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Inhibitors of commercial electro mobility and three methods to accelerate introduction an exploratory case study

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Inhibitors of commercial electromobility and three methods to accelerate introduction: an exploratory case study

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Inhibitors of commercial electromobility and three methods to accelerate introduction

an exploratory field study

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There is not a moment in time than more interesting to study the subject of electro mobility than 2012 and the immediate years to come in this decade. Ever increasing welfare across all societies over the world requires the extraction of more and more resources, while pollution must be controlled in order to secure quality of life for all. Pollution-free mobility is by no means the solution for all the issues our society is facing; yet it is an important step towards a safer, cleaner and healthier environment. It has always been a personal fascination to see electro mobility technology progress towards maturity, and I feel privileged have had the opportunity to study the subject in depth. Looking back at my MSc. research, I can only conclude that it was the most interesting and challenging period of my education so far. Six months of researching a topic in a different country at an unknown company enriched my perspective in many ways. Apart from the research, I learned much from being a Swedish citizen for a short period – it changed my view on my own nation, too. It is one of the many rewards for travelling abroad and outweighs the efforts by far.

With a background as entrepreneur and by family related to a small company involved in electro mobility, doing research within a multi-national company was an eye-opening experience I will definitely not forget. Niklas, without your efforts and continued motivation this research probably never started. I would like to thank you for all the opportunities you have given me.

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The insights I have gained during this research came from a number of experts on electro mobility from Sweden and beyond, and my colleagues at Volvo. Thank you all for your time and energy during and after the interviews! Your opinions are invaluable for this research, and helped me to understand exactly what problems commercial electro mobility is facing.

Last, I would like to thank friends and family. Your trust and support made me realize that whenever possible, you should aim higher and further - and never ever, accept status quo.
Abstract

The research at hand aimed to identify current inhibitors and motivators influencing the introduction of commercial electro mobility. Using semi-structured interviews, various stakeholders including manufacturers, operators and local legislators were interviewed; past, current and future factors influencing the introduction of commercial electro mobility were discussed. The research was kept pragmatic by selecting two viable segments of commercial vehicles that are potentially electrified in the near future, being city bus and local distribution vehicle (range 3.5t to 20t). Interview data suggests that current major inhibitor of commercial electro mobility is a much higher TCO, partially caused by lack of information among operators and its related stakeholders. This higher TCO is currently not compensated for by more vehicle productivity or (monetary) appreciation of environmentally favorable performance. With this information in mind this research provides three Design Solutions, aimed at enhancing value for commercial electro mobility; 'measure', 'communicate' and 'elaborate'. The Measure solution aims establish a link between commercial electro mobility and air quality by incorporating air quality sensing into the commercial EV. This creates much more detailed air quality data and potentially enables the effect of electro mobility to be measured directly. The 'communicate' solution aims to inform the general public on air quality, as air quality potentially influences public health. More awareness potentially triggers pressure on local governments to increase local air quality, possibly with electro mobility. The last solution - 'Elaborate' – aims to inform operators and its stakeholders on two distinct subjects; (1) long term technology maturity of EV technology and (2) cooperation methods between operators and its local government to promote value creation. Operators should aim for more productivity on EV’s, while local governments 'win' whenever local air quality improves. Overall, the research offers a starting point for scholars whenever analyzing commercial electro mobility projects - to assess whether prospective introduction of commercial electro mobility makes sense from a TCO versus Vehicle Total Productivity perspective.
Management Summary

At the current state of art, commercial electric vehicles are a small niche and serve only a fraction of the transport needs in our society. Although still developing, and not offering a viable value proposition, commercial electro mobility offers a number of fundamental advantages, which make it a promising technology. From a global perspective, commercial electro mobility is favorable for its (expected) lower CO₂ emission, while making nations less dependent on imported oil. From a local perspective, commercial electric vehicles are favorable for its low impact on local air quality (and possibly also noise). Furthermore, it might also be expected that electric vehicles have lower running costs, as fuel is becoming more and more expensive. While these advantages are known, the introduction of electro mobility is only progressing slowly. Therefore, this research aims to find what is currently inhibiting introduction of commercial electro mobility, and how introduction can be accelerated in the coming years. The formalized research question this research aims to answer is:

“What factors are currently inhibiting commercial electro mobility, and what methods can accelerate introduction of commercial electro mobility?”

To answer the research question, the researcher first conducted a literature review on the topic of electro mobility introduction. Changing from fossil fueled vehicles to electro mobility is a fundamental shift, impacting society at large; therefore the concept of socio-technical regimes was discussed first, in connection to Transition Management. Recognizing that government interaction possibly influences the transition of sociotechnical regimes, and that of electro mobility in particular, government interaction was also discussed. With this background information, concrete literature case studies on the introduction of commercial electro mobility were assessed. Research of literature indicates that there are few concrete case studies on the introduction of commercial electro mobility to be found. This is possibly caused by the fact that commercial electro mobility is a relatively new development. Apart from these subjects and due to specific interest of the company this research took place, the role of electric vehicle emission data was also studied. Electric vehicles potentially ‘save’ emissions compared to their fossil fueled vehicle, and the positive role of vehicle emissions data to the introduction of electro mobility was discussed.

With a selection of literature background on electro mobility in mind, the researcher chose not to focus on a single case of commercial electro mobility introduction, and instead take a wider approach with commercial electro mobility introduction as unit of analysis. This research focus was explicitly chosen as it allowed the researcher to include a wide range interviewees with different perspectives on the subject at hand; it also allowed the researcher to include interviewees across Europe, rather than a single and potentially confined nation. In total 15 interviews were planned and conducted, including stakeholders of local governments, transport operators and automotive producers.

With a total of 15 interviews and 54 documents collected, analysis commenced. Early interview data directly suggested that emphasis should be placed at either city bus- or local distribution – vehicles, as these two vehicle segments are potentially electrified in the near future. Interview data also suggested that factors inhibiting the introduction of electro mobility are often interconnected with multiple relations. A system dynamics modeling approach was selected to map the problem factors, detail relations and establish factor levels. At high factor level, electro mobility is inhibited by three factors; (1) higher Total Cost of Ownership, (2) technology limitations and (3) the absence of additional value creation for favorable aspects of electro mobility. The absence of additional value creation was more researched in-depth; it was found that there is currently no monetary appreciation for the environmental advantages of commercial electro mobility. Research data suggests that local governments and vehicle operators are only mildly motivated to decrease CO₂ emissions. Local air quality is a more immediate issue on agendas of local governments; still external pressure is needed for local governments to address this issue. Also, it remains unclear what the real effect of commercial electro mobility has on local air quality. However, research data suggests that whenever pressured, local governments do see commercial electro mobility as a viable solution (one such case was identified).
Three pragmatic solutions were designed to address the inhibiting factors found. First is ‘Measure’, a practical solution to map local air quality. As research data suggests that local air quality potentially is a very strong factor to stimulate introduction of commercial electro mobility, the researcher proposes to establish a solid link between local air quality and electro mobility (‘measure’). As the majority of commercial electric vehicles are already equipped with communication infrastructure, integrating Mobile Air Quality Measuring (MAQM) into commercial electric vehicles is relatively straightforward from a technical standpoint. This relatively simple solution enables cities to map local air quality in much more detail, compared to current measurement. Literature also coins variants of such local air quality measurement techniques, underlining that mobile air quality measurement is indeed feasible in technological and financial perspective. Mobile Air Quality Measurement might even statistical evidence between the number of commercial EV’s introduced and local air quality measured; this remains speculation and should be observed with real-life data.

Second Design Solution is ‘Communicate’ – creation of (more) public awareness on local air quality issues, possibly resulting in elevated pressure on local governments to consider cleaner vehicles. The researcher found that concrete evidence for the fact that citizens are motivated to exert pressure on local governments once awareness is raised on local air pollution. The challenge is then to transfer the data obtained from solution I to the general public and trigger awareness. Several transfer methods are proposed that are relatively easily implemented into the operations of an automotive manufacturer, and have the potential to influence public opinion. It should be noted that implementation of solution II may be controversial; local governments may experience unwanted pressure from citizens whenever local air quality is low. However, implementation of solution II may also justify additional governmental spending on commercial electro mobility.

The third Design Solution (‘Elaborate’) aims to establish information exchange to and between local electro mobility initiatives with the intent of exchanging value-creating methods. Recognizing that local governments prosper from electro mobility, cooperation between operators and local governments may be a fruitful way of creating value (concrete examples being extended offload times for electric vehicles or allowance on priority lanes). More focused at operators and their stakeholders, detailed information on technology long term reliability may result in better financial estimations. Both research data and literature suggests that operators regularly amortize electric vehicles to low residual value, which negatively impacts the financial case of commercial electro mobility. On a higher (multi-level) perspective, connecting local electro mobility projects and exchanging knowledge potentially triggers more projects to be initiated, using accumulated experience.

From an academic point of view, three contributions are offered. First is the suggestion that scholars should assess commercial electro mobility projects in a cost versus value creation perspective. This research also identified several factors increasing or decreasing value as starting point. Second, offer the suggestion that local air quality is an important driver for the introduction of commercial electro mobility, and measures are needed to link electro mobility to air quality. Last, offer the suggestion that information transfer methods are needed to help stakeholders of local electro mobility initiative increase value for their projects, and establish between-projects communication to sustain learning on a more aggregated level.
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1 Introduction

Our modern society is highly dependent upon the use of fossil fuels. Global energy consumption exceeded 145000 TWh in 2007 and grows with about 2% annually (U.S. Energy Information Administration, 2010). The consequence of extracting energy from fossil fuel is emission of Greenhouse Gasses (GHG’s); estimated in 2008 at about 29 billion tonnes (29×10^{12} kg) CO₂ emission (United Nations, 2009). While being debated, academia generally agrees that GHG emission is directly linked to the process of global warming. According to studies summarized by the IPCC, global temperature rise should not exceed 2° to avoid permanent and irreversible damage to the ecosystems of the earth. Linked to this ‘2° target’, total global GHG emissions should not exceed one trillion tonne CO₂, while up to 2009, 313 billion tonne was already emitted (International Energy Agency, 2010). Simply put, earth’s climate cannot afford two more decades of CO₂ emission at the current emission rate, while CO₂ emission increase is predicted. Besides emerging knowledge on global warming, western society is increasingly becoming aware of the fragility of oil supplies. Despite technology advances in oil extraction, it remains unsure if oil supplies and reserves can fulfill future global energy demand. In fact, theories that major oil producing countries’ productions have already entered into terminal decline are the subject of ever intensifying discussion. Saudi-Arabia, world’s largest oil producing country faced a production decline of 28% between 2005 and 2010. A number of academia suggest this trend to persist (Salameh, 2011) (Simmons, 2006).

More tangible and closer to human perception is the worsening issue of local air quality pollution. While air quality regulations are gradually set at tougher levels for all types of emitters, economic growth is counteracting these efforts – thus not improving the air quality in the built environment. Meanwhile, the negative effects of air pollution on public health are determined with greater certainty – raising public awareness and causing more and more pressure on cities to take action. This leaves cities with the huge and vague task of increasing air quality. Sticking to business-as-usual is not a tolerable approach for the cities of the near future.

These major issues offer a favorable starting point for the introduction of electro mobility. For consumers, the trend towards electro mobility is already visible as a number of automotive competitors are offering (semi) electric vehicles. While electrification of commercial vehicles may be less visible to the general public, commercial electric vehicles offer the same advantage – and potentially a viable business case for operators to invest in. However, commercial electro mobility is at current state of art (2012) not applicable in all segments of commercial road transport. In commercial settings, electric vehicle technology must fulfill operational requirements of operators such as uninterrupted driving range. Long-haul heavy-duty transport is such an example application where electric vehicle technology cannot meet operational requirements, as long-haul heavy-duty transport vehicles consume large amounts of energy incapable of being stored in current battery (or hydrogen) technology. There are however a number of commercial vehicle segments where electric vehicle technology potentially meets operational requirements. City buses and local distribution vehicles are potentially electrified in the near future – and these segments will probably trigger the introduction of commercial electro mobility. Therefore, the researcher chose to focus at these segments when discussing the introduction of EV technology.

As discussed, commercial electro mobility potentially resolves a number of issues. Local air pollution is avoided where it should be – in inner cities, at public transport terminals and close to the homes environments of the city inhabitant. Next to the air quality argument, conventional city buses and distribution vehicles tend to have high fuel consumption and are used intensively throughout daily operation. High operational fuel costs can be avoided using this more sustainable technology.

With such a number of compelling advantages, one might assume that commercial electro mobility will soon gain market acceptance. Unfortunately, this is not the case. At the current state of art, only few niche projects of electro mobility are initiated, and the acceptance of commercial electro mobility is relatively slow. Realizing the advantages and current status quo, the author formed its main research question this thesis aims to answer:

"What factors are currently inhibiting commercial electro mobility, and what methods can accelerate introduction of commercial electro mobility?"
As with every academic research, a thorough literature review was conducted to have proper understanding of past research and current academic status. Recognizing that the introduction of electro mobility is a fundamental societal change, the first section of the literature review starts with a discussion on socio-technical regimes, their transition (and management thereof) and the influence of governmental actions on transition. Following, literature case studies on introduction of commercial electro mobility are discussed. The second section of the literature review focuses on vehicle-sided emissions. Lowering CO2 emissions is an important argument for introducing electro mobility – and EV CO2/km data is relatively easily retrieved. Guided by literature, the potential role of EV CO2/km data as motivator for electro mobility is discussed. Both sections are found in Chapter 2.

Following literature review, the General Research Methodology presents the general project approach and strategy, data collection and analysis and design methods. As the project was defined from the start to be an exploratory study, this research methodology gradually evolved as the project progressed; this was anticipated and a justification of this research method is found in Chapter 3.

Using inputs from the literature study, the semi-structured interviews and the document data, the Problem Analysis presents the factors that inhibit the introduction of commercial electro mobility for the segments chosen, as the researcher was able to determine. It should be noted that the factors that inhibit the introduction of commercial electro mobility are vague, complex and dynamic and continuously evolving. Representation of such an environment is only possible using a system modeling approach, as this approach allows factors to be positive, negative or neutral. In addition, multiple relations can be defined. The full problem analysis model can be found in Chapter 4.

Based on the Problem analysis model, the researcher aimed to provide a small set of simple yet powerful set of Design Solutions. These are (1) measure, (2) communicate and (3) elaborate. The ‘Measure’ solution suggests to radically improve Local Air Quality Measuring with the objective of establishing a strong link between (commercial) electro mobility and Air Quality. The ‘Communicate’ solution aims raise awareness among public on local air quality, and enhance the public image of electro mobility. The ‘Elaborate’ solution targets the vehicle operator and local governments, as there are numerous ways to increase value for electro mobility such as establishing operator-city cooperation. The full Design Solutions chapter can be found in Chapter 5.

Finally, the conclusion reflects on the Problem Analysis and Design Solutions. The overview of both problem and solution leans that the advantages of commercial electro mobility are not fully leveraged at the current state of art. Research data indicates that this value creation is much needed to offset for the higher TCO of a current commercial electric vehicle. Among other findings, the mindset of value creation vs. increased TCO is currently not properly debated in literature; these contributions and limitations are discussed in the final Chapter.
2 Literature background

As the introduction mentioned, this research focuses at how stimulate the introduction of commercial electro mobility. The first section of this literature background chapter adopts the wide perspective that takes societal aspects into account - electro mobility as a socio-technical regime; how active participation might change the regime using transition management and the role of governmental influence on socio-technical transition. Some concrete electro mobility introduction cases provided by literature are discussed to link theory to practice.

Due to specific interest of the company at which this thesis was conducted, the second part of the literature study focuses on the potential role of electric vehicle (EV) emissions data/km (as this data proves the 'environmental performance' of electro mobility) To keep the research conceptual and non-specific, electro mobility is in the second case conceptualized as a system innovation.

2.1 Societal perspective on the introduction of electro mobility

While electro mobility is without doubt a niche topic in the academic landscape, in potential a huge amount of research areas are connected to this subject. The author was therefore forced be critical and set strict limitations with respect to selecting academic research areas. A limited number of areas were considered critically relevant and elaborated below. These are: socio-technical transition literature, transition management literature, literature on the social-technical transition to electro mobility, literature on legislative efforts to introduce electro mobility, and concrete academic contributions on electro mobility in case studies.

2.1.1 Review methodology

For all subjects discussed below, the author used Google Scholar to find literature contributions. Research needed to be published within the last five years, and referring relevant literature was also included. To increase literature source availability on sparsely covered subjects, limited sources older than 5 years were allowed. In addition, references from and to the academic contributions were checked.

For the four subjects in this section, the author researched Google Scholar on the logical combination of following keywords: (1) electromobility; (2) 'city distribution'; (3) 'business case'; (4) 'vehicle productivity'; (5) 'transition management'; (6) 'socio-technical transition'; (7) 'commercial'; (8) 'policy'; (9) 'city'; (10) 'sustainable'; (11) 'electric'. Potentially, this methodology leads to a huge number of search strings (10 x 10! or 36 million combinations) However, when using logical search strings, the number of potential strings drops to about 50. Then, limiting the allowable strings to those that describe electromobility in some form leaves 29 feasible combinations open. Another pragmatic selection by the author resulted in 10 relevant combinations. A last selection was then made to match the specific research areas relevant in this thesis.

2.1.2 The concept of socio-technical regime and its relation to electro mobility

Socio-technical systems are deeply rooted and widespread technological systems that serve the needs of a society in its broadest form. Examples of these are the electricity grid system, automobile transport and phone communications. Whenever external pressure on a socio-technical system rises sufficiently, transition is invoked. Smith, Stirling & Berkhout (2005) suggests regime change to be a function of two processes; 1) shifting selection pressures bearing on the regime and 2) the coordination of resources available inside and outside the regime to adapt to these pressures. Regime transformation can be achieved by governance intervention in these two processes. Through regulation and policy, regimes can be pressured. Through internal and external regime innovation, adapted or new regimes emerge.

Van Bree, Verborg & Kramer (2010) describes the socio-technical transition of fossil fueled vehicles to novel drivetrain technologies. In this review, two major external pressure shifts are recognized: tightening vehicle emission regulations and higher fuel prices. Both factors are directly influenced by government policy – illustrative for how government policy might influence socio-technical transition, thus influencing the emergence of a system innovation.
(Fossil fueled) mobility is deeply rooted into our societal and technological systems. Mobility does not only revolve around the vehicle itself; it is the fuel infrastructures, markets, industries, maintenance networks, road infrastructures and cultures around fossil electro mobility that defines the total socio-technical regime. The massive influence in society of fossil fuels goes even further; the majority of modern countries are financially dependent on the taxation of fuels. This extensive set of technologies, infrastructures, regulations, policies and human perception is regarded by academia as a socio-technical regime. Changing the energy resource (from fossil energy) to electrical energy is not just a technical challenge, but a socio-technical transition that requires change by all actors of the mobility system.

Literature on socio-technical transition in relation to electro mobility is often accompanied by scenario-based forecasting of how this transition is to take place. Van Bree, Verbong & Kramer (2010) provides a recent insight in how academia might see the transition to electro mobility occurring. The authors adopt a multi-level perspective with levels defined as (1) technological niches, (2) socio-technical regime and at high-level (3) landscape developments. In their review, the transition from fossil fueled passenger cars is envisioned in two sets of different scenarios. In the first set, transition is said to be triggered by governmental pressures on automotive manufacturers to lower CO₂ emissions, and raise local air quality. As this invokes lower fuel consumption due to technological change, less oil dependence is also achieved, a national objective that is then also attained. In the second scenario set, fuel prices rise up to such a level, consumer car purchasing alters and automotive manufacturers need to follow new customer demand. Other sources follow similar approaches in forecasting the process of transitioning, albeit with different perspectives. Marletto (2011) defines three scenarios; (1) “Auto mobility” in which incremental innovation of the automobile dictates the socio-technical transition timing and speed; (2) “Electricity” in which electro mobility becomes deeply integrated with the electricity network and (3) “Eco city” in which the car is largely abandoned as inner-city transportation on the longer term.

Both approaches can be placed in the ‘passenger car’ perspective, while this thesis focuses commercial electro mobility. However, the same pressures that apply to the passenger car segment may also influence the introduction of commercial electro mobility. Van Bree, Verbong & Kramer (2010) assess that tightening emissions may steer developments. It is these same emissions that might also influence technology progress on commercial vehicles. On the other hand, commercial electro mobility is heavily characterized by rational economic behavior. Commercial electro mobility may only switch when a solid business case is present, without any space for ‘non-rational’ consumer behavior. Of the three scenarios Marletto (2011) sketches, is it very unlikely that commercial transport will cease to exist in current form, since a valid alternative is not there. On the other hand, Marletto (2011) provokes thinking towards vehicle integration into the electricity grid, as an alternative for the more business as usual oriented, incremental vehicle improvement scenario.

2.1.3 Transition Management contributions and commercial electro mobility

While the scenario based thinking approach serves forecasting, the area of transition management aims to take an active role in the transition process. This may seem contradictory, since transitions are envisioned as processes, which cannot be influenced and are steered by high-level societal processes. Loorbach (2007) takes a different view and suggests that the proper application of Transition Management can indeed invoke a socio-technical transition. Citing the core of Loorbach’s (2007) discussion: “Transition management views social change as a result of the interaction between all relevant actors on different societal levels within the context of a changing societal landscape. Managing societal change thus becomes the organization and coordination of this interaction; a way of indirectly influencing, adjusting, redirecting and guiding actions.” In other words, proper management might trigger something as large as a socio-technical transition. Transition Management as practice is subdivided by Loorbach (2007) into three distinct types of activity, being strategic, tactical and operational transition management. Strategic transition management aims to create shared understanding among a small group of innovative stakeholders (‘the front runners’) By then creating shared insights, ambitions and long-term goals, individual action is invoked in the collective direction. Tactical transition management aims to gain societal support, using networks and coalitions. Barriers to overcome using tactical transition management are market conditions, regulations and technology limitations. Operational transition management is the most concrete action level – setting up experiments to demonstrate viability of concept, in the end developing more sustainable practices.
2.1.4 Legislative pressure and the transition to commercial electro mobility
As Loorbach (2007) already describes, exerting pressure on existing regulations is a key component in transition management. As can be expected with a current socio-technical regime, rules, regulations and legislations are specifically designed with the dominant technology of fossil fueled vehicles in mind. New rules and regulations should ideally recognize the favorable aspects of electro mobility – such as zero emission, low noise operation. However, since no technology has yet been able to deliver such properties, little regulations can expected to exist today.

However, this is changing; legislation is more and more anticipating towards electro mobility. Leurent & Windisch (2010) provides an overview of legislations to-be introduced in favor of electro mobility. As with much research, this research is private passenger car oriented – but still useful in the orientation on legislation. The research detects five different policy instruments; being Command and control instruments (1), Economic instruments (2), procurement instruments (3), collaborative instruments (4) and communication and diffusion instruments (5). Command and control instruments (1) are the core instruments of a governments’ toolbox. These are legally binding rules and legislations that influence market competitors’ behavior. One such instrument is the application of Euro 6 emission regulation for road transport. Economic instruments (2) support EV’s directly with economic stimuli, such as preferential road tax (the authors specifically mention that this instrument should not be implemented as stand-alone measure). Procurement instruments (3) are all instruments a government has at its disposal to either purchase greener vehicles itself, or command greener purchasing in public procurement processes. This tool is of special interest to this study, as commercial vehicles are frequently involved in a public procurement process (such as for example city buses) Collaborative instruments (4) refer to the high level governmental obligation of creating coordination among stakeholders to establish and promote desirable societal direction. The last instrument, communication and diffusion (5) consists of public awareness influence and education. This instrument can be as wide as setting up demonstrators with the pure goal of attaining more public awareness.

2.1.5 Academic contributions on the introduction of commercial electromobility in practice
This literature section started by elaborating the concept of socio-technical regimes; then transition management was researched as means to invoke socio-technical transition. The prominent role of governmental action is also discussed briefly. It is interesting to see the concepts interact in concrete cases. Of course it is preferential to have commercial electro mobility projects discussed in relation to these concepts. Two relevant contributions were found; Loorbach et al (2008) that describes two cases of sustainable product integration (being eco-friendly roofing and gas-driven city buses, the first one is neglected) and Whiteman, de Vos Chapin et al (2011) that describes the introduction of a commercial electric distribution vehicle in the city of Rotterdam, the Netherlands. Below, these cases will be discussed – in relation to the concepts of socio-technical regimes, transition management and governmental stimuli.

Loorbach et al (2008), second case
Pon Holdings is a corporation active in automotive and power equipment. In 2004, the Dutch government initiated strategic discussions and experiments among companies, NGO’s and knowledge institutes on climate change and air quality. This led to engagement from the CEO of Pon Holdings and that same year, the first sustainability platform within Pon Holdings emerged. A concrete result of forming this sustainability platform was the forming of the CROB coalition (Coalition Driving on Biogas) for city buses. Several relevant companies joined this coalition with the joint intent of introducing biogas buses in the Netherlands. While CROB was rooted because of initiations by the Dutch government, this same government was now the aimed (and unenthusiastic) customer. The initial purchase price of biogas buses was higher, thus needing an additional subsidy to overcome these economic barriers. The CROB coalition clearly needed governmental support – and in 2009 the first subsidized buses were put on the road.
Whiteman, de Vos, Chapin et al (2010)

The City of Rotterdam is the second city in the Netherlands and is coping with serious air quality problems. Partially pushed by this fact, and partially by recognizing climate issues, the city of Rotterdam initiated the Rotterdam Climate Initiative (RCI), a platform including Port of Rotterdam, DCMR (Rotterdam milieudienst) and Deltalings, an organization representing multiple logistics companies in Rotterdam. RCI started cooperating in 2004 with Logistics company Translogis, with the join target of reducing the environmental footprint of the company and in turn, the city. Under the supervision of the CEO of Translogis, the company set ambitious targets of becoming the first zero-emission global transportation and Logistics Company. Concrete action was taken by adopting two fully electric distribution vehicles in the city center of Rotterdam. After implementation, technical problems emerged. The vehicle was not able to perform for extended range, while it was operated on longer-range routes, since the distribution depot was located in the city of Dordrecht. In addition, the vehicles were leased from a third party with no experience with EV’s. It was unclear if these vehicles could operate technically for more than three years, so the vehicles were amortized to zero in this period. This made the leasing very expensive. During the project, Translogis managers became increasingly focused at vehicle limitations and cost, failing to recognize the positive environmental impact of the EV’s operated.

These two cases illustrate the great efforts that are needed to invoke socio-technical transition. Both cases were started with enthusiasm and a clear target, but also in both cases great hurdles are to be taken. Underlying both cases the ‘iron law’ of profitability emerges; if a sustainable option is more expensive, additional value creation is needed to keep projects running. In case of Pon Holdings, government action was indeed invoked, leading to a more substantive project.

It is interesting to see the transition management levels in both cases. On the strategic level, Pon Holdings participated in sustainability discussions with the Dutch government, and developed a strong sustainability focus. On the tactical level, co-operation platform CROB was formed, and the co-operation platform recognized several barriers to fight. On the operational level, a number of projects were started, after which more difficulties were countered. In the case of Translogis, the Dutch government once again initiated strategic discussions leading to the start of the RCI. On the strategic level, Translogis participated in these discussions, leading to tactical transition management action in the form of a co-operation between RCI and Translogis, setting mutual goals and targets. On a tactical level, two EV distribution vehicles were implemented. However, the case of Translogis also shows that while concurrent transition management steps are taken, on strategic level issues are present that hamper the complete transition management efforts. In the case of Translogis, RCI and Translogis ultimately did not share mutual objectives and ambitions.

It is also interesting to see what the role of legislative pressure is. In the case of Pon Holdings, collaborative instruments (4) and communication and diffusion instruments (5) were applied to stimulate companies in engaging more sustainable behavior. Economic instruments (2) were then applied to fund R&D. However, this was not enough; procurement instruments (2) were needed too for successful vehicle introduction. For the Dutch government, adhering to EU procurement regulations, this proved to be extremely difficult. Once again applying economic instruments (subsidy) was needed for the project to be successful. In the case of Translogis, collaborative instruments (4) and communication and diffusion instruments (5) were applied, and the RCI was funded also with public funds. However, no record of direct economic instruments were found in the case of Whiteman, de Vos, Chapin et al (2010) For Translogis, this resulted in lack of business case. In addition, no procurement instruments were applied, while the Dutch government does send parcels (and was in the position to ‘favor’ Translogis on its sustainable efforts)
2.3 Technology perspective on the introduction of electro mobility

Due to specific interest of the company where this study was conduced, the prospect of EV (CO₂) emissions / distance travelled was specifically researched. While the practical implications of availability of EV emissions/km are very clear (for example, it allows for direct comparison with conventional vehicles on environmental 'performance'), concrete academic knowledge on this subject is not available. The researcher therefore had to find a constructive approach to research the potential contribution of EV emissions/km data to the introduction of electro mobility. That approach was found by regarding electro mobility as a system innovation. This more concrete conceptualization allowed the author to research the influence of EV emissions data on electro mobility.

It is widely accepted that EV’s emit less CO₂ (exotic cases ignored). The primary role of EV emissions/km data is to provide how much CO₂ is ‘saved’. Thus, EV emissions/km data is by no means an innovation of itself - rather a supporting instrument to support the overarching innovation of electric vehicles. As discussed, there is a widespread consensus that shifting from fossil-fueled vehicles to electric vehicle technology is an architectural innovation. For example, van Bree, Verbong & Kramer (2010) indicate that all social-technical system elements of transportation will encounter change when adopting Electric Vehicles. Therefore, EV emissions/km data might not just support an innovation – it might also support a technology shift that influences society at large.

Johnson & Suskewicz (2009) agrees that shifting to electric vehicles is indeed a societal change, and offers greater insight in what factors positively affect a system innovation leading to infrastructural shift. System innovation is achieved when four major factors are aligned: (1) an enabling technology, (2) an innovative business model, (3) a favorable government policy and (4) a careful market adoption strategy. The approach of Johnson & Suskewicz (2009) is noteworthy for its overview; multiple factors ultimately define the success of an architectural innovation. It is interesting to see where the influence of EV emissions/km data might contribute. The data can be regarded as enabling technology, sustain the design of an innovative business model, be part of a favorable government policy - or all three factors. The fourth factor is the only factor of little relevance in EV emissions/km data context; ‘careful market adoption strategy’ is related to within-business innovation strategies to become early entrant. This factor is ignored in the remainder of this review.

Recognizing that Johnson & Suskewicz (2009)¹ offers a thorough overview, its (adapted) model is now used to guide the review. Research methodology is briefly discussed, then literature contributions on the definition of the factors are considered. EV emissions/km data is thereafter analyzed - as enabling technology, as part of a business model, or as part of a favorable government policy - on its factor role to EV technology as system innovation. The review ends with conclusions and venues for further research.

Figure 1: Electro mobility, EV emissions/km: the result of power plant emissions

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¹ This review uses the phrase ‘factor’ when mentioning the individual contributing components of Johnson & Suskewicz (2009)
2.3.1 Review methodology
The author used Google Scholar and ABI/Inform to find literature contributions on all factors. The keywords "enabling technology", "business model" and "government policy" AND "innovation" were deployed. Research needed to be at published within the last three years and referring relevant literature was also included. To increase literature source availability on sparsely covered factors, limited sources older than 3 years were allowed. In a similar fashion, the role of EV emissions/km data was searched. The keywords "enabling technology" AND EV AND "emission data", "business model" AND "EV", and "policy AND EV" were used. EV was for thoroughness replaced by variations (electric vehicle, clean vehicle) in all queries as well.

2.3.2 Factor influence on system innovation
As mentioned in the perspective paragraph, the most rigorous method to analyze the contribution of EV Emissions/km data is to place it in a system innovation perspective. Johnson & Suskewicz (2009) provided four factors of importance for system innovation, of which three are relevant. These factors are now first analyzed as concept.

2.3.2.1 The influence of favorable government policy on system innovation
In the first section of this literature review, government policy was discussed in concrete details, as desirable socio-technical transitions are supported without the need for more philosophical debate. When it comes to supporting technology, this debate should be pursued, because it is not the task of governmental agencies to stimulate system innovations – it is the task of governments to steer society in generally desirable directions. Therefore, a scant elaboration is done on governmental policy in general. (the governmental stimuli approaches of the first section in this review should be regarded as the more operational part of policy making)

Bergh (2011) analyzes government policy influence on the introduction of sustainable technologies. Two major policy forms are suggested to influence introduction; 1) policies to stimulate and guide environmental innovation and 2) innovation or technology-specific policies. The first policy attempts to lower negative effects of non-sustainable technology, while the second aims to stimulate innovations and technologies that have a positive sustainable impact. Both policies need to be in place to avoid unwanted transition behaviors such as ‘green-paradox’ effect (in which oversupply of sustainable energy leads to lower energy prices, thus higher fossil fuel consumption) and lock-in effect (in which technology is highly stimulated and becomes dominant, blocking the introduction of more efficient technologies) Bergh (2011) also stresses the importance of consumer prices on polluting technology. Literature therefore suggests it is a vital tool in the policy toolkit of governments is to steer prices in such a way, environmental externalities are represented. For example, Van Bree, Verbong & Kramer (2010) see fuel prices as the potential driver for an entire socio-technical transition. Governments have the power to alter prices – also that of fuel and energy – to stimulate innovation, and ultimately socio-technical transition.
2.3.2.2 The influence of enabling technology on system innovation

Enabling technology is a well-known and frequently used term to describe a technology that enables novel possibilities or technological progress and developments that were unavailable or inaccessible before. It is worth noting that the term is often used but also not strictly defined, and no rigorous debate revolves this term. Every scholar article by the researcher, referring to the term ‘enabling technology’ uses the term in accordance with the definition given here. No reviews discuss a relationship between enabling technology and system innovation, so the research focuses on enabling technology as definition in relation to innovation in broader aspect.

The relationship between radical innovation and enabling technology is obvious, but not strictly defined. While probably unintended, some reviews refer to enabling technology as product of radical technology. Hall & Kerr (2003) recognizes this and also cites ‘the automobile’ as an enabling technology, thus concluding that enabling technology is not strictly a technology. In this sense, ‘technology’ may also be a technological system such as computer technology or the Internet. Johnson & Suskewicz (2009) disagrees with this definition, and takes a more structured approach. In this review, the inventions of the microprocessor, electricity or the steam engine are referred to as the enabling technology. The system that forms around the enabling technology ultimately determines the value of the enabling technology itself. In dealing with the lack of definition, it is interesting to assess the attitudes of reviews that coin the phrase ‘enabling technology’ in relation to ambiguous phenomena such as Internet technology. Bentley, Horstmann & Trevor (1997) refers to ‘the internet’ as an enabling technology, thus describing multiple technologies and system elements as a single enabling technology. In more defined research topics, it is not unusual that a body of science progress is also defined as enabling technology. For example, Steele (2001) refers to material science and engineering as enabling technology for the introduction of fuel cells.

While not defined by literature consensus, it remains clear that ‘enabling technology’ is at least a technology that enables novel possibilities or technological progress and developments that were unavailable or inaccessible before. Literature indicates that enabling technology might be more than just technology, as it may also be a set of technologies, and even a set of technologies with a value adding system – ultimately referring to a broad technology artifact as the automobile or internet technology.

2.3.2.3 The influence of business modeling on system innovation

Opposed to the concept of enabling technology, the business model concept received elaborate attention from academia. While receiving elaborate attention, there is no consensus on the definition of what a business model exactly is. A cause for the lack of consensus is the applicability of the term in numerous contexts. Different scholar areas therefore coin the same phrase to discuss very different subjects leading to multiple definitions of what a business model is (Zott, Amit, & Massa, 2010). Some reviews rather describe the business model as a set of functions, together creating value. Chesbrough & Rosenbloom (2002) defines six functions, being 1) value proposition, 2) market segment identification, 3) cost structure and profit potential estimation, 5) value network description and 6) competitive strategy formulation. These six functions collectively justify financial capital, a scale up path and ultimately economic value. Osterwalder & Pigneur (2010) describes the business model as follows: “A business model describes the rationale of how an organization creates, delivers and captures value”. This description leaves specific factors out, agreeing on the value creation aspect.

The consensus among literature remains that the business model is vital to corporate success. While some sources agree that the business model is an important factor, others suggest the business model might be more important than the influence of a successful technology. Chesbrough (2010) explicitly mentions: “a mediocre technology pursued within a great business model may be more valuable than a great technology exploited via a mediocre business model".
Within the role of system innovation this statement might not be correct. In low disruptive technology settings, the business model may indeed prove to be more important than the technology it builds on. Chesbrough (2007) for example highlights the business model of GE Aviation, in which not aircraft engines are sold, but active flight hours. This enabled GE to enter into very profitable maintenance service operations and outperform competitors. In system innovation landscapes the role of technology may be a stronger determinant – however the business model may very well be a large determinant for the successful introduction of a system innovation. In line with this paradigm, Johnson & Suskewicz (2009) includes the business model as one of the four fs that determine system innovation success. In this perspective, the business model is as important as technology – and system innovation will only be successful if both fs are aligned.

In conclusion, literature has yet to reach a consensus on the specific definition of the phrase business model. The definition in Chesbrough & Rosenbloom (2002) is widely adopted and offers a guideline of what factors define a business model. All scholars agree on the importance of the business model for competitive success. In low innovative context, the business model may be a larger determinant for success compared to technology. In system innovation context, literature suggests equal importance.

### 2.3.3 The factor role of EV emissions/km data

The previous section provided an overview of the influence of the factors on the successful introduction of a system innovation, as proposed in Johnson & Suskewicz (2009) In succession, the factor role of EV emissions/km data is now discussed.

Overall, literature review results indicate that research on vehicle emissions, especially on electric vehicle emissions, is yet to be developed. Vehicle emission data is either assumed to be available in the coming future, or suggested to be unavailable regardless of technology progress. Another major assumption of current literature is that if vehicle emissions data is available, vehicle operators will be uncooperative, since (punitive) taxation is based on this data. This subsection will assume that EV emissions/km data is available. More important, it is assumed that vehicle operators will be supportive of providing EV emissions/km data, as EV emissions/km are lower, thus providing evidence of ‘good behavior’ (in turn leading to financial incentives) With this assumptions in mind, literature on the use of vehicle emissions in a competitive context was assessed.

#### 2.3.3.1 EV emissions/km data in government policy context

As described in section 2.3.2.1, the role of governments it to steer society in generally desirable directions. In this section, also the concept of socio-technical transitions was introduced – and the power of governments to trigger socio-technical transition using policies and regulations. This section provides an elaboration on the possible application of EV emissions/km data, specifically as a driver for the socio-technical transition to electric vehicle technology.

**Integration into Tradable Permit (TP) structure**

 Tradable permits are a form of taxation in which businesses are allowed to emit up to a predefined level. Above the predefined level, a competitor would have to purchase permits from another competitor that has excess permits. In this way, the most economic overall emission saving is achieved, while capping emission to a certain level. Within the EU, EU Emission Trading System (ETS) requires industries to obtain CO\textsubscript{2} permits. Recently, EU has announced aviation to be subjected to ETS too. Literature unilaterally agrees on the idea that all transport means should and will in some form be subjected to ETS too (Flachsland, Brunner, Edenhofer, & Creutzig, 2011). (Raux, Transport moving to climate intelligence, 2011) Literature suggests a major issue clouding the introduction of ETS is the issue of large stakeholders; ETS can only be managed if the number of stakeholders is manageable. While for the EU energy sector the number of stakeholders was limited, introduction of the trading system in transport results in the inclusion of millions of vehicles and users. All these users are required to manage their permits and enter into transactions to offset lower or higher emissions, requiring huge administrative systems (Raux, The potential for CO\textsubscript{2} emissions trading in transport: the case of personal vehicles and freight, 2009)
Literature recognizes the huge obstacle of administration and non-cooperative user behavior and suggests several alternative methods. Albrecht (2000) therefore suggests automotive manufacturers should be accounted for the amount of CO₂ their product emits at a predetermined lifetime, at average fuel consumption. This would result in inefficient cars being more expensive and vice versa. Major downside of this approach is that users are not stimulated to lower emissions in any way. Therefore, several authors mention an alternative upstream integration of ETS in which fuel prices include the cost of permits (Raux, The potential for CO₂ emissions trading in transport: the case of personal vehicles and freight, 2009), (Watters & Tight, 2007) While the benefits are clear (less stakeholders in the ETS system), vehicle operators would still not be fully integrated into ETS. The most fundamental solution suggested to solve the large stakeholder issue is still integrating end users into ETS. Some authors suggest modern computer and communication systems might solve the issue of large administration and uncooperative operator behavior altogether. Integration of electronic payment of fuel and permit administration would eliminate fraud and vehicle operator inconvenience altogether. Additionally, uncooperative vehicle operators should be offered to have a ‘safety valve’; a fixed taxation that exempts them from ETS overall. As such, a penalty for non-cooperation is offered (Raux, Downstream Emissions trading for transport, 2011)

The relation between ETS, electric vehicles and EV emissions/km data is straightforward: all literature on ETS requires an estimation of CO₂ emitted. Upstream ETS solutions do not require specific vehicle data; such as the case when automotive manufacturers are made responsible for vehicle emission. However, recent literature suggests that vehicle operators' inclusion into permit structure is a more attainable form of ETS – a form not possible without EV emissions/km data.

2.3.3.2 EV emissions/km data in enabling technology context
This subsection identifies how EV emissions/km data acts as enabling technology for the introduction of the EV, identified by literature. ETS literature generally agrees on the assumptions that vehicle operators are uncooperative, because that data results in (higher) taxation (Raux, Transport moving to climate intelligence, 2011). The introduction of electric vehicles that provide emissions/km data fundamentally alters this situation. Opposite to the first assumption, EV vehicle operators are inclined to provide emissions data – proving lower emissions and evidence for permit excess. In turn, these excess permits are a potential value stream (Hughes, 2005). Interestingly, this proposition is hardly recognized by literature – and not at all by ETS related literature. Hughes (2005) describes the positive externalities of low emission vehicles in a Tradable Permit (TP) structure. In this review, Fuel Cell Vehicles (FCV) are recognized to be more expensive in terms of Total Cost of Ownership (TCO); the income from selling unused CO₂ permits offsets the higher TCO. EV's and FCV's are comparable in this case; both potentially offer CO₂ savings and do not produce emissions directly. Therefore, the suggestions of Hughes (2005) can be projected on EV's in a similar fashion. In conclusion, EV emissions/km data is suggested in literature to support EV's economically, if integrated into ETS. While recognized in literature already in 2005, this economic proposition has yet to receive more attention of scholars in the ETS domain.
2.3.3.3 EV emissions/km data in business modeling context

Section 2.2.3.1 described literature contributions on the function of EV emissions/km data in TP perspective; section 2.2.3.2 identified the enabling role of EV emissions/km data as a potential value stream. This section will continue by analyzing literature on business models in relation to EV emissions/km data, using insights gained from 2.2.2.3. As mentioned in 2.2.3.1, past literature suggested a form of ETS in which vehicle manufacturers would be required to purchase CO₂ permits matching the emissions of vehicles produced on basis of average fuel consumption, and average vehicle mileage (Wang, Cost savings of using a marketable permit system for regulating light-duty vehicle emissions, 1994), (Albrecht, 2000) It is very clear that this form of ETS can only be imposed if EV emissions/km data is available. There would be no other method to determine the number of permits producers are required to purchase to offset prospective vehicle emissions. The consequences for vehicle manufacturers would be quite straightforward in this situation: the overall vehicle taxation for more energy efficient vehicles is lower.

While identifying this form vehicle inclusion into ETS, Hughes (2005) primarily proposes the inclusion of FCV’s (thus zero emission) vehicles into ETS, to create an additional value stream. In effect, the author proposes a business model for utility vehicle operators to take the full advantage of ETS – by purchasing clean vehicles – and selling excess permits Salon et al (2010) refers to this as carrot-style (rewarding) behavior of the tradable permit system. Hughes (2005) does not go into any further details as to the business model consequences of using ETS to create an additional value stream. It is not the objective of this review to draw any conclusions on business model success of ETS inclusion – but it is interesting to compare the emerging paradigm to the insights of section 2.2.2.3. Of the six business model functions retrieved from Chesbrough & Rosenbloom (2002) at least three functions would change significantly. Cost structure and profit potential changes, as the incorporation of green-tech vehicles will alter corporate capital expenditure. The businesses’ value network would also change – permit auction creates a new network of complementing customers. Overall the business competitive strategy changes as well; huge capital investments are needed – in return enabling lower emissions for municipalities.

In conclusion, it can be stated that ETS literature, electro mobility and business modeling literature are highly developed but yet totally uncorrelated. The potential of adequate business modeling in an ETS environment is apparent; business model literature indicates the business model impacts are strongly significant. Hughes (2005) is a rare exception in literature attempting to bridge these two areas of literature, also recognizing the sensitive topic of how to determine vehicle emissions/km data. More research on this area may be needed – as both ETS and alternative (electric) vehicle technologies quickly gain terrain in normal business settings.
3 General research methodology

Academic- versus business –objectives
Following the literature section, this section describes how the research is structured in general. The research aimed to offer a practical solution that serves the interests of hosting company, but also aimed to provide a solid academic contribution by offering general insights that are applicable to the automotive sector, and possibly beyond that. To achieve this, the regulative cycle by Van Aken et al. (2007) was applied. The practical problem was analyzed, after which business specific designs emerged. While practical implementation was unfeasible in this research setting, the concepts were compared to existing literature knowledge. The figure below displays the regulative cycle from van Aken et al. (2007)

The research started by further detailing the problem definition. Analysis and diagnosis and design formed the main body of the research; these two were closely linked and iterated several times during the research. The resulting (set of) model(s) were translated into academic knowledge after reflection on existing literature knowledge.

3.1 Project approach

The general research design proposed in the section above translated to a practical research setting outlined below. Key point of the figure below is the iterative process of this research; using input of experts, emerging concepts evolved into solutions. Expert interviews and additional data served as information source to shape and validate the solutions produced. The result is a set of industry wide applicable solutions that served the problem situation of the company where this research was done directly, and academic knowledge indirectly. The next section will elaborate on the project approach in more detail. Figure IV is included to further explain how the research approach is applied in reality.
3.2 Analytic strategy

As the literature background already mentioned, there are limited cases available on the introduction of commercial electro mobility projects. Without preceding case material to compare with, a priori it was highly unknown what the solution directions could emerge. This situation dictates the type of research; focused at knowledge-creation. As with every knowledge creating research, it aimed to create fundamental new knowledge, mentioned in literature as ‘[…] presenting new, perhaps framebreaking insights’ (Eisenhardt (1989) To do so, several strategic choices are defined here.

Key strategic decision was to structure the research following the framework of Eisenhardt (1989). The framework is outlined below, after which strategic research elements are detailed. Some of the Eisenhardt framework steps were not relevant for this type or research and are striped through (as this research is a single case, single researcher study)

<table>
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<tr>
<th>Step</th>
<th>Activity</th>
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<tbody>
<tr>
<td>1</td>
<td>Getting started</td>
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<tr>
<td>2</td>
<td>Selecting cases</td>
</tr>
<tr>
<td>3</td>
<td>Crafting instruments and protocols</td>
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<td>4</td>
<td>Entering the field</td>
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<tr>
<td>5</td>
<td>Analyzing data</td>
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<td>6</td>
<td>Shaping hypotheses</td>
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<tr>
<td>7</td>
<td>Enfolding literature</td>
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<tr>
<td>8</td>
<td>Reaching closure</td>
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Preceding the draft of this research proposal, an elaborate literature review was done on the concepts of socio-technical regimes and transitioning, legislative interaction, business modeling, EV emission data and ETS, to have grounded à priori knowledge. Research questions are defined in the problem definition of the next chapter. These inputs were used to define the ‘instrument crafting’ in phase 3; preliminary ideas and concepts were formed. These concepts then served as guidance during interviews, and will in later stage became a set of solutions– the unit of analysis (more is outlined below)
The field phase was dominated by data collection – interviews and written documents. The researcher aimed to combine documents wherever possible and triangulate data. Another prominent tool applied in this phase is the use of field notes. Eisenhardt’s definition is closely followed here: “an on-going stream-of-consciousness commentary about what is happening in the research, involving both observation and analysis – preferably separated from one another” A diary was updated with separate observation and analysis following every interview. The subsequent phases of analysis, hypothesis and literature reflection were closely connected. In the analysis phase, the contribution of an individual interview or document is reflected on, in relation to the concept defined before. Wherever possible, hypotheses arising from field notes are tabulated to increase testability– creating a strong bridge between the qualitative evidence and the theories proposed (Eisenhardt & Graebner (2007)). Academic knowledge here served to support hypotheses wherever possible. Resulting, the solution concepts were adapted. After completion of phase 4-7, the research iterated. The adapted ideas and concepts again served as guidance for the subsequent interview. Implicit in this research methodology, data collection altered. While this is allowed (and necessary) within the context of a theory-building research, the researcher aimed to inform the interviewed on disputed changes in the concepts guiding the interview. Using this cautious progressive approach, data collection flexibility is allowed, while irresponsible flexibility is avoided.

Iteration stopped once theoretical saturation was reached. Eisenhardt (1989) follows the definition of Glaser & Strauss; ‘the point at which incremental learning is minimal because researchers are observing phenomena seen before’. In this research it implied that adding interview data yielded in little or no solution concept alteration. Data addition beyond this point leads to ‘data asphyxiation’; the point at which data becomes a burden, instead of increasing validity. Pragmatic insight of the researcher balanced the amount of data for this research.

### 3.3 Unit of analysis

The primary unit of analysis was the (environmental competitive advantage of) commercial electro mobility and its interaction with reality. Analysis of the competitive advantage of the EV resulted in emerging concepts. The unit of analysis was discussed intensively during interviews - this led to incremental insight on the (environmental) competitive advantage of the commercial EV, and led to the emergence of concepts that accelerate the introduction of the commercial EV.

### 3.4 Data collection & analysis

#### 3.4.1 Data collection strategy

The analytic strategy already outlined the role of data collection in this research. This section will further detail how data was acquired and analyzed. As mentioned before, this research accumulated (with every iteration) into a commercial EV reinforcing concepts. The data collection and analysis process changed accordingly during this transition. At the start of the research, the results from the preceding literature review, the research question and the preliminary thoughts of the author formed solution concepts. Documents formed a possible contribution, whenever available to the research. The outcome of this phase formed the à priori research guideline for the interview phase. Following this phase, the main data collection period commenced. The author aimed to conduct at least two interviews per identified stakeholder group (EV producer, governmental / general stakeholders, EV operators) to obtain more valid results.

The nature of the research dictated the type of interview used. Closed question interviews would not yield into rich, detailed information, while open interviews are unable to pinpoint certain challenging aspects of emerging solution concepts at hand. Therefore, this research was set-up using the semi-structured interview (Qu & Dumay, 2011). The interview opportunity was also used to request interviewee for additional document. There were included to achieve as much triangulation as possible. Field notes served in this context to track progress; interview outcomes and subsequent analyses were written down separately in the research diary. This document serves both as analysis guidance, and as internal validation tool for the research.

Analysis was mainly done after interviews; using the discussions with the supervisor as input and interview data as critical guideline. While the semi-structured interview at start served to explore the
outlines of the solution concepts, at later stages the interviews served more and more as validation. At the point that additional data did not lead to new insights, criteria for saturation is met – the endpoint for data collection and analysis.

3.4.2 Interview results
As mentioned in the introduction, this research aims to find methods to accelerate the introduction of commercial electro mobility. However, the term 'Commercial electro mobility' potentially describes all commercial vehicles in the field of transport. Due to the unavailability of electrification technology for all types of commercial mobility, and interests of the researcher and the supporting company the thesis was executed, focus was specifically directed to 2 categories; (1) city bus transport, and (2) city distribution transport (a detailed technical discussion is provided in the problem statement)

Complementing the definition of these categories is the geographical focus; this research focused at the EU. This limitation was chosen for multiple reasons: (1) the researcher of this review was unable to collect data outside of the EU and (2) the EU is a relatively important sales market for the supporting company this thesis was executed and (3) the EU is a diverse area with different electro mobility influencing factors other markets might also have (the validity of this review outside of the EU however is outside of the scope of this discussion)

The researcher had extensive access to interviewees within Volvo Corporation and its separate entities. Outside of the Volvo Group, key interviewees were identified and requested for cooperation to this review. These leads allowed the researcher to collect data outside of Sweden – in Belgium, France and England. It also allowed the researcher to collect data from a variety of key stakeholders, such as Vattenfall (a large energy corporation with subsidiaries in the EU); DB Schenker and ACEA (the lobbying organization representing all major global automotive competitors). The table below provides an overview of the persons interviewed. As can be seen, city bus and commercial distribution vehicle interviews were separated. In addition, it was interesting for this research to include interview data of persons related to electro mobility – one such stakeholder would be an energy supplier (in this research represented by Mr. Martin Bölander of Vattenfall)

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<th>Company</th>
<th>Name</th>
<th>Position</th>
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<td>Volvo Bus</td>
<td>Edward Jobson</td>
<td>Environmental director</td>
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<tr>
<td></td>
<td>Volvo Bus</td>
<td>Ulf Gustafsson</td>
<td>Tool Manufacturing &amp; Design Manager</td>
</tr>
<tr>
<td></td>
<td>Veolia</td>
<td>Jean-Laurent Franchineau</td>
<td>Research director, head R&amp;D Veolia</td>
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<td>Göteborgs staden</td>
<td>Anette Thorén</td>
<td>City Traffic Office</td>
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<td>Transport for London</td>
<td>Mike Weston</td>
<td>Director</td>
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<td>Truck</td>
<td>Volvo 3P</td>
<td>Cecilia Gunnarsson</td>
<td>Senior Specialist / Environmental Manager</td>
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<td>Karine Forien</td>
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<td>Miguel Halgren</td>
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<tr>
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3.4.3 Data processing & analysis
The outcome of the general research design is a data set that needed to be organized in such a way, fast and accurate analysis was possible. The first step in organizing this was separation of data types. Three types of data could be distinguished:

a) Closed interview responses, with argumentation aligned to the question posed
b) Closed interview questions, with argumentation un-aligned to the question posed
c) Open interview argumentations, potentially without any alignment to the subject of interest
d) Documents, reports and other written data of interest to this study, supplied by interviewed persons.

While options a-c and d could be separated quite easily, it was not so straightforward to separate data type a and b. The scientific value of this research would drop whenever un-aligned arguementations would
be deleted from the data. Therefore, the author chose to separate data in either a) closed question replies or b) open question replies (and of course, the documentation data type d) To still keep the link between question posed and reply given, un-aligned argumentations were still labeled in accordance with the question where the argumentation was given. To clarify how this labeling works, some sample labels are displayed below.

Closed Question reply by Mr. Mike Weston on Question 2.2:

CQM2.2 The influence is that the new vehicles have to meet the new Euro standards. And the only other influence is if they are awarded on basis of ‘hybrids’ or some alternate technology. And in that case they have to meet that specific standards. But if we say at the moment: it has to be a hybrid, it doesn’t say it has to be a Volvo or an Alexander-Dennis.

Open Question reply by Mr. Jean-Laurent Franchineau in relation to question 2 (first reply, so 2a):

OQIF2a Here in France it is not the case. Here it is the cities that buy the vehicles. And we sell the operation cost. And in this case, the cities want the best vehicles with the highest reliability and the lowest operating cost.

Document data is organized in order of receiving, by the name of the persons supplying the data. For example, a document supplied by Mr. Niklas Thulin, quote on page 12:

DDNT7p12 In 2009 TNO analyzed records of fuel-card usage in the Netherlands to understand the differences between real world driving and the test-based, published fuel consumption and tailpipe CO₂ data

3.5 Design method

The design approach of this research was strongly defined by the visual management tools of the Board of Innovation (2010) As mentioned, data collection and design was done subsequently and repeated until final designs were retrieved. At the start of the research, the results formed the preceding literature review, the research question and the preliminary thoughts of the author formed solution concepts. Interviews data added insight to the correctness of the models. As the interview data collection progressed and the solution concepts solidified, the interviews then served as validation for the designs. The result is a set of solutions that enhance the competitive advantage of the commercial EV, serving the specific interest of Volvo Technology AB. In the final stage of this research the obtained designs were complemented with contextual description, and implementation recommendations. Contextual description allowed the proposed design to be used in different settings – and offer insights for literature. Implementation recommendations are provided, as Volvo AB needs pragmatic advice to implement the suggested business model at hand.

Parameters

Within the boundaries of the normal business re-design, parameters are the ‘knobs’ available to the researcher to improve the current setting. A priori, the researcher defined two research parameters that are possible strong influences on the current business setting.

- Stakeholder setup defines how stakeholders interact, and what their interaction is. Proper management of this parameter will yield to cooperative behavior – a fundamental assumption of the framework presented
- Communication setup defines how stakeholder data exchange is realized. Communication setup implies constraints, but also opens possibilities in communicating with stakeholders. Proper setup also enables sufficient legal compliance.


3.6 Quality criteria

Research quality is determined on three factors; validity, reliability and controllability. Eisenhardt (1989) provides several suggestions to improve the research on these three factors, all addressed below. First, validity is discussed, divided into construct, internal and external validity.

Validity
Construct validity refers to the validity of the used instruments to study the phenomena at hand. It should be noted that in this highly contextual research situation, no quantitative tools are helpful – only interviews are the right tool to reveal (detail rich) information. Whenever possible, interviews were complemented with documents, so the advantages of data triangulation were used at full extent. Intermediate results are also discussed with the principal supervisor at Volvo AB.

Internal validity refers to the validity of internal conclusions in the research. As previously mentioned, field notes – observations and analysis separately documented – were deployed. Again, the supervision of the principal supervisor helped to eliminate any erroneous conclusions at any time.

External validity refers to the applicability of the research conclusions outside of the current research setting. As the outcome of this research is a solution concept with recommendations to deploy, external validity refers simply to the applicability of the business model outside of the current setting. As the solution concepts tend to be very context dependent, this research therefore also explicitly defined contextual consequences. Explicit definition of context and possible adaptation recommendations should sufficiently deal with the issue of external validity.

Reliability
Second factor of research quality is reliability, respondent selection, researcher and instrument reliability. Respondent reliability is normally judged on randomness of sample; in this case the opposite is aimed for. This research is best served by non-random data. Respondent selection reliability is in this best obtained by selecting persons from different ranks and companies – this procedure is preferred throughout the research. Instrument reliability of open interviews is more difficult to safeguard, as there is no real structure to follow. However, the researcher aimed to cover four basic subjects in every interview: (1) stakeholders, (2) communication & technology, (3) legislation and (4) overall integration (the business model at hand) Further, triangulation was used to complement interview data. This way, the subject at hand was discussed fully (in a way, standardizing an open interview) Researcher bias was safeguarded in this research by including as much supervisor interaction. Pivotal arguments were discussed and agreed on by multiple persons, lowering personal bias.

Controllability
Final research quality criteria is controllability; the repeatability of this research. The use of field notes allowed in-depth tracking of research progress, thus providing any repeating research the path of inference generation. Also, following the research outlines of Eisenhardt (1989) provided a clear repeatable path.
4 Problem analysis

Commercial electro mobility is a slowly developing trend in the automotive landscape. Whereas electric passenger cars tend to draw lots of (public) attention, the development of commercial electro mobility does not receive large amounts of media attention. However, the potential environmental gains from commercial electro mobility are imminent – since commercial vehicles operate close to public at all times – in the city, at public transport hubs and at city centers for goods distribution. From the perspective of CO₂ emissions, electrification of commercial mobility is even more interesting; a small amount of vehicles (and participants) are responsible for a large stake of CO₂ transport emissions. In addition to these facts, one could argue that fuel consumption costs of a commercial vehicle are relatively high compared to its initial investments – opposite to private vehicles where vehicle purchase cost is much higher than the TCO fuel consumption cost. With so much fundamental advantages, the researcher therefore determined the following research question:

"What factors are currently inhibiting commercial electro mobility, and what methods can accelerate introduction of commercial electro mobility?"

This section aims to answer the research questions above in a systematic order. From the start, it is obvious that the research questions are extremely broad and vaguely defined - there was no possibility to define a solid problem statement before entering the field for data collection. Therefore, this section does was not defined before research started, and finished after completion of all data collection.

The problem statement contains multiple factors that are interrelated, potentially influencing the introduction of commercial electro mobility through multiple paths. Therefore the author used a system dynamics representation of the problems and their relations – as this allows definition of cross-factor relations. The modeling approach was also used to provoke thought on the ‘strength’ of factors; factors may increase or decrease in importance, thus potentially changing in direction or become zero if unimportant. The discussion will start from inside out; first, the core of the problems model is discussed, after which the branches of problems are detailed. The concluding section presents the full model, along with a discussion on interactions among the factors listed. For clarity, the full model is also directly shown below.

![Figure V: full problem statement model](image-url)
The very core of problems revolving the introduction of commercial electro mobility is defined by economic reasoning. Regardless of segment (city bus / distribution vehicle), vehicle operators will always keep vehicle Total Cost of Ownership in mind. As current commercial vehicles are the outcome of decades of improvement, electric vehicles face the tough challenge of offering a better financial proposition. A popular thought is logically that EV’s potentially have a lower TCO due to lower operational cost. While the assumption of no fuel consumption, thus lower operational cost may hold true, a higher vehicle purchase price overrules this advantage. Chapter 4.2 offers an elaborate discussion on this factor.

Less related to economic reasoning is the fact that commercial electric vehicle technology is not yet mature enough to compete with conventional vehicles in its segment. For example, long-haul heavy-duty transport vehicles tend to drive large distances before stopping. At the current state of art (2012) there is no alternative vehicle technology available that meets the power requirements of this type of transport in economic sense. Therefore, as mentioned in the research methodology sector, long-haul heavy-duty transport is not discussed as feasible application of electric vehicle technology. Chapter 4.3 offers an elaborate discussion on the technological limitations of electric vehicle technology.

In the commercial vehicle segments where electric vehicle technology has the potential to serve operational demands, operators tend to switch to electro mobility (as this was also observed) whenever factor § 3 offers enough positive reinforcing. Again, positive reinforcing is very much dominated by economic reasoning – as operators of commercial vehicles are in most cases acting rationally – and their objective is ultimately optimizing corporate profit. Positive reinforcing of commercial electro mobility is the core of this research and will be discussed extensively in Chapter 4.4
Higher vehicle TCO is a very dominant factor in the process of electro mobility introduction – therefore a discussion on this factor is justified. While the author had access to the networks of an automotive competitor, it had no in-depth insight in the pricing strategies of vehicles, or information on vehicle operational costs. This would also violate generalizability of the research, as every automotive competitor and vehicle has a different purchase price and operational cost profile. The discussion at hand will therefore not go into deep details of vehicle pricing and operational cost characteristics. Instead, the commercial electric vehicle is discussed as-is, with its (financial) interactions with stakeholders. Main factor §1 presumes that commercial electric vehicles systematically have a higher TCO. Interview data suggests this might not always be the case. The discussion is started with definition of TCO as coined by interviewees, followed by a discussion when the TCO of commercial EV’s may be lower, as indicated by interviewee data.

Interview questions on TCO as driver for the sales of vehicles (regardless of vehicle segment) indicate that there are multiple definitions for TCO. The ordinary definition of TCO is the long-term perspective cost of a vehicle, with all relevant operational costs taken into account. The interview data suggests that a majority of the interviewees list TCO as a top sales argument; 5 out of 9 relevant interviewees (#CQHE2.1 / #CQEJ2.1 / #CQJF2.1 / #CQAT2.1 / #CQRW2.1) confirm a pivotal role of TCO in the process of acquiring new vehicles for commercial operation. Also, TCO is indicated by interviewees to be more important than environmental aspects such as local pollutant emissions or GHG emissions. One step further in the integrated cost approach thinking is the concept of Vehicle Total Productivity (VTP) One has to keep in mind that this research was not undertaken to find the correct definition of Vehicle Total Productivity – a rather complex and potentially disputable concept. Instead, the concept is discussed shortly and placed in context. Vehicle Total Productivity is coined twice as most important decision factor in the purchase process of commercial vehicles, and specifically by stakeholders in the truck segment (#CQCG2.1 / #CQMIH2.1) It is suggested to be a more holistic view of vehicle cost versus vehicle economic merit and includes also vehicle operational capabilities, such as reliability. Therefore, it does not replace TCO, rather it complements it. This would explain why price attractive commercial vehicles might not be the most economic decision – as reliability may lower, incorporating lower vehicle up-time (or worse, costly vehicle salvage operations) Vehicle Total Productivity is therefore also dependent on operational circumstances; operators incurring high vehicle downtime penalties tend to have a different view on Vehicle Total Productivity.

### 4.2.1 Payback unfeasible over average operational time

An external factor that influences vehicle TCO is vehicle operational period. A commercial EV has a higher up-front cost, which is expected to be recovered during operational phase, as electricity consumption costs are expected to be much lower\(^2\) than fuel costs. Therefore, it is important that the time window in which upfront costs are compensated for is long enough. A short time-frame will not offer enough operational discount costs to fully recover initial investment costs, so a sufficiently large timeframe is critical for the introduction of commercial EV’s. Interview data suggests that vehicle operators tend to focus only on their own operational time frame, as they do not expect higher vehicle resale price at the end of their operations (discussed later in full detail) From this point, commercial distribution vehicles and city buses differ significantly, so both are discussed separately.

The city bus segment already has some experience with electrification; the city of London requested hybrid technology from city bus manufacturers since 2008 (#QOMW0g). This resulted in bus manufacturers delivering hybrid systems to the city of London, and beyond. Due to this development, there is some commercial experience with hybrid systems and their economic pay back time. The payback time is at time of writing indicated to be 5 to 7 years (see #CQ3.1) This time-frame is nearing market acceptability, as indicated by one of the interviewees: “[...] we see a payback time of 5 to 7 years. We think that is a healthy period (in economic terms)” Of course, this payback time is related very much to the operational distance covered. One interviewee indicated that operators aim to optimize this by putting hybrid vehicles in intensive revenue (#CQEJ3.1) – potentially shortening the economic payback time of electro mobility.

\(^2\) Interview data indicates that exotic cases may violate this assumption
In the distribution vehicle segment, electric vehicle technology has progressed much less. As a result, there is no technology offering a feasible payback time. However, the payback time should be about the same as for city bus to be acceptable; (#CQKF3.1: “At the moment, there is no payback time at all. The accepted payback time should be four or five year. At the moment, we are twice as expensive”) Other interviewees indicated similar time frames. This is again on average the mean operating time of the first vehicle operator.

4.2.2 Vehicle value amortized to zero after operational period
With some clarity on the importance and definition of TCO, it is interesting to see why it is indicated to be much higher. As mentioned, the researcher keeps distance from a discussion on vehicle purchase price or vehicle operational performance in terms of fuel economy advantages. Apart from these items with their own dynamics, interview data suggests also that amortization is much higher on Electric Vehicles versus conventional vehicles. This is caused by the estimation of vehicle residual value after the intended first operating period. Not only is evidence found for this in the interview data, also in the case study of Whiteman et al (2011), the commercial EV’s used were amortized to zero (“the terminal value of the EV’s is unknown”) Needless to say, the practice of completely writing off the value of electric vehicles bears a huge cost for the business case of the commercial EV.

4.2.2.1 Technology reliability and applicability uncertain over longer time
In a sense, there are parallels recognizable with electric passenger vehicles – passenger vehicles have the same technology uncertainty issue. Commercial vehicles are however much more capital intensive, and therefore a risk for vehicle operators. The combination of a lack of feasible business case, and the relative increase in uncertainty on technology reliability hinders operators in adopting commercial EV’s in revenue. Several interviewees indicated that operators are indeed adopting EV’s, but in very small numbers to see how the technology performs in daily operation – as also is the case in the pilot described by Whiteman et al (2011) In a sense, this is one of the fundamental hindering factors electro mobility is facing during introduction.

4.3 EV technology not meeting operational demands

Apart from the rather complex and dynamic conceptual framing of TCO, one should keep in mind the technological limitations of electro mobility. One reason why electric passenger vehicles are now being sold, whereas commercial EV’s are still very much in experimentation phase, is the fact that commercial vehicles have to fulfill an operational duty that is in most cases fixed. Limited operating range may for example be acceptable for a number of EV passenger car early adopters – it is not for competitors whose longevity is dependent on reliable and economic vehicle operations.

As mentioned in the introduction of this thesis, the focus of the research was directed at the segments of city bus and distribution vehicle. Factor § 2 is the main cause why. Apart from the economic shortfall of electro mobility (at current state of art), for some segments of commercial vehicles there is no technology able of fulfilling vehicle operations yet. Especially for the segment of long-haul heavy-duty transport it is unclear how a transition away from fossil fuels is going to be achieved. Interview data suggests that the at current state of technology, the automotive focus might be in the distribution vehicle weight between 3.5 to 20 tonnes (#CQFK3.2, “So it is only distribution trucks, not long haul trucks”) Similar to this, long haul bus (coach) transport is disregarded (this vehicle segment has the same power requirements electric vehicle technology cannot fulfill)
In the segments where electro mobility is feasible, electric vehicles are most of the times expected to perform just as any other conventional vehicle. Several (city bus segment) interviewees indicated that technology required to perform in business-as-usual operations – and if not, technology needed upgrading. These requirements can be extreme, as one interviewee indicated: “[...] but the vehicles only had an operating time of 10 hours a day. [...] So the next trial, two years we set very clear that our objective was to get a fuel cell bus that could do 20 hours a day” Whiteman et al (2011) offers a similar operations requirement profile, but also shows that operations might be adjusted to a certain extent (the reason for this being very practical – the case study testifies vehicles were already purchased and needed an operational adjustment for the project to continue)

It is important to keep in mind the strict operational requirements commercial electro mobility is facing. Whereas some segments are excluded by definition, for some segments electric vehicle technology offers a feasible alternative. Literature and interview data suggests limited operational adjustments are tolerated. Commercial electro mobility has to perform within operational requirements of competitors. There is very little space for re-alignment of business operations to meet the specifics of electric vehicles. A very striking citation can found in the interview data: “[...] it does need to work and make sense from the productivity point of view. The product cannot be a suffer” (#OQCG8a)

4.4 Commercial EV’s not offering additional value for operators

Whereas the last paragraphs were needed to shape a complete overview of the issues commercial electro mobility is facing, the paragraph at hand is the core of this research – creating value for commercial electro mobility (both in ‘niche’ setting as in larger context). Financial or technical aspects of commercial electro mobility are very hard to change parameters, as they are the result of technological progress (and / or competitive pricing strategies) Creating value to counter financial or technical disadvantages is more within reach of the Innovation Management researcher. To do so, one must fully understand how value creation is currently achieved (or not) and where the value creation process can be enhanced. In a sense, the financial and technological disadvantages of a commercial EV are in some cases already outweighed – since commercial EV projects are already taking place on small scale.

The system dynamics model below captures all aspects the researcher found during research (being interview data, document data and literature research) As mentioned before, it is important to keep in mind that the model is initially set up as a system dynamics model; factors in the model below can be negative, positive or be zero in influence. Therefore this (problem statement) model is also applicable for the cases where commercial electro mobility was able to start; factors in these cases were non-negative (positive) and contributed to introduction of electro mobility. The case study of Whiteman et al (2011) for example extensively discusses a mix of positive factors § 3.1.2, § 3.1.3, § 3.2.1 and § 3.2. This section will discuss the factors as the system model below illustrates in numerical order.

![Figure IX: Limited additional value factor in problem statement model](image-url)
In broad sense, this research sees two main factors that either promote or hinder introduction of electro mobility; governmental support (§ 3.1) or stakeholder cooperation (§3.2). Factor § 3.1 is suggested by interview data to be the most complex of factors, influenced by four sub-factors (one shared with § 3.1).

### 4.4.1 Insufficient governmental support to increase value for electro mobility

The factor of governmental support in this research is by no means limited to financial support. Governmental support potentially ranges from technology oriented congestion charge to the allowance of commercial distribution EV's to offload for longer periods - in essence, every support an operator of EV's might receive from local, regional, national or international governmental bodies.

This research will not go into detail of why there is insufficient governmental support for electro mobility for two reasons; first, interview data suggests behavior of regional and national governments differs per geography. Defining government support for electro mobility would therefore result in non-generalizable research outcomes, aimed at a specific region. Second, the author had no deep insight into the motivations different governmental bodies; so there would be insufficient data to draw any inferences from. Instead, the factor of insufficient governmental support for EV's is in this research conceptualized 'as is', and not further discussed. The research at hand did collect data on the sub-factors of § 3.1, and – opposed to § 3.1 - its sub-factors are generalizable, albeit with different relative factor strength. For example, interview data suggests that Nordic governments are facing more pressure from sub-factors § 3.1.1 and § 3.1.2.

The sub-factors this research suggests that are of great influence on local government behavior are five factors; (1) (city) inhabitants pressure (or lack thereof) to increase local air quality, (2) the absence of monetary value of local air quality, (3) the limited governmental attention on CO₂ emission and global warming, and (4) (stakeholder) unawareness on opportunities to create value for electro mobility.

### 4.4.1.1 Insufficient pressure on governments to increase local air quality

The first factor to be described is the (lack of) pressure on local governments to increase local air quality and reduce noise pollution. It is discussed first because interview data suggests that this factor has a huge potential to promote commercial electro mobility, and it is already a promoter of electro mobility today. This section will limit itself by only discussing inhabitants’ pressure; pressure applied by other stakeholders (such as the EU) is discussed in § 3.1.1.2. Almost all interviewees indicated that the need for increasing local air quality is of major importance and a reason to experiment with electro mobility. It is a remarkable finding, since the general and dominant assumption that electro mobility is mainly started because of concerns of global warming, might not be valid.

Starting point for this discussion is the set of measures that are currently taken to decrease local air pollution by commercial transport, as suggested by interview data. The most apparent and well-known measure that is taken to decrease air pollution is regulation of vehicle emissions. Binding legislation active in Europe is well known under the ‘Euro I / II / III / IV / V / VI’ norm; it sets standards on CO, HC, NOₓ and PM and is set stricter over time. Currently, Euro IV norms are active, while the Euro VI norm becomes active as of January 1st, 2014 (European Union, 2011). These norms are not hollow promises as the diagram to the right illustrates (Cummins, 2012) One would therefore assume that local air quality improves year by year, as newer vehicles slowly replace older vehicles. Interviewees indeed assume this, especially with the Euro VI norms to be introduced soon. However, this is not the case. Interview data also suggests that local air quality is becoming more and more of an issue. One interviewee indicated that the Paris air quality did not improve over the last ten years, while another indicated that the city of London is expected to be fined by the EU this year for local air quality norm violation (more of this in section 4.5.2.2) While a discussion on the contributors of local air pollution quality is a very cumbersome one, it is suggested that economic growth increased the number of vehicles in inner-cities, thereby outweighing efforts of lower vehicle exhaust emissions.

![Figure X: EU emission standards; Pi Innovo (2012)](image-url)
Therefore, while at high-level (EU) directives efforts are in place to decrease emissions from (commercial) vehicles, an unexpected increase in traffic is acting as counter-effect.

Next to high-level EU regulations (2007/715/EC) on vehicle side, there are also directives in place for local air quality in cities (directive 2008/50/EC). This directive is directly the responsibility of the city itself, and it offers citizens some form of tool to actively enable pressure on local governments to take action. One would expect that measurement reports would then mobilise citizens to take action. Interview data suggest two findings of importance here; first, citizens are very much unaware of local air quality. Second, when citizens do find out, the consequences are serious – factor §3.1.1 potentially enables the immediate introduction of commercial electric mobility.

4.4.1.1.1 City inhabitants are unaware of local air quality issues <3.1.1.1.>

Local air quality is very much an intangible problem; it is invisible and in most cases odorless. However at sufficient levels, local air pollution poses an immediate threat for human health. Citizen awareness is therefore a very powerful ‘tool’ in the process of introducing commercial electric mobility. There are however a number of hurdles to take in the process of citizen awareness to pressure, discussed in order: (1) measurement is mostly point-wise; (2) air quality is dependent on a huge number of factors; (3) commercial mobility is just one of the active polluters and (4) the citizen information process (which is sub-optimal).

First, air quality measurement is a very difficult process. Research data suggests it is common for cities to measure air quality at point locations (see for example #DDNT16-p9; #DDJH01; #DDJH02). Illustrative is the map of the city of Gothenburg; air quality is measured at known air quality problem locations. However, the air quality of the majority of the city is not measured and reported. As can be seen from the Gothenburg Air Quality map, air quality differs very much from location to location. In a sense, air quality is therefore only reported for a marginal percentage of the inhabitants of the city of Gothenburg.

Second, air quality differs on a daily (and even hourly) basis. Even at measured locations, air quality values may differ significantly (see for example #DDNT16; #DDJH02; #DDJH03). There is no possible statement to make on real-time air quality, so air quality reporting generally resorts to statistical inferences as ‘number of days of violation’ (see #DDJH02). This adds a factor of complexity to the data.

Third, air quality is directly influenced by a number of factors, mobility being one of them (albeit a dominant one). This means that if citizens were to enable pressure on local governments to increase local air quality, a defensive response would be that other factors are the main culprit. This would complicate discussions. While discussing the air quality issues of the city of London, one interviewee indicated: “So our base emissions are from traffic and sources and so on, but what’s tipping it over is the emissions coming in from other areas, from main land Europe for example. You can argue what’s tipping it over, but it is not just about local air pollution emissions, is it?”

While satellite imaging overviews do confirm that industrial activity is high on European mainland (see Whiteman et al (2011)) and possibly a significant influence on air quality in London, literature consensus remains that road transport is one of the largest origins of local air quality (see for example Vestreng et al (2009); estimations are at 40% for anthropogenic emissions).

While all factors mentioned above are possible barriers for citizens to grasp air quality issues in relation to commercial vehicle operations, possibly the most important reason for citizen unawareness on local air quality issues is the process of information. It would be too much of a departure from the main research question of this review to discuss information flow processes on local air quality to citizens. Therefore, this research relies on previous work (which is also abundantly available).
problem statement describes two major aspects worth discussing in this context; current information methods and the sensitivity of citizens to air quality information. At the moment of writing, every citizen is more or less capable of determining the air quality of its environment. Different web sites offer overviews, ranging from municipal to European aggregation are at the disposal of everyone with internet connection (#DDNT16; #DDJH01, #DDJH02, #DDJH03, #DDJH04). These portals do not shy to use words as ‘poor’ whenever the situation justifies it (see all of above sources).

On the other hand, it remains unclear whether there is enough interest from citizens’ side. #DDJH01-p20, the report by the Dutch Environmental service recognizes this aspect: “[…] One can wonder if the Internet is the best way to reach the public. Experience shows that air quality websites in the Netherlands generally receive relatively few hits: the average air quality is not a point of concern for most of the Dutch citizens. Experience in Paris shows that most people know the ATMO air quality index broadcasted on the daily news together with the weather information. The number of visits on that website shows a dramatic increase during episodes when people actually notice that air quality is poor: they seek confirmation (or complementary information) on the website.”

Concluding, two main inferences can be drawn from the collected data; first, air quality data is available for the general public, but since local air quality is up to certain levels an ‘invisible’ problem, general public attention seems to be low. Second, the Internet is in some sense a passive medium – it only displays the data a user chooses to see, opposed to actively informing the user of problems it is not aware of. Once interested, the average citizen encounters data that is possibly not fully applicable (eg. a different region, see for example #DDNT15, #DDJH02) or too complex to grasp (for example, what does ‘poor air quality’ mean to me?) On top of this, the influence of commercial vehicles on this air quality is not apparent. In the current setting, air quality is therefore not interesting for citizens, and certainly not improving the position of the commercial electric vehicle.

4.4.1.1.2 Local air pollution has no monetary value

Next to pressure on local governments by citizens, higher institutions, and in some cases private organizations are possible sources of pressure on local governments to improve air quality. Interview data suggests that this is of direct influence on commercial electro mobility – if present. In most cities and most cases, factor § 3.1.1.2. is probably never relevant, but if present, the consequences can be major. First and logical pressing factor that of EU seeking for adherence to directive 2008/50/EC from local governments. Local air quality is strictly set in levels and days of violation are limited. If systematically violated, the EU has the authorization to enforce punitive measures, such as heavy fines. Public confirmation that the EU is not withholding its power in enforcing this directive is found in popular media (Daily Mail, 2012) Next to pressure by the EU, local governments are by exception also pressured to increase local air quality by private organizations. At time of writing the London Olympics has yet to start – but already, private organization IOC (Olympics organizer) is warning the city of London to adhere to air quality regulations – or face a fine of potentially £175m (Guardian, 2012)

It is very interesting to have knowledge on the relation between fines on local air quality violation, and the introduction of commercial electro mobility. Research data suggests that there is a relation – and it might be stronger than anticipated. One interviewee responded on this issue as follows: “[…] in terms of NOx and NO2; central London and Heathrow airport are exceeding air quality limits based on EU regulations. So London stands to have a fine of 200M pound because of exceedings in central London. So what the government now is doing is giving us funding to improve buses.” Although it cannot be stated that in all situations, the same relationship is existent, resulting in more rapid introduction of electro mobility. However, this research data does prove that in at least one situation, a relationship existed. While any inference beyond this is pure speculation, one could say that there is a probability that whenever air quality becomes a tangible monetary asset, commercial electro mobility is diffusing more rapidly.

The argument of above might shape the assumption that the main factor to introduce electro mobility is already in place. Sadly, the city of London is a rare exception of EU punitive measures actively being applied. Especially cities in West German, Belgian and Dutch areas are without exception violating European air quality (a striking evidence can be found in #DDJH2) The EU has not communicated openly
on any other violation penalties at the time of writing. In addition, the Olympics committee is one of the rare organizations that has the power to fine municipalities. The probability of such an event occurring more often is estimated to be very low by the researcher.

4.4.1.2 CO2 and GHG issues have limited governmental attention

As described in the section above, local air quality is largely invisible and therefore not noticed by citizens. However, local air quality (or pollution) has a direct effect on human health – thus creating incentive at citizens to take action whenever needed. This is not the case with CO2 emission and the global heating issue. CO2 is inert, odorless and non-toxic (exotic cases ignored). Contrary to local emissions, one cannot state that CO2 decreases life expectancy. Therefore, raising awareness for CO2 emissions and global heating is much harder. The consequences of excessive CO2 emissions are shared by 7 billion people on this planet, rather than directly impacting personal health. Although literature explicitly recognizes the pivotal role of municipalities in lowering CO2 (see for example Whiteman et al (2011)), cities that impose heavy regulations create a competitive disadvantage for themselves; as do nationalities. In general therefore, the only governmental level willing to impose tough and binding regulations on CO2 emissions for mobility is the European Union itself (therefore the researcher also included an interviewee close to the legislative power center of the EU, involved with automotive CO2 emissions) This presumption does not dictate that only the EU is taking measures to lower CO2 emissions for mobility; national governments have a number of (taxation) tools in place which indirectly influence CO2 emissions from mobility. A short discussion is presented on CO2 emission from mobility and the role of governments. First, government taxation is discussed, followed by (2) ETS taxation and its influence on transportation, leading to a concluding overview (3).

As discussed in the literature background section, governments have a number of tools at their disposal to steer society into generally desirable directions. In the case of (commercial) mobility, it is the common objective of local and national governments to limit the number of vehicles on the road to such an extent, excessive congestion (and also local air pollution) is avoided. Tax on fuel is in most (EU) cases the heaviest of all mobility taxes, and also generating incentive to lower fuel consumption – thus CO2 emissions. In general, this taxation has never been presented as CO2 tax – as the tax is always added per unit of fuel tanked (liters) instead of per kilo of (potential) CO2 emission. More recently, nations with frontrunner aspirations have attempted to make the link between fuel tanked and CO2 emitted more apparent. For example, Norway labels a part of the fuel tax as CO2 tax, while Sweden has a similar labeling system in place. It remains very debatable if this actually helps lowering CO2 emissions. Most probably, high fuel costs will pressure operators to purchase more efficient vehicles – CO2 emissions not being on the agenda.

In essence, it does not matter if CO2 emissions are resulting from mobility or other sources. The highest achievable objective when dealing with the greenhouse gas issue is therefore to lower CO2 emission as efficient as possible (at the lowest cost). Since 2005 the European Union therefore started enforcing EU ETS – an integrated trading system for CO2 emissions, regardless of emitter. The literature section in this thesis already discussed the working principle and literature background of EU ETS in detail. The problem section will discuss why EU ETS is currently not an enabler for the introduction of electro mobility. Two major issues were discovered during research that hinders EU ETS in fulfilling its role for electro mobility, (1) the stakeholder problem, and (2) the permit price issue.

The first issue of having too much stakeholders is suggested to be a dominant factor reason for not including transport into ETS. ETS requires cooperation from all stakeholders for the system to operate (for example: trading credits, communicating on CO2 emissions) – this requires a limited number of stakeholders to be involved. The inclusion of commercial transportation into ETS would require a large number of stakeholders to cooperate, which increases the cost of the system. Diverse literature sources (and document data also; see #DDNT18-p28) recognize this and suggest upstream introduction of ETS to be the most efficient way of introducing ETS. In reality however, interview data suggests that upstream inclusion might also be very difficult: “The problem that you have when you focus at the fuel supplier, actually you would start the discussion, that also for stationary power you have fuel suppliers. They are delivering coal, fossil fuel, palm oil, you name it. How do you deal with sectors that are not transport but still have the same situation. So it would actually be much better, in my view, to start with ETS in the fuel sector. But then you have the problem that some get taxed, and some not.” (#QSL6f)
A second and also very pressing issue is the permit price of ETS, with two sub-issues to be identified. First, ETS permit prices are much too low to actually influence commercial transportation (average of € 7 / tonne CO₂ at time of writing) Illustrative is the fuel tax premium on diesel in the Netherlands versus potential EU ETS permit premium; one liter of diesel incurs about € 0.74 of tax, versus an emission of 2.68 kg of CO₂. For that same amount of CO₂ emitted, the EU ETS premium per liter would be € 0.007 with today’s permit prices. That would amount to a price increase of 0.4% - an insignificant amount. Even at 10x increase, the impacts on mobility would be minor, while all other actors in the ETS sector would suffer heavily. In essence, mobility is already heavily taxed when compared to other sectors. Inclusion of road transport into the ETS system would therefore be a painful process, requiring ‘patchwork’ legislation (such as creating different permits for mobility) This disconnect was also revealed during an interview session: “We are not against introducing it for transportation, but we are against to establish a separate ETS only for the transportation sector, because we don’t think that is the right way to do it. So the problem that we have now is: who is the trading partners in the ETS system. We have already found out that, in our discussions, the reasons others don’t want us to be involved in the ETS system is because of the high cost vehicle manufacturers have to abate CO₂.” Next to the low ETS permit price, one has to recognize the economic system of permit trading introduces price volatility. Fuel price volatility can be very disruptive for society, while at this moment ETS is an unmanaged economic system in which the permit price potentially fluctuates by a multitude of the base price, creating politically unacceptable situations (see also #DDNT16-p28)

Apart from these issues, the researcher was also in the position to sense the general opinion of interviewees on ETS, and the possibility of introduction in the coming years. The general indication is that if ETS were to be introduced, the form will probably be upstream (#DDNT16, CQ6.2 (all responses)) Opinions on whether EU ETS will cover mobility in the future differ; some interviewees suggest in the next five years, some are unsure. Indicative was a consensus opinion offered by one interviewee: “The introduction of ETS is very path dependent. It might happen, if other major countries take the initiative and go ahead with tax on basis of ETS. The EU is not heading in this direction at the moment. It might very well be the case that legislation will be too late, and that the automotive sector already moved to low-carbon technologies so far” (#CQ6.2)

In conclusion, research data suggests that EU ETS for mobility is facing a number of major issues. It will take time before these issues are politically resolved – and possibly, the crucial early introduction period of commercial electro mobility will not benefit from EU ETS. This remains speculation until the EU publishes its longer-term plans.

4.4.1.3 Stakeholders are unaware of opportunities and technologies to create value for electro mobility

The last issue related to the sub-factor ‘insufficient governmental support’ is the issue of unawareness on value creation. In the system dynamics model of the problem statement, this factor is phrased as a general stakeholder issue. In this case, local governments are the target stakeholder. Research data suggests local governments are potentially unaware of opportunities and technologies to create value for electro mobility. There are two basic information limitations local governments are dealing with; (1) vehicle technology performance potential and (2) situational opportunity potential. This factor is strongly related to § 1.1.1: Technology reliability & applicability uncertainty on long term (already discussed in section 4.2.1.1) The discussion starts with vehicle technology potential unawareness, then continues with situational opportunity unawareness.

In general, local governments have limited information gathering potential. Focus on air quality to the extent real action is necessary, is a relatively new – requiring in-depth understanding of air quality dynamics and influencing factors. Reason for the fact that air quality is rapidly becoming more pressing is on one hand the ever-increasing traffic in cities; on the other hand it is the EU (enforcing 2008/50/EC) and increased citizen awareness on air quality problems. Confronted with new legislations and more pressure, governments need to take action. However, there is no uniform, out of the box solution; every city is impacted by different air pollution specific factors and requires a different set of mitigation measures. Section 4.5.2.1 already discussed how difficult it is to pinpoint local air quality issues and polluters. It is even more difficult to determine what actions are needed to achieve acceptable air quality limits – actions that are possibly a hindrance for the (mobility of) general public.
Whenever cities have air quality issues, reducing air pollution from traffic is a viable solution. The introduction of commercial EV’s would help here since in most cases, EV’s replace vehicles with heavy environmental loads. However for this to happen municipalities have to be knowledgeable on two aspects; what (commercial) electro mobility might offer in terms of improving air quality, and how far commercial EV technology has matured. Research data shows that cities can be very proficient on this aspect; for example the city of London actively cooperates with city bus manufacturers and knows very well what technology can offer for the city in terms of air quality improvement, and what technology can offer in terms of daily operations (see #DDMW1 for an impressive insight in city awareness on city transport electro mobility) However, one has to realize that this may very well be an exceptional case; the city of London has great air quality issues and needs to be front-runner to cope with intense traffic air pollution. The researcher very much doubts if all cities encountering air quality issues have the same capability of analyzing technology progress on commercial electro mobility, and the same insight commercial electro mobility might offer to resolve air quality issues. Research data supports this doubt, as stated by an interviewee involved in EV public transport projects in London: “In reality, politics and technology will drive what technology we have, affordability will drive the pace of progress. Cause I am sure that if every European city would put out a tender tomorrow, to have 30 electric buses, the pace of the manufacturer would improve dramatically. Because, I suspect that the progress of technology is partly driven by their idea of how far the market is” (#OQMW3b) Resulting, the justifiable link between air quality issues and electro mobility might not be fully developed in all relevant cases in the EU.

Second and major information shortfall of local municipalities is unawareness on how to create value for electro mobility. In the current research setup, two cities were inquired on aspects that might promote the introduction of commercial electro mobility. When specifically asked what factors might improve the introduction of cleaner (electric) vehicles, very few single stakeholders suggested any effective methodology to improve value for EV’s. One interviewee indicated that there are methodologies to improve vehicle productivity for commercial stakeholders, but so far these have not been implemented (or even discussed); “Well, there should be both a stick and a carrot. For example, if a city proposes to allow EV distribution trucks over bus lanes, this would speed up our operation, and that allows us to use the vehicle for more parcels in less time. This could be a very good promoter.” (“#CQMHH3.4) Interestingly, the author was also unable to find any developed literature on this – indicating that also the academic field is not yet supporting cities in gathering data and obtaining best-practices to promote the introduction of commercial EV’s. The author has to place a positive note also. Interview data suggests that cities are gradually becoming more aware of electro mobility as technology, what it can do and how it can be promoted. One interviewee (city of Göteborg) indicated thoughts into meaningful direction to support EV’s: “[...] Also, we want to allow electric vehicles to offload with larger time frames, so small shop keepers do not have to be working during offload time” (#OQAT4b)

So far, both literature as collected research data indicates that within the emerging field of (commercial) electro mobility, there is lot to gain in the information process of stakeholders. Local governments and cities need to be aware of progress of electric vehicle technology, what it can offer in terms of local air quality, and how to promote EV technology in such a way, its introduction is accelerated. However at the current time of writing, commercial electro mobility is so new for a host of local governments, this information process is yet to start.

4.4.2 No stakeholder cooperation to reinforce value for commercial electro mobility

Research data and literature indicates that also commercial stakeholders are not fully aware of emerging possibilities commercial EV’s have to offer. The very concrete and positive solutions suggested by interviewees in this research (e.g. driving over bus lanes and offering wider offload times to improve commercial EV productivity) are relatively unknown methods to improve commercial EV productivity. Even very recent literature fails to mention whether or not actions were taken to improve vehicle productivity in any meaningful way (see Whiteman et al (2011)) This is remarkable, as the case in the research mentioned had full cooperation of the city. The researcher therefore wonders why very concrete, and positive measures are so rarely put into concrete action. Partly the newness of commercial electro mobility must be factor – as technological developments are relatively recent. Partly, the researcher suggests that local distribution companies have yet to realize, that when introducing EV’s, cities can play a vital role in improving vehicle productivity – and what the resulting productivity then will be.
4.5 Overview of analysis

The research data collected indicates that introduction of commercial electro mobility is influenced by a number of dynamic, interrelated factors. Going from large to smaller factors, the basic requirement is that electric vehicle technology has to fulfill operational needs of both city bus operators and local distribution vehicles. In the case of city bus, one interviewee indicated (as discussed) that it cooperated with vehicle manufacturers until technology was mature enough for heavy daily operations, while for distribution vehicles the same productivity is generally aimed for ("the product cannot be a suffer") Whenever within technological reach, commercial electric vehicles face the tough challenge of offering a competitive value for the operator, comparable to conventional vehicles. Whenever the TCO is higher, commercial electro mobility remains a niche product. However, the definition of TCO might be under scrutiny. Electric vehicle amortization and payback time are important Whenever the vehicle TCO is the same or higher compared to conventional vehicles, EV’s face the difficult task of outweighing a higher TCO with environmental advantages, or with methods that add meaningful vehicle productivity to the total proposition. Environmental advantages of EV’s are apparent, but first the (local air quality) situation must be sufficiently critical before local governments are willing to take action, possibly influenced by its own citizens, higher governmental legislation or (in niche situations) empowered institutions. Adding vehicle productivity on the other hand can also outweigh higher TCO; wider offload times for EV’s or bus line driving adds direct and meaningful value to the proposition of commercial EV’s. But first of all, stakeholders need to be aware of the possible air quality impact, operational performance, long-term reliability and methods to add productivity to electric vehicle technology. Only with widespread, unambiguous information on these aspects will help local governments and commercial stakeholders raise the bar and adopt commercial EV technology.

Figure V: Full problem statement model
5 Design solutions

The last section provided an overview of all problems commercial electro mobility is facing, as supported by literature, interviews and document data collected during this research. This section will offer three solutions that aim to resolve the problems mentioned in Chapter 4. These solutions are concrete solutions to assist the company this research was done for in reaching its objective to stimulate the introduction of commercial EV technology to the market. It should be noted that the solutions offered in this chapter are the end of this review; no attempt is done to implement the solutions this chapter offers into reality. This chapter will also refrain from describing potential implications for academic literature; the conclusion chapter will offer an elaborate discussion on this topic.

This chapter will offer three interrelated solutions summarized by its core objective; (I) Measure, (II) Communicate, and (III) Elaborate. Solution I is specifically designed to reduce uncertainty among stakeholders on what the effect of electro mobility is on air quality. As discussed, local air pollution itself is a very dynamic and complex issue – and the effect of electro mobility on local air quality is very much unknown at this very moment. Measuring air quality with a more dynamic approach is a major step in the direction of realizing better air quality, with electro mobility as enabler. However, measuring alone is not enough. As discussed, local air quality is a passive problem; it can impact human health without being noticed by citizens. Active information presentation is needed to raise awareness with citizens to such extent, pressure on local governments raised. This is the direction of solution II (‘Communicate’) Elaboration - the last solution - targets operators and their influencing stakeholders. Both need to have up-to-date, reliable and relevant information on the technological progress of electro mobility in their application, information on best-practices performed in other but similar situations, what the environmental impacts were in these cases - and most important what the financial consequences are. All solutions are discussed in the order just given.

5.1 Solution I: Measure

The solution proposition starts with measure – measuring of local air quality in the inner city. As already discussed in the problem statement section (see 4.1.1.1) air quality is mostly statically measured, at fixed positions in the city. The researcher poses the question: is this really the only way to measure air quality? It does not seem to be so. Several academic and non-academic developments prove that mobile air quality measurement is in fact feasible, and quite possibly a low-cost commercially available product in the near future. To concretize how mobile air quality measurement works, this section will start with a short background report on air quality so far. Then, a discussion is started why commercial EV’s are the perfect platform to incorporate local air quality on from multiple viewpoints (public opinion, business, technological) Then, the direct advantage of air quality measurement for commercial EV’s is discussed, followed by an overviewing conclusion.

5.1.1 Mobile air quality sensing in reference projects

While it is not the objective of this section to present an elaborate literature review on mobile air quality, a short discussion is presented to substantiate the case for Mobile Air Quality Measurement (MAQM) Mobile air quality has been the interest of several independent initiators. From the private field, the MIMAQ initiative (Mobile Individual Measurements for Air Quality) has been started in the city of Leiden, the Netherlands. Initiated by group of private enthusiasts and local government of Leiden, MIMAQ aimed to map air quality in the city of Leiden using continuous mobile sensing. Resulting, a map with NOx concentrations emerged with the objective of informing citizens where air quality is good or bad. The MIMAQ initiative has been completed at the end of 2010, showing that mobile air quality sensing is indeed feasible (see more information at www.mimaq.org)

Separately, the Common Sense project initiated by a group
of fellow academics related to the University of Berkeley, California aimed for a similar result and being more focused at the sensing device itself. Aoki et al (2009) reported progress of the ‘Common Sense project’, along with some results of measuring air quality on street sweepers in the city of San Francisco, California. This project thus directly confirms technical feasibility of on-vehicle air quality measurement. Without further elaborating on technical details, the Common Sense project (http://www.communitysensing.org) proves for itself that mobile continuous air quality sensing is feasible from a technical, financial and scientific viewpoint.

\[\text{Figure XIV: Vehicle-sided implementation of air quality sensors on street sweepers in San Francisco, California. Source: the Common Sense Project (2012)}\]

5.1.2 Presentation consequences of Mobile versus static Air Quality Measuring

The last section provided a couple of projects with the objective of proving feasibility; now the discussion turns to the attained results of mobile versus static air quality measuring. During research, multiple static air quality representation sources were consulted (#DDNT16, #DDJH01, #DDJH02, #DDJH03, #DDJH4). Below an overview is given from two sources (being air quality presentations from Rotterdam and Gothenburg city).

\[\text{Figure XV: Air quality report graphic from the city of Gothenburg, Sweden. Source: #DDNT16-p9}\]

\[\text{Figure XVI: Air quality report graphic from specific point in the city of Rotterdam, the Netherlands. Source: #DDJH02}\]

Without again entering the discussion the problem statement already covered, one should ask: is this the data that will raise awareness enough for citizens to require better air quality from their legislators? Is it unambiguous, clear to understand does it answer more questions than it raises? The initiators of MIMAQ, Common Sense and the author of this research disagree. The results of MIMAQ and a sample display from the Common Sense project are displayed below (city of Leiden, Netherlands and the city of San Francisco, California).

\[\text{Figure XVIII: Air quality report graphic from the city of Gothenburg Sweden; Common Sense project (2012)}\]

\[\text{Figure XVIII: MIMAQ air quality results in Google Maps overlay. Source: MIMAQ (2012)}\]
Using a standard Google Maps overlay, the MIMAQ initiative produced measuring per measuring device, per separate day. From a practical viewpoint this makes sense since the mobile measuring devices were operated by citizens that lack the routine of driving the same route every day for multiple times. In the Common Sense initiative, street sweepers were used, which cover the whole city with a limited number of vehicles. In addition to these two initiatives, the researcher of this thesis proposes to integrate mobile air quality measuring on vehicles that run specific routes multiple times a day in high frequency. This adds another dimension to MAQM; air quality statistics on a certain point become available such as pollution mean, pollution standard deviation and (with enough data) even forecasting becomes available. The author has to point out that this was already available with static measuring. The main difference is that a fine-grained data set becomes available whenever MAQM is adopted. The image below shows what MAQM will deliver, once properly setup on city buses.

![Figure XIX: Fictional air quality report in Google Maps overlay](image)

### 5.1.3 Commercial EV’s as platform for MAQM

As discussed, EV’s are very much a suitable platform to measure air quality. However, MAQM also offers advantages for the commercial EV. These mutual advantages are discussed in four different perspectives; first in measuring perspective, followed by a business rationale perspective, product value proposition perspective and finally from a communications perspective. First, from a measuring perspective, commercial EV’s (and all EV’s in general) have the ability to measure local air quality and not influence it at the same time. While the Common Sense project very much envisions what the author aims for in this solution direction, air quality measurement on a street sweeper in a sense very much incorrect; the air quality directly behind the vehicle will be worse than measured. The impact of exhaust gases from the measuring platform MAQM travels in may be negligible; but ironically the reason for introducing MAQM is not to estimate any factor, instead to obtain reliable data valid in all situations. EV’s clearly offer the advantage of measuring, but not influencing its measuring environment. Second, the company at which this research was conducted is in the position to implement air quality sensing devices into its commercial vehicle products. In addition, this company has extensive experience with vehicle-to-infrastructure data communications, thus using current in-house competences to enhance future product proposition.
Third, from a product value proposition perspective, the commercial EV would offer an extra product feature. In the coming years of EV technology introduction, commercial EV purchasers should be categorized as front-runners - quite possibly the kind of operator that appreciates the additional feature of evidence gathering for its environmental choice. Research data also indicated this as one interviewee replied after being presented the option of air-quality sensing: “One of the reasons fares will go up is the investment in green technology. Indirectly you justify why your fares have gone up. So it helps reinforcing this.” (#CQM7.2) Remaining is the question whether both distribution vehicles and city buses will profit from the addition of MAQM. For city bus EV’s, the advantages of integration of MAQM are apparent; local governments are directly ‘rewarded’ when adopting city bus EV’s with a local air quality data stream. For commercial distribution vehicles the value proposition is less straightforward; private stakeholders will then be the owner of the data stream of the MAQM system. Establishing a link with the general public is then much harder and requires voluntary cooperation (involving data-communication) and a public service taking care of data analysis, storage and display. Finally, from a communications perspective integration of MAQM into a commercial EV will probably always enhance product value, regardless of vehicle segment. The combination of commercial electro mobility with MAQM helps citizens to establish and understand the positive influence of commercial EV technology on local air quality – a link that is very much needed and justified.

5.1.4 Limitations

MAQM has so far been discussed as a supporter for commercial EV’s as local air quality data potentially raises awareness among citizens on the issue of local air pollution, as well as establishment of linking air quality to electro mobility. Figure XX displays how the communication between actors is potentially realized. Hypothetically, the combination of MAQM and the commercial EV might offer another advantage; concrete air quality improvement evidence when introducing more EV’s. The author has to point out that all statements in this section are by no means grounded on any concrete proof. However, the author challenges the reader to follow a simple reasoning; would 100% adoption of commercial EV’s in a city improve local air quality? There is a probability air quality improves – so somewhere along the EV adoption curve (being from 0 to 100%) a statistical effect is bound to appear. The author has no proof when a statistically significant effect emerges – only that at some point, an effect will materialize. This advantage should therefore used with care until practical evidence is gathered. But one has to realize: whenever the effect of commercial EV’s is indeed measurable using MAQM, the value proposition of a commercial EV will probably grow. Local governments are empowered to require more (commercial) EV’s in their city limits to fight air pollution, thus enhancing the introduction rate of commercial EV technology.

5.2 Solution II: Communicate

The last section discussed MAQM as additional feature to the commercial EV. This section continues by assuming that the Measure solution is actually implemented, and retrieved data is available. One has to realize that extensive knowledge on communications literature was not consulted for this research, as this area is too much departure from the general theme the research at hand. Instead, the solution at hand was established with research data and few literature sources. With this limitation in mind, first general objectives are discussed, followed by communication methods to achieve these objectives. Interview data suggests that just informing general public on the sensitive issue of air quality may have adverse consequences; the sensitivity issue is therefore also discussed.

5.2.1 General objective

The overall objective of this research is to accelerate the introduction of the commercial EV. The objective of the communication solution is to stimulate citizen awareness on local air quality. This may indirectly result in the introduction of more commercial EV’s, such as when air quality becomes more important on the political agenda (see #CQHE2.2) Resulting, politicians may opt for (or be required to) stimulate the introduction of cleaner commercial vehicles. More preferable is the direct link between local air quality and adoption of EV’s. Whenever citizens feel that local air quality is insufficient and see traffic as a major source of pollution, local governments may even be forced to implement cleaner commercial (city bus) vehicles. The researcher encountered exactly this situation at an interview: "Yes, we've got a street in London called the Pattney high street and there are local groups complaining about air quality, and they are
coming to TfL and they are asking what are you doing about it? And we got some plans and we are sharing that with the local public but in the way that system reinforces where we are failing as a city. [...] And in reality we are giving them hybrid buses or some and share what we can do. And that is because they are aware of the issue, they got a hold of some local data and they made their case, and they need some improvement.“ This concrete case suggests that a higher level of awareness is a powerful tool to stimulate electro mobility. Appendix II illustrates how stakeholder is set-up as envisioned by the author of this research.

5.2.2 Preferred communication channels

To reach the objective described, the author suggests that active communication methods are to be preferred. Three types of communication are presented in this section; (1) in-vehicle display, (2) in-app display and (3) website display.

5.2.2.1 In-vehicle display

The first option of in-vehicle (city bus) display is very logical; the company at which this research was executed is in the position to include this type of technology in its vehicles. Also, in-vehicle display offers high levels of exposure at a relatively low cost. On top of this, passengers leaving the vehicle are possibly immediately informed on their personal local air quality, as a proportion of passengers leaving the vehicle will have reached its destination. Interviewees in this research were in general supportive for in-vehicle display as well (see #CQ5.3) In-vehicle display may therefore be the key communication means for local air pollution to be displayed.

5.2.2.2 In-app display

The second type of display is in-app communication. In a sense, in-app display is passive; it requires users to download the app before information transfer can start. However, in-vehicle display can already inform the user of availability of the app and thus cancel this initial hurdle. The real added value of in-app display is location availability of the user; average and real-time air quality data can directly be displayed. This enables users to determine air quality wherever requested – potentially even to influencing users where to do running exercises. Once installed, apps also have the opportunity to run in background mode, informing users whenever air quality is at unacceptable levels. This potentially raises citizen awareness to very high levels.

5.2.2.3 Website display

The last communications channel proposed is normal website display. Although already discussed in the problem section as an insufficient method to inform the general public, website display has a number of advantages and complements in-vehicle and in-app display. In-app display is limited due to average mobile phone screen size. In addition, apps are controlled by touch, requiring large control buttons and few options to choose from. Information transfer via app is therefore limited. In-vehicle display is in this sense even more limited; only key figures can be displayed, as it must catch the focus of commuters. Website display is therefore an addition. It enables users to consult background information whenever triggered confronted by in-vehicle display or in-app display. The author realizes that website communication of air quality is already extensively chosen as communication form (see for example #DDJH01, #DDJH02, #DDJH03) However, one has to realize that in-app and in-vehicle display might not be the right information transfer method, and no current website is capable of communicating the rich data obtained from the measure solution suggested here. The company at which this research was conducted may have to be forced to take an active role in setting up website communications, although cooperation with local governments may also be a fruitful path for setting up website communications. The researcher has no in-depth information on cooperation strategies to achieve this; it is left up to the implementation
phase of this solution direction to establish a productive approach for setting up website display.

5.2.3 Limitations

Before proceeding, one has to realize that the proceedings of this section are hypothetical – assuming that solutions 1 & 2 are to be implemented. However, research data suggests that adverse consequences may mount if solutions 1 & 2 are introduced; thus a short discussion is justified. Multiple interviewees have suggested in this research that the proceedings of the 'Measure' solution in combination with communication strategies of the above section may lead to preferable consequences. Local air quality, thus personal health is an important issue for citizens, and when communicating air quality data, a cautious approach is probably necessary. This section discusses what adverse consequences accurate measuring and display of air quality may bear. These are (1) not serving interest of stakeholders, (2) unwanted political pressure, (3) the empowerment of citizens to take legal action against stakeholders. The section closes with a discussion on mitigation strategies.

5.2.3.1 Not serving interest of stakeholders

Various stakeholders are influenced by local air quality communications; being the general public, the commercial stakeholder and the local government. We will shortly discuss stakeholder interests and what local air quality does with these interests. In general, the interest of the general public is better air quality and information to assess air quality. However, this interest should not be served at any cost. For example if air quality is stated to be mediocre for a type of neighborhood, real estate prices may drop. This is an adverse impact that would not serve the interest of the general public (see also #OQCG5b). It is in the best interest of the general public that awareness is raised to such an extent, politicians are triggered to take action – without creating any other adverse effects.

Local governments are motivated by both serving the interests of the general public and keep popularity of the general public (see also #CQHE2.2). The interests of the general public are by no means served when focus and funds are 100% directed at improving air quality – the financial consequences would be unbearable. The general approach of local governments is probably to balance focus, protect economic activity and initiate air quality improvement action at the same time. While communication on air quality helps the general public to understand spending on local air quality resolutions (such as EV city buses) – it might also trigger public pressure a local government is not waiting for. In this case, local air quality communication would not serve the interest of a pivotal stakeholder – and a very likely effect is the loss of support for air quality communications. In effect, local governments do not want to be dictated what the adoption rate of air quality improvement projects should be, and decide for itself without additional pressure what actions should be taken (as described by one interviewee: "I don’t believe [there is] the possibility to communicate: here you are in a very polluted area. So for the mayor it is terrible. Everyone is going to phone and say: please give me the mayor. They are killing me."(#CQH7.1). Local governments need in some way to be protected against excessive pressure.

In general, commercial stakeholders have the objective of maximizing profits. On short term, communication local air quality would therefore be counter productive; informed general public would for example call for measures that hurt mobility (such as closing busy inner-city roads) For the EV segment of distribution vehicles, the case might be further complicated as there is no clear advantage for this stakeholder to implement MAQM – unless required by local governments.

5.2.3.2 Mitigation strategies to control adverse consequences

Clearly, mounting the right pressure on local government politics to prioritize local air quality is a major challenge. However, measuring air quality and choosing not to communicate honestly can be very unwise, since general public should not be mislead. On the other hand, solutions 1 & 2 are to be integrated into commercial EV’s (mostly city bus segment) Whenever MAQM is implemented, local governments can already argue that efforts are in place to increase local air quality. Instead of having to answer ‘why not take action’, local governments are possibly confronted with ‘why not do more?’ To answer this question, the only solution local governments have at their disposal is to communicate what efforts are in place now and in the future. Solution three (‘Elaborate’) offers a strategy to help local governments answer this difficult question.
5.3 Solution III: Elaborate

The first solutions offered in this chapter have the primary objective to communicate air quality to the general public and establish a clear link between local air quality and commercial EV’s. While influencing the general opinion might be a very powerful ‘tool’ to accelerate introduction of commercial electro mobility, it is a single-sided solution that needs to be complemented. Introduction of commercial electro mobility will only accelerate if operators are presented with a realistic and positive case – being an advantageous proposition with such strength that additional investments are acceptable. To do so, the third solution will focus specifically on the operator and its relevant stakeholders. For distribution vehicles, the operator is the most important decision making unit. For the city bus segment, local governments are (once again) relevant stakeholder, as the city has the power to demand cleaner vehicles. This section presents a solution applicable for both segments. First, the objective of the solution is discussed, and a general approach is presented to reach this objective. Then, specific aspects of the approach are discussed. The section ends with a short discussion on limitations of this solution.

5.3.1 General objective
The general objective of the Elaborate solution is to demonstrate vehicle operators and their stakeholders that commercial electro mobility can indeed offer competitive value for money and is worth investing in. Apart from the positive argument that commercial EV’s contribute to better local air quality and are capable of normal operations application, the strong argument of equal total vehicle productivity should be transferred. As already discussed in chapter 4.2, VTP is the total calculation of funds invested versus meaningful vehicle productivity. In cooperation with local governments, vehicle total productivity may be enhanced. Financial consequences need to be clear and acceptable for operators. Appendix III illustrates how stakeholder is set-up as envisioned by the author of this research.

5.3.2 Presentation format
For an efficient and uniform presentation format, the use of conventional websites is recommended. At solution II, website use as information transfer was suggested to be insufficient, for its passive approach to inform the general public. However Solution III aims to inform vehicle operators and its stakeholders. The number of persons and operators to inform here is relatively small, and the company at which this research took place already has established connections with a number of these operators and stakeholders. Reaching out to this target audience is probably simpler – the reason why passive communication in this case can still be productive. With regard to presentation details, the researcher limits itself to discussing only what information should be transferred. It is up to the implementation phase to work out details (it should be noted that these details have enormous influence, so careful implementation is needed).

5.3.3 Positive reinforcement of commercial electro mobility
Communication towards operators and stakeholders should at least cover three essential positive reinforcements of commercial electro mobility; technology maturity demonstration, value enhancing cooperation methods and financial viability demonstration. All these reinforcements are ideally supported by best practices transfer from comparable cases, further underlining the strength of the reinforcement methods.

5.3.3.1 Technology maturity demonstration
As already extensively discussed in the problem section, a large portion of operators and stakeholders seem to be interested in testing different technologies from different manufacturers with the intent of building knowledge on (EV) reliability and operability. There seems to be need for unambiguous information, and the most reliable source of information is deemed to be proprietary R&D testing. While it is understandable for private companies to keep this information proprietary, as there is a competitive advantage to be secured, this is not so understandable for R&D projects set up with public funding.
Regarding the city bus segment, the researcher found evidence in its interview data and literature for ‘isolated’ city bus R&D efforts to establish the reliability and operability. In the most ideal situation, these R&D projects – cross-nation and region - are all closely linked to each other to stimulate learning between these R&D projects. It should be noted that the company at which this research took place cannot in any way force either local governments or operators to openly communicate this data; however it can set up communication between operators and stakeholders that are willing to ‘trade’ R&D data. In this way, stakeholders and operators give up a limited amount of knowledge, and receive a huge amount in return. Information sharing also enables local governments with less R&D funds to participate in electro mobility, since these smaller participants are empowered to learn from larger R&D trajectories – thus feeling more secure to apply commercial EV technology on smaller scale.

For the commercial distribution vehicle segment another approach needs to be adopted, since commercial operators are probably not willing to openly share R&D data, even if this results in access to information from other R&D projects. In this case, the company at which this research took place should take an active and central role. Two additional activities should be initiated; (1) incentivizing and (2) knowledge balancing. First, commercial stakeholders should have a meaningful motivation to share R&D data. This may be a simple discount in vehicle purchase price, or any other applicable incentive that fits into the commercial strategy of the vehicle producer. Second, the company should provide clear boundaries to what information is shared, and how. For example, if battery degradation information is transferred onto an open platform in anonymous form in return for a lower initial vehicle purchase price, companies may be willing to participate.

To evidence just how important information transfer is, the researcher encourages the reader once more to check problem statement factor § 1.1. Interview data suggests that even at the current state of art, leasing companies still routinely amortize commercial electric vehicles to zero after operational use. This is an enormous disadvantage for the business case for the commercial EV. Accurate, reliable and unambiguous research data on long term vehicle performance helps operators (and their leasing companies) understand that vehicle amortization to zero is not a good reflection of vehicle long term performance.

### 5.3.3.2 Value enhancing cooperation methods

Next to technology maturity demonstration, vehicle operators should be educated actively on methods that improve VTP. While the researcher did not have a broad overview of all options available to create value for commercial electro mobility, this section is provided to provoke more thought on value creation for commercial EV’s, specifically the distribution vehicle segment. Two value creating cooperation methods were suggested by interviewees, which deserve attention here; (1) city-to-operator cooperation on increased goods off-loading time, and (2) city-to-operator cooperation to allow commercial EV’s on priority lanes. The first value creation method was mentioned by one interviewee as a viable value creation method; allowing distribution vehicles to make more deliveries. If implemented properly, the increase of offload time would directly communicate to added productivity. In a sense this is also justified, as (inner city) offload times are enforced to reduce nighttime noise, and electric vehicles are in general more silent. The second value creation method is to allow commercial EV’s on priority lanes. One interviewee specifically mentioned that priority lane access (in this case bus lanes) would help add to vehicle productivity: “if a city proposes to allow EV distribution trucks over bus lanes, this would speed up our operation, and that allows us to use the vehicle for more parcels in less time. This could be a very good promoter.”

One cannot just argument that for all cities and regions these exemplary solutions are viable. In some circumstances, these exemplary value creation methods may not work, while others do. But the examples do point out that explicit city-to-operator cooperation and communication is needed to create value. While expertise on value creation for electro mobility varies from city to city and from operator to operator, communication on successful projects involving electro mobility and value creation methods will probably invoke a two-sided development. First, informed operators will likely become more inclined to think about value creation in cooperation with cities, and possibly in some cases, operators will push for value creating cooperation. Second, local governments are presented with possibilities to realize better local air quality at (relatively) marginal costs. The ideal situation would be two-sided motivation, potentially setting the right circumstances for commercial electro mobility.
5.3.3.3  City-to-city practices transfer (and competition creation)

The chapter at hand has discussed motivating operators and local governments to introduce commercial electro mobility. From the operator side, motivation should arise whenever VTP is higher such that economic profit is created; local government are motivated whenever local air quality is increased. Still, research data suggests that local government are motivated by yet another aspect: that of competition. It is not correct to assume that local governments are just interested in meeting local air quality; interview data suggests that cities are more and more interested in going beyond norms, and compete on air quality. This is a factor that should not be disregarded. Whenever implementing solution III, it should always be kept in mind that case demonstration also serves cities to show its efforts and progress. Implementation should be realized in such a way, city efforts and progress is comparable. This very subtle but important nuance stimulates competition on air quality and electro mobility projects, which is probably positive for the introduction of commercial electro mobility

5.3.4  Limitations

Every solution has its limitations; solution III is no exception to this rule. The most important limitation of Solution III is the fact that it aims to create value for commercial electro mobility to compensate for higher TCO. Compensating this premium purchase price may prove to be a harsh endeavor – especially whenever motivated operators face uncooperative local governments or vice versa. It may even be so that with all the mutual cooperation possible, the sum of productivity is still not competitive with conventional technology. With great probability this will be reality for years to come. However, continuous technological progress should steadily lower the purchase premium of commercial electro mobility. Whenever the solutions mentioned in thesis offer insufficient value at the current state of art, it will with great probability in the (far or near) future.
6 Discussion, conclusions and academic implications

This chapter presents the most important conclusions from the research at hand. The thesis started with the research question "What factors are currently inhibiting commercial electro mobility, and what methods can accelerate introduction of commercial electro mobility?" The problem statement offers an answer to the first part of the research question, while the second part is answered in the Design Solutions chapter. This chapter starts by reflecting on all presented sections in the discussion section, followed by a conclusion. Then, academic implications are discussed.

6.1 Discussion

As with many Innovation Management research originating from a practical problem setting, the researcher was à priori not in the position to fully grasp the implications of the issue at hand. It should be noted that commercial electro mobility is a huge segment and industry. As mentioned in the research methodology section, the researcher allowed itself limited flexibility; early data collection helped to pragmatically redefine electro mobility into (1) city bus vehicles and (2) distribution vehicles ranging from 3.5 to 20t. As mentioned in the problem statement section, this limitation was primarily envisioned because of technical limitations of current electro mobility technology. The outcome of this pragmatic approach led to the fundamental implication that the area of stakeholders shifted. Commercial city bus and local distribution vehicles operate mainly in cities; opposed to long-haul heavy duty vehicles which operate mainly outside of the attention of cities, influenced by other stakeholders (such as national governments)

This focus (on local operated vehicles) also dramatically changes the factors that influence the introduction of electro mobility technology. While the initial literature study was very much focused at CO₂ emission data as motivator for the shift to electro mobility, pragmatic research data indicated that CO₂ was not one of the main factors influencing the introduction of electro mobility. While CO₂ is on the agenda of all stakeholders that were interviewed for this research, research data suggests that even at today’s public awareness of GHG and global warming, stakeholders are compelled to focus at short-term issues. Whenever the topic of CO₂ is discussed, interviewees generally indicate that CO₂ reduction is used as marketing, rather than being a fundamental factor influencing the introduction of electro mobility (see for example #CQRW3.2, #CQMH3.3 and #CQEJ3.3) While the author does not seek to pinpoint false interest of stakeholders, literature seems to confirm that innovation and environmental experiments are perhaps sometimes used more to shape external image, rather than being invoked by true care for the environment, as described by Schot & Geels (2008): “In a critical interpretation, one might say that many of these exercises have become rituals, where actors express good intentions as a form of public ‘impression management’.” Instead, local governments are suggested by research data to be more interested in short-term, pressing issues. Local air quality is such a driver. Not only is European legislation set at stricter levels, also citizens are becoming more and more aware of air quality and the adverse effects of poor air quality to human health.

While commercial electro mobility is in general much better for both local air quality and GHG emissions, the downside is a higher vehicle TCO. Interviewees indicate that above all, electro mobility should be financially more attractive for operators to switch. Multiple factors were found that influence TCO for electro mobility negatively; amortization and operational period for example are disadvantageous for electric vehicle technology. To counter this disadvantage, currently there is little upside, or as interviewees suggest, more vehicle total productivity. Literature case studies confirm this obvious inhibitor for commercial electro mobility; see for example Whiteman et al (2011).

The Design solutions chapter aimed very much at creating more vehicle productivity (or more value) for electro mobility. Local air quality should be more emphasized; commercial electro mobility is resolving pressing air quality issues, but it remains very much invisible what the concrete impacts are. On the other hand, operators need to be aware of value creating opportunities. These opportunities can be created in cooperation with local governments, creating a business case for commercial electro mobility.
While the researcher took a very pragmatic approach in creating solutions to increase value for electro mobility, and tried include literature case studies as much as possible, in retrospect the literature topic of Strategic Niche Management (SNM) would have supported the thesis at hand. As said, à priori the researcher had no overview of the issues encountered and studied Transition Management as supportive literature (see Loorbach (2007)) Transition Management emphasizes a more vision oriented approach of changing a regime, while Strategic Niche Management scholars have expressed more the need for a hands-on approach in demonstration projects. The SNM approach in this case suggests that an innovation journey (commercial electromobility) can be facilitated shaping the ‘technological niche’; the (artificial) environment in which an innovation is nurtured and protected from outside pressures. The solution Design chapter very much parallels this approach, albeit without the formal labeling of SNM. For example, setting up cooperation between operators and local governments with the objective of increasing vehicle productivity creates a nurturing environment for electro mobility. Creating more pressure through air quality information publication can also be regarded as part of niche creation, although SNM scholars assume that eventually a niche setting will disappear, while emphasizing air quality information may be a lasting approach.

The literature studied at forehand also included the topic of socio-technical regimes and change. Using the perspective of Strategic Niche Management (SNM), the solutions from this research can also be placed larger (Multi-Level) perspective. Creation of individual experiment settings (niches) alone will not invoke regime change; it is the combination of multiple niches (successful and failed) that leads to societal insight on commercial electro mobility, shape developments, and accelerate introduction of commercial electro mobility on larger scale. In the solutions design chapter, elements of this thought already in place. For example, solution III emphasizes learning across niches wherever possible, to create accumulated insights from all projects the company at which this research took place. Distributed learning will help build aggregated knowledge on electro mobility. However, solution III also suggested that the learning platform to be created should be proprietary, as it would add to the competitive advantage of the firm this research took place. It remains up to the implementation phase to decide what should be prioritized; commercial electro mobility at large, or development of a competitive advantage for a single competitor that potentially sells more commercial electric vehicles.

Reflecting on the work as a whole, it should be noted that this thesis focuses at commercial electro mobility. By no means, electro mobility is the only solution to resolve the problems mentioned; however interview data suggests that electric vehicle technology is a likely candidate. Technology improvements of the next years will ultimately decide the technology path commercial mobility will follow. Whenever interviewing and analyzing, the researcher aimed to keep an open mind whenever possible, while steering away from ungrounded positivism. Therefore also, this research completely refrains from estimating when (and if) commercial electro mobility becomes a dominant technology.

6.2 Conclusions

Commercial electro mobility is in its early stages of introduction, and the accumulation of individual projects involving electric vehicles will probably start the emerging transition away from current technology. However, when starting these individual projects, it should be realized that commercial stakeholders rarely embark on EV projects unless the financial outcome is positive, assuming that electro mobility technology is mature enough to withstand daily normal operation. At the current state of art, financial outcome is in most cases negative; commercial electro mobility TCO is higher, reliability is unknown, operation seems (in some cases) to be problematic and there is no financial compensation for the fact that commercial EV's contribute to a better local and global environment. However, all of the issues just mentioned have deeper causes that can be resolved today with the right management approach, and the right technology match. Creating the right setting ('niche') is extremely important for the success of commercial electro mobility projects. The issues and solutions are discussed in order of importance.

Vehicle TCO greatly depends on vehicle residual value. Literature and interview data suggest that it is common practice to amortize commercial EV's to zero after operational use. This common practice is caused by uncertainty - among operators and lease companies – what the long-term reliability of EV technology is. Also at current practice, commercial EV's have the same (short) operational period as conventional vehicles, while EV's tend to have a lower TCO at longer operational period caused by lower
operational cost. These two compelling inhibitors can and should be mitigated, but require an extensive, reliable and detailed information and learning process, aimed towards decision making stakeholders.

Next to mitigating these negative financial issues, there are possibilities yet largely unexplored in project setting to create value for electro mobility. The introduction of commercial EV’s is advantageous for local governments since local air pollution and noise pollution is potentially lowered. Therefore, in an ideal situation, local governments and operators jointly cooperate to create value for electro mobility. Interview data suggests that operators benefit from simple, yet powerful solutions as nighttime cargo offloading or priority lane access in cities. Joint cooperating will then result in higher Vehicle Total Productivity for the operator, while local governments gain with better air quality. For this type of cooperation to emerge, both local governments and commercial operators probably need more information, and whenever possible, access to reference cases – not only to stimulate the current project, but also to create an overarching learning process.

Still, even without technology reliability data or close cooperation, commercial electro mobility projects are realized in small numbers today. Concern for the environment is probably a major trigger for the introduction of commercial electro mobility – yet little research is available on the exact interaction between these two. Surprisingly, while public debate tends to focus on CO₂ emissions as the major environmental issue, research data suggests that the decision to introduce commercial EV’s is much more influenced by local air quality. Local air quality is an immediate issue especially for the general public as it potentially endangers personal health on medium to long term. It would therefore be very compelling to have publicly accessible, accurate air quality data and an indication of the effect of commercial electro mobility has on local air quality. Research data suggests that local air quality measuring and communication today is relatively inaccurate and passively communicated. The solution this thesis offers is to integrate Mobile Air Quality Measuring onto commercial EV’s, as means for electro mobility to substantiate its own case. Again, this would help to create a mindset in which electro mobility prospers.

The general image arises that the introduction of commercial electro mobility has much to gain by developing appropriate information channels that helps operators and local governments to create value for electro mobility projects. The long-term costs and benefits of commercial electro mobility need to be communicated to all stakeholders, and from electro mobility project to electro mobility project. With the data already available and so much to gain for all stakeholders, there is no reason to refrain from better communication and cooperation, today.

6.3 Contribution

This thesis aims to contribute on three different aspects to academic knowledge. First of all, raising awareness for the paradigm of value creation versus additional (operating) cost to increase the viability of commercial electro mobility initiatives, as well as identification of what factors create value and what factors decrease value. Second, offer the suggestion that local air quality measuring is important for the introduction of electro mobility, but that current measurements are insufficient to offer a meaningful contribution. Last, offer the suggestion that information transfer methods help stakeholders of local electro mobility projects identify value creation methods (such as cooperation) and assess technology reliability. This information transfer method aims not only to sustain projects, but also sustain project-to-project learning. All contributions are discussed below.

The first contribution this research intends to provide is to provoke scholars to discuss introduction of commercial electro mobility projects in a TCO / VTP context. Commercial electro mobility (in local projects and larger socio-technical regime) can only succeed if the additional costs are outweighed by an increase in vehicle productivity, while even relatively recent literature does not recognize this important tradeoff enough (see for example Whiteman et al (2011). This tradeoff is not a detail, but should be the very first starting point of an analysis on the introduction of commercial electro mobility projects. It should be noted that businesses already understand this tradeoff very well – yet explicit academic discussion seems to be behind on this important factor.

In relation to this, the research at hand provides an overview of relevant TCO and VTP factors, gained from the inclusion of multiple interviewees related to commercial electro mobility. Whereas literature tends to discuss commercial electro mobility either in a single case perspective, or in a very broad
(scenario) perspective, this research adopts a broad overview but still aimed to study in detail what inhibitors and motivators influence introduction of commercial electro mobility. Resulting, the researcher was able to define concrete Design Solutions that potentially enable the introduction of commercial electro mobility in a wide range of settings. For example, commercial electro mobility at large is suffering from uncertainty of long-term technology reliability – so an information process towards all stakeholders is needed. Cooperation with operators and local governments might enhance the commercial value of electro mobility – yet such cooperation need to be initiated. These details are vital for the introduction of commercial electro mobility in the coming years, and yet not fully recognized by recent literature.

Second contribution of this research is the recognition of local air quality as relevant factor in the introduction of commercial electro mobility. So far, the relation between local air quality and commercial electro mobility is recognized, but yet academia have not even started to materialize this relation. Research data shows that local air quality is measured today with relatively crude and generic methods. This is recognized by literature and also, improvements are suggested by scholars (see Aoki et al (2009)). The added value of this research is that it proposes to use state of art air quality measurement to support the introduction of commercial electro mobility, by establishing the direct air quality impact of commercial electro mobility, and by informing the general public on air quality issues.

Last contribution of this research is to propose an information transfer method to help stakeholders of local electro mobility projects identify factors that increase value. As seen in the case of Whiteman et al (2011), still there is uncertainty at local commercial electro mobility projects how value (such as vehicle productivity) can be increased. The information transfer process to these projects, and from project-to-project has yet to start. The implications of information transfer from project-to-projects should not be underestimated here. Only by explicitly connecting commercial electro mobility projects with experiences and data, a larger societal movement towards a cleaner vehicle technology can be started.

6.4 Limitations and directions for further research

As with all research, its conclusions are dependent upon the data collected. This research aimed to include a wide range of stakeholders into this research to shape an accurate image of what factors influence commercial electro mobility. While the interviewees were all influential stakeholders, time constraints limited the researcher in researching in-depth what knowledge the total field of operators and local governments have. Most probably, the size of local governments influences its knowledge and its motivation to start with commercial electro mobility, as also the size of the operator is relevant. It would be very relevant to study what the exact effect of stakeholder size is, as commercial electro mobility most probably also influences the smaller city and operator.

Likewise, it should also be noted that not all relevant TCO and VTP factors were discovered with the data collected in this research. Other factors might play a role in the introduction of commercial electro mobility. It is up to further research to further complement or debate the factors this research offers. For example, interviewees in this research suggested that commercial electro mobility might also be introduced to gain independence from imported oil. Research data could not confirm this; as for the time of writing it was not relevant enough to concretely promote electro mobility. However, geopolitical events might change this in the far or near future, thus altering the factors model of this research. It is up to further research to identify additional factors that influence the introduction of commercial electro mobility.

Still, the model presented in this research offers scholars a concrete framework to further research the introduction of commercial electro mobility in concrete projects, and on larger scale. Factors and solutions identified in this research may help scholars to understand what inhibits and enables introduction projects of commercial electro mobility today - and in the future.
Reference


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## Appendix I: List of abbreviations

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<thead>
<tr>
<th>Abbreviation</th>
<th>Full definition</th>
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<tbody>
<tr>
<td>AB</td>
<td>Aktiebolag (Swedish abbreviation for legal business entity)</td>
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<tr>
<td>ACEA</td>
<td>European Automobile Manufacturers’ Association</td>
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<td>AQ</td>
<td>Air Quality</td>
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<tr>
<td>BEV</td>
<td>Battery Electric vehicle</td>
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<tr>
<td>CO$_2$</td>
<td>Carbon Dioxide</td>
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<tr>
<td>CROB</td>
<td>Coalitie Rijden op Biogas (Coalition for Motoring on Biogas)</td>
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<tr>
<td>DB</td>
<td>Deutsche Bahn</td>
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<tr>
<td>EC</td>
<td>European Committee</td>
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<td>EU</td>
<td>European Union</td>
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<td>EV</td>
<td>Electric Vehicle</td>
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<td>ETS</td>
<td>European Trading System of CO$_2$ permits</td>
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<tr>
<td>FCV</td>
<td>Fuel Cell Vehicle</td>
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<td>GHG</td>
<td>Green House Gas</td>
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<td>HC</td>
<td>Hydro Carbon</td>
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<td>IOC</td>
<td>International Olympic Committee</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>MAQM</td>
<td>Mobile Air Quality Measurement</td>
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<td>MIMAQ</td>
<td>Mobile Individual Measurements of Air Quality</td>
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<tr>
<td>MLP</td>
<td>Multi-Level perspective</td>
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<tr>
<td>NO$_x$</td>
<td>Nitrogen Oxide (x being number of O atoms)</td>
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<tr>
<td>SNM</td>
<td>Strategic Niche Management</td>
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<tr>
<td>PM</td>
<td>Particle Mass</td>
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<tr>
<td>RCI</td>
<td>Rotterdam Climate Initiative</td>
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<td>TCO</td>
<td>Total Cost of Ownership</td>
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<td>TFL</td>
<td>Transport for London</td>
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<td>TP</td>
<td>Tradable Permit</td>
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<tr>
<td>VOC</td>
<td>Volatile Organic Compounds</td>
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<tr>
<td>VTP</td>
<td>Vehicle Total Productivity</td>
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<tr>
<td>WTW</td>
<td>Well-to-wheel (type of analysis)</td>
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