focuses on the interaction with other firms in the value chain, and since the T/C describes the leverage on the value chain and the strength of partnerships, this factor was kept the way it was. Additionally, the factor comes from an organisational level application of the 3C-model, as the product level metric for this would be the PMP (Beelaerts van Blokland et al., 2008a). No other suggestion for a metric was recommended to measure the this factor, which is why it was kept the way it was. The definition of this factor was defined a bit more clearly in the section 4, in order to make the fact that it refers to value-chain companies, rather than competition, more evident. Most of the other feedback referred to the way several of the factors were defined or what aspects were named in their description. This lead to some good points, which strengthened the framework by a lot, as some aspects were placed in the wrong clusters, as a result of updated definitions (mostly because the factors were updated to reflect both the incumbent technology as well as the innovation, where before a distinction was made is several factors, see section 5). The largest change here involved the factor 'State and image', which included both the company and the technology. Feedback here suggested moving the aspects referring to the technology to the 'Adopters/ Consumers', as this factor is clearly influenced by what adopters think of an technology, and having the state and image factor refer solely to the company. This was found to be a very good suggestion, and as such, it was incorporated into the research. Lastly, 'Regulation' was renamed into 'Government', and few aspects were moved to better suited the changes. For instance, 'Operational supremacy' was moved to State and Image. Some feedback was offered on measuring the 'Characteristics of the technology', namely by looking into research by Juran, concerning quality. This research uses a Likert scale to determine quality, which was found to be a good suggestion. The points on that scale are determined qualitatively however, and since a qualitative measuring scale was already in place, this feedback was deemed to be better suitable when strengthening the framework in any subsequent research. As such, the current metric was kept. The metric used for 'Characteristics of the market' was found to be suitable. All in all, the second verification round provided a lot of usable feedback, many of which is either incorporated already, or are recommended for future research regarding the framework. Feedback on the usage of the 3C-model is certainly taken into consideration, but the fact that the theoretical background as to why these metrics were chosen is solid and were unknown to the interviewee, these are mostly kept the way they were. However, the fact that critique was offered on them, indicates that further research into the way they are operationalised can be of value, and as such this will also be recommended in the next section.

The framework as is, presents many opportunities for further applications. It was designed to be generic, allowing it to be applied to any (high) technological industry in which there are radical and disruptive innovations. This was already demonstrated by applying it on two very different industries in the case studies. In short, the framework is very generally applicable when research the process of an innovation taking over from an incumbent technology. The specific application of the framework to research the influence of a scandal or other disruptive event is also not limited to the case used in this research. The framework is build up from factors that apply to any industry (due to it being generic), and a disruptive event is regarded as an influence on those factors, rather than being a factor in itself. This makes it so, that the framework doesn't change as a result of the type of disruptive event that is researched, meaning that it is also very generally applicable to investigate all types of disruptive events, in all sorts of industries.

## 9.3 Recommendations

On the basis of this research, several recommendations can be made for future research. These pertain to the two main parts of this thesis, namely the framework itself, and research into dieselgate and EV's.

Regarding the framework, further research is recommended into the ways the factors are measured. The feedback form the second verification round, as discussed in section 8, can be of use here. On the basis thereof, the recommended research by Juran into the quality of the technology can be investigated further, as well as usage of the Likert scale to score each factors' influence. Furthermore, additional testing is required. The framework was tested on one case study, and while this suffices for the purposes of this thesis, a theory can't be proven through one case study. As such, more research can go into more testing, in order to see if the framework also works for other cases. Lastly, the thesis mainly focused on the usage of the market share variant of the framework (the SIFIT-model). There is however, also the phases-framework, which may be used to study the phases of the process in more detail, and as such provide new insights.

While the outcomes regarding dieselgate and EV's are considered to be strong, because different methods turned out more or less comparable results, and provided more insights, some recommendations can be made for further research. For one, the factors measured using the 3C-metrics considered key figures pertaining to the entire company. In other words, for BMW and VW, no distinction was made between finances related to non-EV's and to EV's. Doing so might provide more accurate insights into the influences of these factors. Additionally, the research was done taking the entire group and not just the brands into consideration. Volkswagen is a huge automotive company, with many brands and the figures related to the entire group. Doing the same research, but on a brand level might turn up some additional insights. The case study included only 3 companies to represent the industry. While these companies were chosen due to high representation (as they are market leaders), further research involving more, if even possible, all companies in order to create a more complete representation of the industry. Furthermore, the case study specifically focused on pinpointing differences between the pre- and post-dieselgate era's, in order to determine differences, and on the basis thereof warrant further investigation. As such, the influence of dieselgate on the rise of EV's was specifically found as a result. However, the framework offers the possibility to analyse it into a more general direction as well. In other words, further research could look into other factors that have driven the rise of EV's, and gain more understanding regarding other influences on this process (like for instance, the influence of Tesla showing the feasibility of EV's). The phases-framework might also be of use for this. Lastly, as was also mentioned in the discussion of section 8, many underlying, indirect influences were found between the affected factors. These relations were found to be one-sided, namely the effect of factor 1 on factor 2. It stands to reason however, that many of these factors are also true in reverse. It could be that factor 2 also affects factor 1, thereby creating a feedback loop. These reverse relations were not researched specifically in this research, but it stands to reason that this might be the case for several underlying relations. Therefore, it is worth to see investigate further if these relations exist, and what they entail exactly. This not only leads to more insights regarding the automotive industry and dieselgate, but also leads to more insights regarding the underlying relations of the factors in general, something that is also not researched in this thesis, as all factors of the generic framework were treated and analysed separately.

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# A Search terms in the literature review

- Dieselgate
- Dieselgate + causes
- Dieselgate + effects
- Dieselgate electric vehicles
- Rise of electric vehicles
- Uptake of electric vehicles
- Recent developments + automotive industry
- Recent developments + electric vehicles
- Dieselgate + innovation + automotive industry
- Dieselgate + innovation + electric vehicles
- Standard battle
- Standard battle + innovation
- Standard battle + electric vehicles
- Innovation frameworks
- Innovation frameworks + automotive industry
- Innovation frameworks + electric vehicles
- Innovation theory
- Innovation theory + automotive industry
- Innovation theory + electric vehicles
- Innovation diffusion
- Innovation diffusion + automotive industry
- Innovation diffusion + electric vehicles
- Disruptive innovation
- Disruptive innovation + automotive industry
- Disruptive innovation + electric vehicles
- Radical innovation
- Radical innovation + automotive industry
- Radical innovation + electric vehicles

# B Interview transcripts

## B.1 Overview of interviewees

Table 29: Interviewees, alongside a description and how they were found

| **Name** | **Description** | **Found through** | **Date of interview** |
|---|---|---|---|
| Interviewee A | Author of several papers on standard battles | Literature research | 8 May 2021 |
| Interviewee B | Author of a paper on radical innovation | Literature research | 15 May 2021 |
| Interviewee C | Author of several papers on standard battles | Recommendation by Interviewee A | 18 May 2021<br>17 September 2021 |

## B.2 Transcript of Interviewee A

Nou heel fijn. Fijn dat je er bent en hier even tijd voor hebt. Heeft u kans gehad om het framework even te bekijken dat ik heb gestuurd?

- Nou nee, eigenlijk niet. Ik loop een beetje achter met de mails. Wanneer heb je het gestuurd?

Vrijdag

- Oh ja, nee daar heb ik nog niet naar kunnen kijken nee.

Helaas. Nou dan zal ik het er snel even bij pakken, dan kunt u het even zien en dan leg ik het even kort uit. Dan kunnen we het daarna snel even bespreken. Als het goed is kunt u het nu zien? [framework wordt gedeeld op scherm]

- Uh, ja. Oeh. Zo, dat is complex.

Ja, dat lijkt zo, hoor. Het valt eigenlijk best wel mee. Wat ik heb gedaan is, ik heb een aantal frameworks met betrekking tot innovatie samengevoegd om het proces van een innovatie die het overneemt van de incumbent technologie, te beschrijven. En in dit deel [tweede fase] zit uw werk over de standard battle verwerkt. Want wat ik doe is namelijk... Ik heb geobserveerd dat eigenlijk vrijwel elke autofabrikant overstapt van verbrandingsmotoren naar EV's. Nou dat beschrijft u ook in uw paper over de standard battle, dat de standard battle tussen EV's en ICE vehicles eigenlijk gewonnen is door EV's. En wat ik hier beschrijf, is eigenlijk van links naar rechts, een nieuwe innovatie, die wordt geïntroduceerd op de markt. Nou hierboven, dit frame is eigenlijk de diffusion of innovation theory. Dus die wordt geïntroduceerd op de markt door innovators en snel opgepakt door early adopters. Daarna breekt het door op de markt als het succesvol is, en hier begint eigenlijk het proces van waarin de standard battle plaats heeft tussen de innovatie en de incumbent technology. En waarbij uiteindelijk dus de innovatie het proces wint. En dat is dus wat er nu gaande is in de auto-industrie. En ik heb eigenlijk daar wat vragen over. De eerste daarvan is: denkt u dat dit proces op deze manier juist beschreven wordt? En de tweede, en dat is eigenlijk mijn hoofdvraag, is of dieselgate invloed heeft gehad op dit proces, en zo ja: via welke factoren. Dat zijn eigenlijk de vragen die ik u vandaag wil voorleggen. De blauwe vakjes zijn de factoren, een del daarvan komt ook uit uw werk omtrent de standard battle. Dus die 29 factoren zijn geclusterd in een aantal van deze. Ja, u zult ze niet aan naam herkennen, maar in de thesis zelf wordt dat wel wat beter beschreven.

- Hee, heb jij gekeken naar dat paper van Suarez uit 2004 in research policy? Ken je dat?

Nee, dat heb ik niet bekeken.

- Want wat hij... Ik begrijp een beetje uit jouw verhaal dat je die factoren een beetje wil toekennen aan stadia toch?

Ja, exact

- Ja, en dat is precies wat het doet. Het is wel een conceptueel paper, dus er zit geen empirische data achter zeg maar, maar op zich zijn redenering is wel duidelijk. En ik heb ook wel wat onderzoek daarna gedaan. Niet expliciet, zeg maar, maar daar komt het vaak in naar voren, dat ik dan concludeer dat een bepaalde battle die ik bestudeer, dat die dan in een bepaalde fase zit, en dat dan eigenlijk blijkt dat een bepaalde factor dan ook belangrijk is. dus dan zeg ik: oké, nou het lijkt zo te zijn dat die factor dan ook in die fase belangrijk is. Maar ja, dat kan je nooit echt zeggen met duidelijkheid, want het is natuurlijk maar case hè. Daar zou je eigenlijk heel veel cases voor moeten bestuderen, als je dat echt wil concluderen met zekerheid.
- Ik kan je daar wel wat over vertellen, over die cases, maar ik kan dat ook niet met zekerheid zeggen, zeg maar. Misschien dat je daarvoor beter gewoon die papers kan lezen. Ik kan ze je wel sturen na het interview. Want dat we dan beter misschien op die andere kunnen focussen. **Dus jouw eerste vraag is, is dit raamwerk een beetje logisch? Ja, ik denk het wel. Ik weet niet of die factoren ook inderdaad echt in die fases zeg maar thuishoren. En of je deze fasen zou moeten onderscheidden. Want wat Suarez bijvoorbeeld doet, is die zegt: er zijn echt 5 fases.** Dus je begin echt met alles tot het moment dat er een eerste echt werkend prototype is. Dat is de eerste fase, dat is een hele lange fase. R en D eigenlijk hè. En dan kom je bij de fase tussen het prototype en het echte product. Dus echt een working prodct zeg maar. Dat is de tweede fase. Derde fase is het moment dat inderdaad zo'n product de markt betreed, en een eerste ... early frontrunner. Dan is de vierde fase echt die battle. Echt die technology battle, daar richt ik me vaak op. En die vijfde fase is eigenlijk alles wat daarna plaats vindt, dus eigenlijk het moment nadat het dominant design is established, dus eigenlijk die area of incremental change.

- Ben je een MoT-student?

Nee, TIL. Engineering- specialisatie.

- Aha, ja dan is het logisch dat je die paper... Die paper heb ik ook in een van mijn colleges ook gebruikt, maar ja die heb je niet gevolgd, dus dat is dan logisch. ja, dus even kijken of die factoren echt... Ja ik weet natuurlijk niet welke factoren er onder elk van de categorieën vallen... Ja kijk even naar die paper van Suarez en naar die follow-up papers. Ja, ik zal ze je wel opsturen.

Ja, hele goeie. En dan zou u eigenlijk adviseren om wellicht eens even aan de hand daarvan mijn fases wat meer te structureren dan? Want ik moet eerlijk zeggen... de witte blokken zijn in mijn ogen de fases, en dat heb ik dan in 2 grote groepen opgedeeld aan de hand van diffusion. Maar ik moet eerlijk zeggen dat dat...

- Ja het hoeft niet. Je kan ook gewoon zeggen van... Kijk, het is meer zo van, ik denk neem in ieder geval dat paper mee. en ik ken nog een aantal andere papers die ook spreken over verschillende fases. Je kent dat model van Roland Ortt ook wel natuurlijk. Ja die heeft dan weer 3 fases, bijvoorbeeld. **Ja, ik denk meer dat je die wel zou moeten beschrijven in je stuk, om dan uiteindelijk te komen tot jouw model. Dan zeg je van: nou ik wil 2 fases omdat ik die duidelijk wil hebben, of dat ik het wat simpeler wil maken zeg maar.** Het is aan jezelf. je bent zelf de onderzoeker, dus je hoeft niet te zeggen van; nou dan ga ik... Maar je kan ook zeggen van: Nou, ik ga gewoon voor dat model van Suarez, want ie is al zo vaak gebruikt. Die is ook vaak geciteerd, dus dan ga ik eens kijken... **Want dat kan je ook doen, dat je forward search doet op dat paper van Suarez, want volgens mij is dat 200-300 keer geciteerd. Het zal best wel een paar keer ook zo zijn, nou ja dat moet haast wel, dat die factoren ook daadwerkelijk zijn bestudeerd, in empirische data.** Met een case, of zelfs meerdere cases.
- Wat was je tweede vraag ook alweer?

Mijn tweede vraag is eigenlijk of u denkt dat... aan de hand van deze factoren, dus de blauwe vakjes, waarvan u denkt dat dieselgate daar invloed op heeft gehad.

- Dieselgate... moet je even uitleggen, wat dieselgate ook alweer was.

Dat was het Volkswagen emissie schandaal. Dus Volkswagen die sjoemelden met software, waardoor het op papier en in de testen leek alsof ze 40 keer minder NOx uitstootten, dan dat ze daadwerkelijk op de weg deden. En dat is in 2015 aan het licht gekomen, en mijn observatie is eigenlijk dat vooral daarna de hele markt in de richting van EV's is gaan evolueren, omdat dat schandaal liet zien dat diesel geen sustainable technologie was, in de zin van... dat het aan de regels kon voldoen. En mijn hypothese is dat dat heeft doorgewerkt in deze factoren, en dat daardoor de markt in de richting van EV's is gaan bewegen.

- Ja, nou kijk, het is eigenlijk zo dat, ik zie dat dieselgate dan, dat zou ik zien als een chance event, eigenlijk. Zomaar gebeurt iets, je kan het niet verklaren, en ja dat is iets daar heb je als bedrijf ook geen invloed op, maar dat zorgt ervoor dat bepaalde factoren dat bepaalde factoren worden beïnvloed. **En dat is bijvoorbeeld reputatie, de reputatie van Volkswagen gaat daardoor naar beneden. En dat zorgt er dan weer voor dat bedrijven in die hele value chain, maar ook consumenten, zeggen van: Nou, ik ga niet meer voor een Volkswagen auto, of een Volkswagen auto die elektrisch is natuurlijk dan, of hybride. Dus dat is dat. Maar wat het natuurlijk ook direct betekent, ik denk dat het ook effect heeft op technologische superioriteit van zo'n technologie, van zo'n product. Die neemt af. Want technologische superioriteit, dat is een hele grote container-notion, dus eigenlijk een hele grote black box. Maar dat bestaat ook natuurlijk, uiteindelijk, uit dat aspect van sustainability. Ik denk dat je dat er ook onder zou kunnen zetten. Helpt dat een beetje? Dus ik denk niet dat het een directe factor is. Het is gewoon een event, een chance event.**
- Schillling zegt daar ook wel wat over. Ken je Melissa Schilling? Melissa Schilling heeft ook wat onderzoek gedaan hiernaar in 1998, in the *Academy Management Review*. Maar ook in 2002, in *Academy Management Journal*. Die zegt dus bijvoorbeeld, 'By chance, certain events occur that influence certain factors'. Dat zegt ze dan, dat is dan iets wat dan... Daar is ook weinig empirisch bewijs voor. Maar je ziet inderdaad in heel veel verschillende cases, dat dat inderdaad wel wordt herhaald, dus dat dat bewijs steeds sterker wordt. Heb je daar wat aan?

Zeker, zeker. En mijn idee met deze interviews is, ik heb een aantal hypotheses opgesteld over waar ik denk dat dieselgate op deze blauwe blokjes invloed heeft gehad. En wat u zojuist beschrijft, zou ik dan bijvoorbeeld... rechts bovenin heb ik staan 'External influences/ Context'. Even gewoon puur afgaande op wat ik nu hoor over zo'n chance event, zijn dat inderdaad wel de suggesties die redelijk resoneren met mijn eerdere bevindingen.

- **Ja, zo zou ik het inderdaad zien, als een external influence.**

Nou, dat is heel fijn. En verder als u dit zo ziet, denkt u van: nou daar wil ik nog wel even wat over zeggen? Van: Ik denk dat dieselgate daarop doorwerkt. Of heeft u nog verduidelijking nodig bij vakjes? Het punt is natuurlijk: ik moet eventjes kijken hoe ik hier een handige middenweg, maar in mijn thesis wordt het natuurlijk wel wat uitgebreider beschreven wat er onder elke factor valt, dus wellicht moet dat even in dit documentje ook opnemen.

- Ik kan het wel ongeveer begrijpen. **Kijk,een aspect als regulaties, of regulations speelt daar natuurlijk ook wel weer in mee, want het heeft alles te maken met CO2 reporting. Dat daar ook iets in zit. Maar regulations, zoals ik dat zie is meer, van een standaard, of wat een technologie wordt opgelegd in de markt. En dan betekent het dat er eigenlijk geen battle is.**

**Omdat het eigenlijk in principe daardoor bepaald is? Zo van: je mag niet zoveel meer uitstoten dan dit, en dus valt dan de ene technologie eigenlijk per definitie af?**

- **Ja, bijvoorbeeld. Dat zou je natuurlijk dan ook kunnen zien, dat dan een aspect is. Het is ook vaak zo, dat het een verzameling is, eigenlijk, van factoren die ervoor zorgen dat een bepaalde technologie dan succesvol wordt of niet. In dit geval, ja, een incumbent eigenlijk niet voortzet, zeg maar.**

Ja, dat is dus eigenlijk wat de tweede helft probeert te beschrijven. Dit is echt heel erg gestoeld op uw standard battle framework. Dus deze 4 factoren [rechts onderin] zijn dan van toepassing op dit hele deel, terwijl deze [rechts midden] dan bijvoorbeeld alleen op dit ene deeltje van toepassing is. **Dus inderdaad een samenspel van factoren. Wellicht zou ik inderdaad nog even iets beter kunnen aangeven dat deze dingen [rechts onderin] ook nog samenwerken. Want, ja, regulation heeft toch ook wel invloed op de strategy van een bedrijf. Dus misschien onderlinge... als een groep... dus dat het wellicht ook onderlinge invloed heeft.**

- **Ja**

**Nu lijkt het een beetje alsof ze los erin komen, terwijl er eigenlijk verbindingen tussen moeten zitten. Is dat...?**

- **Er zitten zeker verbindingen tussen, ja zeker. Als je daar wat meer over wil weten, dan is er weer een paper waarin wij onder andere dat uitleggen, die verbindingen.**

Is dat die battery electric/fuel cell battle?

- **Nee, dat is de system dynamics model of standard competition. Die zit in *IEEE Transactions on Engineering Management.* Meest recent, dat is 2020.** En dat is een... Die vertelt eigenlijk aan de hand van verschillende cases, zet ie eigenlijk een... gebruikt simulatie als methode. En dat gaat over verschillende factoren, en dat gaat over verschillende pijltjes tussen de verschillende factoren. dus dan krijg je echt een soort van complex model. En zo complex zelfs, dat eigenlijk alleen door middel van simulatie echt goed kan worden doorgrond.

Maar, dan begrijp ik dat dat vooral een kwantitatief model is. Dus bijvoorbeeld, moet je de invloed van regulatie daarin meenemen, of begrijp ik dat verkeerd? Of sorry, dan zou je de regulatie een soort factor toekennen, van succeskans of iets dergelijks, voor een standard battle? Een win-kans?

- De regulator is een belangrijke actor, die er voor kan zorgen dat een bepaalde standaard succesvol wordt. Want die wordt opgelegd hè. Ik kijk nu even naar het model, maar ik zie. Ik kijk even bij regulator, dan is er geen relatie tussen die regulator en een van de andere factoren. Dat is gebaseerd op heel veel verschillende cases. En in een andere zie ik het ook niet, dus dat is... Ja, nou dan weet je dat. Maar kijk, als jij dat wel kan vinden, dan is dat natuurlijk erg interessant.

Ja, dat is natuurlijk de lol van een thesis, de nieuwe verbanden leggen. [...]

- Er zijn nog andere dingen die je wil weten? Ja, ik kan er natuurlijk heel veel over vertellen, wat zijn je specifieke vragen?

Nou vooral eigenlijk of u nou nog zegt van: Ik zie hier factoren die ik... Of ik weet een factor die ik hierin echt in mis, of juist eentje waarvan ik zeg dat is helemaal overbodig? Het doel van deze interviews is tweeledig. Namelijk aan de ene kant wil ik graag dit model valideren en aan de andere kant wil ik de invloed van dieslegate testen aan de hand van deze interviews. En wat ik ook een belangrijk dingetje vind, wat ik zeker niet wil overslaan: Ik heb vooral bedacht om aan mijn interviewees te komen via snowballing methode, dus ik zou u ook heel graag willen vragen of u namen te binnen schiet, waarvan u zegt: benader die eens voor een interview?

- Maar ja, dan is de vraag: Wat voor expertise moet die persoon hebben?

Ja, ik zou zeggen inderdaad, onderzoek naar innovatie, onderzoek naar de automarkt, EV's, standard battle of gerelateerde...

- Oh ja, dan zou je eigenlijk **Daniël Scholten moeten spreken. want die heeft meegewerkt aan dat artikel over EV's, dus die weet veel over EV's. Niet zo specifiek over standaard gevechten, maar wel over EV's.**

Nou perfect, hij kan dan bijvoorbeeld een heel andere hoek belichten, wat hij denkt wat invloeden zijn geweest op die EV... Ja, perfect, dat soort mensen zoek ik. Weet niet of er verder nog eentje heeft waarvan u zegt: dat schiet me te binnen.

- Ja, kijk, als je het hebt over puur standaardisatie gevechten, dan moet je toch meer kijken naar de mensen die daar onderzoek naar hebben gedaan. Al die mensen hebben in principe ook expertise, dus noem maar op. ja, de mensen waarbij ik bijvoorbeeld samen heb gewerkt natuurlijk, maar ook bijvoorbeeld mensen die ik net noemde. Dat is misschien wat lastiger om te contacteren, omdat die in Amerika zitten.

Ja, dus u zou zeggen, kijk even naar de coauteurs van... Ik heb dus met name naar twee specifieke artikelen van u gekeken. Eentje uit 2011, die echt daadwerkelijk de 29 factoren beschrijft, en eentje uit 2017 waarin de battery versus fuel cell electric vehicle word beschreven. Dus u zou zeggen, benader de coauteurs daarvan?

- Ja, of van andere papers. Je moet maar even op Google Scholar kijken. Dan zie je wat andere mensen. **Dan kom je bijvoorbeeld bij mensen als Henk de Vries. Maar ook andere mensen die onderzoek hiernaar gedaan hebben, waarmee ik niet heb samengewerkt, zoals bijvoorbeeld... Ja, daar heb ik ook mee samengewerkt, Simon den Uijl, die weet ook wel veel van deze materie. maar die werkt nu in het bedrijfsleven.** Maar die heeft misschien ook wel tijd.
- **Als je kijkt naar een factor die hier mist, voordat we aan het einde van het interview komen, we zijn er bijna natuurlijk... Characteristics of the firm.**

Oke, ja, die heb ik zelf opgenomen in Company Strategy and Finances. Wat ik aangaf, uw factoren heb ik inderdaad geclusterd met andere dingen, en daar zit die wat mij betreft in...

- Oke, nee dat is mooi.

Ik kan hem misschien iets duidelijker eruit lichten.

- Kijk, want nu is het eigenlijk Company Strategy and Finances. Dus dan zou je zeggen, **dingen als reputatie, die dus hier heel erg belangrijk zijn,** die zitten daar dus niet in.

Ik ga u even snel laten zien hoe ik dit gedaan heb. Als u rechts kijkt [afbeelding factor matrix], dit zijn de 29 factoren uit uw paper uit 2011. En in die Company Strategy and Finances, heb ik dus zaken zitten als Learning Orientation, Appropriation Strategy...

- Oh, ja ik zie het. Maar ja, dat is natuurlijk... **Maar die Company Strategy and Finances die zou ik dan hernoemen, want nu lijkt het alsof het alleen die strategie is en financial resources. Ja, dat is dan een beetje onduidelijk misschien. Maar dat is misschien een detail.**

Nee, ik vind het wel een sterke strategie en finances vallen wel onder characteristics, terwijl misschien het tegenovergestelde niet waar is. Hele goeie. en inderdaad 'Brand reputation' heb ik staan onder...

- State and image of (the manufactuer) of the incumbent technology

Ja, dat vond ik, zeker gezien het feit dat dieselgate natuurlijk een redelijke knauw gegeven heeft aan het hele proces, leek me dat een sterke om er toch uit te lichten. En in andere frames kom ik een specifieke factor.

- Oke, en waar staat die dan in dat model.

Ik heb hem hier [rechts midden in framework] als invloed op de lock-in, dus het feit dat de wereld zeg maar heel erg geijkt is op 1 technologie, dat ie dat direct beïnvloed. en ik heb hem hier[ links onderin] staan,. als wat een aanleiding kan zijn om een nieuwe innovatie naar de markt te brengen. Dus een technologie presteert slecht, dat geeft aanleiding om iets nieuws te gaan maken. Een nieuwe oplossing te verzinnen

- Oke. Ja, ik kijk nu even naar het model van Suarez, en dan zie ik dat hij dat heeft geplaatst... **Reputatie... Phase 1 en Phase 4. Dus het is ook in Phase 4 belangrijk. Ja logisch he, reputatie wordt natuurlijk dan belangrijk, want ook dan spelen expectations een rol.** Maar goed.

Oke, ik ga dat Suarez zeker bestuderen.

- Ja, zou ik doen. **Maar je hebt 'm al staan, want kijk, je hebt die state en image, die heb je al bij lock-in ends staan. Die zit dus eigenlijk al in die growing phase. Dus wat dat betreft is het een mooi model, maar ik zie ik ook dat je veel literatuur hebt gebruikt, dus dat ziet er goed uit.**
- Maar goed we komen aan het einde van het interview, ik denk we ver zijn gekomen.

## B.3 Transcript of Interviewee B

Nou, heel fijn dat je er bent, en ik vroeg me af heeft u tijd gehad om even te kijken naar het documentje dat ik u al had gestuurd?

- Heel snel, heel snel. Niet in detail. Dus misschien kan je me nog een beetje erdoorheen lopen?

Natuurlijk. Ik zal het even op het scherm zetten, dat is net even wat makkelijker. Als het goed is kunt u het nu zien. Wat ik heb gedaan is op basis van wat literatuur, of aardig wat literatuur, heb ik 8 verschillende frameworks gevonden die naar mijn idee verschillende fases en manieren van innovatie beschrijven. en die heb ik samengevoegd tot dit framework. En wat hier eigenlijk in te zien is, is hoe een nieuwe innovatie ontstaat, op de markt wordt gebracht, dan wel door een incumbent, dan wel door een nieuwkomer. En op het moment dat het succesvol is, op e grote markt, dus de macro markt eigenlijk gaat concurreren met een incumbent technologie, en het het daar uiteindelijk van overneemt. En aan de hand van dit framework beschrijf... Nou ja, dit is dus een iets algemener framework, maar een proces dat je hier bijvoorbeeld ook kunt zien is, de doorbraak van EV's, dus elektrische voertuigen, dat is een innovatie die zowel door incumbents, als door nieuwkomers op de markt is gebracht, en die is op dit moment, dat is de observatie die ik heb gedaan, is het op dit moment aan het overnemen van verbrandingsmotoren, en zal het daar op den duur volledig van overnemen. En dan vervolgens heb ik aan de hand van de frameworks die ik voor dit proces heb gebruikt, in die blauwe vakjes, allerlei factoren aangegeven die daar mijns inziens invloed op hebben. ook weer gebaseerd op de frameworks die ik heb gebruikt. En ik heb hier [links midden] onder meer uw framework over radical innovation in gebruikt, dat zit met name bij de incumbents die een technologie naar... een innovatie naar de markt brengen. En ik wil het eigenlijk met u hebben over de vraag of u aan de ene kant denkt dat dit framework inderdaad het proces beschrijft wat ik zojuist uitlegde, en of de factoren daarin naar uw idee kloppen, anders zouden moeten, andere plekken zouden moeten staan, nieuwe erbij, sommigen eruit, bijvoorbeeld. En het tweede deel is eigenlijk dat ik aan u wil vragen om met mij mee te denken over: waar denkt u dat de invloed van dieselgate gezeten heeft? Dus het Volkswagen emissie schandaal. Mijn theorie is dat een aantal van deze factoren versterkt dan wel versneld zijn door dieselgate, dus even een voorbeeld: dat een bepaalde factor aanvankelijk minder invloed had, maar door dieselgate meer invloed heeft gehad op dit proces.

- En dan is dieselgate met name als trigger voor versnelling van elektrische aandrijflijnen?

Ja, mijn hypothese is dat dieselgate daar inderdaad invloed op heeft gehad. Wat we nu zien is dat eigenlijk alle grote automaatschappijen overstappen van verbrandingsmotoren, naar elektrische voertuigen. En mijn theorie is dus dat dieselgate daar invloed op heeft gehad. En mijn vraag is dus eigenlijk: via welke van deze factoren heeft die invloed gespeeld? Mijn theorie is dus dat het geen directe invloed is geweest, maar dat het bijvoorbeeld een invloed kan hebben gehad op een van de factoren die u hier ziet staan.

- En dus dat zijn de blauwe factoren, dus dat is other firms, characteristics of the market in het begin...

Ja, ik heb ze dus ook hieronder in een soort lijstje ook staan...

- Ik zag het. Allright, en de starting phase gaat in dit geval dus echt over de innovatie-kant, dus dat zijn elektrische aandrijflijnen.

Ja, dus daar zou ik dan bijvoorbeeld in dit geval Tesla en Nissan, met de Leaf, in plaatsen. Dus 2 maatschappijen die toch wel echt aan het voorfront stonden van de EV-opkomst.

- Ja, welke frameworks heb je grosso modo, niet in detail hoor... maar even een paar termen?

Dat kan ik je ook snel laten zien [afbeelding factormatrix]. Van der Kaa heb ik gebruikt, dat gaat over standard battles. Hier heb ik ze staan. Dus van der Kaa gaat over standard battle, dus dat gaat over twee technologieën die om dominantie met elkaar strijden. Ik heb gebruikt Oldenberg, die eigenlijk gebaseerd is... Dat is de innovation diffusion theory, de welbekende S-curve. Uw eigen framework omtrent radical innovation bij incumbents. Een framework van Dijk, over disruptive innovation die doorbreekt op de markt. En Hardman , die een serie gemeenschappelijke eigenschappen beschrijft van succesvolle disruptieve innovaties die op de markt doorbreken. en Cowan, een wat oudere, die beschrijft welke factoren het einde van een lock-in kunnen betekenen. Dus in dit geval, lock-in zou dan bijvoorbeeld refereren aan dat de hele maatschappij is ingericht 1 technologie en dat daarom een andere technologie veel moeite heeft om daarin door te breken.

- Ik ken deze niet, maar dat is niet erg hoor, want ik ben al een tijdje uit het theoretische veld. Zijn een of meerdere van deze auteurs ook gerelateerd aan het werk van Frank Geels, Jan Rotman, over niche-management en dat soort zaken?

Niet dat ik weet, nee. Die zaken ben ik ook nog niet tegengekomen, die u beschrijft.

- En Marco Hekkert, innovation-systems?

Nee, ook niet.

- Oké, maakt niet uit. Hoever ben jij? Van laat ik zeggen, als jij het nog leuk vindt om nieuwe frameworks toe te voegen, dan kan ik daar een tip geven misschien nog. Maar als je zegt: ik ben eigenlijk een fase dat... ik moet eigenlijk gewoon data verzamelen, en dit framework testen. Dan kan ik daar wat meer focus op leggen?

Nee, graag. U bent de tweede persoon die ik interview en een groot deel van deze interviews draait toch wel om de verificatie van dit framework. Dus ja, als u zegt: ik heb een framework waarvan ik zeg dat zou van goede toepassing hierop zijn, dan absoluut. Graag. Ik luister.

- Nou prima. He, dus eventjes kort gezegd waar ik zelf vandaan kom. Dan komen we vanzelf op een paar factoren, die wel erin staan, en een paar factoren die misschien niet erin staan. Hoe ik... het lijkt natuurlijk behoorlijk op de case study, die ik op een andere manier met brandstofcellen heb gedaan. Ik heb een iets andere focus, maar vergelijkbaar, dus echt leuk dat je belt en we het erover kunnen hebben. In mijn promotie-onderzoek was toch wel een beetje de vraag van onder welke voorwaarden... Sowieso, hoe moeten we chocola maken van wat we nu zien gebeuren met die brandstofcel technologie en waterstof in de automotive industrie, wetende dat het klassieke incumbent is. En dat die niet het meest geneigd zijn om over te stappen. Elephants don't dance, and dinosaurs don't fly, dat idee. En je zag toch wel een kleine... je zag wel dingen veranderen in de industrie. De vraag is natuurlijk wat zie je nou precies veranderen. Want je ziet...de verkopen die zijn natuurlijk nog vergelijkbaar. Diesel en benzine, allemaal fossiel. Je ziet wat prototypes ontstaan, maar ja hoe moet je dat dan duiden? Je ziet wel wat patenten ontstaan, dus dan zie je aan onder de oppervlakte van: He, dat zou er wel eens over een jaar aan kunnen komen. Zien we daar nou al veranderingen in? En ik ben toen tot dat framework gekomen.
- Voor me zelf ook wel enigszins opvallend, ik ben toen institutionele theorie ingerold. Waarbij ik een industrie niet beschrijf als een collectie bedrijven, die zijn allemaal strategisch bezig om posities te creëren, dat gebeurt ook. Maar we weten dat er ook een hoop onderligt: norms, values en regulations. Ik noem het maar even gedeelde normen, maar dat noemen ze dan instituties. een institutionele omgeving die eigenlijk voor al die bedrijven eigenlijk vooral beknellend is, dan dat ruimte laat voor strategische besluitvorming. Dus kort samengevat: al die bedrijven doen precies hetzelfde. Er is maar een hele marginale rol waarop ze kunnen afwijken. **Zo zie ik niet. Ik denk dat al die bedrijven binnen de ruimte die die institutionele omgeving biedt, dat ze daar ruimte kiezen om hun eigen strategie te bepalen, maar die institutionele omgeving is heel erg belangrijk om te beschrijven wat zo'n industrie doet. En dan is de vraag: hoe kan je meten om te zeggen: ja, maar wat dan die institutionele omgeving? Een aantal dingen zijn logisch: dat zit in die regulering, dat is het makkelijkst.** Weet je wel, California Air Resources Board, de eis was 2030, extreem belangrijk. Inmiddels is Europa gelijk getrokken dus dan zie je gewoon wel de CO2, voluntary agreement, nou die ken je allemaal. Dus dat levert een omgeving op van: nou, daar moeten het mee doen.
- **Maar wat minder makkelijk te vatten is, en daarom heb ik zo'n ellenlang proefschrift geschreven, is dat je in die industrie een veranderd beeld krijgt van: waar gaan we heen, wat is het eindbeeld?** En een hele interessante om dan te kijken, is Harro van lente, dat is een professor in Maastricht, vroeger bij Utrecht. **Een belangrijke indicator van R en D ontwikkelingen binnen bedrijven gaat over 'waar denken we dat het heen gaat? Expectations.** De rol van expectations, daar gig zijn proefschrift ook over. **En ik denk dat er heel veel aan het veranderen is over de expectations hoe de aandrijflijn van de toekomst eruit ziet. En dat betekent dat 20-30 jaar gelende, was er echt nog de verwachting bij die industrie: We gaan het rijden met die verbrandingsmotor, dat gaat we allemaal wel redden.** Dus ik heb 20 jaar geleden interviews gedaan, en die bedrijven zeiden allemaal: Tuurlijk, we moeten steeds schoner, maar die hybride, dat ziet er ook goed uit. En de Prius was toen net uit, dus iedereen dacht: Daar verlengen we het nog wel een tijdje mee. Óóit moeten we naar elektrisch, fair enough, maar we redden het hier wel mee. **En dat is een beeld wat de afgelopen jaren natuurlijk langzamerhand, echt gekanteld is, in de afgelopen 3 tot 5 jaar extreem.** Dat het beeld van elektrische aandrijvingen niet alleen iets is wat er aankomt, maar gewoon daar kun je niet meer omheen.
- Jouw vraag gaat dan over de rol van dieselgate, **ik ben het eens met je hypothese: dat is niet de aanleiding geweest, maar het heeft een enorme versnelling gebracht aan het beeld binnen die industrie: hoe we ook sjoemelen, die verbrandingsmotor, daar komen gewoon uitlaatgassen**

**uit, en die moeten naar nul emissie. Dus laat ik zeggen, de verwachtingen over toekomst, vind ik een hele belangrijke variabele om te omschrijven hoe dat in de sector gaat.**

Ja, en als u zo dit framework dan bekijkt, waar zou u denken: Daar zou ik dat inzien? Ziet u dat dan bijvoorbeeld bij de Adopters, of bij de company strategy?

- Ja, ik denk dat daar helemaal links, innovation or new technology. Voor mij, een van de belangrijkste dingen van mijn framework, of waar ik het meest over na heb gedacht, waarvan ik denk: waar gebeurt dat nou? Volgens mij is de term 'Institutional arena', als ik het goed heb. Dan zou je mij proefschrift even... Zo zie je maar, ik ben mijn proefschrift vergeten inmiddels, en welke termen ik precies gebruik. Maar, Institutional arena' is de zeg maar de plekken waar de industrie elkaar tegenkomt, bij elkaar informeert, waar verwachtingen worden gewekt, waar beeldvorming ontstaat over hoe ziet die toekomst eruit? Het is supervaag en conceptueel, dat besef ik aan alle kanten. Maar ik was er op een gegeven moment wel van overtuigd: He, op een gegeven moment, op sector niveau, begint het te schuiven. Dat is denk ik wat er gebeurt. **En dat zie je bijvoorbeeld terug, als je kijkt, en zo heb ik allerlei congressen, je hebt een aantal van die congressen daar ben ik eigenlijk, daar heb ik een soort data-analyse gemaakt, van wat voor topics komen daar eigenlijk op de agenda? Wat wordt daar besproken?** Uiteindelijk kon ik dat niet publiceren, maar ik probeerde te vatten wat speelt er nou precies binnen die industrie, en zie je daar, kan je dat coderen en kan je op die manier verandering van focussen vaststellen? En dat begint natuurlijk met de titel van het congres, maar dat ook gaat ook over welke papers worden gepresenteerd en dan zie je mondjesmaat brandstofceldingen langskomen. Ja, als je een brandstofcelpaper presenteert, dan zit daar iets van werk achter. Dus dat zijn R en D uitgaven geweest, weet je wel. Dus op die manier kan je flinters opvangen van wat er speelt, en daarbij een beetje het sentiment binnen de industrie vaststellen. op die manier ben ik er mee bezig geweest. **En dat begint dus op dat soort congressen, waar R en D mensen elkaar tegenkomen, en die gaan natuurlijk hun baas weer informeren, over de R en D plannen. En dan worden er op een gegeven moment verzoeken gedaan van: Joh, we hebben en brandstofcel programma nodig, en sommige bedrijven honoreren dat en sommigen weer niet. En daar ontstaan dan die kleine innovatie. dus die motoren die worden gestart uiteindelijk binnen die bedrijven, dus je innovation helemaal links, en dat is ingebed in het wetenschappelijk discourse tussen die sector en wetenschappers.**
- En wat daar dan ook gebeurt, laat ik zeggen, nou er zijn dan **3 grote gamechangers die daar kunnen plaatsvinden, zo beschrijf ik dat in mijn proefschrift. 1 is External shocks,** dingen als... In die tijd... 9/11 vond toen plaats. Dat was iets waarvan we dachten: Jongens hoe zit het nou met die olie ook, moeten we daar echt niet serieus... het verandert het beeld ook wel flink. **Een tweede was Newcomers,** dus toch die partijen... Nou, ik vind het verhaal van Ballard wat dat betreft een mooie anekdote: Ballard die was met brandstofcellen bezig, en die mikte er eens een keer een ander membraan in, kan ons het wat schelen? We doen er eens een ander membraan in, kijken wat er gebeurt. En dat was een proton-exchange membrane van Nafion, dat was de bedrijfsnaam die ze van DOW Chemical kregen. En wat bleek? Dat die een ongelooflijk hoog rendement had, dus ze stonden daar echt te klapperen met hun ogen, ze wisten niet wat ze zagen. en toen ze dat eenmaal zagen, dachten ze: Maar als dit kan, dan moeten we nu Mercedes bellen. Ze hebben echt iedereen daar over de vloer gehad, en de enige die meteen zag hoe veel effect dit zou kunnen hebben, was Daimler, omdat die al een brandstofcel-programma gehad had, als een van de weinigen. Die zagen meteen: dit is een gamechanger. Er werd meteen geïnvesteerd, aandelen in Ballard genomen. En zijn toen gaan rennen. **Dus dat soort een-op-een contacten van bedrijven, noem ik ook maar even deel van dat wetenschappelijk concours.** Dus die institutional envrironment, dus op die manier heeft Ballard een enorm effect gehad. en zo heeft Tesla natuurlijk nu een enorm effect, dat kan je niet... Ik kan niet beginnen... Ik ben alle objectiviteit kwijt met Tesla. **Die hebben op zo veel levels, hebben die effect gehad op het aannemelijk... legitimeren van elektrisch rijden. Niet alleen coole auto maken, laten zie dat je... Ook de legitimiteit van deze oplossing hebben ze volledig op de kaart gezet. dus dat is ook weer... heeft enorm de verwachtingen verandert.**
- Nou goed, er was nog een derde geloof ik. Maar die kan ik even niet.

Als u naar het scherm kijkt, ik heb hier [factor matrix] even een lijstje van uw factoren inderdaad. Dus, ik heb hier inderdaad onderaan de External shocks staan, die staat in mijn framework opgenomen in External Influences.. en inderdaad, Incumbents feeling threatened by the new entrants heb ik onder Other Firms geschaard, **maar als ik u zo hoor, zou ik zeggen dat de derde grote dan de Performance of the new technology zal zijn?**

- **Ja, volgens mij klopt dat.**

Dus zoals u ziet, dit is een beetje waar uw factoren in opgenomen zijn, in mijn framework. Maar ik had even toch een vraag, want u gaf aan dat U die expectations, die zou u hier [helemaal links] bij innovation or new technology zetten. Moet ik daar van u begrijpen dat u expectations als een aparte factor ziet? Of zou u zeggen: Nou, nu ik weet van die clusters, zou ik het ook wel daar onder sharen? Of begrijp ik u verkeerd?

- Ja, ik zit even te denken. Dus de vraag is of ie er in moet, he? Het is een beetje, waar begint het model en waar eindigt het model?

Temeer ook, omdat ik deze [innovation or new technology] ook eigenlijk meer als een... niet zozeer als een echte stap had, maar meer als een... hier begint het framework mee, en dan inderdaad, hier [starting phase] is de eerste fase.

- Ja, in feite zeg je: Er is een nieuwe stap gemaakt, en waar dat nou precies vandaan komt, of dat nou door een discource komt in de institutional arena, dat maakt even niet zoveel uit. Maar op een gegeven moment is er een nieuwe stap, volgens mij begint jouw model daar.

Min of meer. Ja. En eigenlijk zelfs hier [starting phase] wanneer het door een incumbent of newcomer wordt opgepikt, of eigenlijk begint te maken.

- **Ja, kijk daarvan zeg ik wel he, over het algemeen die innovation is er niet zonder een incumbent of newcomer.**

Dat is zeker waar, dat is niet een dingetje dat uit het niets komt. Nee, dat is... Misschien is dat meer een weergave-fout in mijn framework hoor, dus dat je bijvoorbeeld zou kunnen zeggen van nou we knippen dit eerste deel [innovation or new technology] eraf en we beginnen met een incumbent start met een technologie of een newcomer start met een technologie. Dus dat we dit stuk een beetje weglaten.

- **De optie is om dat eerste blokje iets meer te framen als een... ik heb dat in mijn proefschrift volgens mij, een soort... vruchtbare grond.**

Geen aparte stap, maar meer een beetje waar het idee vandaan komt ofzo?

- Ja, kijk, hoe ik het in mijn proefschrift heb proberen te duiden, is dat op een gegeven moment is er een vruchtbare grond of niet, voor innovaties. **Dat er de expectation is, dat we over 10 jaar elektrisch gaan rijden, dat zet allerlei bedrijven aan om te gaan zoeken. Die innovatie is er nog niet, maar het zet aan tot R en D activiteiten. Het zet aan dat Ballard zegt: dat zero emissie van Californië, dat was een van die dingen, daar moet gewoon nul emissie, en batterijen zijn onvoldoende, het werkt simpelweg niet, we gaan toch eens kijken naar brandstofcellen. Dus zonder die expectation, zonder een soort vruchtbare grond, of een stimuleerden omgeving, gaat niemand zoeken.**

Nee, het komt niet uit de lucht vallen. **Het is niet dat ze op een dag bedenken van laten we voor de grap hier naar gaan kijken, er moet een noodzaak zijn om er naar te kijken. En dat zou die eerste stap eigenlijk moeten zijn?**

- **Ja, een noodzaak of kans.**

Een noodzaak of kans.Kijk, dit zijn het soort inzichten waar ik nou echt naar op zoek was.

- Very good.

- En dat is met, **30 jaar geleden was dat met nul emissie en California Resources Board was dat eigenlijk... was dat een stepping-stone. Dat was al van: Wow, we moeten 10% van onze auto's over 10 jaar moeten een elektrische aandrijving hebben. Dat was een noodzaak dus hè, het was nog niet zozeer een kans, want elk bedrijf wist: die batterijen zijn niet goed genoeg. Maar het leverde wel op dat moment een enorme push om allerlei R en D activiteiten,** want er zitten die kansloos waren. ook type batterijen die het echt niet zijn geworden. Maar voor het zelfde geld, had het het wel geweest. Hadden die wel een doorbraak doorgemaakt. **En daarom ben ik ook enorme voor een sterke pressure vanuit overheden op thema's die het niet redden als daar niet ene natuurlijke commerciële noodzaak of kans ligt, dan moet een overheid ingrijpen en moet die push er maar op zetten. Technologie-neutraal, en dan kan het wel eens 10-15 jaar duren, en dat heeft het geduurd met batterijen.**

Ja. Begrijpelijk.

- Oke, maar als je daar... dat eerste blokje is dan misschien wel die omgeving, heb je dat dan zie je zowel newcomers als incumbents die gaan daarmee aan de slag. Dan ontstaat er vanzelf iets.

Ja, dus zoals u ziet omdat ik ook de starting phase en growing phase heb, hebben sommige.. Kijk dus deze drie [blauwe factoren] hierboven, die slaan op het hele traject. Terwijl deze [links onderin] bijvoorbeeld... **u ziet hier bijvoorbeeld twee Company Strategy and Finances staan, omdat die in de start-up phase een andere invloed hebben dan in de growing phase.**

- **Oke, daar kan ik me wel iets bij voorstellen.**

Ja, simpel gezegd, zou dat bijvoorbeeld betekenen dat, in the growing phase, wanneer the early mayority en late mayority het oppakken, dat dat is omdat zij hebben gezien dat een Tesla of een Nissan, het in de starting phase al hebben kunnen... vatbaar kunnen maken. en dus companies die er in de starting phase mee begonnen, die hebben andere Company Strategy... He, dus dat zijn de innovators en degenen die in de Mayority zitten, die hebben de strategy: Zij hebben het al ontdekt, en wij gaan het nu toepassen. Zonder dat ze het zelf ontdekt hebben. Dus vandaar dat sommige factoren er dubbel inzetten.

- Ja, ik vind die single starting phase, dat is nu een vrij klein blokje hè. Vrij, gesimplificeerd, dat moet ook in een model, dus dat snap ik. **Maar wat hier zo ingewikkeld aan is, is dat eigenlijk een hele belangrijke fase hier is, is dat je nog geen auto verkocht hebt.** En dat is zeker 10 jaar gebeurd, en dan zit je echt in de early-early-early innovators, echt. Early adopters is nog helemaal niet aan de orde eigenlijk, en dat hebben we natuurlijk de afgelopen 15 jaar... Nou, laat ik zeggen, die fase. die echte starting phase, dat je echt aan het ontwikkelen bent... Nou, zelfs Tesla is 5,6,7 jaar... Eigenlijk bouwden ze al voort op werk van anderen. Die 3,4 al bezig waren... Ik denk dat het bijna 10 jaar geduurd heeft voordat ze überhaupt een auto verkocht hadden. Laat het 6 jaar zijn.
- Dus, die fase is eigenlijk extreem belangrijk, en in die fase was er natuurlijk... al die incumbents die hadden natuurlijk wel hun programmaatjes, maar dat was meer gewoon kennisontwikkeling, als het ware. Ze vulden, zo noem ik het maar, de kennis-stuwdam. En om de echte ontwerpfase te maken... Wat voor type auto is kansrijk, welke match kunnen we maken? Gegeven de market characteristics, dus dat klopt. Heel belangrijk. en de auto, zoals die er nu uit ziet, dat vind ik zo interessant aan technologie-dynamica, die beschrijft welke ontwerpkeuzes allemaal zijn gemaakt. Dat het nu een Tesla is geworden, daar zitten 100 of 1000 keuzes achter. Die auto had er ook anders uit kunnen zien: dat had niet een schermpje kunnen hebben, of had misschien wel 6 wielen kunnen hebben, ik noem maar wat. **Dus, dat is eigenlijk een hele bepalende fase, om vast te stellen of iets succesvol wordt of niet. De vraag is of dat noodzakelijk is om in te voegen in jouw model. Maar ik zou die starting phase uitbreiden. die voelt nu als heel erg compact. Die tweede fases, komen die uit een bepaalde theorie ook?**

Nee, die heb ik... nou ja, die innovators, early adopters, early mayority, die wel. Dat komt uit de Innovation Diffusion Theory. Ik heb die fases eigenlijk zelf een beetje bedacht. Maar ik vind het bijzonder interessant dat u dit zegt, want ik heb eerder een interview met Geerten van der Kaa, op wie ik dit deel [rechts midden] heb gebaseerd, en hij raadde ook een paper aan waarin iets meer aandacht wordt besteed aan fases die betrekking hebben op dit model. Du sik vind het bijzonder interessant dat u dit zegt, want dit is dus duidelijk een mankement aan mijn model, dat u dat beide opvalt.

- **Ja, dus de optie is om eigenlijk te zeggen: misschien is er wel een R en D-phase. Dat dat misschien startup-phase is. Dat je vervolgens zegt; Ja, klopt, dan gaan we naar de innovators en de early adopters. Misschien alleen innovators, omdat dat echt nog wel distinctly different is. Ik denk dat die gewoon kan blijven staan, innovators and early adopters, en dan inderdaad de fase...**

Deze dus nog even opdelen dus, de starting phase?

- **En, ik snap heel goed, je wil iets zeggen over lock-in en hoe dat eindigt, dus ik snap heel goed dat je veel aandacht wil besteden aan de growing phase, dus dat lijkt me prima.**

Oke, nou dat is heel fijn om te horen. Nou, we hebben het er net natuurlijk ook al heel even over gehad, en toen kwamen we vooral uit op dat expectations... maar als u dit zo ziet, en ook wetende dat sommige factoren uit uw eigen werk in dit model een andere naam hebben gekregen... U gaf aan bij die expectations, zit ie invloed van dieselgate. Maar als dit zo ziet, waar zou u dan nog meer denken van: Waar heeft dat doorgewerkt, en ook vooral waarom denkt u dat?

- Dieselgate?

Ja, dus de invloed van dieselgate op dit hele proces. Dus via welke factoren zou u zeggen dat dat gespeeld heeft?

- Ik ga nu even blauwe blokjes langs, dan denk ik? **Nou, wat jij beter weet dan ik denk ik, is of dieselgate ook tot veranderde regulering heeft geleid? Sowieso in de test-cyclus.**

Ja. Sorry, test-cyclus?

- Ja, ik kan me voorstellen dat er iets in de procedure waarin testen worden uitgevoerd.

Oh, op die manier, omdat het allemaal draaide om een test. Ja, nu u het zegt, heb ik daar eigenlijk niet specifiek naar gekeken, maar dat is zeker mogelijk. **Maar mijn onderzoek wijst wel uit dat er inderdaad veel, laten we zeggen, milieu-zone-achtige regulaties zijn gekomen naar aanleiding van dieselgate, inderdaad. Dus regulaties, kan ik, zie ik.**

- **Ja, dat is een belangrijke. Ja, kijk, regulering is niet iets wat ook plotsklaps er is hè. Dat wordt ook ontworpen., Sterker nog, dat wordt negotiatied. En wat wij natuurlijk allemaal niet zien aan de achterkant, is... We zien alleen het resultaat, we weten dan uit de kranten hier en daar dat er een sterke lobby is geweest.** En ik heb wel eens bij dat soort sessies gezeten, toen ging het over het clean energy directive. Dan zit je daar in een grote zala met 60 man, en driekwart is gewoon lobbyist hè. Daar wordt gewoon standaard wordt er geduwd en getrokken, dus dat zijn enorme... Dat is nota bene nog zichtbaarder dan wat er achter de schermen gebeurt. **Met andere woorden: het onzichtbare gedeelte van die ijsberg zeg maar, wat onder water zit., daar heeft dieselgate volgens mij heel veel... Je moet je voorstellen, hoe een onderhandelingspositie, hoe dat verandert is gevolg van dieselgate. De onderhandelingspositie van de auto-industrie, die komen na dieselgate weer aan tafel met de Europese Commissie. De Europese Commissie zegt: we willen naar EURO 6, en we willen dat eigenlijk versneld gaan doen. En Volkswagen zit daar tegenover en die wil ik eigenlijk zeggen: Ja, dat willen we niet, en dat is slecht voor jobs en dat soort dingen. Ja, zo'n Europese Commissie lacht zo'n Volkswagen dan natuurlijk dubbel en dwars uit.** Die negotiators geen poot om op te staan. Dus ik denk, en dat is natuurlijk iets wat je heel moeilijk kan aantonen, maar wat ik wel verwacht, is dat... **Generieker zou je op z'n minst, suggestie kunnen wekken, waarschijnlijk heeft Dieselgate met name aan de onderhandelingstafel, in het zicht van nieuwe regulering... heft niet geholpen, laat ik het zo zeggen, de auto-industrie. En het zal de legitimiteit van de Europese Commissie, dat is een andere kant, als de Europese commissie niks of weinig had gedaan, hadden zij ook op hun kop gekregen van de milieugroeperingen of van de Europese burgers, zal ik maar zeggen. De legitimiteit om met de stok te slaan is zoveel groter, dus aan beide kanten is de onderhandelingspositie totaal skewed. Dat is denk ik een hele belangrijke geweest.**

Ja, nou dat is goed om te horen. Maar u gaf ook aan, door de burgers en zo, worden ze weggelachen want... Dat heeft een beetje te maken gehad met het vertrouwen verloren in de technologie. Begrijp ik dat goed, dat u dat bedoeld?

- Ja, dat is het interessante, ik zit even te kijken aan de market-kant.

**Ik heb namelijk ook, the state and image, het gaat natuurlijk deels, zoals u het hier ziet, deels om reputatie en dergelijke.**

- **Reputatie, ja, ik denk dat reputatie een hele belangrijke is.**
- Ik vraag me af, het is wel een interessante vraag, heb jij misschien wel een veel beter beeld bij, ik vraag me heel erg af, of het aantoonbaar tot een ander beeld van consumenten heeft geleid. In zekere niches wel, maar de grote massa?

Dat beeld krijg ik wel, maar... Ten minste, op basis van mijn literatuur onderzoek, ja. Ik krijg veel papers van rond die tijd geschreven, die stellen van: Ja, inderdaad, het heeft invloed gehad en het beeld is veranderd. Aan de ene kant sowieso van Volkswagen, maar vooral ook van diesel technologie. En dat vond ik een interessante observatie, want inderdaad, alle bedrijven stoppen met het produceren van diesel, maar we weten allang dat dat niet aan 1 factor ligt, getuige het hele framework. en aan de andere kant zie ik dat Volkswagen amper heeft geleden onder het hele verhaal. Die zijn inmiddels weer de grootste verkoper van zowel normale auto's, als EV's. Grootste bedrijf naar omzet. Maar ja, je zou kunnen zeggen dat... **Aanvankelijk was het zo: Volkswagen gaat hieronder lijden, uiteindelijk viel dat mee, maar met name de diesel technologie heeft eronder geleden. Daarom heb ik die ook maar geclusterd in 1 zo'n vakje.**

- **Ja, ik denk dat dat een hele goeie is. Daar ben ik het gewoon mee eens. Ik denk dat dat een belangrijke is. Dus dat is meer de technologie zelf, dan individuele partijen.**

Ja, wat ik ook opmerkelijk vond hoor, want waar die papers op wezen van: Nou, dit is voor Volkswagen een enorme klap, en dit en dat. En dat bleek allemaal in de praktijk erg mee te vallen. Ze hebben wel flink moeten betalen, 30 miljard aan settlements. Ja, dat was geen sinecure, maar ja.

- **En ze hebben, het heeft bij Volkswagen het hele elektrisch rijden in gang gebracht hè?**

Zeker weten.

- Ja want ik was van oudsher, vind ik Volkswagen een van de bedrijven die hebben... Weet je, elk bedrijf presenteert zich, maar ten tijden van de brandstofcel technologie, 20 jaar geleden, waren zij een klassiek conservatief bedrijf. Ze hebben wel hun modelletjes gemaakt, ze hebben wel wat dingetjes geprobeerd, maar niks was écht. Daimler die was écht bezig met brandstofcel technologie, dat waren echt meer techneuten-gedreven. Volkswagen vind ik toch iets meer marketing-gedreven. BMW was écht gedreven, maar die geloofden er gewoon niet in, en dan gingen ze het ook gewoon niet doen. Zij waren ook de uitzondering op de regel, iedereen zat in de brandstofcellen op een gegeven moment, behalve BMW, die is er mee gestopt op een gegeven moment. Zo van: We geloven er niet in. Dus ook heel erg technisch gedreven, ook geen aandeelhouders, hè. Ze hebben een hele grote aandeelhouder, de familie Brand. Dus zij hebben zich ook vrij gehouden van dat soort gedoe. Maar de rest ging allemaal mee. Maar Volkswagen was altijd het laatste jongetje van de klas, voor zo'n groot bedrijf. Dus ik was heel sceptisch. En nu voor het eerst zie je, dat ze echt een slag hebben gemaakt, er heel serieus werk van maken. Dus ik vind het mooi om te zien.

Ja, en het is dus niet onmogelijk dat dat gekomen is door het feit dat ze al flink waren zijn getikt?

- Zeker. Moet haast wel.

Nou, leuk, lijkt redelijk aansluiting te hebben met mijn bevindingen, dus dat is fijn om te horen. Verder nog zaken in hier, waarvan u denkt: Goh, daar zou het nog wel eens mee te maken kunnen hebben, of wat bedoel je daarmee, of...

- Ja, met Research Development helemaal onderin, dat rode blokje.

Ja, dat zal ik even uitleggen. Dat is een kwantitatieve factor, in een verder vrij kwalitatief framework. Maar het is een onderdeel uit een framework dat gemaakt is door een van mijn begeleiders, Wouter Beelaerts van Blokland, en i vond het een hele interessante, want het biedt namelijk de mogelijkheid om een kwantitatieve manier een focus op innovatie binnen een bedrijf te duiden. Dus zijn model stelt dat, als je de hoeveelheid geld die wordt uitgegeven aan Research en Development op basis per employee, dan kan je bepalen of een bedrijf veel focus heeft op innovatie. En dat zal ik heel even laten zien, hoe dat er vervolgens uit gaat zien. Want daar heb ik al wel een heel interessante in ontdekt... Ja, dus dit [plaatje RD per C] zijn de 10 grootste bedrijven op het gebied van BEV's en Hybrids. en wat je hier dus ziet, is dat het gemiddelde ligt ergens tussen de 60 en de 20, en dat zijn allemaal clubs als BMW en Nissan, eigenlijk veelal westerse bedrijven. En hieronder zie je, misschien wel onder de 10, zie SAIC, BYD en Geely, allemaal Chinese bedrijven. Dus wat je hier dan op basis van kan stellen, is dat deze bedrijven niet zozeer degenen zijn die zelf hun batterij ontwikkelen, maar wachten tot dat al door anderen is ontwikkeld en vervolgens gewoon de technologie gewoon inkopen.

- **Nou, Build Your Dreams, SAIC en Geely, dat zijn batterij-bouwers hè. En die zijn op een gegeven moment er maar een auto omheen gaan bouwen, zo van: Joh, als wij de batterij maken, die leveren we aan al die bedrijven, dus... Misschien noemen ze dat geen R en D meer hè, dat is natuurlijk altijd een hele lastige bij die jaarrapporten. maar in principe zijn dat batterij-bouwers. Laat ik zeggen, als Volkswagen die activiteiten had gedaan, had dat onder R en D gestaan.**

Oh, dat is een hele goeie. Dan moet ik hier nog eens even kritisch naar gaan kijken.

- Kijk, Build Your Dreams heeft veel batterijen geleverd aan klassieke automotive bedrijven, maar die wilden op een gegeven moment, die gingen verticaal integreren. Zelf dat allemaal gaan bouwen. SAIC heeft volgens mij, heeft met een automotive bouwer, volgens mij Volkswagen maar weet ik niet eens zeker, een samenwerking. De meeste bedrijven hebben hier samenwerkingen omdat ze ook batterijen leveren. Dus dit is een ingewikkelde, zeker die Geely, SAIC en BYD ben ik heel benieuwd... dit komt uit hun jaarrapporten waarschijnlijk, of niet?

Ja, zeker.

- Ja, ik ben heel benieuwd hoe die Chinese rapporteren over R en D activiteiten, of ze dat op dezelfde manier of volgens dezelfde standaarden doen als de westerse bedrijven.

Dat is een goeie. Ik meen wel dat in elk van die jaarrapporten staat uitgelegd hoe ze dat bepalen. Maar dan is denk ik een goeie take-away hiervan, dat ik dat eens even kritisch ga lezen, voordat ik op basis hiervan harde uitspraken ga doen als: Chinese bedrijven zijn minder innovatief. Maar dat was in ieder geval...

- Hee, maar per capita is interessant, ik heb destijds gedaan per omzet. en er zijn vast redenen voor omdat niet te doen. Dus ik had die factor ook om de geneigdheid van een individueel bedrijf... dus mijn model bestond uit een soort meso-industrie level, kijken naar hoe de industrie bepaalde verwachtingen krijgt, en dat het een bepaalde kant in wordt geduwd. Ja, binnen die context heb je natuurlijk ook verschillen tussen bedrijven. En toen was een van de factoren die een invloed had, of een bedrijf linksaf of rechtsaf gaat, of veel investeert of weinig, is inderdaad je research development expenditures. Dat zag je heel duidelijk. Dus die kan je... Mocht je daar ondersteuning voor willen, dat staat in mij proefschrift. Dat was een van mijn werkhypotheses. Bedrijven met veel R en D, zullen wél investeren in nieuwe technologie. Dat gebeurde ook.

Ja, nou is inderdaad een beetje waar dit... En per employee gedeelte is dan puur om het te benchmarken, dus om het uit te drukken op een bepaalde basis.

- Ja, dat zou wel eens beter kunnen zijn dan wat ik deed, percentage... Ik zat op de percentages van de omzet. Maar ja, de omzet... en wat versta je onder de holding weet je wel? Dat blijf je bij alles houden, maar daar voelde ik mezelf een beetje zwak. er waren vast slimmere dingen voor.

Nou ja, goed, ik neem aan dat dat toch varieert per onderzoek. Maar daarom heb ik hem eronder staan. En Company Strategy and Finances krijgt waarschijnlijk een andere naam, gaat waarschijnlijk naar characteristics of the company toe in het model, op basis van eerdere feedback. Maar ik heb deze er apart in laten staan, omdat het een kwantitatieve factor is die vervolgens een bijdrage levert aan het model door een focus van innovatie... En u ziet, het zit in deze hele fase, dus het slaat zowel op nieuwkomers, als op incumbents.

- Ja, wat hier... Die verschillen tussen die bedrijven dat is wel een... Kijk, het is net een apenrots, die auto-industrie. En helemaal bovenin zitten toch een beetje de klassieke... Daimler is gewoon een ongelooflijke technologie-reus. Als Daimler wat doet, dan kijkt iedereen daar wel serieus naar. En in feite Toyota ook, sinds een jaar of 30. Sinds die Hybrides is iedereen zich het leplazarus geschrokken. General Motors zit natuurlijk heel hoog, en Ford. Maar die apenrots is aan het veranderen ook. Maar de plek waar je zit, bepaalt ook een beetje wat je doet. Honda, die innoveert ook wel hoor, maar die kijkt vooral de hele dag naar de patenten die Toyota uitbrengt. Als Toyota wat doet, gaat Honda daar achteraan. En dat geldt eigenlijk voor meerderen. Dus er is een... Ik wil niet zeggen, er zijn geen werkafspraken, maar de rollen zijn verdeeld binnen die industrie. En dat wordt nu allemaal een beetje shaken up. En dat wordt alleen maar versterkt door alle samenwerkingen die er nu zijn. Dat zijn conglomeraten, goed beschouwd zijn er ook nog maar 10 grote bedrijven eigenlijk langzamerhand. Terwijl er wel 30-40 merken zijn. Maar dat wordt natuurlijk wel behoorlijk op de kop gezet door Tesla, en met name die Chinese bedrijven, want dat groeit ook als kool. Dat BYD, en Geely, dat zijn echt enorme conglomeraten inmiddels. **Dus, het is wel heel interessant om na te denk over hoe kwalificeer je company strategy in individuele bedrijven? Een van de dingen die ik hoog in het vaandel vond, is de mate waarin je echt technologisch georiënteerd bent. Je moet gewoon echt je engineers op orde hebben, of je moet je contacten hebben met bedrijven die complementair zijn.** Waarom is Toyota/Honda heel goed? Omdat ze heel veel met Panasonic samenwerken, die elektronica zit helemaal in de genen van de Japanse industrie. Daardoor waren ze in staat om die hybridisering veel sneller door te voeren dan in Amerika, waar dat gewoon heel mechanisch is, allemaal. Dat ontbrak gewoon. En dat zie je nu ook met batterij-technologie en alles wat je daarbij nodig hebt. **Dus dat is nog wel interessant: hoe je dat kwalificeert. Dat gaat om technologie, dat gaat om het type partners dat je ook aan boord hebt waardoor je sneller kan schakelen.** Daarom willen ze in Europa nu de batterij-fabrikanten weer terughalen, omdat ze simpelweg beseffen: als wij die cellen niet kunnen maken, als wij niet weten hoe we die system-integration doet, dan zijn we de klos. Dan moeten we het inkopen. we kunnen niet optimaliseren. De is de key-competance van de toekomst.

Ja, anders loop je altijd achter. Duidelijk. Toch nog even terug naar de vraag: Vermoed u dat daar enige invloed van dieselgate is geweest, of zegt u...

- In die Company Strategy? Dus dan is de vraag een beetje: **Zijn er bedrijven op een andere manier met het dieselgate omgegaan? Dan zou mijn verwachting zijn dat de bedrijven die eigenlijk**

**zwaar afhankelijk zijn van diesel, dat die minder snel zullen reageren dan degenen die het eigenlijk sowieso al een beetje hadden uit gefaseerd.**

**Minder snel?**

- **Die hebben grotere belangen om te verdedigingen.** Moet je me even helpen weer: Want diesel was heel sterk in Europa, en juist heel klein in Amerika, klopt dat?

Ja, omdat zij inderdaad de regulaties van dat California Air Board inderdaad in Amerika al strikter waren, dan wat regels die wij hier hadden. Ik meen EURO 4, uit m'n hoofd. Dus ja, diesel heeft daar weinig voet aan de grond gekregen.

- Dus dat zou betekenen, dat de bedrijven die heel groot zijn in diesel, dat zijn dus de klassieke... Onder andere Volkswagen, BMW, dus de Duitse clubs. De Franse clubs volgens mij ook? Behoorlijk wat Spaans, Italiaans ook?

Ik durf het niet te zeggen, ik heb me met name gericht op de paar grote. Italiaanse clubs zijn, met uitzondering van Fiat, vaak niet..

- **In de analyse hiervan zijn het interessant zijn om te kijken welk deel, in jaarrapporten kijken, in hoeverre was 10 jaar geleden, welk aandeel was dieselverkoop? Van de 10/15 grootste clubs. Mijn werkhypothese zou zijn, degene die het grootste aandeel, voor wie dat eigenlijk een hele grote markt is, die zullen minder geneigd zijn... Die zullen het er moeilijk mee hebben.**

Is dat niet eigenlijk ook weer State of the Manufacturers of Incumbent Technology? Of zou ik deze [State en Company Strategy] toch een beetje aan elkaar moeten verbinden? Omdat je strategy natuurlijk anders is als je producent bent van de incumbent technologie, dan als je bent van een... Want wat ik nu zou zeggen... U zegt: Nou, het is sterker als je... De reactie is heftiger als je in de diesel zit, dat is logisch want dan ga je het verdedigen. **Maar dat zou dan inderdaad eerder bij deze [state and image of...] vallen toch?**

- **Ja, maar ik had de indruk dat dat meer een industrie niveau was. Dus dat dat een meso-level indicator is. een indicator van: Hee, hoe kijkt de hele markt of de industrie aan tegen deze incumbent technology en dan komt ie negatief uit. En bij Company Strategy ga je naar een individueel bedrijf kijken, en dan zeg je: Wacht eens even, deze bedrijven, het verdienmodel zit in diesel. Voor 30, 40, 50 procent. En bij Ford verwacht ik dat dat bijvoorbeeld heel erg klein is, en bij General Motors bijvoorbeeld ook.**

**Omdat dat Amerikaanse clubs zijn.**

- **Ja, en ik denk bij Japanners ook.**

**Ja, dit klinkt... Dit is eigenlijk wel een betere manier van het te bekijken ja.**

- **Nou ja, ik ben benieuwd. Dus ik denk dat dieselgate op die manier veel effect gaat hebben op de individuele besluitvorming en strategie. En dat kan ook 2 effecten hebben. Het kan ook zijn... Misschien de partijen die weinig afhankelijk zijn van diesel, die zullen zeggen: Joh, we zijn niet zo afhankelijk, we laten het een beetje lopen, maar wij hoeven niet veel te veranderen. De partijen die juist enorm moeten veranderen, omdat ze zien dat 40 procent van onze verkopen vallen weg. Het zou zomaar kunnen dat zo óf heel erg gaan lobbyen daartegen, of dat ze door dieselgate hebben gezegd: Ja, maar dan moeten we echt een grote omslag maken. Dus dat is de contra-hypothese: de partijen die heel afhankelijk van diesel waren, dat zijn de eersten die helemaal in elektrisch rijden stappen. Simpelweg omdat een heel groot deel van de markt wegvalt.**

Goed, dat is wel een hele interessante, want ik zat namelijk te denken: Als ik u zo hoor, dan zou het met name op deze [Growing phase] Company Strategy hebben omdat dit een beetje degene zijn die erachteraan lopen maar dat is dus eigenlijk niet het geval: Want u zegt: juist degenen bij wie de markt wegvalt, zullen er sneller instappen, dus dat zullen dan eerder deze [Starting phase] worden dan. Dat is wel een goeie. Dus het valt op eigenlijk alle twee dan wel... Okee.

- Hee, ik moet een beetje afronden, dus heb jij nog hete hangijzers? Of 1 of 2 dingen waarvan je zegt: Nou die zou ik nog heel graag willen bespreken?

Absoluut, ik vind eigenlijk mijn interviewees via snowballing, dus ik zou u eigenlijk graag willen vragen: Heeft u, gezien ons gesprek, nu een paar namen voor mij, waarvan u zegt: Benader die eens, die kunnen hier ook wat interessants over zeggen?

- Oh ja. Wat ik zou doen... Ik zou sowieso, ik weet hoe makkelijk hij bereikbaar is, maar je zou in de groep van hem eens kunnen kijken... Kijk eens naar publicaties van Frank Geels. Hij is professor in Manchester, hij gaat over co-evolution van technologie en markt. Dus de markt is niet statisch, de technologie is niet statisch, dat co-evolueert. En hij heeft heel veel nagedacht over transities. Veel van energie, van mobiliteit, en ook van energie. En hij beschrijft op macro-, meso- en micro-niveau hoe dat zo processen verlopen. Frank Geels is een hele belangrijke, ook in... Op het transitie-denken vind ik hem dominant. Dus ik vind hem heel goed.
- Zijn denken komt ook terug in het werk van Jan Rotmans, die is iets meer Jip en Janneke vind ik. Die zit aan de Rotterdam School of Management. Hij is bekend geworden met zijn transitie-theorie, dat heeft hij heel goed vermarkt. Vind ik ook, dat is wat laagdrempeliger, maar Frank Geels is net even wat meer ingebed in technologie dynamica, en institutionele theorieën ook, en innovatie-systemen. Dus dat zou zeker aanraden.
- **En ik zou kijken naar Marco Hekkert, professor Universiteit Utrecht. Die zit helemaal in de innovatie-systemen. Eigenlijk als je zegt, er zijn eigenlijk... Hij kijkt heel erg naar transities, en dan zijn er eigenlijk 7 factoren die beinvloeden of een innovatie-systeem verandert. En je moet aan die 7 randvoorwaarden voldoen, simpelweg gezegd, zitten heel veel links met wat jij doet. Check op Marco Hekkert en innovatie-systemen.**
- Maar die zijn allemaal heel moeilijk te bereiken verwacht ik voor een interview. Maar wie je wil zou kunnen bereiken voor een interview is Yoeri Wesseling, van de Universiteit Utrecht. Die is ook gepromoveerd op mobiliteit. Denk ik wat benaderbaar. Dus die zou je wel aanraden.

## B.4 Transcripts of Interviewee C

**Transcript 2**
Nou, nogmaals heel veel dank dat u hier bent. U werd mij aangeraden door [Interviewee A]. Ja, ik had u een documentje gestuurd met daarin een beetje een uitleg over mijn thesis, en met name het framework, waar ik het vandaag met u over wil hebben. Heeft u daar naar kunnen kijken? En zo ja, heeft u daar vragen over?

- Nou, net maar heel kort. Want ik kijk nu net naar m'n mail en ik zag het 2 minuten geleden, dus dat is niet goed genoeg.

Nou, dat is helemaal geen probleem. Dan zal ik u het gewoon even kort uitleggen. Ik zal hem even op het scherm zetten, dan kan ik even wat dingen laten zien. Als het goed is kunt u hem nu zien. Het zit zo: ik ben aan het kijken naar de uptake van EV's binnen autobedrijven. Ik heb geobserveerd dat heel veel autobedrijven hun verbrandingsmotoren aan het uit faseren zijn en met z'n allen massaal overstappen op EV's. En mijn onderzoek gaat eigenlijk om de vraag of dieselgate daar in rol in heeft gespeeld. Nou, om dat te onderzoeken heb ik een framework opgesteld wat eigenlijk het proces beschrijft van een innovatie die het overneemt van incumbent technologie. En allerlei factoren die daar invloed op hebben. En dat is dit framework. Dat is deels op het werk gebaseerd van Geerten van der Kaa. Mijn hypothese is eigenlijk dat dieselgate geen directe invloed was, maar dat het een versterkend of een versnellend effect van een van deze blauwe factoren heeft gehad. En die factoren zijn gebaseerd op clusters van overeenkomende factoren uit de frameworks die ik heb gebruikt.

- Ja, ik denk dat dat klopt, jouw hoofdaanname.

Nou, kijk eens aan, dat is goed om te horen. En waar ik het vandaag over wil hebben, is aan de ene kant de vraag of u denkt dat dit framework accuraat het proces van een innovatie die doorbreekt op een markt, en vervolgens het overneemt van een incumbent technologie. Of het proces accuraat weergeeft. En ten tweede op welke van deze factoren u denkt dat dieselgate invloed heeft gehad. Als in: versnellend of een versterkend effect. Neem aan dat u daar nog wel en vraag over heeft voor we die vragen kunnen bespreken, ik hoop dat dit framework een beetje, nu iets duidelijker is?

- **Ja, en dat ziet er in ieder geval op het eerste gezicht heel plausibel uit.** Ook de fases. Dus een begin met Innovation or a new technology, dus een uitvinding of met een idee. En dan tot een werkend prototype. Die zijn er natuurlijk al lang in deze markt. Zelfs al 100 jaar of zo, dat de elektrische auto er was. Maar goed, niet op een manier zo dat er nu is. En dan heb je incumbents die beginnen, en hier heb je een paar kleintjes waar... Je hebt natuurlijk ook een Tesla, die dan flink aan de weg getimmerd heeft. Vervolgens, nu al weer wordt ingehaald, begreep ik. Maar er gebeurde dus wel iets in de markt. Dus ja, er komen anderen bij.

Ja, Tesla zou ik dan de newcomers scharen in deze fase.

- Ja, inderdaad. En dan bij de volgende fase... Wil je meteen eerst naar de invloed-hebbende factoren kijken, of eerst het totaalproces?

Eerst het totaalproces lijkt mij het handigst, want dan kunnen we vaststellen wat u denkt van: dit klopt wel, dit klopt niet, dit moet je er nog aan toe voegen. En als u zaken heeft waarvan u zegt: dit moeten je nog toevoegen, daar kunnen we dan later even op terugkomen met de vraag of die invloeden...

- **Ja, is goed. Dus dit ziet er heel plausibel uit. Dus zowel nieuwkomers als ook bestaande autoproducenten die het ook gaan doen.** Je hebt ook nog hybrides natuurlijk, maar goed dat is ook elektrisch en benzine gecombineerd. **The innovation is succesfull... dat is natuurlijk even de vraag hoe je dat definieert.**

Ja, dat kan ik even uitleggen. Daar heb ik een aantal factoren achter zitten die komen Hardman, die 7 gemeenschappelijke factoren historisch succesvolle disruptieve innovaties heeft gedefinieerd. Die heb ik alleen niet als aparte invloeden erin gezet omdat die eigenlijk al via de rand... de factoren die aan de boven- en aan de onderkant staan erop inspelen.

- Ja, ik weet niet of dat zo is. **Ja, succesvol is in ieder geval van: de markt pakt het op. Dus op die manier kan je hier spreken van succes. Voorlopig leidt het nog tot verliezen voor die autoproducenten. Tesla heeft nu net voor het eerst winst gemaakt, maar die heeft gigantische verliezen geleden in het recente verleden. En het milieueffect is averechts, voorlopig. Omdat er nog te weinig alternatieve energie. Dus op korte termijn is dat juist een falen, in plaats van een succes. Maar op lange termijn moeten we wel deze kant op. Maar het zou waterstof in de**

**weg kunnen zitten, wat misschien de betere optie is. Dus 'succesvol', dat heeft verschillende dimensies en ik ben er nog niet zomaar van overtuigd dat je dit als succesvol moet zien. Wel qua marktacceptatie, want daar lijkt het nu allemaal naar toe te gaan, er komen steeds meer oplaadpunten, er komen steeds meer auto's. En dat versterkt elkaar ook.**

Ik moet wel zeggen, dit framework heb ik wat generieker ontworpen dus dit is niet... Ik heb dit uiteraard wel met mijn casus rondom elektrische voertuigen in het achterhoofd ontworpen. Maar ik heb het ook ontworpen zodat het in wat generiekere termen het proces van een innovatie die doorbreekt op de markt, en het overneemt van een incumbent technologie. Dus wellicht dat dat...

- **Ja maar dat heeft te maken met de definitie van innovatie. En als je teruggaat naar Schumpeter... Zoals je het nu gebruikt, heeft innovatie een technische connotatie. Maar dat is niet zoals Schumpeter het als econoom definieerde. Dat was vrij vertaald: 'iets nieuws dat een commercieel succes is '. Dus het twee elementen: nieuw en succes. En dan heb je nieuw voor het bedrijf, of nieuw voor de markt. En succes, dat beperkte hij tot commercieel succes. Maar dat zou je ook breder kunnen zien. Als je even dan kijkt... als je dat onderscheid maakt, dan is het een beetje vreemd om in de tweede fase, die over groei gaat, om daar succes aan het begin te zetten.**

Ja, ik begrijp wat u bedoelt. Ik heb inderdaad 'succesvol' in een zichtbaarsheids-perspectief erin gezet. Zo van: bedrijven hebben... Laten we zeggen, een Tesla heeft laten zien dat de elektrische voertuigen op basis van een lithium-ion batterij kunnen. Dat dat een rendabel voertuig oplevert. En dat daardoor andere bedrijven hebben gezien: Oh, als zij dat kunnen, dan kunnen wij dat ook en dan durven ze die stap te nemen. En toen zijn ze het gaan overnemen. **En wat ik hier met 'succesvol' wil zeggen, is dat de technologie misschien 'bewezen' is. Dus 'proven' zou hier een beter woord zijn eigenlijk.**

- **Ja, maar in een technische zin heb je dat al op het moment dat je een werkend prototype. hebt. Dus dat is in technische zin dan bewezen.**

**En dan commercieel ook? Dat je hebt laten zien...**

- **Ja, dan heb je de commerciële kant, dus als er 1 bedrijf is dat... En dan is het ook pas nu net. Want Tesla gaat nu net pas winst maken. Dus zo gedefinieerd, ja dan zou je hier kunnen staan.**

Dat is een goed punt, om even goed na te denken over hoe begint die fase dan. **Want inderdaad succes is dus niet zo'n vanzelfsprekende term. Het is meer een overkoepelend... Het kan veel dingen betekenen.** Dit is precies het soort feedback waar ik vandaag naar op zoek ben. Dus dank u wel. En graag meer van dit soort observaties als u ze heeft.

- En wat je daar hebt staan, is 'lock-in ends'. Dat is een beetje een gekke. Misschien kan je die even toelichten, wat je daarmee bedoelt?

Met de 'lock-in'... Dat is een term die ik veel tegenkwam in de literatuur omtrent standard battles en disruptieve innovaties. Dat ging eigenlijk vooral om.. De lock-in is eigenlijk dat de hele wereld is ingericht op de ene technologie...

- **Ja ja, je bedoelt lock-in van de oude technologie?**

Ja, de wereld is ingericht op de ene technologie en dat de andere technologie... In dit geval dus elektrische auto's plus batterij wordt al steeds beter, maar waterstofauto's die infrastructuur die ontbreekt en die komt er maar niet omdat... **Dat is die lock-in.**

- **Ja, oke, nou dan klopt dat. Als je 'innovatie is succesvol', als je daar ook aan toevoegt dat er een eerste... dus dat het niet alleen technisch een succes is, maar ook een markt succes voor het eerste bedrijf dat het commercieel... winstgevend kan doen. Als je het zo definieert, dan kunnen ze dat doen, omdat er iets is op de markt, en in dit geval ook, je hebt genoeg klanten. In dit geval horen daar dan ook nog eens die oplaadpunten daarbij. En dan heb je inderdaad daarmee, die lock-in doorbroken.** Als we even de parallel trekken met het waterstof-alternatief, met op dit moment nog maar 3 tankstations in Nederland. en alleen wat niche-applicaties, van busvervoer. Dat heeft nog niks doorbroken. Oke, dus dat is goed.
- **Ja en dat tast dan inderdaad, je hebt hem daar al als factor erbij, State and Image of the manufacturers of the incumbent technology... Ja, want die is niet meer vanzelfsprekend. Dus dat klopt ook.**

- **Firms abandon path dependency and start with innovation. Dat is een beetje vreemd. Aan de ene kant klopt dat, maar je hebt dat ook al staan bij de starting phase, want sommigen zijn natuurlijk daar al begonnen.**

Ja, ik zou hier moet verduidelijken dat ik daarmee refereer aan de firms die... U ziet daarboven de diffusion of innovation theroie termen staan: innovators, early adopters, early mayority, late mayority, laggards. **Met firms bedoel ik hier eigenlijk de early en late mayority. Dus laten we zeggen: Degenen die niet zelf aan het voorfront stonden van de innovatie, maar die hebben gezien: Goh, het werkt. Met name, de late mayority hier zou ik zeggen. Goh, het werkt, we zien dat de markt daarheen gaan, dus nu stappen wij ook in.**

- **Ja, of nog sterker: Ja, we kunnen niet meer achterblijven, want wie weet mag het straks niet meer, een bezine-auto.**

Ja, exact. En inderdaad dat is dan... Path dependency, daar bent u uiteraard bekend mee: dat het niet zomaar mogelijk is om over te stappen, omdat je al je kennis... En we zien nu toch wel dat bedrijven die 100 jaar lang verbrandingsmotoren hebben geproduceerd, nu ineens toch aangeven: Nou, vanaf 2030 zijn wij een volledig EV-bedrijf. **En ik zie dat in die stap [Firms abandon...] zie ik dat heel erg terug. Dat veel bedrijven die er lang tegen gestreden hebben, toch het roer omgooien.**

- **Ja, en die laatste fase. Ja dan kan het inderdaad compleet vervangen zijn.** Zoals de cd de langspeelplaat heeft vervangen. Die nu op een nostalgische manier weer terugkomt. Maar daar zou het in deze case ook naar toe kunnen gaan.

Ja absoluut. Ik heb ook in de literatuur gevonden dat een van de... in eerdere papers kwam dat tegen... Een kenmerk is van disruptieve innovatie, is dat de incumbent technologie vaak nooit helemaal vervangen wordt. Dus bijvoorbeeld, dat zie je ook moet fototoestellen en inderdaad langspeelplaten... Toch mensen die liever naar een langspeelplaat luisteren, of liever een fototoestel gebruiken met een rolletje, gewoon puur voor de nostalgische waarde. En wellicht zien we inderdaad op den duur toch auto's die verschrikkelijk duur zijn, maar wel een verbrandingsmotor hebben, omdat het nostalgisch is. Laten we zeggen: old-timers of iets dergelijks. Zoiets zie ik dan voor me.

- Ja dat denk ik ook. Als dat mag, dat is dan de vraag.
- **Oke, misschien even los van die andere factoren. Kun je je ook afvragen, heeft dieselgate hier op deze hoofdlijn invloed? Misschien wel een beetje, want dieselgate was meer dan alleen Volkswagen. Dat was het hele systeem van de auto-industrie. TNO zat ook daarbij. Werkten er ook aan mee, was ook gewoon bekend. Was een soort gezamenlijke leugen. Duizenden ingenieurs wisten hiervan en werkte daar allemaal aan mee. En concurrenten van Volkswagen deden hetzelfde. En daarmee heeft die hele sector zichzelf niet geliefd gemaakt, bij de beleidsmakers en in beperkte mate ook bij het publiek. Maar hier zijn vooral de beleidsmakers van belang. Als een sector zich zo weinig aan de maatschappij gelegen laat liggen, dit bewust doet. Bewust het publieke belang opzij zetten voor commercieel belangen, ja dan hoeven wij ze ook niet te sparen. Dan mogen we als maatschappij zeggen: Nou we hebben nu een klimaat akkoord. Er is tot ons doorgedrongen dat er issues zijn. Je werkt maar mee. Jullie kunnen het best, jullie hebben diepe zakken met geld, wat je gedeeltelijk op onjuiste manieren hebt binnen geschraapt. Werk maar mee aan de transitie. Punt.**
- **Ik denk dat op die manier het werkt, en dat betekent dat die bedrijven in die sector... kijk, die nieuwkomers die komen toch wel, want die zien kansen vanuit een technologische punt en die zijn op z'n minst een niche-markt van mensen die wat meer milieubesef hebben. Of die verwachten bepaalde binnensteden, dat je op een dag daar niet meer in mag. Maar die hoeven nog niet het totale issue van klimaatverandering in het oog te hebben. Maar bestaande industrieën, die voelen nou nattigheid dus dat vakje 'Incumbents start with innovation', dat wordt hier denk ik wel door getriggered. Dus alleen niet door concurrentie van een exotische Amerikaan, maar ook van: Misschien mogen we straks niet meer leveren op de Europese markt. Maar ook op een paar andere markten, Korea of Japan. Of China.**

Maar wat u zojuist beschrijft, in die eerste fase, ziet u inderdaad aan de onderkant staan... Die factoren zijn de drivers van dit proces. Ik heb daar inderdaad staan The Image of manufacturers of the incumbent technology. Ja, u geeft aan: Het was inderdaad niet alleen Volkswagen. Ik moet wel zeggen bij veel andere bedrijven was de schaal wel echt totaal anders. Dus bijvoorbeeld, uit m'n hoofd, ik zeg even Renault, die zijn gepakt met 100.000 auto's waar zo'n defeat device inzat, tegenover ik geloof dat er uiteindelijk ergens in de orde

grootte 11 a 14 miljoen Volkswagen modellen... **En eigenlijk is Volkswagen natuurlijk degene bij wie dit het hardst speelde, die hebben 30 miljard aan fines en settlements moeten betalen. maar ik ben het met u eens dat het niet alleen zij het waren, en daarom dacht ik ook dat zo'n 'state and image' wellicht een sterke was om er in op te nemen, omdat ik denk dat daar... En als ik u zo goed begrijp, is dat een beetje ook wel waar dan ook wel de invloed van dieselgate heeft gezeten?**

- **Ja, en als het Renault was geweest, zeg maar van de Latijnse landen, verwacht je eerder gesjoemel dan van Duitsland. Dus als het juist bij Volkswagen, waar ze zo in Duitsland op de normen zijn en het houden aan eisen, en als dáár dan zo gesjoemeld wordt, ja dan tast dat de hele sector aan. Want juist daar verwacht je het niet.**

Ja, dat is tekenend voor de rest. ik heb ook verschillende papers gelezen, die geven het verschillende namen, maar dat wordt ook wel een inertial effect genoemd. Dat is dat onder meer een bedrijf als BMW, dat niets fout had gedaan, ook tegenvallende verkopen ervoer, door een soort van 'Guilty by Association'. Zo van: Oh, dat is ook een Duits bedrijf, die zullen ook wel hebben lopen rommelen.

- Ja, bovendien was het natuurlijk niet allen Volkswagen, het was ook zijn toeleverancier, Bosch, was dat dacht ik. Klopt dat?

Zo heb ik dat niet begrepen. Ik heb echt begrepen dat zij die dieselmotor hadden , die EA-189, en daarvoor een soort filtratie-systeem nodig hadden, om aan die Amerikaanse normen te kunnen voldoen. en dat ze die niet hadden, en dat ze daarmee dachten: Nou, dat wordt te duur, dus we gaan gewoon doen alsof ie aan de normen voldoet. **Ik moet zeggen dat ik de rol van Bosch hier niet in heb gevonden, maar ik neem het zo van u aan. ik zal daar ook zeker meer over uit gaan zoeken.**

- **Ja, want Bosch is de producent van de software. En Volkswagen van de auto. Maar het gaat om de combinatie.**

Ja, dus dat zij uiteindelijk Bosch de opdracht hebben gegeven.

- Ja, dus die hebben toegegeven. en dat is wel een van de grootste toeleveranciers, dat is een mega Duits bedrijf. Die ook aan BMW levert. Maar ook, denk ik, aan Renault.

Ongetwijfeld.

- Er is getest bij TNO in Helmond, maar ook in andere landen, en daar wisten ze het ook allemaal. Ik heb een ... die heeft autotechniek gestudeerd in Eindhoven, nou die wist dit gewoon. Dat was ook daar bekend, aan die universiteit van Eindhoven. en hij heeft stage gelopen bij TNO, die wist dat gewoon. Dus die hele kennis sector, is medeplichtig daarmee. Als je weet van een misdrijf, en het is een misdrijf, dan moet je naar de politie gaan. Niemand deed dat. Duizenden ingenieurs hebben gefraudeerd.

Ik moet eerlijk zeggen dat ik die schaal no niet heb opgenomen, maar daar ga ik zeker meer onderzoek naar doen, want dat is voor mij...

- Dat is moeilijk om daar naar onderzoek te doen, want dat zal niemand toegeven. Maar zo is het wel.Hetzelfde geldt ook voor het Fraunhofer instituut. En ook voor Jan en alleman. Allemaal ingenieurs die hierbij betrokken zijn. Dus die test-instellingen, certificerende instellingen en zo, maar ook... De vraag is of die dat doorhadden, de Rijksdienst voor het Wegverkeer, ik denk dat het voor hun teveel in detail gaat. Maar de instanties die gaan over het toelaten van auto's op de markt, wat weten die ervan? Wisten die dat of niet? Of hebben die alles uitbesteed aan de TNO's van deze wereld? Die wisten het in elk geval wel.

Nou, dat is niet zo mooi.

- Nee, dat is dus echt een ingevreten onrecht. Dus je hebt een heel mooi onderwerp voor je scriptie.

Ja, ik blijf de meest interessante dingen ontdekken. Maar, goed...

- Ja, ik weet niet... Je moet je beperken, maar wat interessant zou kunnen zijn, is om eens te kijken naar publicaties van **Beatrice de Graaf**, dat is een hoogleraar die doet onderzoek naar criminaliteit, naar veiligheid, naar jihadisten en al dat soort... En die probeert patronen in systemen te ontdekken van hoe komen mensen to het criminele gedrag wat ze vertonen? **En dit is een hele andere context dan waar zij onderzoek naar doet, maar wellicht dat dat ook nog wat helpt. Want het gaat veel verder dan een toevallige beslissing van een klein groepje binnen Volkswagen, dit is een ziekte binnen de sector die dep is doorgevreten.**

- **En als je dan in die sector een grote verandering gaat onderzoeken, namelijk die naar elektrische auto's, dan zie je denk ik, in feite precies hetzelfde. Dat iedereen doet alsof dat milieuvriendelijk is, terwijl het dat voorlopig niet is. Omdat die energie-transitie heel erg traag gaat. Dus het wordt gepresenteerd als milieuvriendelijk, terwijl het dat op korte termijn niet is. Als het goed is, wordt het dat wel. Zij het dat je, ook nog eens, het is niet alleen de energie zelf, maar je hebt ook die katalysatoren en al dat soort schaarse metalen, die onder de mest mensonterende omstandigheden in landen als Congo uit de grond gehaald worden. Daar kijken we dus ook massaal weg. Dus het niet zo simpel, ook niet van: Good Guys vs. Bad Guys. Het zijn sowieso dezelfde guys grotendeels, en ze zijn nog net zo pervers als ze waren.**

Ja, ik moet wel zeggen dat gezien de scope van mijn onderzoek, kijk ik daar dan ook helaas even weg van. Maar ik vind het zeker interessante zaken om wel even in het achterhoofd te houden, dat het allemaal niet zo vanzelfsprekend is. Maar ik heb mezelf echt beperkt tot: Wat heeft de sector gedreven om na 100 jaar verbrandingsmotoren, ineens toch over te stappen op EV's? Of het nou inderdaad de redding is, is in mijn optiek, voor nu even... Je moet natuurlijk absoluut stilstaan bij de ethische kwesties die eromheen spelen, maar ik heb vooral gekeken naar wat drijft zo'n beslissing.

- Ja, maar de vraag is dus hoe lang ze dit... of ze dit vol houden. Dan hebben we juist een nieuwe lock-in. Hoe lang politici het spel willen meespelen, al wegkijkende, want dat doen ze in feiten. of niet. **Ze hebben niet allen het Parijs-akkoord gesloten, ze hebben ook de sustainable development goals van de Verenigde Naties omarmt. Dat gaat verder dan alleen klimaat. Speelt dat enige rol of niet? Het lijkt van niet. Goed, nou. En, wat ik nu zeg, dat heeft in ieder geval te maken met regulation. Alleen regulation zelf loopt altijd achter. Dus het begint met beleid. Maar je kunt wel verwachten dat dit... Het kan leiden to beslissingen, zoals we in Nederland hebben van het gas af. En dat er straks wordt gezegd: van de benzine-auto af. Een uitfasering. En op een geven moment mag het helemaal niet meer. En je hebt nu al dat je op bepaalde plekjes niet meer mag komen.**

Ja, milieuzones. Ja, en dat... Ik denk dat dat inderdaad ook een factor is die dus zo'n EV-opmars drijft. Dus vandaar ook onderin in het frame in beide fases de invloed van regulations opgenomen.

- **Dus dieselgate heeft daar denk ik invloed op. Dat zulke wetgeving er gemakkelijker komt. Dieselgate heeft ook invloed op die Company Strategy. Nou daar hadden we het net al over.**

**Maar u zegt daar hadden we het net over, dat ging met name over degenen die hadden besloten om dieselgate te doen...**

- **Dat betekent dat nu het er is... Dus wat ze zien is dat de reputatie van de auto-industrie, die juist heel positief was, heel innovatief. Zeker, dat verschilt per land, maar zeker in Duitsland, maar ook in andere landen ook wel, want dat is een sector die wordt gekoesterd en bescherm dook. Maar die heeft het nu verbruid. Bij in ieder geval een deel van de politiek en een deel van het publiek. En dat dringt door to in de directie-kamer, en dat kan die bedrijfsstrategieën van: Zullen we ook niet eens gaan experimenteren met... Of in gaan zetten op elektrisch. Dat kan invloed hebben. En finances: Daar moet je dan in investeren.**

**Daar moet voor betaald worden. Oh, ja, duidelijk. begrijp helemaal wat u bedoelt en ik kan me er ook helemaal in vinden.**

- **Bovendien heb je... Voor zover die bedrijven externe financiers hebben.... Je ziet ook een trend onder investeerders. Vooral onder pensioen fondsen, dat soort investeerders, dat die ook vraagtekens gaan zetten van: Wil ik nog wel in dit bedrijf beleggen? Dat speelt ook een rol. En dat is niet alleen de Triodos en het ABP. Maar dat is ook in toenemende mate bij gewone banken, en daarna bij gewone beleggers, want ie zien ook de bui hangen van: straks is mijn aandeel niks meer waard.**

Nee, je belegt niet meer in een bedrijf dat nu loopt te pronken met z'n goeie diesel-technologieën.

- Nee, dat spreekt niet echt aan. Investeren in een innovatie in de diesel technologie, wat nog steeds zou kunnen, daar worden die aandeelhouders niet warm van.

Nee, maar inderdaad elektrische auto's en waterstof, en batterijen, dat vinden we allemaal heel mooi. Helder.

- Die State and Image daar hadden we het al over gehad. **Research and Development expenditures per employee. Die staat daar een beetje vreemd, want ik zou het pijltje net andersom verwachten.**

Nou, ik zal hem even toelichten. Het is een specifieke factor. Het is afkomstig uit het werk van een van mijn begeleiders, Wouter Beelaerts van Blokland. En hij is een andere kleur omdat het een kwantitatieve factor ten op zichtte van de rest, die meer kwalitatief zijn. Dit is echt wat meer een daadwerkelijke uitdrukking van de hoeveelheid geld die er wordt uitgegeven binnen een bedrijf aan Research and Development op een employee-basis. En het drukt eigenlijk de focus op innovatie uit binnen een bedrijf. En daarom heb ik hem als onderdeel van strategy gezet, want met deze factor kan je laten zien hoe innovatief een bedrijf eigenlijk is.

- Ja ja, dus bedrijven die veel aan innovatie doen...

Ja relatief dan hè, die employee-basis die gebruik je dan om bedrijven te kunnen vergelijken. Want het budget van het ene bedrijf valt in het niet bij die van een anderen. dus op deze manier kan je dan een soort eerlijke factor... een gebenchmarkte factor maken.

- **Ja ja, en hoe meer ze gewend zijn te investeren in R&D, hoe eerder ze ook geneigd zullen zijn om ook dan nu naar elektrische aandrijving te kijken.**

Zou ik wel denken ja, ik denk dat elektrisch rijden DE grote innovatie in de markt is. Hoeft natuurlijk niet per se om batterijen te gaan,. zou bijvoorbeeld ook kunnen gaan om elektro-motoren of een innovatie... veel research and development steken in autonoom rijden. Maar wat ik hiermee vooral uitdruk is: Bedrijven die hier hoog in scoren zijn waarschijnlijk degenen die zelf die batterijen hebben ontwikkeld, en degene die laag scoren zijn degenen die wachten tot de technologie bewezen is en het vervolgens dan inkopen. Dus die niet zelf op zoek gaan. Dat is eigenlijk waarom ik deze er apart in heb opgenomen.

- Oke. Ja. Adopters and Marketing. Adopters, daarmee bedoel je hoe het aanslaat in de markt...

Ja, alleen omdat... in dit geval is het dus... Het is een beetje krom, hier kijken we natuurlijk naar bedrijven die de innovatie oppikken. Niet zozeer naar klanten, **dus hier zou je eigenlijk bijna zeggen dat de adopters in dit geval bedrijven zijn. Dus die kijken naar...**

- **Dat is zo, maar dat staat niet helemaal los van de klanten. Want er moet wel enige bereidheid in de markt zijn om het aan te schaffen. En daar zit dan een factor tussen, in sommige landen, namelijk dat overheden dat kunnen stimuleren met fiscale maatregelen bijvoorbeeld, of subsidies. Om early adopters aan de klantenkant over de streep te trekken om een elektrische auto of een hybride aan te schaffen.**

Oke, ja, heel goed punt. Ik moet deze even aanscherpen, om even iets meer het onderscheid te maken tussen wie de adopters zijn in dit geval.

- **Want de rol van de overheid... Je hebt natuurlijk wel staan 'regulation', en de 'regulator' is de overheid. Nationaal of Europees. En ook nog eens plaatselijk, als het gaat om die milieuzones. In de gemeente Utrecht bijvoorbeeld. Maar die overheid heeft ook andere instrumenten. Die kan subsidies geven voor onderzoek, bijvoorbeeld. Die kan ervoor zorgen dat bussen elektrisch gaan rijden. Die kunnen subsidie geven aan klanten, die kunnen fiscale voordelen geven, die kunnen besluiten: In ons land mag in 2050 niet meer met een benzine-motor de grens overkomen.**

**Dus die [adopters en regulation] zijn eigenlijk verbonden met elkaar?**

- **Ja, dus dat is dus de overheid met allerlei instrumenten.**

Ja, zowel negatief als positief. en dat heeft invloed ook op de adopters. Ja.

- Dan gaan we naar de rechterkant van het model.

**Ja, daar staan een aantal dubbele in, omdat ik heb aangegeven dus... de starting fase en de growing fase heb ik apart... heb ik sommige twee keer opgenomen.**

- **Ja, maar dat is ook terecht, want...**

**Ja, ik zou zeggen dat company strategy bijvoorbeeld voor bedrijven die in de starting fase zitten, heel anders is dan voor bedrijven die in de growing fase pas instappen.**

- **Ja. Regulations speelt daar ook. Characteristics of the market speelt daar zeker ook. En dan is even de vraag waar heeft dieselgate invloed? Ik denk dat dat... een effect waar we het eerder over hadden, wat je nu alleen bij de start fase hebt staan, state and image[...] dat dat ook voor die volgende fase nog steeds van belang is**, want daar... 1 is de technologie en 2 zijn de producten. Oh ja, die heb je tussen haakjes staan, dat zijn allebei inderdaad.

**Ja ik heb hem er... daarvoor heb ik hem erin staan, bij de lock-in, maar u zou zeggen: hij geldt eigenlijk voor de hele fase?**

- **Ja daar geldt ie eigenlijk ook nog wel, zou ik zeggen.** Want wordt het nou... We zijn net die tweede fase ingegaan, vorig jaar denk ik dan, als je er jaartallen aan moet hangen. Het moment dat Tesla winst ging maken, ik weet niet of dat vorig jaar voor het eerst was, ik denk het wel.

Ja, dat klopt, ik zou hem alleen iets eerder zetten. Ik zou hem denk ik op 2017 want toen werden er voor het eerst in 1 jaar meer dan een miljoen EV's verkocht. Ik denk dat dat een redelijk tekenende periode is geweest. Gelet op verkoop cijfers.

- Nee, want verkopen terwijl je er verlies op maakt, zou ik nog niet als succes zien.

Nee, maar dat was Tesla hè, die er verlies op maakte. Weten we... maken die andere ook geen winst?

- Misschien waren er eerder al winstgevende, dat weet ik niet. Nou ja, dat is een kwestie van definitie. **Maar we zitten nu in ieder geval in die fase, maar ik denk dat nog steeds... dat imago dat beïnvloed is door sjoemel-software, dat dat een effect heeft, namelijk in het niet meer zonder meer met zachte handjes aanpakken van de auto-industrie.**
- Hoewel. Dat moet ik ook meteen relativeren, want toen dit was gebeurd en toen bleek dat andere fabrikanten ook sjoemelden... Toen is het eerste wat de Europese Commissie heeft gedaan, was de eisen versoepelen. Dat is wel gebeurd.

Oke, en wat was daar dan dan de logica achter? Omdat ze anders de industrie te veel zouden beschadigen.

- Ja, anders zou de sector teveel beschadigen. Duitse lobby. Dus je kan wel zeggen: Dat image is beschadigd en politici durven die industrie niet beter aan te pakken. Nee, de industrie is juist beloond. Voortaan moesten ze zich wel aan de regels houden, natuurlijk... het is ook voorgekomen die regels zelf zijn aangepast, zodat ze nog even konden doorgaan met sjoemelen. En dat is de Brusselse politiek.
- Maar goed, de totaaltendens is: Meer aandacht voor het milieu. Je ziet ook... Ja, het kan ook zo weer draaien hè. Maar Biden versus Trump. De huidige Franse president, de huidige Duitse regering. Een aantal leidende... Ook de Britse regering, voor zolang dat duurt,. Die zijn om, naar de milieuvriendelijke kant, dus ook naar elektrisch rijden. En China, ook. De houding van China zal waarschijnlijk beslissend zijn, want die hebben de grootste auto-markt, en die hebben autocratisch leiderschap, dus die kunnen het afdwingen.

**Ja, en dat is natuurlijk allemaal het gevolg van het feit dat de incumbent technologie niet meer... meer non grata is geworden?**

- **Inderdaad.** En de grootste problemen met smog zijn in China. Dus die moeten wel.

Ja die hebben een paar jaar geleden ook al die brommertjes verplicht ge-elektrifcieerd.

- Precies, en daarin lopen ze nu voorop.
- **Dus ook aan die kant heb je invloed dieselgate.**

**Ja, middels die regulation weer, middels die state and image, middels die... Nog anderen daar dan waarvan u zegt: Invloed van dieslegate? Zo op het eerste oog.**

- **Ja, dus eigenlijk allemaal. Characteristics of the market, want daar komen nu dus twee technologieën naast elkaar. En je ziet nu ook innovaties binnen elektrisch rijden. Sneller opladen bijvoorbeeld. En je krijgt de combinatie met zelf zonnepanelen op je dak en je eigen auto opladen. Waardoor je het batterijprobleem wat er is bij zonne-energie gedeeltelijk oplost met de accu van auto's. Dus daar zijn ander innovaties ook gaande. Dus binnen elektrisch rijden heb je een ecosysteem van verschillende innovaties. En dat kan ook, omdat het momentum heeft gekregen. Dus dat gaat vanzelf dan steeds beter. Dat ook weer. Er is een soort dynamiek, dat beïnvloedt ook de... Maar dat is dan de positieve dynamiek, dat hangt niet meer samen met dieselgate.**

Nee, dat is meer een after-the-fact phenomeen?

- Ja. En dat beïnvloedt Company Strategy and Fianances opnieuw. Maar nou zit het in de moves, dus nou moeten ze wel mee.
- **External influences. Dan neemt natuurlijk dieselgate af. en de nieuwe dieselgate zit er natuurlijk toch wel aan te komen, namelijk het eerlijk berekenen van de milieueffecten. En dan blijkt dat het voorlopig nog even negatief is, en slechter dan benzine.**

Ja, dat iedereen het zo verkocht heeft als dit is hosanna, maar als het inderdaad brass tacks, dan... Ja, ik begrijp wat u bedoelt. Maar het is wel zichtbaarder al. Deze zorgen worden al wel breder gedeeld dan... Van dieselgate wist inderdaad, u zegt, veel ingenieurs wisten daar vanaf, maar het brede publiek niet. Maar het feit dat als een elektrische auto laat rijden op elektriciteit die uit een kolencentrale is opgewekt, kijk naar Duitsland... Ik denk dat dat een iets breder... Ik denk niet dat dat pats boem als een schandaal uit zal komen. Ik denk dat het meer is dat het rapporten zijn, en dit iedereen geleidelijk aan: oh ja dat wisten we wel...

- Ja, maar ook daar wordt gesjoemeld. Als je ons klimaat-akkoord hebt. Niet voor auto's, maar wel voor huizen. Die beslissing van het gas af... Voordat een nieuw huis wordt gebouwd, moet je een bouwvergunning hebben en die is gebaseerd op een berekening. Een energie-prestatie berekening, dat is voorgeschreven in het bouwbesluit, en daar is een norm die aangeeft hoe je dat moet berekenen. De berekeningsmethode. En daarin is gesjoemeld met de berekeningsmethode voor elektriciteit. Dus op dit moment, is daar een factor... Ik weet niet meer precies wat het was... **Elektriciteit is ongeveer 2 of 2,5 maal zo slecht voor het milieu als gas. Die factor hebben ze expres gemanipuleerd, zodat gas er slechter uitkomt. Daardoor lijkt verwarming of energiesystemen gebaseerd op elektriciteit beter. Dat is hetzelfde als dieselgate. Maar dan in de bouw.**

**Oh. En u zou zeggen: als zoiets uitkomt dan zou je dat een External Influence noemen?**

- Nou dan krijg je een nieuw schandaal. Alleen kijk, degenen die dit nu al roepen, dat zijn die rechts-populistische partijen. Die worden niet serieus genomen, maar op dit punt hadden ze gelijk. Dus de vraag is hoe dat verder gaat. **Je kunt ook zeggen: Ja, dit is een tijdelijk iets, want naarmate we meer duurzame energie krijgen, en er meer innovaties zijn in elektriciteitsproductie en -opslag, lost zich dit vanzelf op.** En dan heb je inderdaad echt meer duurzamer autoverkeer dan met fossiele brandstoffen, dat is zo.Alleen de vraag is hoe snel we daar zijn en of we nu niet eigenlijk te snel lopen. Het gekke is ook dat we de nieuwe capaciteit van duurzame energie hier in Nederland... Nederland loopt sowieso achter, en als er dan iets nieuws is, dan gaan we daar data-centra voor Google en Amazon... Gaan we het daarvoor gebruiken en dan zetten we de Flevopolders vol voor dat doel En niet voor eigen gebruik.

Ja, dat is ook weer een lastig punt inderdaad. Helder.

- Maar goed, je kunt hier een nieuw schandaal krijgen. En dat kan weer de opmaat zijn om waterstof weer in the picture te zetten. En er kunnen ook nog andere schandalen bij komen, dat overzie ik niet. Zou me niks verbazen.

Ja, dan zou de Maurits Terwindt van over 15 jaar zou proces mijn framework erbij kunnen pakken, en dan zeggen: Nu is de incumbent is de batterij, en de challenger is de waterstofauto.

- Ja, dan hoeft die afstudeerder maar een woorden te verwisselen in jouw scriptie.

Ja, hartstikke goed. Heeft u nog opmerkingen, vragen of iets wat u hier aan toe wil voegen? Want ik denk dat u mij tot dusver flink geholpen heeft.

- Graag gedaan.

Heel duidelijk, ik heb nog een laatste vraag, tenminste, heeft u nog iets te zeggen over het framework of dieselgate?

- **Qua literatuur. Want er is literatuur die gaat over een dominant design. Dat is ook waar Geerten over schrijft. Maar er is ook een beetje literatuur, maar heel weinig, over multiple designs. Onder welke voorwaarden kunnen meerdere technologieën naast elkaar blijven bestaan. Daar heb ik wat over geschreven, ik kan je een paper toesturen. Dan gaat dat over standards, en dit is wel een heel breed gebied van technologie. Dus de vraag is of de factoren die we daar hadden gevonden, of die zomaar hiervoor geleden. Misschien niet. Was ook incompleet. Ik heb nog wat later onderzoek, maar dat is allemaal nog niet gepubliceerd. Met nog wat meer factoren.**

Interessant, ja. En dan denk ik even, simpel gezegd, aan het feit dat we meerdere soorten spelcomputers hebben.

- Bijvoorbeeld, ja. Dat is een handig voorbeeld. En dat blijft ook bestaan. Dus gedurende de verschillende generaties van die spelcomputers blijven er een paar naast elkaar bestaan.

Ja, precies, terwijl ze eigenlijk in principe... Ja, hoeveel verschillen ze nou eigenlijk he? De ene is iets beter in dit, en de andere is beter in dat. Maar ze hebben min of meer dezelfde capaciteiten, dezelfde spellen, zelfde controllers.

- **In deze markt zou ik verwachten dat er twee technologieën tot een lengte van jaren.. In ieder geval nog decennia naast elkaar blijven bestaan. Voor meer dan alleen old-timers. Tenzij, de productie van de benzine-auto, en het gebruik ervan worden verboden.**

Ja, dus u zou wel zeggen: Ze worden steeds schoner, dus met duurdere filters en zo. Maar u zegt: Voorlopig zullen die nog wel...

- **Nou, tenzij overheden ingrijpen en dat is best plausibel dat ze dat doen.** Zolang overheden alleen lokaal... Je mag Oslo niet meer in, als je niet elektrisch rijdt. Dar gaat het in ieder geval naar toe. Utrecht ook. Dat worden geleidelijk meer plaatsen, **dus dan wordt het minder aantrekkelijk om een benzine-auto te hebben, want dan kun je bepaalde punten er gewoon niet mee komen.**
- **Omgekeerd is het nu nog een probleem, als je lange afstanden wil rijden, dan is elektrisch rijden nog niet helemaal geschikt. Dat gaat allemaal opgelost worden.**
- **Dan heb je nog een prijsverschil wat kleiner zal worden of verdwijnt.**
- **Dan heb je nog misschien persoonlijke voorkeur. Beetje nostalgische gevoelens of zo. maar het zal als vanzelf nog wel best een lange tijd naast elkaar blijven bestaan. Zou ik verwachten.**

Maar dat zou dan wel gaan met auto's die er al zijn denk ik. Want ik heb toch wel van veel grote autoproducenten de plannen erop nageslagen, en eigenlijk geven ze allemaal aan: We faseren brandstofmotoren uit, en wij stappen over elektrische voertuigen in 2030, of... De meeste hebben toch wel plannen om de hele productie-lijn dan wel als hybride aan te bieden, dan wel volledig elektrisch.

- Maar er kunnen nog steeds fabrieken staan in Turkije of in andere landen. Die nog doorgaan met oude productie.

Ja, de kleinere bedrijfjes bedoelt u? Niet de giganten?

- **Nee, juist de Lada-producten zeg maar. Die het ook tehcnologisch helemaal niet aankunnen om zo'n moderne auto te maken. Of de modellen van westerse producten mogen maken, en ja die moeten nog doorgaan.**

Duidelijk. Ik had nog een allerlaatste vraag. Ik probeer via dit soortinterviews ook nieuwe interviewees te vinden. Heeft u basis van ons gesprek van vandaag een paar namen waarvan u zegt: Goh die zou je hierover kunnen spreken? Wellicht mensen uit de industrie of zo? Of anderen waarvan u zegt... Om over mijn framework of dieselgate te interviewen.

- Ja, ik heb niet direct namen. Maar dus, TU Eindhoven, de groep autotechniek. Want Eindhoven doet daar meer aan dat Delft. TNO Helmond weten het allemaal. Die zitten hier bovenop. Of ze open willen vertellen dat is een tweede. En ik weet ook niet wie je daar moet hebben, maar zeker de TU dat is transparant. Dus dat is die kant
- We hebben natuurlijk ook nog auto-producenten. DAF is dan vrachtwagens, dus dat is net wat anders, maar daar speelt hetzelfde. Dus in die zin, is dat toch nog wel een aardige misschien, want zij staan buiten het schandaal maar ze gaan ook over op elektrisch.
- En dan VDL. Die fabriek in Born, dat is net bekend geworden, die gaat over op de productie van elektrische auto's. Die hebben net een deal gesloten met een Amerikaanse, kleine club. Stond deze week in de krant. Dus die maken de transitie. Ook. En dat is een assemblage-fabriek, dus die zitten niet in de leiding, maar die kennen de markt natuurlijk wel goed genoeg. Dat zij net die overstap maken, ja daar hebben ze over nagedacht. Ze gaan nu met zo'n kleine speler in zee, dat kan misschien niet eens uit. Maar BMW gaat daar weg. Dus ze moeten andere bedrijven hebben die hun auto's in Born willen assembleren. En nu hebben ze juist in elektrisch rijden... Dus dat is ook de moeite waard.
- Ja, en dan zou het mooi zijn als je in het Brusselse iemand kon vinden, in de Europese commissie.

- Ja en dan voor de eisen-kant... Er zijn vrijwillige eisen en verplichte eisen voor auto's En de vrijwillige, dat volgens mij de UN-CAP, en de partij die daar naar Nederland naar kijkt, is de ANWB, en ook de RAI is interessant, dat gaat meer om importeurs. Dus als het gaat om eisen aan auto's... Misschien gaat dit wel te ver hoor, voor jouw onderzoek. Want de ANWB is het aan zijn stand verplicht om ook naar de klanten-kant te kijken. het zit nu heel erg aan de producten-kant, maar die klanten-kant is er ook. En dan, als het gaat om de toelating, dan zit je bij de Rijksdienst voor wegverkeer in Veendam. Maar die moeten gewoon toetsen aan de bestaande eisen. Ja die hebben er [producentenkant] vast wel ideeën over, maar dat gaan ze je dan ook niet vertellen want dat zijn natuurlijk ook ambtenaren, die mogen dat niet zomaar zeggen. Dat is dan misschien minder interessant.
- En dan zou het kunnen zijn dat er mensen vanuit de bedrijfskunde kant een speciale interesse hebben in deze sector. Dus meer gewend zijn in termen van bedrijven en bedrijfsstrategieën te kijken. Ik weet niet of die er zijn, ik zo'n collega, maar die is weg naar het bedrijfsleven. Dus dat heeft geen zin meer om die te interviewen, die heeft er in ieder geval geen eigen onderzoek meer naar gedaan. Misschien ook wel bij TBM in Delft, en anders zou ik die ook verwachten in Eindhoven, bij innovatie-management daar. En misschien ook wel in Twente.

**Transcript 2**

Fijn dat u er weer bent. Zoals u ziet heb ik het framework geupdate. En ik zou graag dat nog even heel kort met u bespreken. Heeft u er een blik op kunnen werpen?

- Ja, ja ik heb nog wel wat opmerkingen.

Oke, nou heel fijn. Dan maak ik gelijk even aantekeningen. Nou ik hoor ze graag. Tenzij u wil dat ik er nog even een keer doorheen loop om alles toe te lichten? - Nou ik denk dat dat niet nodig is. Ja dus de feedback gaat over de verschillende... Je hebt geprobeerd factoren in feite te groepen. En de vraag is of dat altijd goed gelukt is. En of het de lading goed dekt.

- Dus bij het begin beginnen. Company strategy and finances, Daar heb je ook bijstaan, operational supremacy... Dat is sowieso belangrijk, maar dat zou ik niet scharen onder strategy, en ook niet onder finance. Dus dat zou ook iets als 'Company Strength' kunnen zijn of zo. En dan de manier van meten, als je uitgaven voor Ren D meet, dan weet je nog niets of die ook goed besteed worden he. Want als je met lage uitgaven, heel veel kan bereiken, is dat natuurlijk beter dan hoge uitgave. Dus die incidactor wordt ook wel vaker gebruikt, bij innovatie-onderzoek, maar ik weet niet zeker of dat een goeie is. De vraag is of het dan wat anders is. Maar bovendien relateert de meetmethode dan ook niet aan de naam je hebt gegeven aan de factor. Dit gaat over innovatie, R and D expenditures, en dat noem je nou juist niet bij strategy, en ook niet bij finance.

Oke, ik heb dit gekozen omdat de papers waar dit uit komt, geven aan dat een focus op innovatie een belangrijk onderdeel is van strategie, omdat je een richting aangeeft voor de strategie. namelijk dat je dus betere producten wil blijven produceren.

- Ja, maar dan zou ik de factor 'Innovation-focus' noemen. In die richting,. Je kunt namelijk ook als strategie hebben, om altijd nummer twee te zijn, en zoveel mogelijk van anderen te kopiëren. Akzo nobel heeft dat decennialang toegepast en dat was er nog succesvol mee ook.

Dat is een goed punt. Daar ga ik eens even over nadenken.

- Dan de tweede, Adopters/ Customers. De vraag is even of je je beperkt tot consumenten-markten, of ook professionele. Sowieso customers, dat is een samenvattende term. Als je die überhaupt wilt kiezen, dus dat ligt aan jou. Maar dan ook hier weer, is de vraag of je dat op de goede manier meet. Profit per employee lijkt me geen goeie, want het gaat hier om market share die toeneemt. Een van de manieren omdat te bereiken is penetration-pricing. Dus dat je in het begin een verlies op de koop toeneemt, Maar dat je door die lage prijs veel early adopters krijgt, waardoor later anderen ook zich aansluiten, bandwagoning, zodat je die grote adoptie krijt. En dan later ook die financiele revenuen. Maar eerst niet. Dus dat is een verkeerde methode om het te meten.

Oke, dan wil ik u even iets laten zien. Ik heb dit toegepast voor Tesla, Volkswagen en BMW. Hier is dat bijvoorbeeld goed zichtbaar. Dus bijvoorbeeld bij tesla zie je dat heel goed, die hebben jarenlang ontzettend verliezen geleden om inderdaad door te breken. En dat maak je op zich inzichtelijk via deze metric, toch?

- Uh ja, maar het is een factor voor succes. En in die beginperiode, suggereert die factor falen voor Tesla. Maar wat je wil zien, is doordringen in de markt. Dus je zou installed base hier als meet-factor kunnen nemen. En dat zie je bij elektrische auto's, dat Tesla in de beginfase juist voorop liep.

En dat installed base, dat doe je dan als market share?

- Ja dat zou kunnen ínstalled base' is trouwens nogal een verwarrende term, die wordt op verschillende manieren gedefinieerd. Market share zou beter kunnen zijn ja.
- Dan, other firms. Dat is ook weer de vraag... hoe je dat ziet. Want je gooit nu alles op 1 hoop. Al die other firms. Maar wat vooral interessant is, dat zijn de concurrenten, versus anderen. Toeleveranciers zijn weer heel anders. En producten van complementray goods is ook weer heel anders. Ik vind dit een beetje een moeizame.

Staat concurrentie daar ook in? Dit ging vooral om de value-chain, dus inderdaad network of stakeholders. ik zie dat daar ook staat, incumbents feeling threathened by new entrants. Ik boedel hier toch eigenlijk wel mee... Niet-concurrenten zeg maar. Dus het verhaal eromheen.

- Ja, zijn dat dan network-partners? Maar het zijn niet allemaal partners, dus dit is een beetje vage groep. en de meetmethode vindt ik dubieus. Turnover per employee, dat zegt niks over die anderen.

Nogmaals, deze komt uit een paper waarin aangegeven wordt, dat dat betekent dat je... hoeveel je van je waarde van je product en je suppy chain kunt overhevelen op andere bedrijven in je supply chain.

- Ja maar dat zegt dit niks. Bovendien wat hier door elkaar loopt, is het product-niveau en het organisatie-niveau. want die battle gaat over product-niveau. De meetgegevens... turnover per employee, die employee hoeft helemaal niet bezig te zijn met deze nieuwe technologie. Dus hier kun je niks mee.
- Dan 'State and Image of the manufacturers of the technology'. Er zit natuurlijk een groot verschil tussen de manufacturers en de technologie zelf. Dat gooi je nu op een hoop. En vervolgens blijkt dit een container begrip te zijn. Price/performance advantages.. Resource scarcity, dat is een vreemde eend in de bijt.

Nu u het zegt, realiseer ik me inderdaad dat deze eigenlijk vooral over de bedrijven zelf moet gaan, omdat de technologie eigenlijk al gevangen wordt in characteristics. Dus eigenlijk moet ik deze even loskoppelen en hem puur over het bedrijf maken.

- Ja, maar ook dan geldt nog steeds dat er dingen bijstaan, die niet bij bedrijf horen.

Ja klopt, dat is een gevolg van het clusteren. Maar als ik hier de technologie uithaal, dan denk ik dat dat wel recht komt. U bedoelt bijvoorbeeld de user base en resource scarcity en zo. Ja, eens.

- Ja wat we eerder hadden, die operational supremacy, die hoort hier dan weer bij.
- En dan krijgen we characteristics of the technology. Die moeten dan ook gaan over echte karaktersiteken van de technologie zelf. En die moet niet gaan over development, en ook niet over scientific support. Want dat is het proces om tot de technologie te komen. En het gaat ook niet over Complementary Goods. Dat zegt niets over het gebruik van dat product.

En niet bijvoorbeeld dat het gebruik van het product... Ja, maar dat de karakteristieken van de technologie zijn dat ze in samenwerking met complementary goods. Alhoewel, dan is het niet complementary waarschijnlijk.

- Dat zou kunnen. En dan heb je het in feite over, wat Geerten van de Kaa noemt 'technologicial superiority'. En daar kan 'fitness voor use bij horen'. En dan past het er wel bij. Dat is een term van Juran. En dat doe je ook... En de meetmethode past daar ook bij. Want Juran was een guru op het gebied van kwalitateitsmanagement. Dit was de definitie van kwaliteit voor hem. Dus als je dat... die meetmethode past daarbij.

En dat is een meetmethode, een kwantitatieve meetmethode?

- Nee, kwalitatief. Die kun je hoogstens kwantitatief maken als je daar een Likert scale voor gebruikt. Dat kan bij je anderen ook.

Ja, ik doe het eigenlijk met een Likert scale van 3, maar het is eigenlijk inderdaad wel wat logischer om het numeriek te maken.

- Ja, 1 tot 5, of 1 tot 7.

Ja, dat is een goeie. Ik ga eens even kijken of dat voor anderen ook van toepassing kan zijn. Ik moet heel even kijken hoe en wat ik op dit punt. Ik vind dit hele fijne feedback, want wellicht kan ik dat inderdaad nog meenemen. Een Likert scale vindt ik een sterke suggestie.

- Dan, Regulator en Regulation. Dat zou ik, gegeven wat je er allemaal bijschrijft, zou je dat kunnen veranderen door 'Government'. Die overheid kan het stimuleren of afremmen, of zelfs verbieden of verplicht stellen. Maar dit is niet alleen via wetgeving, maar ook via inkoopbeleid en andere overheidsinstrumenten. Dus je hebt dat breder getrokken, dat is ook terecht, maar dan moet je het niet 'regulator' noemen.
- Nou, dan characteristics of the market, daar had ik geen opmerkingen bij. Meetmethode is ook goed.
- Ja, de laatste is een restpost, maar daar hebben...

Ja, die heb ik verkeerd in het document staan, die heet nu eigenlijk 'Environmental factors'.

- Ja, dat is inderdaad beter. En of daar al die overblijvende factoren... We hebben net natuurlijk ook een aantal keer gezien dat iets ergens niet helemaal goed onder past... Of dat dan allemaal in deze categorie past, of dat je dan nog wat overhoudt. Dat durf ik niet te zeggen.

Oke, fijn dank u wel. Ik zit nog heel even te denken want ik heb toch veel... Vooral met die eerste drie heb ik inderdaad veel al gedaan. Ik zit even te denken over wat nou wijs is om daar aan te veranderen. Ik zit even hardop te denken, wellicht dat u nog iets te binnen schiet. Dus inderdaad, dus Adopters/ Consumers, zou u eerder als market share suggereren?

- Ja, als meetmethode.

En voor die eerste, want u zegt, als je dus kijkt naar RD per C, dan is het logischer om dat 'focus on innovation' te noemen? Dus dat zou u als een aparte factor dan zien, maar heeft u dan suggesties om strategie of finance te meten, wil je dat in pure winsten doen? Want dat is een beetje het idee van deze 'per employee' metric. Is dus om per bedrijf te stellen, van: we kunnen nu vergelijken, want de winst van Tesla vergelijken met de winst van Volkswagen, bijvoorbeeld... Ik heb ook een test case gedaan, waarbij ik Apple en Nokia vergelijk, dat zegt niet... Tenminste, dat is waarom ik dat doe, maar dus gewoon puur de winst vergelijken dat zegt niet zoveel. Heeft u suggesties voor...

- Die komt achteraf. Daar gaat het hier helemaal niet om. En die winst kan ook komen uit hele andere producten of diensten. Dus je moet die financiële karakteristieken linken aan deze specificatie, aan deze technologie. En anders niet.

Ja, er is natuurlijk ook een mogelijkheid om het op een een 'per unit produced' basis uit te drukken.

- Ja, dus dan krijg je winstpercentage.

Ja, in zekere zin.

- Maar, zoals dat Tesla voorbeeld als liet zien, dat zegt niet zoveel, want dat verlies in het begin, sluit niet uit dat het daarna toch nog goed kan komen.

Nee, het is wel zo dat daar, wat we ook doen, ik kijk naar een hele grove trendline inzake deze, de ontwikkeling van zo iets. Dus dan, zie je bij Tesla bijvoorbeeld wel een positieve stijging erin zitten, dus op zich kijk je niet zozeer puur naar de RD/C... ja die is dan weer bij Tesla zeer negatief, maar dat komt omdat zij in het begin natuurlijk heel veel geld hebben uitgegeven. Maar dat laat op zich zien hoe het zich ontwikkeld over tijd, in een grove manier.

- Ja. Maar Tesla had ook gesneuveld kunnen zijn. Het is niet normaal om jaar in jaar uit zulke verliezen te maken.

Ja, dan zou je bijvoorbeeld moeten denken of het misschien een... Zal even laten zien hoe dat dan bij Apple en Nokia verliep. Daar zijn de dingen wat meer voor zichzelf sprekend. Dus daar zie je inderdaad dat een zich een negatief ontwikkelende trend zich uiteindelijk, tot een verlies leidt, omdat je als bedrijf gewoon niet meer innovatief bent en daarmee je zelf eigenlijk obsolete maakt. Maar goed, daar ga ik eens over denken. Dus ik moet iets hebben wat meer de finances echt bevat, in plaats van een focus op innovatie? En focus op innovatie vindt u niet een indicatie van strategie?

- Strategie kan over van alles gaan. Kan over gender-gelijkheid gaan, het gaat over niet produceren in China, met het oog op Oeigoeren, kan echt van alles zijn. Dus dat zegt niks. Het gaat jou om R en D.

Dus misschien is het sterker om het Company R&D focus te noemen, en finance, ja dat kan van alles zijn... En dan voor finances een beter metric verzinnen.

- Of helemaal weglaten.

Helemaal weglaten lijkt me lastig. Want dat lijkt me toch namelijk wel ook door middel van literatuur een redelijk essentieel onderdeel van dit proces.

- Je literatuur heeft een Amerikaanse bias, en dus geld bias. En dit model, jouw kernmodel, gaat over market share. De vervanging van een bestaande technologie door een nieuwe. En natuurlijk verwacht je, en dat is ook nodig, dat er geld binnenkomt, anders kunnen ze niet doorgaan met die nieuwe technologie. Er zit wel een financiële component aan, vanzelfsprekend. Door financieel succes tot maat te maken, krijg je juist korte termijn... Dan zou je succesvol zijn als je meer winst hebt. En dan ligt het vervolgens aan de tijdsperiode, nou dat laat het verhaal met Tesla zien, ook zonder winst te maken, kun je toch uiteindelijk succesvol worden. Maar dan is geld dus niet de goede maat voor uiteindelijk het verdringen van die oude technologie.

Dat is een interessant punt eigenlijk.

- Dus dat geld is op een later stadium, de vrucht van het verdrongen hebben van die oude technologie.

Aha, dus eigenlijk geen inherente drijvende factor? Meer een resultaat van...

- Het kan natuurlijk wel een drijvende factor zijn voor de investeringen.Dat is het bij tesla zonder meer, maar het is gekoppeld met langere termijn visie. En iemand die dat zo overtuigend heeft weten te brengen, dat ie leveranciers zo gek kreeg om in z'n droom mee te gaan, en het is nog positief uitgepakt ook. Hoewel nu natuurlijk de concurrentie het helemaal ook oppakt, dus de vraag is wat straks uiteindelijk de plaats van Tesla is in het geheel, en wat wordt door Volkswagen en weet ik wie allemaal gedaan? Maar dat de dieselmotor verdrongen wordt, dat wordt wel steeds duidelijker.

Ja, zeker, dat is iets waar alles wel op uitwijst. Goed. Duidelijk. En, even kijken. Dus other firms hebben we het ook over gehad, dat u vindt van, nou dat is een vage groep en de meetmethode is dubieus. Delen daarvan moeten ook naar anderen. Maar als je puur naar de rest van de value chain kijkt, dus echt van, hoe zijn jouw partnerships. Want daar draait het eigenlijk om hè, dus die metric komt uit literatuur waarin staat dat deze metric aangeeft, hoeveel van je waarde je kunt, wat heet leveragen, dus kunt overhevelen naar anderen, zodat zij een deel van je value voor jou produceren alvast. Het komt uit papers omtrent manieren om te meten hoe lean een bedrijf is. Wat zou dan, in uw idee, een betere metric zijn om de sterkte van partnerships... Want ik denk dat ik dan deze partnerships, alliances, maar ook supply chain-bedrijven... Dus dat is wat ik hiermee wil zeggen. Dus een beetje bedrijven die er omheen zitten. Heeft u daar een idee over, van wat nou een sterkere metric zou kunnen zijn daarvoor? Een idee, je zou kunnen zeggen, maak hem kwalitatief?

- Nee. Want het gaat om heel specifieke partners. Je noemt nu heel specifieke vormen van partnership.

Oh ja, oke. Dus omdat het zo'n bijzondere hoop is, is het lastig om daar een kwantitatieve uitspraak over te doen, zegt u?

- Ja, ik zou het echt niet weten.

Nee goed, ik begrijp het. Ik denk dan, dat wij een heel eind gekomen zijn. iets langer dan ik dacht, maar heel erg fijn, want ik heb hier absoluut waardevolle inzichten uit opgedaan. Ik ga ermee aan de gang. Ik ga kijken hoe ik het erin kan verwerken, of aan te dragen als input om het model te verbeteren. Heel erg veel dank. Fijn dat u hier tijd voor had.

# C Interview questions, and explanation documents

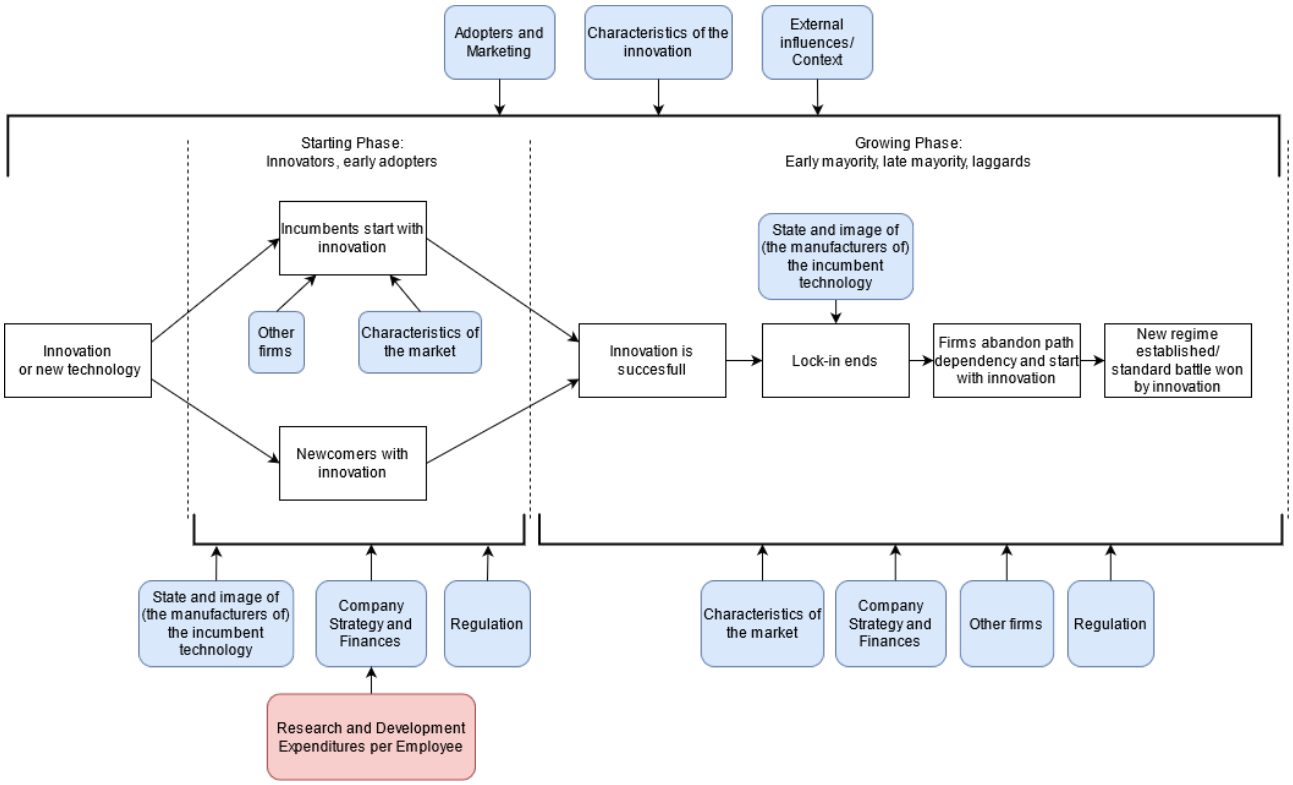
**Each interviewee is sent a short document explaining the framework ahead of the interview. The following interview questions refer to that document.**

## C.1 Interview questions

- What is your first impression of the framework and it's underlying factors?
  - What questions do you have regarding the framework?
- Do the underlying factors explain the process of EV's replacing ICE vehicles in automotive companies well enough?
  - Why or why not?
  - What factors do you feel are missing, or are redundant?
- Which of the factors in the current framework, and the ones just added by you, do you feel are affected (negatively or positively) by dieselgate?
  - Why do you feel that these factors were affected by dieselgate, and to which degree?
- Do you have any other remarks about the influence of dieselgate on the uptake of EV's in automotive companies, the framework or the research in general?
- Who else would you recommend to approach for an interview about this subject?

## C.2 Short explanation of the research and framework (first iteration)

The main research question in this thesis is whether dieselgate has had an influence on the observation that many automotive producers are announcing to move away from Internal Combustion Engine (ICE) vehicles, and move towards Electric Vehicles (EV's). To this end, the process of EV's taking over from ICE vehicles is framed as an innovation taking over from an incumbent technology. By combining several frameworks pertaining to the various phases of that process, a framework specific for this thesis is created. The underlying factors of the used frameworks were analysed for overlap, and subsequently clustered into factors pertaining to the 'thesis-framework'. The framework and the factors can be seen below.




As can be seen, the process consists of various steps, divided into five phases. Factors influencing those phases are connected to them, either directly or over-arching when they apply to multiple steps or phases. Due to there being multiple phases, the influence of certain factors might be different per phase, which is why certain factors are included multiple times. The red factor signifies a quantitative factor, whereas the rest are qualitative, which is why it is indicated separately. A short explanation of each of the factors can be found at the end of this document.

The main hypothesis is that dieselgate is not a direct factor such as the ones that are seen in the framework, but rather has had an accelerating or magnifying effect on several of the factors that can be seen in the framework.

**The main goal of the interview is to find out on what factors the interviewee thinks dieselgate has had an effect on the factors in the framework (either positive or negative), and if they feel that these factors/phases accurately describe the process at hand, or that certain aspects need to be added, removed or changed. I am also looking for suggestions on who else to interview regarding my research. I ask you to have a close look at the framework, and briefly think about these topics before the interview. Thank you in advance.**

**Characteristics of the innovation**

This factor refers to any aspects of the innovation, both positive and negative, that determine its success or failure with regards to the incumbent technology. This could concern performance, various aspects of the development, quality (which is often worse than incumbent at first), or scientific support for the technology. This factor also includes aspects such as: price (often initially higher than the incumbent technology) switching costs, complementary goods, flexibility, and compatibility with existing structures.

**State and image of (the manufacturers of) the incumbent technology**
Aspects of this factor are related to the state and image of both the incumbent technology itself, as well as it's manufacturers. The state refers to the weakening of the price/performance advantage, the incumbent technology or the company reaching a state of crisis, or resource scarcity driving up cost. but also to the size of the user base. Through the 'image', this factor also includes the manner in which the manufacturers and the technology are perceived by the parties such as environmental organisations, politicians, and the public. In other words, this factor describes the reputation of a company, or the industry. As both state and image influence how well regarded and present the incumbent technology is, they are united in this one factor.

**Adopters and marketing**
This factor concerns the manner in which the innovation is regarded by the consumers. The adopters are described through aspects such as: characteristics of the adopters, customer preferences, (changes in) the social connotations of the innovation, the added value that the innovation has for a consumer, and the bandwagon effect. The marketing aspect of this factor is described through pricing strategy, marketing communications (PR or commercials, for example), the timing of the product's entry on the market, and the distribution strategy. Another important aspect in this factor are 'network externalities', which describe the effect of the value of a product to a consumer increasing when the number of people adopting the product grows.

**Other firms**
This factor refers to all influences that other firms, or the relations between other firms, might have on the innovation or on the incumbent technology. As such, this factor consists of to aspects such as: incumbents feeling threatened by new entrants (or conversely, not recognising the threat), competition within the industry, the suppliers of the industry, and the network of stakeholders related to the incumbent technology or the innovation.

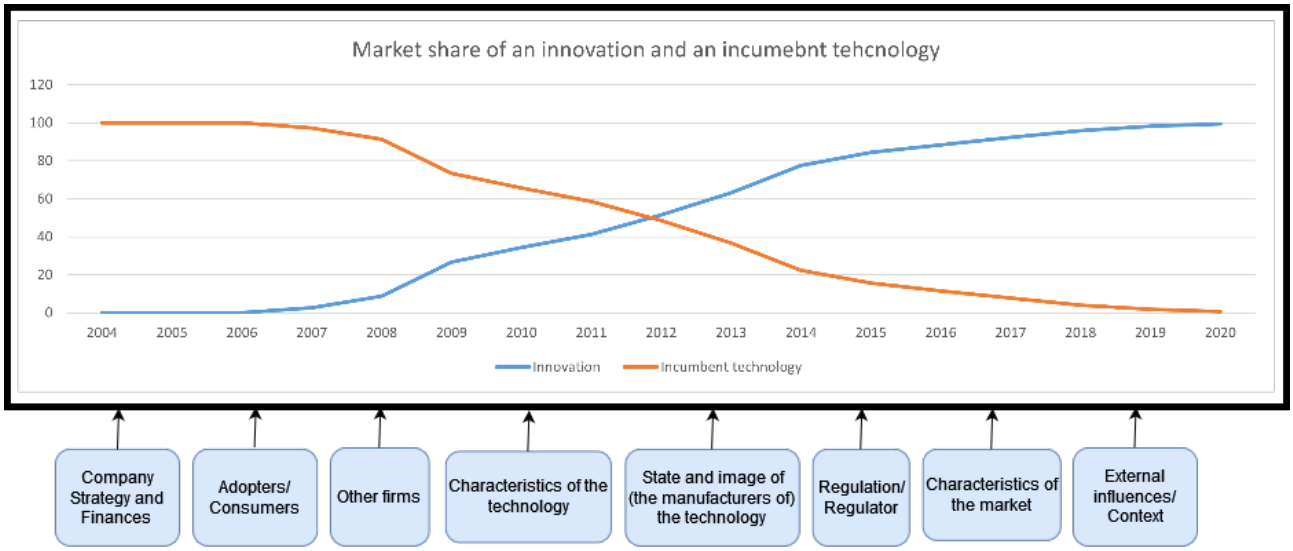
**Regulation**
This factor refers to the innovation becoming more attractive, or an incumbent becoming less attractive, due to changes in regulation. It also refers to anti-thrust laws (which mainly concern fair competition).

**Characteristics of the Market**
Characteristics of the market concerns all aspects that have to do with the market in which the incumbents and the newcomers operate. As such, it concerns changes to the market, the existence of niche markets, and the pattern in which the innovation enters the market (often first niche, then meso, then macro, but this may vary). It also refers to uncertainty in the market (through a number of causes), which could create a favourable environment for one standard (or new technology) to become the dominant one.

**External influences/ Context**
This factor concerns aspects that do not fall in the other categories, or aspects that describe the ecosystem (or environment) in which the innovation and the incumbent technology exist (i.e.: aspects of the industry not described through the other factors). An important aspect in this factor is the influence of an external shock or crisis. It also contains the influence of socio-technological systems, which mainly refers to the link between people or society, and its relation to technology.

## C.3 Short explanation of the research and framework

The main purpose of this framework, is provide a practical way to analyse the process of an innovation taking over from an incumbent technology as the dominant format. This process is driven through various factors which are found through literature. These factors all exert an influence on the process (either positive, negative or neutral), which is determined in various ways. The framework can be seen below, the various factors and the way their influence is determined, are seen below that.




**The main goal of the interview is to verify the framework. That is to determine if the interviewee feels that this framework is indeed right to analyse the process of an innovation taking over from an incumbent technology. , through the defined factors. Hereby it is is also of importance if the interviewee feels that the influence of certain factor is determined in a right way (or if they feel that another way would be more suitable). I ask you to have a look at the framework and factors, and briefly think about these topics before the interview. Thank you in advance.**

**Company Strategy and Finances**
Concerns anything related to the financial and strategical decisions of a company, both for the innovating as well as the incumbent party. Concerns internal company culture and the the focus/commitment to innovations. It also involves the operational supremacy a company can have, and it's ability to claim resources for its own.

**Determined quantitatively through the R&D expenditures per employee (over time), as this denotes a focus on innovation and concerns financial allocation. A positive growth over the period under analyses, denotes a positive influence**

**Adopters/ Consumers**
Concerns the manner in which the innovation is regarded by the consumers. Described through aspects such as: characteristics of the adopters, customer preferences, (changes in) the social connotations of the innovation, the added value that the innovation has for a consumer, and the bandwagon effect. Also concerns pricing strategy, marketing communications (PR or commercials, for example), the timing of the product's entry on the market, and the distribution strategy.

**Determined quantitatively through profit per employee (over time), as this denotes the ability to create value for the customer, and being able to convince them of it. A positive growth over the period under analyses, denotes a positive influence.**

**Other firms**
Refers to all influences that other firms, or the relations between other firms, might have on the innovation or on the incumbent technology. Consists of aspects such as: incumbents feeling threatened by new entrants (or conversely, not recognising the threat), the suppliers of the industry, and the network of stakeholders related to the incumbent technology or the innovation.

**Determined quantitatively through turnover per employee (over time), as this denotes the ability to leverage value onto the supply chain. A positive growth over the period under analyses, denotes a positive influence.**

**State and image of (the manufacturers of) the technology**
State refers to the weakening of the price/performance advantage, the technology or the company reaching a state of crisis, or resource scarcity driving up cost, but also to the size of the user base. 'Image', includes the manner in which the manufacturers and the technology are perceived by parties such as environmental organisations, politicians, and the public. In other words, this factor describes the reputation of a company, or the industry. As both state and image influence how well regarded and present the technology is, they are united in this one factor.

**Determined qualitatively, as positive, negative or neutral.**

**Characteristics of the technology**
Concern performance, various aspects of the development, quality, or scientific support for the technology. Also includes aspects such as price, switching costs, complementary goods, flexibility, and compatibility with existing structures.

**Determined qualitatively, as better, the same or worse than the standard of the market.**

**Regulation/ Regulators**
Refers to any regulation, or the general attitude of regulators that might make either technology more or less attractive. It also refers to anti-thrust laws (which mainly concern fair competition). This could refer to both regulation or regulators' attitude pertaining to the manufacturer (laws pertaining to a certain technology or its production, tax breaks, research funding, fines, loans, bail-outs), and the consumer (financial incentives, or regulation pertaining to the infrastructure surrounding a technology, like governmental investments, or regulation barring usage of technology in certain areas).

**Determined qualitatively, as 'rewarding', 'neutral' and 'penalising'**

**Characteristics of the Market**
Concerns all aspects that have to do with the market in which the companies of either technology operate. As such, it concerns changes to the market, the existence of niche markets, and the pattern in which a new technology enters the market. It also refers to uncertainty in the market (through a number of causes), which could create a favourable environment for one standard to become the dominant one, and the level of competition.

**Determined qualitatively, as 'favourable', 'unfavourable' or 'neutral'.**

**External influences/ Context**
This factor concerns aspects that do not fall in the other categories, or aspects that describe the ecosystem (or environment) in which the innovation and the incumbent technology exist (i.e.: aspects of the industry not described through the other factors). It refers, for example, to the geographical location for a company, which may mean access to supporting companies and technologies, or access to good personnel. Another important aspect in this factor is the influence of a shock or crisis. It also contains the influence of socio-technological systems, which mainly refers to the link between people or society, and its relation to technology.

**Determined qualitatively, as 'favourable, neutral or 'unfavourable'**

# D Groupings of factors of the found frameworks

| | Oldenburg: Succesful diffusion and the rate thereof | Van den Hoed: Radical innovation in incumbents | Dijk: Disruptive innovation entering the market | Cowan: Escaping lock-in | Hardman: Succesful disruptive innovation | Van de Kaa: winning the standard battle |
|---|---|---|---|---|---|---|
| **Company Strategy and Finances** | | | Firms experiencing or expecting higher returns | | | * Learning orientation<br>* Appropriability strategy (or finances)<br>* Commitment of the company to the innovation(s)<br>* Financial strength<br>* Effectiveness of the format development process |
| **Characteristics of the technology** | Characteristics of the innovation | Performance of the new technology | | * Cost or technological breakthrough | * Quality of innovation often initially worse<br>* Innovation is initially more expensive | * Technological superiority<br>* Compatibility<br>* Complementary goods<br>* Flexibility<br>* Switching costs |
| **State and image of the company** | | External shocks or crises | Resource scarcity driving up cost and weakening the price/ performance advantage of the established technology | * Existing tech reaches state of crisis<br>* Threat of innovation not recognized by market leaders | Incumbent technology never wiped out completely | * Brand reputation and credibility<br>* Operational supremacy |
| **Adopters/ Consumers** | Characteristics of the adopters | | * Reframing of customer preferences<br>* Changes in social connotations of the product | *Changes in taste that favour new technology<br>* New technology receiving support from scientific community | Added value for customer | * Timing of entry<br>* Pricing strategy<br>* Marketing communications<br>* Distribution strategy<br>* Network externalities<br>* Bandwagon effect<br>* Current installed base<br>* Previous installed base |
| **Other firms** | | * Incumbents feeling threathened by new entrants | Technology spilling-over from other sectors which compensates the scale and learning gap of the niche with respect to the regime | | | * Big fish<br>* Suppliers<br>* Network of stakeholders |
| **Government** | | | Regulation providing the niche technology with relative benefits over the established technology | Regulation has impact on the industry | | * Regulator<br>* Anti-trust laws |
| **Characteristics of the Market** | | * Market changes<br>* Industry competition | | Existance of niche market | Innovation fills niche market first, then meso, then macro | * Uncertainty in the market<br>* Rate of change |
| **Environmental influences** | Features of the setting or environmental context | | | | Socio-technical systems are ever evolving | * Pre-emption of scarce assets |

Figure 34: Matrix showing the process behind clustering the factors from the selected frameworks

# E Data Case Study 1

Table 30: Data set on smartphone market shares (ZDNet, 2006; Grigsby, 2010; GlobalStats, 2021)

| Year | Modern Smartphone | Old Smartphone |
|---|---|---|
| 2004 | 0 | 100 |
| 2005 | 0 | 100 |
| 2006 | 0 | 100 |
| 2007 | 2.7 | 97.3 |
| 2008 | 8.7 | 91.3 |
| 2009 | 26.615 | 73.385 |
| 2010 | 34.3 | 65.7 |
| 2011 | 41.29 | 58.71 |
| 2012 | 51.45 | 48.55 |
| 2013 | 63.24 | 36.76 |
| 2014 | 77.6 | 22.4 |
| 2015 | 84.4 | 15.6 |
| 2016 | 88.4 | 11.6 |
| 2017 | 92.28 | 7.72 |
| 2018 | 95.92 | 4.08 |
| 2019 | 98.18 | 1.82 |
| 2020 | 99.34 | 0.66 |

Table 31: Data set on Nokia (Nokia, n.d.)

| Year | RD (bil. dollar) | P (bil. dollar) | T (bil. dollar) | C (x1000) | RD/C | P/C | T/C |
|---|---|---|---|---|---|---|---|
| 2000 | 2.38 | 3.62 | 27.95 | 60.29 | 39.43 | 60.09 | 463.53 |
| 2001 | 2.69 | 1.98 | 28.07 | 57.72 | 46.55 | 34.31 | 486.38 |
| 2002 | 2.90 | 3.21 | 28.52 | 52.71 | 55.00 | 60.93 | 540.94 |
| 2003 | 4.28 | 4.00 | 33.37 | 51.61 | 82.95 | 77.58 | 646.69 |
| 2004 | 4.68 | 3.96 | 36.42 | 53.51 | 87.50 | 73.97 | 680.61 |
| 2005 | 4.74 | 4.48 | 42.40 | 56.90 | 83.36 | 78.81 | 745.16 |
| 2006 | 4.91 | 5.43 | 51.81 | 68.48 | 71.70 | 79.22 | 756.57 |
| 2007 | 7.74 | 9.87 | 69.95 | 112.26 | 68.91 | 87.93 | 623.09 |
| 2008 | 8.77 | 5.86 | 74.54 | 125.83 | 69.72 | 46.59 | 592.42 |
| 2009 | 8.21 | 1.24 | 56.97 | 123.55 | 66.48 | 10.02 | 461.08 |
| 2010 | 7.80 | 2.46 | 56.45 | 132.43 | 58.88 | 18.58 | 426.30 |
| 2011 | 7.80 | -1.62 | 53.74 | 130.05 | 59.98 | -12.44 | 413.20 |
| 2012 | 3.97 | -4.01 | 19.87 | 65.55 | 60.64 | -61.13 | 303.08 |
| 2013 | 2.62 | -1.97 | 15.69 | 52.56 | 49.85 | -37.52 | 298.44 |
| 2014 | 2.53 | -1.31 | 15.64 | 51.50 | 49.17 | -25.39 | 303.76 |
| 2015 | 2.31 | 2.04 | 13.94 | 56.69 | 40.73 | 36.07 | 245.93 |
| 2016 | 5.55 | -0.54 | 26.24 | 102.69 | 54.02 | -5.21 | 255.55 |
| 2017 | 5.56 | -1.62 | 26.16 | 101.73 | 54.61 | -15.96 | 257.11 |
| 2018 | 5.64 | -0.65 | 26.62 | 103.00 | 54.73 | -6.29 | 258.49 |
| 2019 | 5.08 | 0.02 | 26.11 | 98.00 | 51.79 | 0.21 | 266.46 |
| 2020 | 3.67 | -2.86 | 24.91 | 92.00 | 39.89 | -31.14 | 270.77 |

Table 32: Data set on Apple (Pratap, 2019abc; 2020)

| **Year** | **RD (mil. dollar)** | **P (mil. dollar)** | **T (mil. dollar)** | **C** | **RD/C** | **P/C** | **T/C** |
|---|---|---|---|---|---|---|---|
| 2002 | 446 | 42 | 5.7 | 10211 | 43.68 | 4.11 | 558.22 |
| 2003 | 471 | 57 | 6.2 | 10912 | 43.16 | 5.22 | 568.18 |
| 2004 | 489 | 266 | 8.3 | 11695 | 41.81 | 22.74 | 709.71 |
| 2005 | 535 | 1328 | 13.9 | 14800 | 36.15 | 89.73 | 939.19 |
| 2006 | 712 | 1989 | 19.3 | 17787 | 40.03 | 111.82 | 1085.06 |
| 2007 | 782 | 3495 | 24.6 | 21600 | 36.20 | 161.81 | 1138.89 |
| 2008 | 1109 | 6119 | 37.5 | 32000 | 34.66 | 191.22 | 1171.88 |
| 2009 | 1333 | 8235 | 42.9 | 34300 | 38.86 | 240.09 | 1250.73 |
| 2010 | 1782 | 14013 | 65.2 | 46600 | 38.24 | 300.71 | 1399.14 |
| 2011 | 2429 | 25922 | 108.2 | 60400 | 40.22 | 429.17 | 1791.39 |
| 2012 | 3381 | 41733 | 156.5 | 72800 | 46.44 | 573.26 | 2149.73 |
| 2013 | 4475 | 37037 | 170.9 | 80300 | 55.73 | 461.23 | 2128.27 |
| 2014 | 6041 | 39510 | 182.8 | 92600 | 65.24 | 426.67 | 1974.08 |
| 2015 | 8067 | 53394 | 233.7 | 110000 | 73.34 | 485.40 | 2124.55 |
| 2016 | 10045 | 45687 | 215.6 | 116000 | 86.59 | 393.85 | 1858.62 |
| 2017 | 11581 | 48351 | 229.2 | 123000 | 94.15 | 393.10 | 1863.41 |
| 2018 | 14236 | 59531 | 265.6 | 132000 | 107.85 | 450.99 | 2012.12 |

# F Data Case Study 2

Table 33: Data set on vehicle market shares (IEA, 2020; Irle, 2021)

| Year | EV's | Non-EV's |
|---|---|---|
| 2010 | 0.01 | 99.99 |
| 2011 | 0.07 | 99.93 |
| 2012 | 0.17 | 99.83 |
| 2013 | 0.28 | 99.72 |
| 2014 | 0.42 | 99.58 |
| 2015 | 0.68 | 99.32 |
| 2016 | 0.90 | 99.10 |
| 2017 | 1.38 | 98.62 |
| 2018 | 2.29 | 97.71 |
| 2019 | 2.50 | 97.50 |
| 2020 | 4.20 | 95.80 |

Table 34: Data set on Tesla (Macrotrends, 2021b)

| Year | RD (mil. dollar) | P (mil. dollar) | T (mil. dollar) | C | RD/C | P/C | T/C |
|---|---|---|---|---|---|---|---|
| 2010 | 93.00 | -146.84 | 116.77 | 899 | 103.44 | -163.33 | 129.89 |
| 2011 | 208.98 | -251.49 | 204.24 | 1417 | 147.48 | -177.48 | 144.14 |
| 2012 | 273.98 | -394.28 | 413.26 | 2964 | 92.44 | -133.02 | 139.43 |
| 2013 | 231.98 | -61.28 | 2013.50 | 5859 | 39.59 | -10.46 | 343.66 |
| 2014 | 464.70 | -186.69 | 3198.36 | 10161 | 45.73 | -18.37 | 314.77 |
| 2015 | 717.90 | -716.63 | 4046.03 | 13058 | 54.98 | -54.88 | 309.85 |
| 2016 | 834.41 | -667.34 | 7000.13 | 17782 | 46.92 | -37.53 | 393.66 |
| 2017 | 1378.00 | -1.63 | 11759.00 | 37543 | 36.70 | -0.04 | 313.21 |
| 2018 | 1460.00 | -388.00 | 21461.00 | 48817 | 29.91 | -7.95 | 439.62 |
| 2019 | 1343.00 | -69.00 | 24578.00 | 48016 | 27.97 | -1.44 | 511.87 |
| 2020 | 1491.00 | 1.99 | 31536.00 | 70757 | 21.07 | 0.03 | 445.69 |

Table 35: Data set on VW (Volkswagen, n.d.; Macrotrends, 2021c; Carlier, 2021)

| Year | RD (mil. dollar) | P (mil. dollar) | T (mil. dollar) | C | RD/C | P/C | T/C |
|---|---|---|---|---|---|---|---|
| 2010 | 8303.04 | 9483.88 | 168477.30 | 389000 | 21.34 | 24.38 | 433.10 |
| 2011 | 10029.46 | 15698.31 | 221924.60 | 454000 | 22.09 | 34.58 | 488.82 |
| 2012 | 12236.29 | 14803.00 | 247800.60 | 533000 | 22.96 | 27.77 | 464.92 |
| 2013 | 15599.40 | 15502.61 | 261684.40 | 563000 | 27.71 | 27.54 | 464.80 |
| 2014 | 17427.30 | 16878.08 | 269127.40 | 583000 | 29.89 | 28.95 | 461.63 |
| 2015 | 15109.32 | -4514.39 | 236127.40 | 604000 | 25.02 | -7.47 | 390.94 |
| 2016 | 15132.17 | 7737.24 | 240427.70 | 619000 | 24.45 | 12.50 | 388.41 |
| 2017 | 14847.80 | 15583.76 | 260739.90 | 634000 | 23.42 | 24.58 | 411.26 |
| 2018 | 16110.20 | 16439.52 | 278537.70 | 656000 | 24.56 | 25.06 | 424.60 |
| 2019 | 16021.29 | 18995.52 | 282947.80 | 668000 | 23.98 | 28.44 | 423.57 |
| 2020 | 15856.67 | 11051.75 | 254600.40 | 665000 | 23.84 | 16.62 | 382.86 |

Table 36: Data set on BMW (BMW, n.d.; Macrotrends, 2021a)

| **Year** | **RD (mil. dollar)** | **P (mil. dollar)** | **T (mil. dollar)** | **C** | **RD/C** | **P/C** | **T/C** |
|---|---|---|---|---|---|---|---|
| 2010 | 3366.60 | 6759.74 | 80141.09 | 94446 | 35.65 | 71.57 | 848.54 |
| 2011 | 5026.56 | 11167.48 | 95853.88 | 97110 | 51.76 | 115.00 | 987.06 |
| 2012 | 5135.00 | 10674.63 | 98834.21 | 102232 | 50.23 | 104.42 | 966.76 |
| 2013 | 6365.69 | 10607.76 | 101027.80 | 107123 | 59.42 | 99.02 | 943.10 |
| 2014 | 6065.02 | 12120.52 | 106887.00 | 116324 | 52.14 | 104.20 | 918.87 |
| 2015 | 4740.81 | 10645.35 | 102286.60 | 122244 | 38.78 | 87.08 | 836.74 |
| 2016 | 5715.52 | 10386.55 | 104200.80 | 124729 | 45.82 | 83.27 | 835.42 |
| 2017 | 6904.48 | 11167.36 | 111535.70 | 129932 | 53.14 | 85.95 | 858.42 |
| 2018 | 8137.78 | 10771.91 | 115123.90 | 134682 | 60.42 | 79.98 | 854.78 |
| 2019 | 7188.64 | 8300.32 | 116715.20 | 126016 | 57.05 | 65.87 | 926.19 |
| 2020 | 7170.62 | 5517.31 | 113076.30 | 120726 | 59.40 | 45.70 | 936.64 |