Master Thesis

Critical success and fail factors of electric busses in public transport: A review on existing European electric bus projects

For the degree of Master of Science in Sustainable Energy Technology at Delft University of Technology

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EXECUTIVE SUMMARY

Present-day transportation pollutes, causing significant damage to the environment and human health. The European Union, together with national and local governmental bodies, is trying to mitigate the polluting effect of transportation. A widely-used measure is the promotion of public transportation. Parts of public transportation can be perceived as 'green' (e.g. electric mobility such as train, tram, and metro). However combustion engine busses are heavy polluters. Specifically in urban areas the greatest sources of NO_x-pollution is freight- and bus-transportation. The use of electric busses can be a solution to this polluting effect. According to reports of IPCC (2007) and TNO (2012) advantages of electric mobility are its energy efficiency, fortifying effect on the transition to sustainable energy technologies, less dependency on fossil fuels, less noise pollution, less emissions in general, and no local emissions (except for small particles from breaks and tires).

Governing bodies in large European cities are interested in implementation of electric busses. But why is this solution at present not being implemented at large scale? Technical feasibility has been met in several electric bus projects, however technical challenges for current electric bus innovators remain. First, the capacity of batteries is substandard. Second, novel charging techniques and the associated supercapacitors or Li-ion batteries of large-sized busses are not a proven technology yet. Political feasibility for the large-scale implementation of electric busses holds challenges as well. The financial characteristics of electric busses, with high purchase costs and high infrastructural investment costs, can be limiting factors for large scale implementation of electric bus projects.

As shown above, simplistic reasoning points out several factors that might influence the implementation of electric busses at large scale. In order to extrapolate a substantiated theory on current drivers and barriers of electric bus implementation in Europe, this thesis has tried to answer to the main research question:

What are major drivers and barriers to the successful adoption of electric busses in Europe?

In this study we define successful adoption as the actual use and continuous use of an electric bus in daily operation on an official public transportation bus route. The electric bus project must at least run for the anticipated period of operation.

In an attempt to identify these major drivers and barriers, eight case studies were analysed using an analytical conceptual framework. In order to increase the external validity of the research, a review on case study findings was performed with the help of a survey. Stakeholders from the European electric bus sector were asked about the drivers' and barriers' impact on the successful adoption of electric busses in Europe. Based on the findings from the case study analyses and survey, we can conclude on the main research questions.

The main driver for successful adoption of electric busses is the innovation's reduced environmental impact. Unlike conventional busses, electric busses do not produce local emissions. Moreover, electric bus operation leads to reduced noise pollution and a potential sustainable energy conversion process. Other major drivers that have slightly less impact on the decision to adopt, are the i.) improved public perception of the decision maker and/or potential adopting organization, as an anticipated result of the implementation of sustainable and innovative solutions; ii.) the innovation policy of the decision maker, meaning stimulation of innovations to enhance economic growth and/or human well-being;

and iii.) the presence of a visionary leader, meaning a powerful individual (e.g. a mayor) who imposes his or her ideas favoring electric bus implementation.

Five major barriers to successful adoption of electric busses can be distinguished. The two barriers that have the highest impact on successful electric bus adoption in Europe are: i.) the higher technical- and financial-risks that are associated with electric bus adoption, due to the high investment costs and the low degree of experience associated with electric busses in Europe; ii.) the perceived high life cycle costs of electric busses, mainly due to the battery purchase and replacement costs and the infrastructure investment costs. Other major barriers, that have slightly less impact on the decision to adopt, are i.) the low degree of compatibility of electric busses to conventional bus transportation systems, stemming from differences in the driving/refuelling (charging is considered to be a type of refuelling) ratio, the reduced action radius, and the disparity in financial modelling (as a result of increased investment costs and often lower operations costs); ii.) the low availability of information on the current technical- as well as financial- characteristics of electric busses, due to the fact that most information on electric busses is confined to information provided by bus suppliers; and iii.) the possible low degree of competition between public bus operators results in risk-averse management with often a low degree of innovation adoption. The overall limiting factor of electric bus adoption is the energy storage system (i.e. battery) in terms of life-time uncertainty, costs, and energy- and power-density. Causing, obstacles such as high risks, high investment costs, and low compatibility.

Research contributions

This thesis contributes to existing work in the field of innovation- and adoption-literature, by the adaption of an analytical conceptual model to ensure incorporation of the characteristics of the public transportation sector.

This thesis contributes to existing literature on electric public transportation busses, by providing an in-depth overview of the current electric bus market. First, an overview of the current electric bus projects in Europe was presented. Second, eight unique case study analyses of electric bus projects in Europe were elaborated upon. Third, the impact of several drivers and barriers on the implementation of electric bus projects was measured, based on a survey answered by stakeholders from the European electric bus sector. Fourth, the major drivers and barriers to the implementation of electric bus projects in Europe were identified. Overall, this study provides an unique socio-political analyses of the current status of electric bus projects in Europe.

It is evident that society will benefit from zero-emission vehicle operations by significantly reducing the damage to the environment and human health caused by transportation. Adoption of electric vehicles is one of the roadmaps to a zero-emission transportation system. This thesis provides an overview and a discussion on the current condition of electric bus implementation in Europe. Based on this information, private as well as public organizations that aim to lower emissions in the transport sector can construct or modify their strategy favouring the introduction of zero-emission vehicles.

This thesis contributes to the field of innovation policy by providing a unique review on the adoption of a particular innovation (i.e. the full electric bus) on a firm-level. Future potential adoption of innovations in the public transportation sector could benefit from the lessons learned from the introduction of electric public transportation busses. In this research, the involvement of the political establishment gave insights in the significance of political feasibility in the decision process on innovation adoption in the public transportation market. In particular the environmental benefits, public perception, innovation stimulation, and economics, directly or indirectly influence this decision. The significance of the technical feasibility of an innovation, more specifically the technical-reliability and –risks, is demonstrated in its perceived high impact on the adoption-decision. The identified drivers and barriers to radical innovation adoption in the public transportation market can be respectively utilized and mitigated by policymakers that pursue an enhancement of social awareness, the creation of economies of scale, and the development and distribution of knowledge. Therefore enhancing the political- and technical-feasibility of the innovation adoption, thus improving the successfulness of innovation adoption.

Recommendations

In correspondence to this research, multiple recommendations can be made for stakeholders in the electric bus sector:

1. Customize the complete operation system of an electric bus (i.e. the bus technique, the operation/charging schedule, the driving plan, and the infrastructure) in order to effectively make use of the battery and charging technique.
2. Enhance the battery technology in order to increase the flexibility and decrease the costs of the electric bus.
3. Educate stakeholders (e.g. by enlarging knowledge platforms, tests and demonstrations) and develop additional knowledge (e.g. on battery lifetime and life cycle costs) in order to mitigate the low availability in information on electric bus implementation.
4. Liberalize the European public transportation sector in order to cope with the low degree of competitiveness in several public transportation systems throughout Europe, thus enhancing the stakeholders' innovation adoption (e.g. of electric busses). Note that possible unwanted secondary effects of this policy should be studied before incorporating this measure.

During the course of this study several uncertainties were not eliminated. Therefore recommendations for future research are provided underneath:

1. Research the current economic viability of electric busses in order to cope with the lack of objective information sources on this matter.
2. Research the existence and influence of outreach programs and subsidy schemes regarding European electric bus projects, so that they can be aligned to work effectively to stimulate the development of the electric bus market.
3. Research the professional opinion of a representative sample of the complete European electric bus market on the impact of the identified drivers and barriers on the implementation of electric busses in Europe. Therefore providing contributing insights in the possibly exploitation of drivers and mitigation of barriers, thus positively impacting the adoption of electric busses in Europe.

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1 PROBLEM STATEMENT

Transportation has always been a global phenomenon with an important impact on economy, society, and environment. Freedom to travel has boosted economic growth, job creation, and has enabled quality of life (European Commission, 2011).

But present-day transportation also pollutes, causing significant damage to the environment and human health. According to U.S.-based research, transport emissions account for a high percentage of emissions regarding a number of pollutants (Davis et al., 2013). Moreover, the health impact per emitted quantity is higher for transport emissions than average emissions. The distance between transportation vehicles and those exposed is much shorter than that for many other polluting sources, such as power plants (Van Wee et al., 2012). Evidently, emissions are the largest contributor to the external costs of road transport due to air pollution and climate change (CE Delft et al., 2011).

The European Union, together with national and local governmental bodies, is trying to mitigate the polluting effect of transportation (European Commission, 2011). A widely-used measure is the promotion of public transportation. Parts of public transportation can be perceived as 'green' (e.g. electric mobility such as train, tram, and metro), but combustion engine busses are still heavily polluting. Specifically in urban areas the greatest sources of NO_x-pollution is caused by freight- and bus-transportation (TNO, 2012). The use of electric busses can be a solution to this polluting effect. Advantages of electric mobility are its energy efficiency, fortifying effect on the transition to sustainable energy technologies, less dependency on fossil fuels, less noise pollution, less emissions in general, and no local emissions (except for small particles from breaks and tires) (IPCC, 2007; TNO, 2012).

Governing bodies in large European cities are interested in implementation of electric busses. But why is this solution at present not being implemented at large scale? According to "The Political Economy of Transport Innovations" (Feitelson & Salomon, 2004) two fundamental requirements are inherent for large-scale implementation of transport innovations: technical feasibility and political feasibility.

Technical feasibility has been met in several electric bus projects, though TNO (2012) points out technical challenges for current electric bus innovators remain. First of all, the capacity of batteries is substandard; free moving electric busses which are charged once a day, require heavy battery packages. In order to use lighter battery packages, small- to mid-sized electric busses are put into service or multiple charges a day of large-sized busses are necessary. The past few years large-sized (≥ 12 meter in length) electric busses, charged once per day were introduced. Although it is uncertain these vehicles can live up to their expected specifications. A second challenge is that novel charging technologies (e.g. fast charging using trolley grids, dynamic induction charging, static induction charging) and the associated supercapacitors or Li-ion batteries of large-sized busses are not proven technologies yet (TNO, 2012).

Political feasibility for the large-scale implementation of electric busses holds challenges as well. Social and economic feasibility are factors that determine political acceptability. An innovation must effectively address an urgent problem in order to mark it as socially feasible (Feitelson & Salomon, 2004). In this case, there exists an urgent problem of emissions that negatively affect the environment and human health. The use of zero-emission vehicles in order to mitigate this problem is widely perceived as an effective solution. Thus the implementation of this innovation can be seen as socially feasible. But is this enough to implement electric busses on a local level?

In addition, economic feasibility determines political feasibility, and therefore the decision to adopt electric busses. The economic character of electric busses characterizes itself with relatively high purchase costs, high infrastructural investment costs and low fuel costs. Although, from a distributional perspective public transportation is mostly viewed as favourable (Feitelson & Salomon, 2004), the high purchase costs and high infrastructural investment costs weighs heavily in the cost-benefit analysis of electric bus adoption[1]. These financial characteristics are limiting factors for large scale implementation of electric bus projects.

As shown above, simplistic reasoning points out several factors that might influence the implementation of electric busses at large scale. Current literature does not provide information on the current status of electric bus adoption in Europe. TNO (2012) as well as Nylund & Koponen (2012) and Tozzi et al. (2014) do contribute with overviews of the current status of a wide range of sustainable energy solutions for public transportation busses (e.g. propulsion technologies such as compressed natural gas combustion, hydrogen fuel cells, hybrid electric, and full electric), but their elaboration on full electric busses is very concise. According to Lajunen (2014), current electric bus literature has a strong focus on hybrid electric busses (Bubna et al., 2010; Bubna et al., 2012; Croft McKenzie & Durango-Cohen, 2012; Glotz-Richter, 2014) and has somewhat neglected full electric bus applications. Recent literature that sufficiently elaborate on full electric bus are Mantovani et al. (2008), Almeida et al. (2009), Sala & Meyer (2009), Santos et al. (2009), Miller (2010) and Lajunen (2014), all focussing on the current or recent techno-economical features of electric busses, such as the energy storage– and power train system. Though, substantiated theory on current drivers and barriers of full electric bus projects in Europe is not available. Therefore, an in-depth analysis on the status of current European electric bus market ought to be done.

This research might facilitate not only academia, but future decision makers regarding the use of zero-emission busses in Europe as well. It is evident that society will benefit from zero-emission vehicle operations by significantly reducing the damage to the environment and human health caused by transportation. Adoption of electric vehicles is one of the roadmaps to a zero-emission transportation system. This thesis provides an overview and a discussion on the current condition of electric bus implementation in Europe. Based on this information, private as well as public organizations can construct or modify their strategy favouring the introduction of zero-emission vehicles.

This thesis tries to elaborate on the question why electric busses are not being adopted at large scale. Successful adoption is defined as the actual use (and continuous use) of the innovation (Nabih et al., 1997). In this study we define successful adoption more specifically as the actual use of an electric bus in daily operation on an official public transportation bus route. The electric bus project must at least run for the anticipated period of operation. Several dimensions can positively increase the 'successfulness' of a project, such as:

1. Operational status. This is a broad dimension directed at the quality and the sustainability (continuous) use of the innovation. The operational status touches upon sub-dimensions such as the travel comfort, charging/driving-time ratio, maintenance time, energy efficiency, etc.

[1] I consider financial cost as an essential factor in the cost-befit distribution in this case. In most European countries public budgets are being cut, that is why investing in alternative technologies, as well as reducing fossil fuel costs in transportation is a heavily discussed subject in politics.

2. Technical status: This dimension is related to the 'operational status' of the project and entails the reliability of the technical components of the bus. Technical failures or necessary technical changes (in order to operate the electric busses accordingly) negatively influence the successfulness of a project.
3. Financial status: Unmistakably a healthy financial situation of a project increases its successfulness. Excessive, unanticipated losses can have an exponential negative impact on the way the complete project is valued. These losses can even lead to a strong negative effect on the longevity of the projects' shareholder(s) activities.

Other dimensions that speak for themselves and that evidently influence the successfulness of a project are: the public perception, the project lifetime, the realization of a project expansion and the realization of a succeeding project. The values of the various dimensions and their impact on the project's successfulness, are dependent on the projects' expectations and the corresponding dimensions of alternative propulsion technologies (e.g. internal combustion engine or fuel cells).

On the contrary, a 'failed' project would be defined as a project in which the decision was made to adopt an electric bus for an anticipated period of time by the project initiator (in this case the local government or the bus operator), but in which the decision was made to terminate the project before the project could be defined as 'successful'. This brings us back to our question why electric busses have not been adopted at large scale and what factors result in the emergence or obstruction of successful electric bus projects. The main research question of this thesis is:

What are major drivers and barriers to the successful adoption of electric busses in Europe?

In order to formulate and explore the critical factors of electric bus projects, the following sub-questions are answered:

1. *What current electric bus projects can be found across Europe?*
2. *Which major drivers and barriers to the successful adoption of electric busses can be derived from a selection of electric bus projects in Europe ?*
3. *Which major drivers and barriers to the successful adoption of electric busses in Europe can be derived from a review by stakeholders from the electric bus sector in Europe ?*

To address these questions we will first set out an approach based on a theoretical basis. In section 2 the theoretical framework is proposed based on an extensive literature study. The literature may provide readers a comprehensive insight in different innovation- as well as adoption-models. It can put the proposed theoretical framework in perspective to current literature. Subsequently the theoretical framework is developed to a useful framework for the analysis of the major drivers and barriers to the successful adoption of electric busses. Section 3 describes the operationalization of the framework by explaining how the different variables are measured. The methodology employed to identify and explore the critical factors of electric bus projects in Europe is presented in section 4. Section 5 answers the first sub-question by providing an overview of the electric bus projects in Europe. The case study selection and cross-case analysis is also conducted in this section. Section 5 ends with the identification of the major drivers and barriers to the successful implementation of electric busses in Europe based on the case study analysis; answering the second sub-question. Section 6 will assess the identified major drivers and barriers in section 5, considering the professional opinion of a sample of stakeholders from the European electric bus sector. Section 7 concludes the research findings with regard to the research- and sub-questions. Subsequently this section reflects upon this study and presents recommendations to stakeholders of the electric bus market and to future researchers.

2 THEORETICAL FRAMEWORK

This section elaborates on the proposed theoretical framework on which this study is built upon. And concludes with the research framework that is utilized for this thesis.

For this thesis we are considering a model which can help us answer our research question and which can be applied on case studies of electric bus innovations in the public transportation sector. The criteria for the proposed theoretical framework are drawn up in Table 1. After an extensive literature study, the model that sufficiently suits the criteria is proposed and by any means adjusted to fit the objectives of this research.

Table 1. Theoretical framework criteria

Criterion	Reasoning
Drawn on innovation- and adoption-theory.	The framework should at least hold an academic basis in order to make a significant contribution to academic literature. It would enhance the validity of the study when the framework is drawn on empirical evidence. Considering that our study is about investigating the implementation of a new technology[2], we come across innovation theories, and more specifically transition- and adoption- theories of technological innovations. These theories try to explain the why and how a certain innovation is being implemented or not.
Analytical conceptual model	Literature distinguishes conceptual and mathematical adoption models. Conceptual models identify the pro/con-variables. Mathematical models solely use empirical data in order to forecast (Bontekoning, 2002). We want to structurally analyse the major drivers and barriers (for the successful adoption of electric busses in Europe) and we want to examine current (international electric bus) projects. Therefore we will use an analytical conceptual model.
Taking into account the main characteristics of the public transportation sector and its main actors	The environment in which the innovation might be adopted is the public transportation sector. As discusses in section 1 of this thesis, the public transportation sector holds distinctive features: First of all, the potential adoption happens on a firm or governmental level; not on an individual level. Second, the main actors are the local government and the service provider[3] (in our case the bus operator), and the transportation vehicle- or infrastructure-supplier. Third, technical- and political-feasibility are requisites in order to make changes to a public transportation system (Feitelson & Salomon, 2004).

[2] In the next subchapter we elaborate on why electric busses are considered to be an innovation.
[3] The service provider can also be a governmental body.

2.1 Is an electric bus considered to be an innovation?

Literature distinguishes two schools of innovation theory that each have their own definition of innovation and diffusion. The influential school of Rogers (1995) defines innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". In this sense, diffusion is seen as a separate process which is determined by communication and persuasion. In contrast, the school of Schumpeter, Barnett, and others declare innovation is the first step of the larger process of diffusion. Barnett (1953) states that "When an innovation takes place, there is an intimate linkage or fusion of two or more elements that not have been previously joined in just this fashion, so that the result is a qualitatively distinct whole" (EPAT, 1999).

In this study we define a 'bus' as an autonomous public transportation road vehicle driving along a fixed route. The vehicle must have a minimum length of five metres. An 'electric bus' uses solely on-board battery- or supercapacitor-stored electricity to drive. An electric bus is considered as an innovation because it is perceived as new by potential adoption units. A medium-sized battery as well as a supercapacitor, linked to a bus has not been joined together in just this fashion before the 2000s [4]. Due to novel energy storage possibilities, it has been possible to store enough electric energy in a medium-sized battery to drive large vehicles (Vana, 2006).

Two bus types that cannot be considered to be as 'new', thus are not considered to be innovations, are the trolley bus and the internal combustion engine (ICE) bus. The trolley bus as well as the widely-used ICE bus are existing technologies and have been around since the 19th century (Vana,2006; Eckerman, 2001). Since trolley busses are continuously supplied of electricity by overhead wires they require vast infrastructural investments and lack the flexibility that is often required for busses in urban environments.

2.2 Selected frameworks based on innovation literature

Appendi shows an extensive literature study on innovation- and adoption-theories. Based on this study, several frameworks based on innovation theory are proposed underneath. We will use this list of frameworks as a starting point for the selection of an useful framework to analyse the major drivers and barriers to the adoption of electric busses. Subsequently we will evaluate each framework using the selection criteria as stated in the beginning of this section.

2.2.1 Chain-linked model by Kline (1986)

The chain-linked model by Kline (1986), as shown in Figure 1, represents an early conceptual model of the more general systems theory of innovation. It shows that development of innovations is not linear, but holds feedback loops. The model combines two types of interaction within the visualized system. First, the interaction within the firm or network of firms itself (as shown in the lower part of the figure). And second, the interaction between the firm or network of firms and the wider technology and science system (as shown in the upper part of the figure). The system as described by the chain-linked model can be seen a narrow definition considering the inclusion of political, social, economic, and cultural characteristics in later system definitions (Leger & Swaminathan, 2007; ICEPT, 2012).

[4] With the exception of the city of Rome, which has had small-sized electric busses in use since 1989. Section 6 elaborates on this particular project.

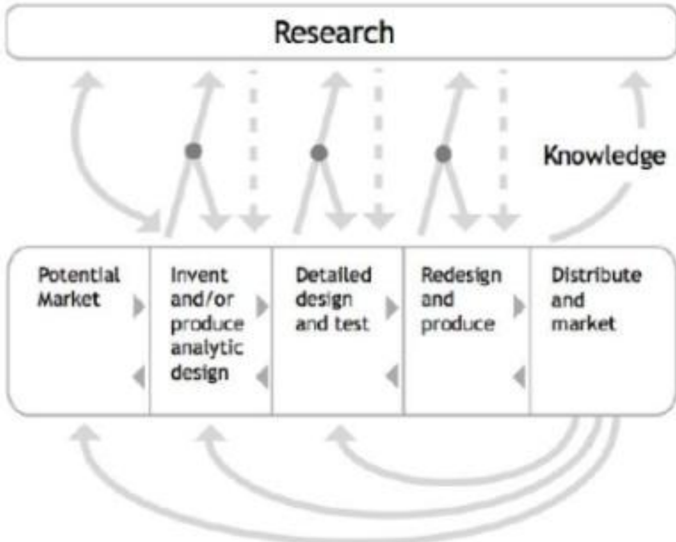

Figure 1. The chain-linked model (Kline, 1986, from ICEPT, 2012)

2.2.2 Innovation System Frame on innovation theory (OECD, 2005)

As shown in Figure 2, the conceptual Innovation System Frame marks four main domains of the innovation capacity of an economy; framework condition, science and engineering base, transfer factors, and innovation dynamo. The innovation dynamo represents the dynamic factors that determine the innovativeness of a firm or entrepreneur. Placing the innovation dynamo in the middle of the frame, shows the reliance of an economy on firms and/or entrepreneurs in order to have a certain degree of innovation capacity (OECD, 2005; ICEPT, 2012).

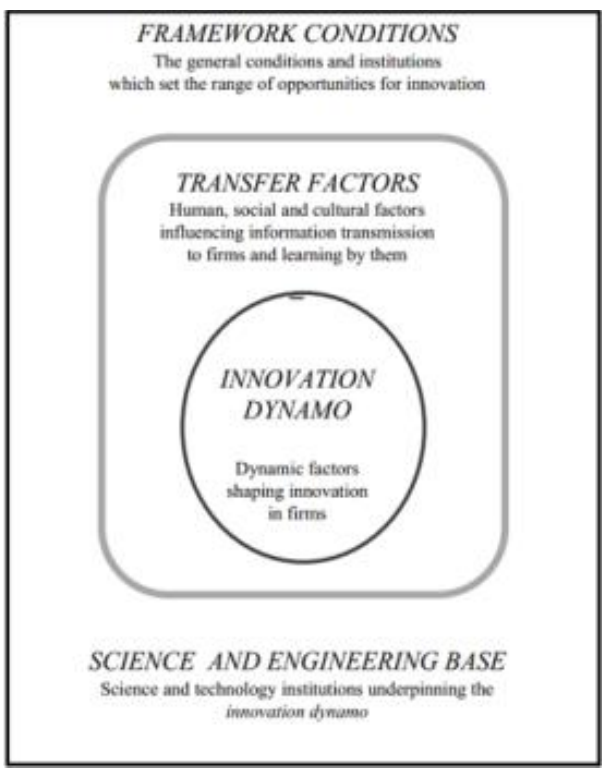

Figure 2. The Innovation System Frame (OECD, 2005)

2.2.3 National Innovation Systems

The National Innovation Systems adds a fundament to innovation literature by focusing on the interactions between all actors within the system. The conceptual approach holds the notion that public and private sectors at the national level result in key institutional drivers (in science and engineering) for the development of innovations. Building upon this theory comes forward a generic model of innovation as shown in Figure 3. It represents several innovative entity clusters that interact with each other under certain framework conditions. Three different interactions between the entities are defined: i.) competition, ii.) transaction, or iii.) knowledge transfer or networking (Speirs et al., 2008).

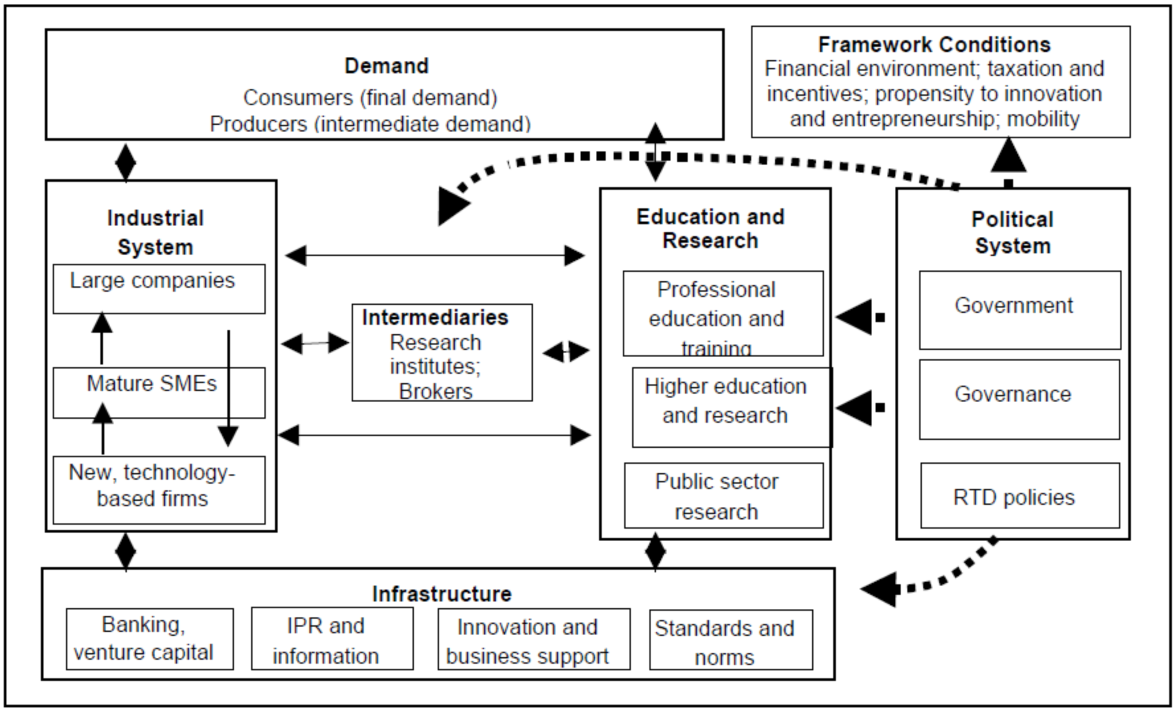

Figure 3. National Innovation System generic model (Arnold & Kulman, 2001; from Speirs et al., 2008)

2.2.4 Technological Innovation Systems (TIS)

The research of technological innovation systems (TIS), also known as the functions of innovation systems (FIS), emphasis on the fundamental processes in successful innovation system. According to Speirs et al. (2008) the approach is considered to be a form of history event analysis. The success of an innovation system is determined by analysing seven important innovation processes defined as 'functions of the innovation system'; 'entrepreneurial activities', 'knowledge development', 'knowledge diffusion', 'guidance of the search', 'market formation', 'resource mobilization', and 'creation of legitimacy'. At the moment of emergence of an innovation often a limited amount of functions pull the other systems functions. Such mobilizing patterns are called the motors of change and are the drivers behind the early phases of innovation development (Hekkert et al., 2007; Kamp & Quist, 2012). TIS theory perceives government policy as essential to aid the creation and development of the functions. At the same time, established technologies and actors can block the advancement of such functions (especially) in the early stages of innovation development (ICEPT, 2012). Compared to the national innovation systems approach, TIS theory usually analysis a smaller system of agents, networks, and institutions. Generally an early innovation only needs a limited amount of institutions and agents aligned in order to emerge successfully. The decreased complexity in the analysis results in a better understanding of the most important dynamics in an innovation system (Hekkert & Negrom 2009).

2.2.5 Innovation Diffusion Theory

IDT, also known as 'diffusion of innovation' theory, comes forward out of the school of Rogers (1995) which sees diffusion as the process in which an innovation is communicated through channels, over time, and among social actors. The IDT at organization level distinguishes three contexts that influence the organizational innovativeness, which is directly related to the organizational adoption process: i.) *individual characteristics*, meaning the leadership style considering change; ii.) *internal characteristics of organizational structure*, whereby the characteristics are defined as "centralization is the degree to which power and control in a system are concentrated in the hands of a relatively few individuals"; "complexity is the degree to which an organization's members possess a relatively high level of knowledge and expertise"; "formalization is the degree to which an organization emphasizes its members' following rules and procedures"; "interconnectedness is the degree to which the units in a social system are linked by interpersonal networks"; "organizational slack is the degree to which uncommitted resources are available to an organization"; "size is the number of employees of the organization"; and iii.) *external characteristics of organizational structure*, which emphasising on the openness of the system (Rogers, 1995; Oliveira & Martins, 2011). Figure 4 gives an schematic overview of the model.

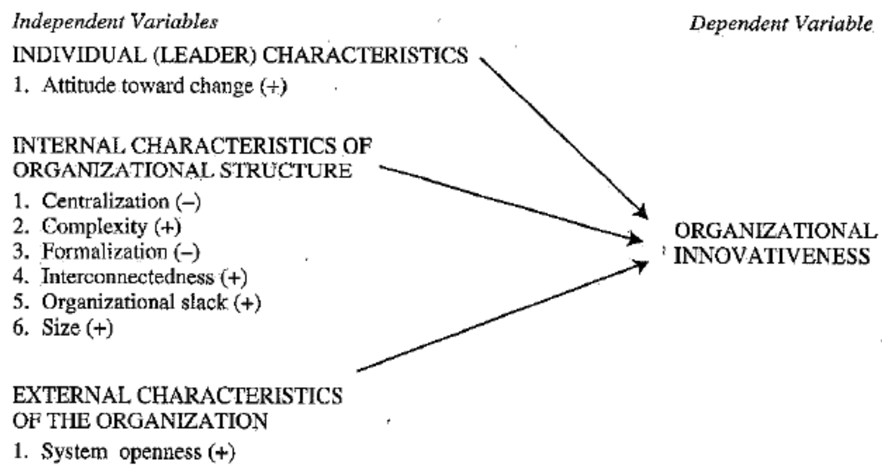

Figure 4. Independent variables related to organizational innovativeness (Rogers, 1995)

2.2.6 Technology, Organization, and Environment Framework

The TOE framework represents how the context of an enterprise effects the adoption process of technical innovations. The TOE framework is similar to the IDT model of Rogers (1995), but also elaborates on the environmental context of an organization. According to Hsu et al. (2006, from Oliveira & Martins, 2011), TOE would better explain innovation diffusion between organizations. As shown in Figure 5 the model divides an enterprise into three elements: i.) *technological context*; international and external technologies relevant to the enterprise, ii.) *organizational context*; organizational characteristics such as size, scope, and hierarchy, and iii.) *environmental*; the surroundings in which the enterprise performs such as relevant external actors, infrastructure and policies (Tornatzky & Fleischer, 1990, from Oliveira & Martins, 2011).

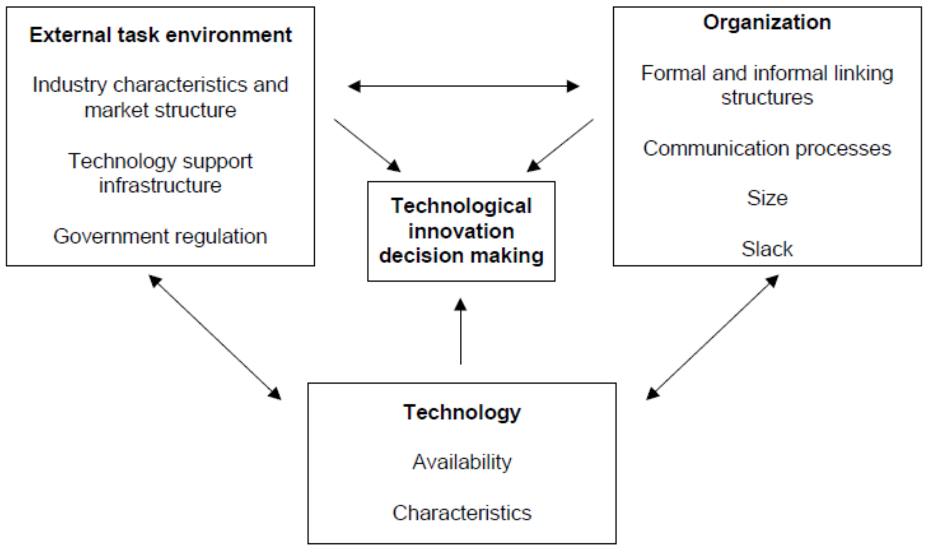

Figure 5. Technology, organization, and environment framework (Tornatzky & Fleischer, 1990, from Oliveira & Martins, 2011)

2.2.7 Conceptual adoption models of Frambach (1991), NEA and KNV/BCT (1998), and Bontekoning (2002)

The conceptual adoption model of Bontekoning (2002) is based on adoption on the firm level in the transport sector. It focusses on specific explaining variables which can stimulate or block successful adoption. The conceptual model was specifically used for the identification of barriers to the implementation of an innovative terminal operations in the terminal sector (Bontekoning, 2002).

It was inspired by the previously discussed innovation model of Rogers (1995) and extended and adjusted by the use of literature from NEA and KNV/BCT (1998), Frambach (1991), and Moon & Bretschneider (1997). NEA and KNV/BCT (1998) specified the model of Rogers (1995) so that it can directly be applied on the transport sector. Though Bontekoning criticizes NEA and KNV/BCT (1998) on its unilateral use of taking the perspective of the government, and ignoring the supply side of the innovation. Bontekoning (2002) believes "that a market driven diffusion process is much more effective and efficient. For this reason we prefer to follow the perspective of suppliers, while acknowledging at the same time that we should incorporate the role of the government". Frambach (1991) produced a conceptual adoption model based on Rogers (1995) by adding the supply-side perspective. Bontekoning (2002) thinks "that this is an important adjustment to the Rogers model, because it provides valuable new insights that suppliers of new-generation terminals themselves could use to further promote their innovation". Moon & Bretschneider (1997) elaborated on the role the government plays "both as a sponsor and as a diffuser" (Bontekoning, 2002) in the diffusion process, which is fundamental for the transport sector in particular (Feitelson & Salomon, 2004).

Bontekoning (2002) identified variables that can positive and negative influence the adoption of a novelty in the transportation sector. Each variable can be measured (qualitative and/or quantitative) in order to conclude on the existence of several obstacles hindering the adoption of the innovation. They can be classified in six main groups: i.) 'Perceived characteristics of the innovation', ii.) 'Characteristics of the potential adopting organization', iii.) 'Characteristics of the communication process, the information that is communicated, and the social system', iv.) 'Characteristics of the competitors of the potential adopting organization', v.) 'Characteristics of the innovator/supplier, vi.) 'The role of the government'. The explaining variables can have a strongly positive (++), normal positive (+), neutral (+/-), negative (-), or strongly negative (--) effect on the implementation process of an innovation. The values of each variable are based on qualitative and/or quantitative measurement. Figure 6 shows a schematic overview of the model of Bontekoning (2002).

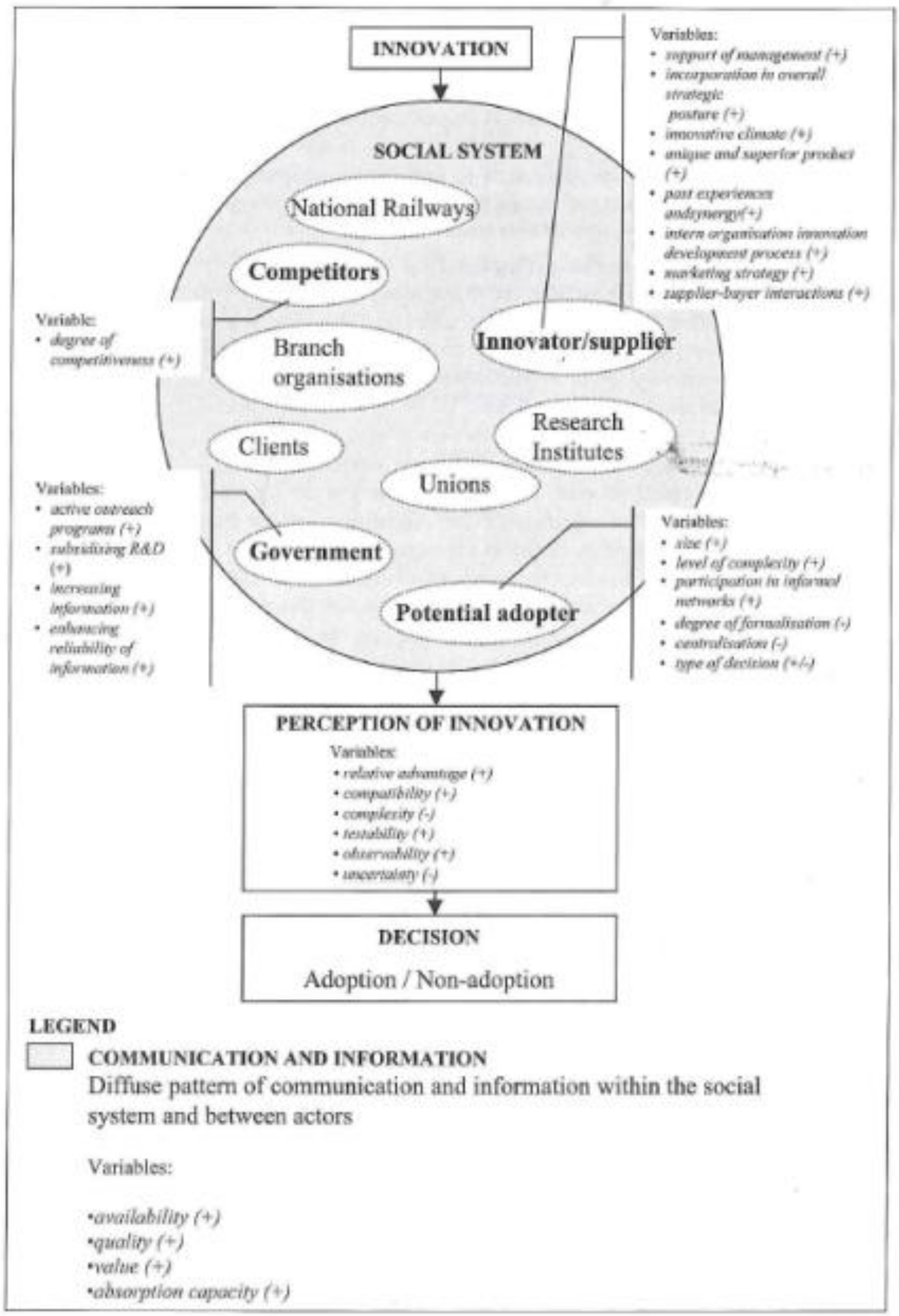

Figure 6. Adoption model in the transportation sector (Bontekoning, 2002)

2.3 Evaluation of the theoretical frameworks

In this subchapter we fall back on our, earlier-described, considerations for the research framework for this thesis. Table 2 shows the theories treated in the previous subchapters that correspond to the criteria of the research framework.

Table 2. Theories matching the criteria for the proposed research model

Criterion	Theory
Drawn on innovation- and adoption-theory.	○ Chain-linked model by Kline (1986) ○ Innovation System Frame (ISF) (OECD, 2005) ○ National Innovation Systems (NIS) ○ Technological Innovation Systems (TIS) ○ Innovation diffusion theory (IDT) (Rogers, 1995) ○ Technology, Organization, and Environment Framework (TOE) ○ Model of Frambach (1991) ○ Model of NEA and KNV/BCT (1998) ○ Model of Bontekoning (2002) *Note: The Chain-linked model, the ISF, the NIS, and the TIS are merely drawn on innovation-theory.*
Analytical conceptual model.	○ Chain-linked model by Kline (1986) ○ Innovation System Frame (OECD, 2005) ○ National Innovation Systems (NIS) ○ Technological Innovation Systems (TIS) ○ Innovation diffusion theory (IDT) (Rogers, 1995) ○ Technology, Organization, and Environment Framework (TOE) ○ Model of Frambach (1991) ○ Model of NEA and KNV/BCT (1998) ○ Model of Bontekoning (2002)
Taking into account the main characteristics of the public transportation sector and its main actors.	○ Model of NEA and KNV/BCT (1998)[5] ○ Model of Bontekoning (2002)

Based on Table 2 we conclude that the models of NEA and KNV/BCT (1998) and Bontekoning (2002) are the closest matches to our criteria. Other models do not take into account the main characteristics of the public transportation sector and its main actors. NEA and KNV/BCT (1998), as well as Bontekoning (2002), focusses on adoption on a firm and governmental level. Also, both theories incorporate the main actors of the public transportati00on sector. Except for the theory of NEA and KNV/BCT (1998), which does not incorporate the characteristics of the adopting organization (i.e. the public transportation service provider or the government). Finally, both theories do not incorporate the 'political feasibility'-aspect of the public transportation sector, which is a requisite to make changes to a public transportation system. In conclusion, we will utilize the conceptual adoption model of Bontekoning (2002) as the foundation of our research framework, because it is the closest match to our criteria.

[5] The model of NEA and KNV/BCT (1998) does not incorporate the characteristics of the adopting organization (i.e. the public transportation service provider or the government).

2.4 Additions and adjustments to the conceptual model of Bontekoning (2002)

Although Bontekoning (2002) focused on the adoption of innovations in the transport sector, the models still holds some imperfections. The criticism and their related implemented model additions and adjustments, are reflected upon in this chapter.

According to "The Political Economy of Transport Innovations" (Feitelson & Salomon, 2004) the adoption or rejection of a technology is the transportation sector is subject to the decision of a particular type organization: the policymaker. The model of Bontekoning (2002) does not take this particular actor into account, therefore the model is modified in order to include a representative local government as possible innovation adopter. In the research of Bontekoning (2002) the potential adopting organizations are terminal operators, which are privately held companies for the most part. For our research we will investigate privately held organizations (bus operators)and publically held organizations (local governments and bus operators). As mentioned before, adoption is defined as the actual use (and continuous use) of a physical innovation (Nabih et al., 1997). In the case of electric bus projects in public transportation, the local government as well as the bus operator make use of the bus (in a direct or indirect manner). But the party that actually decides to adopt the innovation is defined as the potential adopting organization. Whether this means the local government or the bus operator, or both parties, are defined as potential adopting organization is case specific. In some cases, it is not so strait forward which party decides to adopt an innovation (e.g. an electric bus). The adoption of specific busses for public transportation can be the result of an interaction between both parties. For instance in a tender procedure. In this case, the local government tenders a concession to operate public transportation bus lines with certain conditions (e.g. a certain amount of electric busses). Second, each bus operator that is interested in operating the bus lines submits an offer (e.g. a certain amount of electric busses for a specific price). And finally, the local government grants the concession to the bus operator that has submitted the most favourable bid after a cost-benefit analysis. The local government can be seen as a potential adopting organization because it sets the conditions and requirements for the bus operating system. The bus operator can be seen as a potential adopting organization because it can influence the final decision of the local government by offering a specific bid. For example a bus operator can receive a concession without complying with certain predetermined conditions (e.g. a certain amount of electric busses), by submitting an offer which includes the lowest cost.

The local government as an potential adopting organization results in several significant change in the model of Bontekoning (2002). Firstly, the explaining variable of 'political feasibility' will be added to the 'Perceived characteristics of the innovation'. Different than privately held organization, local governments are subject to representative democracy. Therefore, the influence of politics on the adoption process and outcome, needs to be taken into account. Based on research of Feitelson & Salomon (2004) three characteristics of electorates can affect the political feasibility: i.) the perceived problems by the electorates that ought to be (partially) solved by the adoption of the innovation. The problems do not have to affect the individual voter directly, but can also be concerns that are seen as socially problematic. An increased perception of the salience of the problems positively influences the political feasibility of the innovation, and thus positively affects the process to adopt; ii.) the perceived effectiveness of the innovation by the electorates, meaning the perceived success of an innovation to address the problems at large. An increased perceived effectiveness of the innovation positively influences the political feasibility of the innovation; iii.) the perceived distribution of benefits and costs by the electorates, meaning the consideration by the public to what extent the costs are justified with respect to addressing an urgent problem and meeting the public good

Secondly, the explaining variables 'degree of formalization and 'degree of centralization' are deleted from the model. According to different studies these variables do not significantly attribute to the adoption of innovations (Koch & Morse, 1977; Hameed et al., 2012). As there exists a conflict here with literature from Rogers (1995), we will remove these variables from the model in order to remove its impact on the research.

Additional adjustments to the existing model of Bontekoning (2002) are made to the actor groups within the social system. 'Interest groups' are added to the social system, due to their relatively large influence on policy makers (Feitelson & Salomon, 2004). Secondly, 'The role of the government" is changed into "The role of the (inter)national government', so that this variable is not to confound with the local government which is perceived as one of the potential adopters of the innovation in this case. Thirdly, the explaining variable 'complexity' is changed in 'complicatedness', due to the misuse of the concept of 'complexity'. The explaining variable 'absorption capacity' of the social system is transformed to a specific characteristic of the potential adopting organization, in order to reify the indicator. And finally, 'subsidising R&D' is changed in 'subsidising schemes' in order to incorporate all subsidises directly promoting adoption of electric busses in Europe.

2.5 The adjusted model of Bontekoning (2002)

In accordance with the model of Bontekoning (2002), the adjusted model entails the process to decision-making on adoption or non-adoption of an innovation (in this case an electric bus) by a potential adopter (in this case a local government and/or a bus operator). The potential adopting organization's decision process is influenced by the explaining variables used in the adjusted model of Bontekoning (2002). Figure 7 shows a schematic overview of the explaining variables and their relationships. The decision to (non-)adoption is made based on the potential adopter's *perception of the innovation*, which is determined by the *characteristics of the potential adopter* and the *information* that is gathered from the social system through different communication channels. Actors within the *social system* that influence the gathered information through their relationship with the potential adopter are *innovators/suppliers*, the *government* (in this case national and international governmental agencies), *competitors*, research institutes, consultants, branch organizations, opinion leaders, and interest groups.

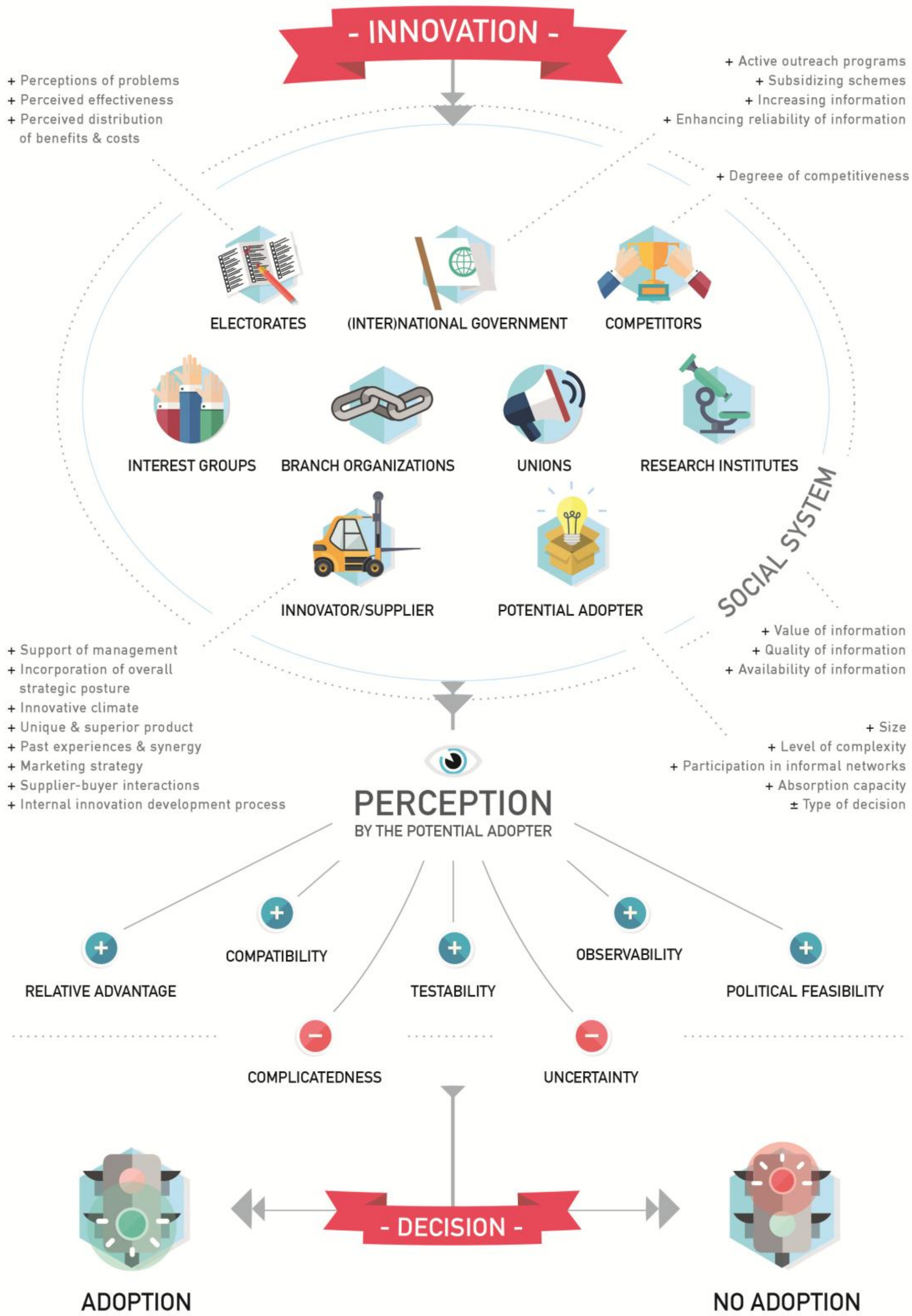

Figure 7. Adjusted adoption model in the transport sector based on Bontekoning (2002).

2.5.1 Perceived characteristics of the innovation by the adopting organization

The extent and speed of adoption are directly influenced by the potential adopter's perception of the innovation. Based on Bontekoning (2002) the description of these factors is as follows: i.) *relative advantage*, meaning the degree to which the innovation is perceived as being better than the current technology prior to the decision to adopt the innovation, often expressed in social status or economic profitability; ii.) *compatibility*, meaning the degree to which an innovation is perceived to meet the current values, demands/needs, and past experiences of the potential adopter.; iii.) *complicatedness*, meaning the degree to which an innovation is perceived to be complicated to understand and to use; iv.) *testability*, meaning the degree to which an innovation may be experimented with on a limited trial basis; v.) *observability*, meaning the degree to which the results of an innovation are visible to others (specifically important in our case considering political feasibility); vi.) *political feasibility*, meaning the degree to which the adoption of the innovation is socially supported and economically feasible (Feitelson & Salomon, 2004); vii.) *uncertainty*, meaning the degree to which an innovation is perceived to have a high chance of (partly) failing, due to the fact that expected advantages are not realistic or additional efforts need to be made to make the innovation function. The factors relative advantage, compatibility, testability, observability, and political feasibility positively influence adoption. The factors complicatedness and uncertainty negatively influence adoption (Bontekoning, 2002).

2.5.2 Characteristics of the potential adopting organization

The decision to adopt is partly influenced by the characteristics of the potential adopter. The distinguished characteristics of an organization according to Bontekoning (2002) are: i.) *size*, based on total resources, slack resources, and organizational structure; ii.) *level of complexity* of an organization, based on the number of specialists and their professionalism, which positively increases the organization's knowledge of an innovation and thus decreases uncertainty; iii.) *degree of specialization*, meaning the degree of division in labour, which also positively increases the organization's knowledge of an innovation; iv.) *interconnectedness,* meaning the informal networking of organization-members, which also positively increases the organization's knowledge of an innovation; v.) *absorption capacity*, meaning the capability of an organization to judge and process information. The *size* and *degree of specialization* of an organization is highly determinant for this characteristic, because a larger size creates more prospects for processing information; vi.) *type of innovation decision*, which can be one of the four decision types distinguished by Rogers (1995): Optional (meaning one individual independently makes the decision), Collective (meaning a group makes the decision), Authoritarian (meaning a small group based on position, expertise, or status makes the decision), and Contingent (meaning one individual makes the decision, which has to be approved by another body). A smaller amount of people involved in the decision process, positively influences adoption. Other characteristics of the potential adopting organization such as size, level of complexity, degree of specialization, interconnectedness, and absorption capacity also positively influence adoption (Bontekoning, 2002).

2.5.3 Characteristics of the communication process, the information that is communicated, and the social system

As stated above, the decision to adopt is partly influenced by the information that is gathered from the social system through different communication channels. Related characteristics can be subdivided into 'what' is being communicated, 'how' this is information is communicated, and 'by whom' is this being communicated (Bontekoning, 2002).

In relation to 'what' is being communicated, the *availability*, the *quality*, and the *value* of the information positively influence adoption by reducing uncertainty (Bontekoning, 2002). The value is determined by the actor providing the information.

The types of *communication channels* determine to 'how' the information is transferred from on actor to another. Channels can be mass media channels or personal channels. According to Bontekoning (2002) "Mass media channels are relatively important in the introduction phase and more important than personal channels for early adopters than for late adopters. The mass media are less important for late adopters, because by that time information from personal contact has reached the late adopter in abundance" (see Appendi Figure 16 for an explanation to early- and late-adopters).

The actors 'by whom' the information is being communicated belong to the *social system* to which the potential adopter belongs. The characteristics of the social system are determined by the different actors (i.e. innovators/suppliers, competitors, consultants, interest groups, branch organizations, and opinion leaders), the role of each actor, and the values and norms which influence the communication process (Bontekoning, 2002).

2.5.4 Characteristics of the competitors of the potential adopting organization

"A high level of competition among firms in a certain industry may increase the pressure on an individual firm to adopt a certain technological innovation. Thus, the speed and rate of adoption of an innovation is related positively to the degree of competitiveness of that industry" (Bontekoning, 2002).

2.5.5 Perceived characteristics of electorates

As discussed above, political feasibility is vital for large-scale adoption of transport innovations. Based on research of Feitelson & Salomon (2004) three characteristics of electorates will affect the political feasibility and thus the decision to adopt or not-adopt, naming: i.) the *perceived problems* by the electorates that ought to be (partially) solved by the adoption of the innovation. The problems do not have to affect to the individual voter directly, but can also be concerns that are seen as socially problematic. An increased perception of the salience of the problems positively influences the political feasibility of the innovation, and thus positively affects the process to adopt; ii.) the *perceived effectiveness* of the innovation by the electorates, meaning the perceived success of an innovation to address the problems at large. An increased perceived effectiveness of the innovation positively influences the political feasibility of the innovation; iii.) the *perceived distribution of benefits and costs* by the electorates, meaning the consideration by the public to what extent the costs are justified with respect to addressing an urgent problem and meeting the public good. In this case assuming the costs are mainly made up out of financial costs. And the benefits are made up out of the perceived urgency of the problem and the extent to which the innovation will solve this problem[6]

2.5.6 Characteristics of the innovator/supplier

According to Bontekoning (2002), the pre-diffusion variables of the innovator/supplier that positively influence adoption are: i.) the *support and involvement of the (general) management*; ii.) the *incorporation of the innovation project in the firm's overall strategic*

[6] I consider financial cost as an essential factor in the cost-befit distribution in this case.

posture; iii.) the *creation of an innovative climate* within the organization; iv.) the *development of a unique and superior product* as perceived by the potential adopting organization; v.) the *advantage of past experiences or synergy*; vi.) the *level of organization and execution of the innovation-development process* within the organization; vii.) the *supplier-buyer interactions and networks*, meaning the degree of cooperation of the supplier with potential adopters in the development of the innovation; viii.) the *marketing strategy of the supplier*. In our case, only the latter two variables will be investigated because they can directly influence and interact with the subject of this research; large-scale implementation of electric busses in public transportation. The remaining five characteristics cannot be changed to speed up the adoption process. They are only related to the activities and decisions of the suppliers, long before the diffusion process began.

2.5.7 The role of the (inter)national government

The adoption process of an innovation can be accelerated by governmental activities such as: i.) *active outreach programs*, ii.) *subsidy schemes,* iii.) *increasing information*, and iv.) *enhancing the reliability of the information* (Moon & Bretschneider, 1997; from Bontekoning, 2002).

3 OPERATIONALIZATION

How do we measure the explaining variables in the proposed conceptual model? This operationalization is based on the findings of Rogers (1995), Bontekoning (2002), and of our own.

3.1 Perceived characteristics of the innovation

The extent and speed of adoption are directly influenced by the potential adopter's perception of the innovation. Based on findings of Bontekoning (2002) and of our own, the operationalization of the corresponding explaining variables is as follows:

- Relative advantage: is subdivided in i.) 'performance', which entails the overall operation of the electric bus, and ii.) 'costs' which entails the economic profitability of the project. The 'performance' is measure qualitatively in terms of very disadvantageous and very advantageous. The 'costs' are measured qualitatively and valued in comparison with the project-shareholders-budget in terms of very unprofitable or very profitable (Bontekoning, 2002).
- Compatibility: is measured as the difference between electric busses and existing busses (i.e. internal combustion engine busses) in the rule-sets that are embedded in the complex of transport characteristics, bus operation procedures, skills of employees, and infrastructural investment and operation consequences. Organizational, technical, legislative, or financial changes have to be made when an innovation is not compatible. It is measured as the degree by which organizational, technical, legislative, financial project changes have to be made in respect to existing bus projects, in order to fulfill the demands or needs of the potential adopter (i.e. the local government and/or a bus operator) and the potential user (i.e. the transported customer) (Bontekoning, 2002).
- Complicatedness: can normally be measured to which extend it takes less or more time to explain the way daily operations are carried out for electric busses compared to existing busses. In this research complicatedness is not measured because it is assumed that electric bus operations are similar to combustion engine bus operations. In practice, for every new bus type a short introduction time is necessary to get used to the new material and procedures. In the case of the implementation of electric busses it is assumed that the explaining variable complicatedness will not play an important role in the drivers and barriers of electric bus projects due to the fact that daily operation is not changed dramatically.
- Testability: is measured as the quality and number of possibilities to experiment with new electric busses and their operations (considering participating in pilot bus projects or using a simulation tool) (Bontekoning, 2002).
- Observability: is measured by the degree to which the relative advantages of the innovation are visible to the public. This measure is expressed in terms of very noticeable and very unnoticeable(Bontekoning, 2002).
- Political feasibility: is measured by the perception of the potential adopting organization on the opinion of electorates and media towards the adoption of the innovation by the potential adopting organization. This measure is expressed in terms over very favourable or very unfavourable.
- Uncertainty: is measured in two ways, based on Bontekoning (2002): First, uncertainty is measured as the amount and level of risks that were expected by the potential adopting organization prior to the decision to adopt the electric bus. Risks are expressed in terms of very low and very high risk. Second, uncertainty is measured as the degree of how realistic the expectations regarding the implementation and operation of the electric bus prior to the decision to adopt were. This measure

is expressed in terms of very unrealistic and very realistic. High/low risks together with unrealistic/realistic expectations have a proportional relationship to high/low uncertainty.

3.2 Characteristics of the potential adopting organization

The decision to adopt is partly influenced by the characteristics of the potential adopter. Based on findings of Rogers (1995), Bontekoning (2002), and of our own, the operationalization of the corresponding explaining variables is as follows:

- Size of an organization: is measured by the number of employees of the local government or the bus operator(Bontekoning, 2002).
- The level of complexity of an organization, degree of specialization, and interconnectedness: are taken together and are measured by the diversity and number of the specialists of the adopting organization. With specialists we mean the employees that are involved in public bus transport projects. Including employees that facilitate their practices such as finance- and legislative-employees(Bontekoning, 2002).
- The absorption capacity: is not measured because we consider the absorption capacity already determined by the size and degree of specialization of the organization(Bontekoning, 2002).
- The type of the innovation decision: is measured in accordance to Bontekoning (2002) as "the time an innovation decision takes, the number of people involved, the number of hierarchical layers involved, the number of department/business units involved and the role of these layers and departments in the process (in terms of advisory or decision making)". Resulting in one of the four distributed decision types of Rogers (1995): Optional, Collective, Authoritarian, and Contingent.

3.3 Characteristics of the communication process, the information that is communicated, and the social system

As stated above, the decision to adopt is partly influenced by the information that is gathered from the social system through different communication channels. Based on findings of Bontekoning (2002) and of our own, the operationalization of the corresponding explaining variables is as follows:

- The availability of information: is measured by the quantity of media providing information about electric busses (such as newspapers, brochures of suppliers, professional magazines, and reports of branch organizations and research institutes) (Bontekoning, 2002).
- The quality of information: is measured as the perceived detail and comprehensiveness of the information experienced by the potential adopter in relation to the benefits, the use, the costs, and the consequences of the innovation(Bontekoning, 2002).
- The value of information: is normally measured as the perceived objectivity of the information experienced by the potential adopter (Bontekoning, 2002). The type of communication channel used is determinant for the value of information: a personal channel versus. a mass media channel. In this case, a personal channel would positively increase the value of information compared to a mass media channel. In this operationalization the 'value of information' is combined with the 'quality of information'. The value and quality of information are expressed in terms of very poor and very good.
- The characteristics of the social system: is determined by mapping and analysing the network of players influencing the potential adoption organization, including the most important competitors, interest groups, research institutes, branch organizations, and unions(Bontekoning, 2002).

3.4 Characteristics of the competitors of the potential adopting organization

In accordance with the model of Bontekoning (2002), this explaining variable is incorporated in the description of the characteristics of the social system. In our case, the 'characteristics of competitors' is only applicable to the bus operator as an potential adopting organization. A local government has no competitors due to their monopoly as a creator and enforcer of policy on a local level. In a tendering procedure for a public transport concession, a high level of competition can positively increase the adoption of an innovation when the latter is required or seen as a positive addition by the concession provider (i.e. the local government). Competitors are other players that can provide the same general function, in this case transporting people from A to B within the boundary limits of a concession issued by a local government. We restrict the possible competitor solitary to bus operators.

3.5 Perceived characteristics of electorates

This explaining variable is not incorporated in the operationalization of this research. As mentioned above, the 'perceived characteristics of electorates' hold a strong connection to the explaining variable 'political feasibility', but different than Feitelson & Salomon (2004) proclaim political feasibility as an essential factor for adoption of transport innovations, the variable of 'political feasibility' will not hold such a prominent place in this operationalization. Merely due to the fact that is not possible to collect substantial data on the perceived characteristics of electorates within the scope of this research. Therefore, only the explaining variable 'political feasibility' is incorporated in this operationalization and the 'perceived characteristics of electorates' is left out.

3.6 Characteristics of the innovator/supplier

According to Bontekoning (2002), the 'Supplier-buyer interactions and marketing strategy' of the innovator/supplier positively influences adoption. Based on findings of Bontekoning (2002) and of our own, the operationalization of this explaining variables is as follows:

- Supplier-buyer interactions and marketing strategy: are taken together and determined as the number and type of the different strategies that the supplier uses in order to approach the potential adopter. Also the impact of each type of marketing is measured and expressed in no impact and very much positive impact(Bontekoning, 2002).
-

3.7 The role of the (inter)national government

The adoption process of an innovation can be accelerated by governmental activities. Based on findings of Bontekoning (2002) and of our own, the operationalization of the corresponding explaining variables is as follows:

- Active outreach programs: in correspondents to Bontekoning (2002) the active outreach programs "are programs which focus on increasing information and enhancing reliability of information about new-generation [electric bus] operations based on objective research finding. These programs have one or several of the following characteristics:
  - reach many potential adopters and players in the social system;
  - reach potential adopters in a very intensive manner (by means of subsidised consultants and consulting programs);

- strongly promote (in a campaigning manner) the importance of the new-generation [electric bus] operations for adopters and society;
- aim at bringing potential adopters and suppliers together in order to build up implementation teams".

This indicator is qualitatively measured.

- Subsidy schemes: is measured as the total size of financial aid from the national or European government to promote the adoption of electric busses in Europe. It is also measured quantitatively for each particular case study individually. The subsidy schemes can be directed to different processes, such as R&D costs or purchase costs (Bontekoning, 2002).

4 METHODOLOGY

In order to formulate and explore the critical factors of electric bus projects, the research has been divided over three different aspects. Each aspect considers a different sub-question. First, an overview of the current electric bus projects in Europe has been created. Second, major drivers and barriers to the successful adoption of electric busses in Europe have been identified based on a selection of the electric bus projects. Third, the identified major drivers and barriers have been assessed by a sample of stakeholders from the European electric bus sector in order to increase the external validity of the research findings. Ultimately, the main research question has been answered by mapping the drivers and barriers to successful implementation of electric busses in the European public transportation sector.

The designed method to answer each specific research (sub-)question is worked out in this section.

4.1 What current electric bus projects can be found across Europe?

Information of different European projects have been collected using project-, company- and government-websites, international papers and reports, and interviews with key actors. A list of the existing electric bus projects in Europe have been drawn up based on project-, company- (bus- and infrastructure-companies) and government-websites and reports.

The list of European electric bus projects as shown in Table 4 includes project information on the located city and country, the charging technique, the project type (pilot or permanent), the number of busses, the bus type, the begin date of the bus operation, the end date of the bus operation, possibly short descriptive remarks on the project, and references to information sources. Several projects lack information, which is illustrated by an '-'-symbol inside an empty cell in the overview.

To help find the information websites different combinations of the words "electric", "zero-emission", "charging", "induction", "bus", "public transportation", "innovation", "transition", "tender", "concession", "government", "manufacturer", "actors", "stakeholders", "barriers", "obstacles", "success", "pilot", "line", "organization", "project", "Europe", "trends", "financials", "subsidizing", "list", and "overview", as well as the particular project name, city name, and country name together with the project's working language translation have been used as input to the search engine https://www.google.com. Specific search-words have been translated in http://translate.google.com/ to the project's working language. Complete websites and reports have been translated into English using the automatic translation tool of web browser Google Chrome.

4.2 Which major drivers and barriers to the successful adoption of electric busses can be derived from a selection of electric bus projects in Europe?

A selection of the bus projects have been investigated more accurately in order to formulate and explore the critical success and fail factors of European electric bus projects. A number of eight projects have been subtracted out of the complete list of projects, because in depth research on all projects is too abundant for this research. In compliance with case study literature, multiple cases have been investigated in order to extrapolate findings to other settings, "not to augment the number of data points to increase the confidence of within-group findings [...] If patterns are found under extreme conditions there is greater confidence (based on logic rather than statistical evidence) that resultant theories are broadly applicable" (McCutcheon & Meredith, 1993). Evidently the selected case studies differ from each other in great extent.

Selection of six 'successful' case studies

In order to filter the eight case studies out of the complete list of European electric bus projects, two selection steps have been performed.

First, projects have been filtered out based upon project duration, charging technique, project size, and project status:

- The selected projects have a duration of more than six months in order to increase the internal validity[7] of the research.
- The different charging techniques of electric busses are covered by three charging techniques genres that fundamentally differ from each other: 1.) slow charging, with a charging time over 1.5 hours per charge; 2.) en route charging, with a charging time of less than 1.5 hours per charge; 3.) battery exchange. Table 3 shows the subdivision of the different charging techniques over the generic charging techniques.
- Of each charging technique genre, the projects with the largest and smallest sizes have been selected from the complete overview of projects. The project size has been determined by the number of electric busses that are in operation. The project size has been used as a prominent selection criterion, because large and small projects often fundamentally differ in project goal and management (including the financial-, institutional/organisational-, and contractual-characteristics). If case information on the charging technique or fleet-size was missing, this particular information has been collected from sources other than internet websites (e.g. contacting project actors by telephone or email).

Table 3. Charging technique subdivision

	Possible charging techniques			
Slow charging	Slow charging 1x per 24 hours (4-8 hours charging time)	Slow charging 2-4x per 24 hours (1.5-2 hours charging time)		
En route charging	Opportunity charging at bus stops (several minutes charging time)	Fast charging using trolley grids, when within the coverage area	Static induction	Dynamic induction
Battery exchange	Battery exchange			

The second selection step has yielded the final six 'successful'[8] case studies. All six case studies should differ as much as possible in the combination of charging technique and project size (i.e. large versus small). Additional selection criteria have been based on differences in geography (i.e. urban versus rural

[7] Internal validity is defined in case study literature as the extent to which "the right cause-and-effect relationships have been established" by the information source or the researcher (Yin, 1989, from McCutcheon & Meredith, 1993).

[8] A 'successful' project is defined in section 1 of this report as the actual use of an electric bus in daily operation on an official public transportation bus route. The electric bus project must at least run for the anticipated period of operation.

environment, culture, temperature), time period, bus type and size, and exact charging technique. In a later stage of the research, the extent to which the project organization has cooperated with the research could have been affecting the selection of case studies (in our case the cooperation of the project organizations was sufficient and did not affect the selection of case studies).

Selection of two 'failed' case studies

To complete the case study selection, two 'failed' cases have been added to the six 'successful' case studies. As defined in section 1 of this report, a failed project is a project in which the decision was made to adopt an electric bus for an anticipated period of time, but in which the decision was made to terminate the project before the project could be defined as 'successful'. 'Failed' projects can provide valuable lessons on obstacles to the implementation of electric busses. The main selection criteria for these projects has been the project's novelty. The project would preferably be as up-to-date as possible to make sufficient conclusions in regard to the current critical success- and fail-factors of electric bus projects. Additionally, the case studies would differ as much as possible from each other, therefor various criteria have been used: geography (i.e. country, urban versus rural environment, culture, temperature), time period, bus type and size, exact charging technique. These criteria are reported in a random order of importance. An additional selection criterion has been the extent to which the project organization is willing to cooperate with the research. This has been of most importance in a later stage of the research. However the latter criterion was not utilized during this research, due to the fact that all project organizations were willing to cooperate sufficiently.

Comprehensive collection of case-specific information in correspondence to the explaining variables of the adjusted adoption model of Bontekoning (2002)

Information that relates to the explaining variables as described in section 3 have been collected for each of the eight projects. Project-, company- and government-websites, and international papers and reports have functioned as information sources. In addition, direct contact with project representatives and key actors have been established by telephone, email or personal meeting. Actors have been selected on their expertise and responsibility (ideally the chief project manager has been interviewed) in order to increase the content validity[9] and internal validity of the research. Three different representatives of the main concerning organizations have been interviewed: one of the local government, one of the bus operator, and one of the bus supplier. The local government as well as the bus operator can be potential adopting organizations. According to adoption literature, the supply side (in this case the bus supplier) directly influences the adoption decision by marketing strategies and supplier-buyer interactions, and therefore is an important factor in the social system. In some case interviewees have been added whenever this was relevant for the case.

The selected interviewees have been receiving emails in which the research project is shortly described[10] and in which he or she is asked to cooperate with an interview. When the actor did not reply, he or she would have received a second email with a reminder referring to the first email. When the actor still did not reply, he or she would have received a phone call asking for an interview. When the actor would have replied positively to the request, he or she would have received a short

[9] Content validity is defined as "how well a measure samples a specified content domain to ensure that the construct is accurately reflected" (Nunnally, 1978, from McCutcheon & Meredith, 1993)

[10] It is important to note in the email to the interviewee that multiple actors will be interviewed on the identical case study. This might influence the truthfulness of the answers the actor will give.

questionnaire with mainly multiple choice questions. Subsequently a Skype-interview would have been conducted.

As shown in Appendix IV, Appendix V, and Appendix VI, the questionnaires include structured questions directly related to the explaining variables of the theoretical framework. Multiple choice questions have been preferred in order to generate a great amount of research data in a short period of time. Subsequently structured, predetermined closed questions have been be asked. The questions on the 'perceived characteristics of the innovation', 'characteristics of the potential adopting organization', 'characteristics of the communication process, the information that is communicated, and the social system', and 'characteristics of the competitors' have been posed to at least one representative of each potential adopting organizations (i.e. the local government and/or the bus operator). With the exception of the questions regarding 'political feasibility, which have only be posed to the local government. Questions on the 'characteristics of the innovator/supplier' and 'uncertainty' about the electric bus project have been directed to the specific electric bus (and infrastructure) supplier. The potential adopting organisation as well as the innovators/suppliers have been providing information about 'the role of the national and European government'.

The Skype-interview has been semi-structured in compliance with the questionnaire and to ensure space for unanticipated discussions that might emerge during the interview. Questions posed have been nondirective in order to uphold objectivity of the interviewer. During the interview answers have been summarized by the interviewer in order to improve the reliability of collected data (Hulshof, 1992). The interviews have started off with an introduction and the main question on the critical factors of implementation of electric busses in the particular project. Also, the potential adopting organization have been asked how the decision to adopt an electric bus was made, because this question was too broad to implement in a questionnaire. The remaining pre-determined questions that have been posed were based on the results of the completed questionnaire. In particular on answers that needed more elaboration in order to generate a more full and detailed result for the sake of the research. Therefore, a customized list of predetermined questions and/or focus points has been drafted up for each individual interviewee based on the completed questionnaires.

After the interview, the collected information has been worked out in a Word-document and emailed back to the interviewee. The interviewee was given the possibility to review the collected information and make modifications/additions where necessary. Additionally, each interviewee has been asked questions regarding unclear statements as well as the permission to cite the interviewee by name.

Utilizing the adjusted adoption model of Bontekoning (2002)

The collected information has been divided over the explaining variables in a separate Word document for each project. In order to avoid repetition, identical answers for all case studies are collected in a Word-document for 'non-case specific explaining variables'.

Subsequently, the collected information has been extensively analysed. An overview of the relevant actors and their role in the case studies has been presented. Each variable has been valued in each of the eight case studies in order to identify their influence on the implementation of the innovation. Based on this analysis, the impact has been valued with '++' (i.e. strongly positive), '+' (i.e. normal positive), '+/-' (i.e. neutral), '-' (i.e. negative), or '--' (i.e. strongly negative). The values render the researcher's impression on the explaining variables. Variables that have been valued a 'negative' or 'strongly negative' impact have been identified as potential obstacles to the implementation of electric busses. Variables that have been valued a 'positive' or 'strongly positive' impact have been identified as potential drivers to the implementation of electric busses. Based on the explaining variable analysis the ‘perceived critical factors’ for the successful implementation of electric busses have been derived from the selection of electric bus projects in Europe.

4.3 Which major drivers and barriers to the successful adoption of electric busses in Europe can be derived from a review by stakeholders from the electric bus sector in Europe?

In order to increase the external validity[11] of the research, the outcome of the case studies (i.e. the answer to the third sub-question: ‘Which major drivers and barriers to the successful adoption of electric busses can be derived from a selection of electric bus projects in Europe ?’) has been reviewed by multiple other stakeholders from the European electric bus sector (e.g. local governments, bus operators, bus suppliers, research institutes, consultants). These stakeholders and their contact information have been collected on sector-platforms such as electric bus LinkedIn-groups and electric bus conferences. Additional contacts have been collected using personal contacts and reference sources from the assembled ‘overview of electric bus projects in Europe’. The contacts have been asked to value the major drivers and barriers, as distinguished in the answer to the third research question, in a short survey, on their impact on the implementation of electric busses in Europe (on a scale from 1 to 5. 1 for a very low impact, 5 for a very high impact, N/A means not applicable). An extensive explanation of the proposed drivers and barriers was incorporated next to the questions in the survey. Furthermore, the contacts have been asked to indicate their profession and experiences regarding electric busses. The survey has been generated and managed using https://www.surveymonkey.net, which provided an easy-to-use recipients management system. The survey has been posted on electric bus LinkedIn-groups and send by email to all other contacts. When recipients did not react to the survey request, they have been receiving a reminder. Up to three reminders have been send to the recipients. The answers to the survey have functioned as an additional assessment method on the drafted major drivers and barriers based on the case studies. Based on a short statistical analyses (i.e. the mean rated value of each driver and barrier is taken into account) of the collected reviews, the “more probable” and generalized critical factors for the successful implementation of electric busses have been derived. In addition, we have been ‘ranking’ the drivers and barriers on their impact on the implementation of electric busses in Europe, based on the survey results.

4.4 What are major drivers and barriers to the successful adoption of electric busses in Europe?

In the finalization of the report we have been concluding upon our findings. First we have been answering the sub-questions. Second, we have been providing an extensive answer to the main research question. Furthermore, we have been providing the recommendations to stakeholders in the electric bus market and to future research. Lastly, we have been reflecting upon our research covering the research limitations and contributions.

[11] External validity is defined as “the extent to which findings drawn from studying one group are applicable to other groups or settings” (McCutcheon & Meredith, 1993).

5 ELECTRIC BUS PROJECTS IN EUROPE

In this section an overview of the European electric bus projects is presented. Subsequently eight case studies are selected using a specified selection procedure. The eight case studies are analysed utilizing the conceptual adoption model. Ultimately the drivers and barriers to successful adoption of electric busses are identified.

5.1 An overview of electric bus projects in Europe

Table 4 shows the overview of European electric bus projects as of December 2013. All projects are commissioned by local governments and include full electric busses (defined as a five-metre autonomous public transportation road vehicle driving along a fixed route, using solely on-board battery- or supercapacitor-stored electricity to drive). Project types that are included are demonstrations, pilot projects, and permanent projects that have been or still are in progress. For some projects that are included, the electric busses will be operational in the near future. Per project, information is given on the geological location, charging technique, project type, begin- and end-date of operation (i.e. the date on which the busses are operated on the road), and references. Several projects lack information, which is illustrated by an '-'-symbol inside an empty cell in the overview.

Table 4. Overview electric bus projects in Europe

City	Charging	Project type	Begin date operation	End date operation	References
Klagenfurt (AT)	Slow charging 1x per 24 hours	Permanent	Jul-13	-	Cemobil, n.d.; Bulut, 2013; Gruber, 2013; Solarisbus, 2013a
Montafon (AT)	-	Pilot	-	-	Gruber, 2013
Salzburg (AT)	Slow charging 1x per 24 hours	Pilot	Aug-12	-	PEGE, n.d.; Elektroautor, 2012
Vienna (AT)	Fast charging using trolley grids, when within the coverage area	Permanent	Oct-12	-	Siemens, n.d.; Wiener Linien, 2012; Dailye, 2012; Magistrat der Stadt Wien, 2012; Siemens, 2012; Wiener Linien, 2012; Clean Fleets, 2013b; Gies; 2013; Siemens, 2013
Bruges (BE)	Static induction	Permanent	Q1-14	-	Bus and Coach, 2013a; Desjardins, 2013
Brussels (BE)	Slow charging 1x per 24 hours	Pilot	Dec-12	Feb-14	BYD Spain, n.d.; Techvehi, n.d.;
Heusden-Zolder (BE)	Slow charging 1x per 24 hours	Permanent	Q1-13	-	Gazet van Antwerpen, 2010; TVL, 2010
Lommel (BE)	Static and dynamic induction	Pilot	Apr-10	Sep-12	Flanders' DRIVE, n.d.; PRIMOVE, n.d.; Desjardins, 2013
Geneva (CH)	Opportunity charging at bus stops	-	Nov-10 May-13	Dec-10	ABB, n.d.; OPI, n.d.; Bus and Coach, 2010b; ITTechEx, 2013
Lucerne (CH)	-	Pilot Demo	Oct-12 Nov-10	Dec-10	Bus and Coach, 2010b; Gruber, 2013
Zermatt (CH)	Slow charging 1x per 24 hours Slow charging 2-4x per 24 hours	Permanent Permanent	-	-	Eltis, 2009
Zurich (CH)	-	-	Nov-10	Dec-10	Bus and Coach, 2010
Plzen (CZ)	Opportunity charging at bus stops and slow charging 2-4x per 24 hours	Pilot	Q1-14	-	Kerkhof, 2013; Weber, 2013
Praque (CZ)	Fast charging using trolley grids, when within the coverage area	Pilot	01-01-2013	-	Tom88CZ, n.d.; Wiesinger, 2014
Aachen (DE)	-	Pilot	-	-	Smartwheels, n.d.; Gruber, 2013
Berlin (DE)	Static induction	Pilot	Q4-14	-	AVEM, 2013; KpVV, 2013; Neumann, 2013
Bonn (DE)	Slow charging 1x per 24 hours and possibly opportunity charging	Pilot	06-06-2013	Jul-13	Eltis, 2013; Lehmann, 2013; Newstix, 2013
Bonn (DE)	Slow charging 2-4x per 24 hours and opportunity charging at bus stops	Pilot	Q1-14	-	Kerkhof, 2013; Weber, 2013
Bremen (DE)	Slow charging 1x per 24 hours Slow charging 2-4x per 24 hours and fast charging at end stations	Pilot Pilot	Jan-13	-	Transport News Brief, 2012; Clean Fleets, 2013a; Vossloh Kiepe GmbH, 2013a

Brunswick (DE)	Static induction Static induction	Permanent Permanent	Q4-13 Q2-14	-	Braunschweiger Verkehrs-AG, n.d.; TU Braunschweig, n.d.; Bombardier, 2013; Desjardins, 2013; Vossloh Kiepe GmbH, 2013
Cologne (DE)	N/A	N/A	2016	-	Lehmann, 2013
Dresden (DE)	Fast charging using trolley grids, when within the coverage area	Pilot	-	-	Wiesinger, 2014
Dusseldorf (DE)	Slow charging 2-4x per 24 hours	Permanent	2014	-	Gruber, 2013; Mücke, 2013; Solaris, 2013a; Transportweekly, 2013
Eberswalde (DE)	Fast charging using trolley grids, when within the coverage area	Permanent	Sep-12	-	TROLLEY, n.d.; Central Europe, 2012; TROLLEY, 2012
Frankfurt am Main (DE)	-	Permanent	-	-	BYD Spain, n.d.; TraffiQ, n.d.; Green Car Congress, 2011; Murr, 2012; KpVV, 2013; Anlauf, 2014
Hanover (DE)	-	Demo	Sep-12	-	Haase, 2012
Jena (DE)	-	Pilot/demo	Feb-13	-	Beier, 2012; Gruber, 2013
Kassel (DE)	-	Pilot Permanent	09-2012 06-2013	-	Going Electric, 2012; Gruber, 2013; NOG GmbH, 2013
Leipzig (DE)	-	Demo	Sep-12	-	LVB, 2012; Gruber, 2013
Mannheim (DE)	Static induction	Pilot	Q2-14	-	Barry, 2013; Desjardins, 2013
Mönchengladbach (DE)	-	Pilot/demo	-	-	Gruber, 2013
Muenster (DE)	Opportunity charging at bus stops	Pilot	Q1-14	-	Kerkhof, 2013; Weber, 2013
Munich (DE)	Slow charging 1x per 24 hours	Pilot	Dec-13	Jan-14	Burgert, 2013; Gruber, 2013
Nürnberg (DE)	-	Pilot/demo	-	-	Gruber, 2013
Offenbach (DE)	Slow charging 2-4x per 24 hours	Pilot	Nov-11	Nov-11	Bulut, 2011a; Bulut, 2011b
Osnabrück (DE)	Slow charging 1x per 24 hours	Permanent	2011	-	Lehmann, 2013
Pinneberg (DE)	Slow charging 1x per 24 hours	Permenant	Sep-12	-	People's Daily Online, n.d.; Chinabuses, 2012; Bus and Coach Buyer, 2013
Reutlingen (DE)	-	Pilot	Oct-12	-	Lokalmagazin Wueste-Welle, 2012; Gruber, 2013
Sollingen (DE)	Fast charging using trolley grids, when within the coverage area	Pilot	-	-	Kühne, 2010
Tübingen (DE)	Slow charging 1x per 24 hours	Pilot Pilot	Aug-12	-	Szelényi, 2012; Gruber, 2013
Wiesbaden (DE)	Slow charging 2-4x per 24 hours	Demo	Jul-13	Jul-13	Guimarães, 2013; Pressereferat Wiesbaden, 2013
Copenhagen (DK)	Slow charging 1x per 24 hours	Pilot	2013	2015	Ventura Systems, n.d.; BYD, 2013a

Barcelona (ES)	Slow charging 1x per 24 hours	Pilot Permanent Pilot	Jun-12 Sep-13 Q1-14 Jul-14	Jun-12	BYD, n.d.; BYD Spain, n.d.; Autobuses-Autocares, 2013; Kerkhof, 2013; TMB, 2013; Weber, 2013
Burgos (ES)	Slow charging 1x per 24 hours	-	-	-	Tussam, n.d.
Córdoba (ES)	Slow charging 1x per 24 hours	Permanent	Jun-13	-	Nexobus, 2013
León (ES)	Slow charging 1x per 24 hours	Permanent	2007	-	La Crónica de León, n.d.; Reporterodigital, 2007; Tecnobus, 2007
Madrid (ES)	Slow charging 1x per 24 hours Slow charging 1x per 24 hours	Permanent Pilot	2007 Jun-12	Jun-12	EMT, n.d.; BYD Spain, n.d.; NoticiasdeAutobús, 2008; Simón, 2012; Transport News Brief, 2012; EMT, 2013; Tecnobus, 2014
Malaga (ES)	Dynamic induction	Pilot	Sep-14	-	Europa Press, 2013
Palma de Mallorca (ES)	-	-	-	-	EEO, 2013
San Sebastian (ES)	-	-	Jul-14	-	Autobuses-Autocares, 2013; Lasenergias, 2012
Segovia (ES)	Slow charging 1x per 24 hours	Permanent	2007	-	Tussam, n.d.; Nexobus, 2007; Segoviaudaz, 2010
Seville (ES)	Slow charging 1x per 24 hours	Permanent Permanent	Apr-07 Jun-08	-	Tussam, n.d.; Reporterodigital, 2007
Soria (ES)	Slow charging 1x per 24 hours	-	-	-	Tussam, n.d.
Valencia (ES)	Slow charging 1x per 24 hours	-	-		Tussam, n.d.
Espoo (FI)	Slow charging 1x per 24 hours and/or 2-4x per 24 hours	Pilot	-	-	ECV, n.d.; Bus and Coach, 2011; Helsinki Times, 2012; Hulkkonen, 2012; Noya, 2012; Nylund, 2012; Erkkilä & Nylund, 2013; VTT, 2013
Alpe d'Huez (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Torregrossa, 2013c
Alpes-Maritimes (FR)	Slow charging 1x per 24 hours	Pilot	Oct-12	-	Torregrossa, 2013d
Arcachon (FR)	Battery exchange Slow charging 1x per 24 hours	Permanent Permanent	-	-	Trans'bus, n.d.
Bordeaux (FR)	Battery exchange	Permanent	-	-	Keolis, n.d.; La Cub, n.d.; Trans'bus, n.d.; TBC, n.d.; Trans'bus, 2001; Delquie, 2014
Chalon-sur-Saône (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Coulommiers (FR)	Slow charging 1x per 24 hours	-	2011	-	Transdev, 2011
Coulsdon (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Trans'bus, n.d.
Faure (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Trans'bus, n.d.
Fréjus (FR)	Battery exchange	Permanent	-	-	Trans'bus, n.d.
Grand Chalon (FR)	Slow charging 1x per 24 hours	Permanent	Oct-11	-	Avere-France, n.d.; Trans'bus, n.d.
Gravelines (FR)	Battery exchange	Permanent	-	-	Trans'bus, n.d.
Ile de Ré (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.

La Rochelle (FR)	Slow charging 1x per 24 hours Slow charging 1x per 24 hours	Permanent Permanent	-	-	Trans'bus, n.d.
Laval (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Le Mont-Saint-Michel (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Le Touquet-Paris-Plage (FR)	Battery exchange	Permanent	-	-	Trans'bus, n.d.
Les 2 Alpes (FR)	Slow charging 1x per 24 hours	Permanent	Jul-13	-	Torregrossa, 2013c
Lyon (FR)	Slow charging 1x per 24 hours	Permanent	2004	-	Trans'bus, n.d.; Mantovani et al., 2008
Maubeuge (FR)	Battery exchange	Permanent	-	-	Trans'bus, n.d.
Nice (FR)	-	Permanent	-	-	Trans'bus, n.d.
Orleans (FR)	Battery Exchange	Permanent	2011 or 2012	-	Avere-France, n.d.; Trans'bus, n.d.; Delquie, 2014
Paris (FR)	Slow charging 1x per 24 hours Slow charging 2-4x per 24 hours Slow charging 1x per 24 hours	Pilot Permanent Permanent	2011 Oct-13	-	CAPRICE, n.d.; RATP, n.d.; Trans'bus, n.d.; Transport News Brief, 2012; Techvehi, 2013; Torregrossa, 2013a
Périgueux (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Provins (FR)	Slow charging 1x per 24 hours	Permanent	2010	-	Avere-France, n.d.; Mairie de Provins, n.d.; Trans'bus, n.d.; Torregrossa, 2013b
Rambouillet (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Rochefort (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Trans'bus, n.d.
Saint-Pierre (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Tarbes (FR)	Battery exchange	Permanent	-	-	Trans'bus, n.d.
Toulouse (FR)	Slow charging 1x per 24 hours	Permanent	Dec-03	-	Avere-France, n.d.; Trans'bus, n.d.
Tours (FR)	Slow charging 1x per 24 hours	Permanent	-	-	Avere-France, n.d.; Trans'bus, n.d.
Valenciennes (FR)	Battery exchange	Permanent	-	-	Trans'bus, n.d.
Ayr (GB)	Slow charging 2-4x per 24 hours	Permanent	-	-	Kane, 2013
Cheshire (GB)	-	Permanent	-	-	Government of the United Kingdom, n.d.
Coventry (GB)	Slow charging 2-4x per 24 hours	Permanent	Jun-12	-	Optare, n.d.; ABB, 2012; Bus and Coach, 2012a
Dorset (GB)	Slow charging 1x per 24 hours	Permanent	Jul-12	-	Government of the United Kingdom, n.d.; BBC, 2012; Dorset County Council, 2012
Durham (GB)	Slow charging 1x per 24 hours and possibly opportunity charging	Permanent	2010	-	Automotive PR, 2010; Bus and Coach, 2010a
Liverpool (GB)	Slow charging 1x per 24 hours	Permanent	-	-	Milk Float Corner, n.d.; Tecnobus, n.d.

London (GB)	Slow charging 1x per 24 hours Static induction and slow charging 1x per 24 hours	Permanent Permanent Pilot	12-2013 Q1-14 Q1-14	-	BYD, 2013b; Future Timeline, 2013; Kerkhof, 2013; Sunderland, 2013; Weber, 2013
Manchester (GB)	-	Permanent	-	-	Government of the United Kingdom, n.d.
Milton Keynes (GB)	Static induction	Pilot	Q1-14	2017	Government of the United Kingdom, n.d.; Mitsui & Co. Europe Plc, 2012; The Wright Group, 2012; Top Engineering Jobs, 2012; Arup, 2013; Bus and Coach, 2013a
Nottingham (GB)	Slow charging 2-4x per 24 hours	Permanent	2012 2013 2013	-	Bus and Coach, 2012b; Nottingham Post, 2013; TransportXtra, 2013
York (GB)	Slow charging 1x per 24 hours	Permanent	-	-	Government of the United Kingdom, n.d.; Stead, 2013; De Courcey, 2014
Budapest (HU)	Slow charging 1x per 24 hours Slow charging 1x per 24 hours Slow charging 2-4x per 24 hours	Pilot Pilot Pilot	Sep-11 Jun-12 Sep-13	-	Hir24, n.d.; Hungary Around the Clock, 2010; Ebrand, 2012; Transport News Brief, 2012; Autopro, 2013; Index, 2013
Debrecen (HU)	Slow charging 1x per 24 hours	Permanent Pilot	Mar-13	-	Istvánfi, 2013a
Szeged (HU)	Slow charging 1x per 24 hours	Pilot		-	Szeged, n.d.; Istvánfi, 2013b
Székesfehérvár (HU)	Slow charging 1x per 24 hours	Pilot	Jun-12	-	City of Székesfehérvár, 2012
Törökbálint (HU)	Slow charging 1x per 24 hours	Pilot	Mar-13	-	Istvánfi, 2013a
Glasgow (IE)	Inductive charging at end stations	Pilot	Q1-14	-	Kerkhof, 2013; Weber, 2013
Bologna (IT)	Slow charging 1x per 24 hours or Battery exchange	Permanent	-	-	Ten Kate, 2014
Florence (IT)	Slow charging 1x per 24 hours or Battery exchange	Permanent	-	-	Tecnobus, n.d.; Tecnobus, 2014; Ten Kate 2014
Genoa (IT)	Static induction	Permanent	2002	-	Conductix Wampfler, 2012; Kerkhof, 2013; GTT, 2014
Milan (IT)	Slow charging 1x per 24 hours Slow charging 1x per 24 hours	Pilot Permanent?	-	-	Transport News Brief, 2012; Automotive PR, 2013
Naples (IT)	Slow charging 1x per 24 hours	Permanent	-	-	Napoli Unplugged, n.d.; Tecnobus, n.d.
Pisa (IT)	Slow charging 1x per 24 hours or Battery exchange	Permanent	-	-	Ten Kate, 2014
Rome (IT)	Slow charging 1x per 24 hours Slow charging 2-4x per 24 hours Fast charging using trolley grids, when within the coverage area	Permanent Pilot Pilot	1989 Q1-14	-	Mannini, n.d.; Tecnobus, n.d.; Mannini,, 2007; Scoppola, 2010; Majo, 2011; Index, 2013; Kerhof, 2013; Webder, 2013; Spirito, 2014; Tecnobus, 2014

Turin (IT)	Static induction	Permanent	2003	-	EPT, n.d.; Sala & Meyer, 2009; Conductix Wampfler, 2012; FCH JU, 2012; Taborelli, 2012; Cavaglià, 2014; GTT, 2014; Zazio, 2014
Rotterdam (NL)	Battery exchange Slow charging 1x per 24 hours	Permanent Permanent	2006	-	Gemeente Rotterdam, n.d.; RKT, n.d.; Messemaker, 2012; Agentschap NL, 2013; KpVV, 2013; Ten Kate, 2014
Utrecht (NL)	Static induction Static induction	Pilot	02-2011 12-2013	-	Bestuur Regio Utrecht, n.d.; Greyhound, 2011; Agentschap NL, 2013; Betlem, 2013; Saint, 2014
Maastricht (NL)	Slow charging 1x per 24 hours Slow charging 1x per 24 hours Slow charging 1x per 24 hours Slow charging 1x per 24 hours	Pilot Pilot Pilot Pilot	05-2013 05-2013 06-2013 Q4-2013	-	Spijkstaal, n.d.; Provincie Limburg, 2012; Agentschap NL, 2013; L1, 2013
Schiermonninkoog (NL)	Slow charging 1x per 24 hours	Permanent	Jul-13	-	Agentschap NL, 2013; BYD, 2013d; Geelhoed, 2013; KpVV, 2013; NOS, 2013
s-Hertogenbosch (NL)	Slow charging 1x per 24 hours Slow charging 1x per 24 hours and static induction	Pilot Pilot	2010	2013	Gemeente 's-Hertogenbosch, n.d.; RKT, n.d.; Agentschap NL, 2013; Provincie Noord-Brabant, 2013
Renesse (NL)	Slow charging 1x per 24 hours	Permanent	-	-	Busfoto, n.d.; Agentschap NL; TCR, 2013; Ten Kate, 2014
Delft (NL)	Slow charging 1x per 24 hours or Battery exchange	Permanent	-	-	Agentschap NL, 2013; Ten Kate, 2014
Trondheim (NO)	Slow charging 1x per 24 hours, flash, induction	Permanent Pilot	2010 2014	-	NRK, 2010; Marie, 2013; Gabriel et al., 2013
Gdańsk (PL)	Slow charging 1x per 24 hours	Pilot Pilot	Aug-12 Jul-13	Aug-12 Jul-13	Koprowski, 2012; Automotive PR, 2013; Gruber, 2013; Potocka, 2013
Gdynia (PL)	Slow charging 1x per 24 hours	Pilot	Jul-13	Jul-13	ZKM, n.d.; Netka, 2013
Jaworznie (PL)	Slow charging 1x per 24 hours	Pilot	Jul-13	Jul-13	PKM Jaworzno, n.d.; Automotive PR, 2013
Kraków (PL)	Fast charging using trolley grids, when within the coverage area Slow charging 1x per 24 hours	Pilot Pilot Pilot Pilot Permanent	Jan-13 Feb-13 2013 Aug-14	-	BYD Spain, n.d.; MPK, n.d.; Blikowska, 2013; Ekonomia, 2013; Nowax, 2013; Weber, 2013; Wiesinger, 2014
Poznan (PL)	Slow charging 2-4x per 24 hours	Pilot	Jun-12	Jun-12	Solaris, 2013

Warsaw (PL)	Slow charging 2-4x per 24 hours Slow charging 1x per 24 hours	Pilot Pilot Pilot Pilot	Jul-12 Jun-13 Aug-13 Oct-13	Jul-12 Jun-13 Aug-13 Oct-13	Wawalove, 2012; BYD, 2013c; TVN Warszawa, 2013a; TVN Warszawa, 2013b
Zakopane (PL)		Pilot	Sep-13	Sep-13	Podmokły, 2013
Zielona Góra (PL)	Slow charging 1x per 24 hours	Pilot	-	-	Gramwzielone, 2012; Weber, 2013
Almada (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Aveiro (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Bragança (PT)	Slow charging 1x per 24 hours	Permanent	Apr-05	-	Santos et al., 2005; Almeida et al., 2009; Alves, 2010a; Alves, 2010b
Cascais (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Castelo Branco (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Coimbra (PT)	Slow charging 1x per 24 hours	Permanent	Sep-03	-	Santos et al., 2005; Almeida et al., 2009; Alves, 2010a; Alves, 2010b
Évora (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Funchal (PT)	Slow charging 1x per 24 hours	Permanent	Sep-06	-	Santos et al., 2005; Almeida et al., 2009; Alves, 2010a
Leiria (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Paço de Arcos (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Portalegre (PT)	Slow charging 1x per 24 hours	Permanent	Sep-04	-	Santos et al., 2005; Almeida et al., 2009; Alves, 2010a
Portimão (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Santarém (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Viana do Castelo (PT)	Slow charging 1x per 24 hours	Permanent	Sep-05	-	Santos et al., 2005; Almeida et al., 2009; Alves, 2010a
Vila Nova de Gaia (PT)	Slow charging 2-4x per 24 hours	Pilot	-	-	Guimarães, 2013
Vila Real (PT)	Slow charging 1x per 24 hours	Pilot	2002-2005	2002-2005	Stüssi & Santos, 2004
Viseu (PT)	Slow charging 1x per 24 hours	Permanent	Aug-05	-	Santos et al., 2005; Almeida et al., 2009; Alves, 2010a
Stockholm (SE)	Opportunity charging at bus stops	Pilot	Q1-14	-	Kerkhof, 2013; Weber, 2013
Brno (SK)		Pilot	-	-	EEO, 2013

5.2 Case study selection

Appendix II Table 16 shows an overview of the European electric bus project after the first selection round. The selected projects i.) have a duration of more than six months; and ii.) are the larger or smaller sized projects per generic charging technique (i.e. slow charging, en route charging, and battery exchange).

Table 5 shows the ultimate eight case studies that we were selected after two selection rounds, and that will be investigated more closely in this study. All eight case studies are mutually different in the combination of generic charging technique, project size (i.e. large versus small), and project status (i.e. successful versus failed). As substantiated in section 4, the selected case studies should differ as much as possible from each other, based on the criteria: geography (i.e. country, urban versus rural environment, culture, temperature), time period, bus type and size, exact charging technique. These criteria are reported in a random order of importance. An additional selection criterion is the extent to which the project organization is willing to cooperate with the research. However the latter criterion was not utilized during this research, due to the fact that all project organizations were willing to cooperate sufficiently.

Table 5. Final case studies

Case study	Criteria first selection round	Criteria second selection round
Madrid (ES)	Slow charging (large project)	Unique charging technique Unique country
Coventry (GB)	Slow charging (small project)	Unique charging technique Unique country Unique bus type (11m Optare) Relatively new (since June 2013)
Turin (IT)	En route charging (large project)	Unique charging technique Inner-city environment Long time period (since 2003)
Vienna (AT)	En route charging (small project)	Unique charging technique Relatively new (since 2012)
Rome (IT)	Battery exchange (large project)[12]	Inner-city environment Hot environment Long time period (since 1989) Experience with different bus types
Orleans (FR)	Battery exchange (small project)[13]	Unique bus type Relatively new (since 2011/2012)
Frankfurt (DE)	Failed	n.a.
Offenbach (DE)	Failed	n.a.

5.3 Case study analyses

In the remainder of this section the conceptual adoption model will be applied on the different case studies. The variables of the model could be distinguished as potential drivers and barriers to the successful implementation of electric busses. Based on the collected data, each explaining variable is analysed for each particular case study in order to determine its positive or negative influence on the implementation of the innovation. Some variables or parts of variables might lead to matching answers between all eight cases. These non-case specific variables or parts of variables are analysed in this section as well. Ultimately, an overview is given on the values of the explaining variables per case study. This overview is analysed in order to identify major drivers and barriers to the successful adoption of electric busses that can be derived from the selected case studies.

[12] In a later stage of this research we found out that the electric bus fleet that was charged by 'battery exchange' has been renewed with slow-charged electric busses (slow charging 1x per 24 hours) in 2008, because the new batteries possess a sufficient energy density to operate a full day of service on a single charge (Tecnobus, 2014).
[13] In a later stage of this research we found out that the electric bus fleet that was charged by 'slow charging' (1x per 24 hours), because the batteries possess a sufficient energy density to operate a full day of service on a single charge (Delquie, 2014).

Appendixes III, IV, V, and VI hold descriptions that are related to the data collection process. Each exception with respect to the ordinary data collection procedure is discussed in this Appendix III. It can be seen as a follow up and expansion of the data collection process as described in the methodology. In the ordinary course of business, the interviewee ought to answer a case-specific questionnaire and subsequently answer interview questions conducting a telephone interview. Each case study ought to have three interviewees (i.e. one contact person of the local government, one contact person of the bus operator, one contact person of the bus supplier). During the communication process with the different case study actors it became clear that several case studies needed to be exempted from this procedure, because several actors were not willing to cooperate (as shown in Appendix III). Appendixes IV, V and VI show each questionnaire template that each interviewee (i.e. each contact person from each case specific local government, bus operator, or bus supplier) receives before conducting the interview. Specific questionnaires hold additional case specific information and case specific questions in order to generate a complete data set on the case study.

5.3.1 Madrid

Overnight charging, Large project

Context
Madrid is a city with a hot climate and currently inhabits circa 3.2 million people (INE, 2013). A notable part of the city is the city center, which is described as a 'historic town' with narrow streets and sharp corners. The City Council has been pursuing to reduce the emissions caused by public transportation (EMT, 2013). As a result, 20 5.2-meter (or 5.3-meter according to Tecnobus (2014)) electric busses operate in the city center since 2007-2008 (Terrón Alonso, 2014).

Madrid's public transportation system primarily consists of an integrated metro- and bus-network. The metro-network is rated as the second-largest of Europe with around 300 metro stops (Metro Madrid, n.d.). With its 1093 bus stops, the urban bus network can be acclaimed to be extensive as well. EMT has a monopoly on operating the public transportation urban busses in Madrid. The organization operates 1964 busses, of which 1825 have a length of 12 meters, 89 have a length of 18 meters, 30 have a length of 8 meters, and 20 (full-electric) busses have length of 5.2/5.3-meters. The major part of the fleet, 1154 busses, are powered by biodiesel. 790 busses operate on compressed natural gas, which makes it one of the largest CNG-bus-fleets in Europe. (EMT, 2013).

The local government (i.e. the City of Madrid) is the 100 percent shareholder of the bus operator EMT. Therefore the City of Madrid sets out the main strategies for public transportation (e.g. striving for cleaner road vehicles in the inner city) and makes the approval decisions on radical propositions from EMT (e.g. purchasing and operating electric busses). Evidently, the operations of the public bus transportation in and around Madrid can be distinguished as 'in house', thus is not concession/tender based (Terrón Alonso, 2014).

Decision
As an impetus to the electric bus project, the City Council of Madrid decided to reduce the emissions produced in the city center by ordering EMT to use cleaner busses in public transportation. EMT followed up the order and studied a range of possible technical solutions. The 'green' busses were expected to be able to operate in the narrow streets of the city center and should be able to cope with the hot climate in Madrid. EMT conducted a theoretical study and tested some prototypes. Mass media that provided information on the electric bus options were mainly professional magazines. Reports from branch organizations provided information on areas of the business-related environment (Terrón Alonso, 2014). Domestic and foreign, urban and suburban bus operators provided EMT with positive

information on their experiences with electric bus systems. Tecnobus, the bus supplier of the electric busses, supplied EMT of a range of financial-, technical-, and operational-information regarding the busses (Tecnobus, 2014). Reports of research institutes did not reach EMT (Terrón Alonso, 2014). Prior, to the decision to implement electric busses, several European and Asian bus suppliers participated in a testing demo of electric busses (Tecnobus, 2014).

Eventually, EMT decided to implement the Tecnobus Gulliver U520 ESP (or 5.3m Tecnobus Gulliver U530 ESP according to Tecnobus (2014)) electric busses (EMT, n.d.; Terrón Alonso, 2014). Because of the narrow streets in the center city, no larger vehicles could be used. Additional criteria for choosing this particular electric bus were the technical specifications of the batteries, the distribution of the passenger seats, the ramp functioning, and the inner structure (specifically the driver cabin). The ultimate approval for buying the electric busses, as part of a supervising task list, was given by the owner of EMT; the City Council of Madrid (Terrón Alonso, 2014).

Although the City Council of Madrid decided to implement cleaner technologies for the bus transport, the actual decision to the specifically implement electric busses was made by EMT (Terrón Alonso,2014). More specifically, EMTs' Department of Engineering made the decision based on a study process of three departments of EMT: i.) Rolling Material, which studied the maintenance procedures and costs; ii.) Operations, which studied the specific bus routes to be driven and the shift-schedule of the drivers; iii.) Engineering, which studied and adjusted the characteristics for the bus to the service provided. An acquisition proposal was approved by the CEO and the Board of Directors (who finally made the purchase).In conclusion, we could say that the decision was made contingent-collectively[14] within EMT because a group (the Department of Engineering) made a decision that needed approval from another body. This means relatively many people, hierarchical layers, and departments are involved in the decision making process (in terms of advisory and decision making).

Current situation

Ten 5.2-meter Tecnobus Gulliver U520 ESP (EMT, n.d.) (or 5.3m Tecnobus Gulliver U530 ESP according to Tecnobus (2014)) electric busses are in operation in Madrid since the end of 2007. Another ten busses of the same type were added in mid-2008. Each bus has a passenger capacity of 25 persons, excluding the driver. The busses are 'plug in' slow charged overnight at the bus depot. According to the Director of Engineering Juan Angel Terrón Alonso (2014) of the bus operator EMT, the ending date of the electric bus project is not planned yet and is dependent on the future economic situation and monitored product lifetime.

Nowadays, the departments of Engineering and Rolling Material are involved in the organization of the electric bus operation. The Engineering department is responsible for the technology, testing, and implementation of the innovation within EMT. The Rolling Material is in charge of the maintenance - and operation-procedures (Terrón Alonso, 2014). Tecnobus provides technical information and supplies components and spare parts for maintenance (Tecnobus, 2014).

The major advantage of the implementation of electric busses is the reduction of inner-city emissions. Another advantage would be the reduction of noise pollution. A minor advantage would be the efficiency improvement in energy use (Terrón Alonso, 2014).

[14] As mentioned in section 3, a 'contingent' decision is made by one individual makes the decision, which has to be approved by another body. And a 'collective' decision' is made by a group.

The major disadvantage is the higher life-cycle-cost of the electric bus compared to conventional busses (i.e. busses that combust diesel or compressed natural gas (CNG)). Although the fuel costs are reduced, there is a costs increase in the purchase-, infrastructure- and maintenance-costs of the busses. The total increase in costs is rather low due to the 50% increased costs compensation given by the national government based on the zero-emissions principle (Terrón Alonso, 2014). An additional disadvantage, based on the experiences in Madrid, is the lower technical reliability compared to conventional busses, (Terrón Alonso, 2014). The latter can be distinguished as a result of the relatively little experience with electric busses in the world, compared to the experiences with internal combustion engine busses.

In conclusion, the electric bus operation in Madrid is considered to be a relative advantage to internal combustion engine busses, according to the Director of Engineering of EMT, Juan Angel Terrón Alonso (2014). For the bus operator and the government, the advantage of zero-emissions weighs heavier than the (relatively low) increase in life-cycle-costs. It must me noted that the size of the electric bus project (with the number of busses set on 20) is tiny compared to the size of the EMT bus operation (with a fleet of around 2,000 busses). Therefore the financial impact of an increase in the lifecycle cost of 20 busses is negligible on EMT's total budget (EMTs' turnover in 2012 was € 440,000,000,- (UITP & EU Committee, 2013). On the other hand, the reduced emission's impact of only 20 electric busses on the inner city of Madrid would be questionable as well. Though we would argue that zero-emission transport in the narrow streets of an hot environment has a substantial positive impact on the close surroundings. The latter statement is substantiated by the fact that the relative advantages of the electric busses are observable to the public, according to Terrón Alonso (2014). Finally, the relative advantage of the electric bus in performance (i.e. zero-emissions) is reduced by the decreased technical reliability compared to conventional busses.

The compatibility of the electric busses to conventional bus systems is considered to be very low. The electric bus needs a longer charging (refueling) time while its action radius is shorter. Also, drivers and maintenance personal need extra training to cope with the operational and technical differences (Terrón Alonso, 2014).

Prior to the implementation of the electric busses, the legislative risks and risks on public/media resistance were valued low to very low. The technical- and financial-risks were valued reasonably high, because the battery lifetime is unknown and the electric bus's relatively high economic value. The risk on operational setbacks were valued moderate. Looking back on the project, the financial- (i.e. investment- and maintenance-costs) and technical-expectations (i.e. reliability) were valued unrealistic by EMT (Terrón Alonso, 2014).

Table 6 shows an overview of the explaining variables as discusses in the case study analysis.

Table 6. Valued explaining variables on the case study of Madrid.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	+	The relative advantage of the electric bus in performance (i.e. zero-emissions) is reduced by the decreased technical reliability compared to conventional busses.
	Costs	-	The life-cycle-cost of the electric bus are higher compared to diesel of compressed natural gas (CNG).
	Compatibility	--	The implementation of electric busses requires many project changes.
	Testability	+	The busses were tested eight hours per day for three consecutive weeks in order to predetermine the precise range and fuel consumption along the fixed route (Terrón Alonso, 2014).
	Observability	+	According to Terrón Alonso (2014) the relative advantages of the electric busses are noticeable to the public.
	Political feasibility	n.a.	Na data are available.
	Uncertainty	-	On average, moderate risks and unrealistic expectations result in a negative impact on the decision to implement the innovation.
Potential adopting organization	Size	+	The bus operator EMT Madrid employs 8182 people (Terrón Alonso, 2014).
	Complexity, specialization, and interconnectedness	+/-	There is a moderate diversified, and moderate sized, group of specialists involved in the electric bus project which results in a diffuse effect (both positive and negative) on the implementation of the innovation.
	Innovation decision	--	Relatively many people, hierarchical layers, and departments are involved in the decision making process (in terms of advisory and decision making).
Communication, information, and social system	Characteristics of the social system	++	The social system can be classified as relatively closed system with a willingness from the major stakeholders to implement the electric busses successful.
	Availability of information	+	Information about the electric bus option was distributed to EMT by multiple media (professional magazines, company brochures of the supplier, and reports from branch organizations).
	Value and quality of information	+	The information value and quality that reached EMT is valued 'good' by EMT (Terrón Alonso, 2014).
	Degree of competiveness	--	EMT has a monopoly on the public bus transportation within Madrid. Competition could only arise from other public transportation means.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	n.a.	Na data are available.
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'[15].
	Subsidy schemes	+	The national government funds 50% of the extra investment costs of electric busses compared to the investment costs of regular diesel busses (Terrón Alonso, 2014).

[15] The is valuation to this variable is substantiated in the sub-chapter 'Non-Case Specific Variables'

5.3.2 Coventry

Overnight charging, Small project

Context

Coventry is a moderate large city with more than 300,000 residents. The city has a predominantly urban character and is located in the West Midlands of the United Kingdom. Human health and social work activities, wholesale and retail trade, manufacturing and education are the main areas of economic activity in the city (Coventry City Council, 2014). According to the bus operator De Courcey (2014), "Coventry has suffered a painful period of deindustrialization and economic decline since the closure of car factories in the 1970s. In achieving a UK first through the operation of large, fast-charging electric buses it was hoped that Coventry would attract positive national and international attention. An important secondary aim of the project was to rebrand Coventry as a low-carbon city to attract inward investment". These ambitions were realized by the extremely supportive media attention of the project and local and national TV coverage of the launch of the electric buses. As a result, three 11-meter Optare Versa EV busses currently operate daily on the 'Park & Ride South' bus route (De Courcey, 2014).

Public transportation within Coventry consists of city bus transport, including 47 regular bus routes and one park-and-ride service (Network West Midlands, n.d.). The park-and-ride service transports people with an interval of 12 minutes at peak hours from the 402 free parking spaces in Coventry South into the city centre (Coventry City Council, n.d.). The public transportation sector in Coventry is fully privatized. Due to deregulation in the UK market in 1986, passengers can choose which bus operator they choose for the similar bus destination (De Courcey, 2014).

Authorities recently estimated that Travel de Courcey now account for approximately a third of the urban bus market in Coventry (De Courcey, 2014). Other bus operators with services in Coventry are 'The A and M Group', 'A Line', 'Blue Diamond', 'Johnsons Coach Travel', 'National Express West Midlands', 'West Midlands Special Needs Transport', 'Stagecoach in Warwickshire', and 'National Express Coventry' (Coventry City Council, n.d.). The latter two are the main competitors of 'Travel de Courcey' (De Courcey, 2014). In order to stay competitive, Travel de Courcey envisages to form an outer circle around Coventry linking the population centres with key destinations by operating 'green' busses. The operation of their 'Park & Ride South'-service is a step in that direction.

Centro is the regional public sector organization responsible for public transportation in the West Midlands by managing concessions, networks, information, and investments (Centro, n.d.). Concessions for bus routes are individually tendered. The concession period for the 'Park & Ride South'-service is approximately four years and will end in 2014.

Decision

The party that took initiative to implement electric busses in Coventry was the bus operator Travel de Courcey. Adrian de Courcey (2014), CEO of the bus operator Travel de Courcey, claims that his company's desire to move to green transport vehicles was the most important driver to choose for electric bus vehicles. Other drivers were the expected increase in the number of customers and the desire of the national government and other stakeholders to move to green public transportation (De Courcey, 2014).

As a first step towards the purchase and operation of electric busses Travel de Courcey "conducted market research in terms of surveys (to both bus users and home-owners/car-owners along the route) to ascertain whether there was sufficient local support for quiet, zero-emission electric buses. After receiving very strong backing from the local community (we) [the bus operator] shared the findings with Centro and Coventry City Council to gain their support for the project". Interestingly, competing bus operators did not believe the project would work. They were dismissive of efforts to move into electric busses until the concept was proven (De Courcey, 2014).

After a financial, organizational, and operational study, the idea of using electric vehicles on a park-and-ride service was officially proposed to the transport manager Centro, the Coventry City Council, the Department of Transport via the Green Bus Fund 1 (GBF 1), and Cenex (Centre of Excellence for Low-Carbon Technologies). The proposed idea was approved and financially supported by the public sector partners, based on their desire to move to green public transport vehicles. 300,000 British Pound was provided by the GBF1 in 2009. In 2010 another 30,000 British Pound of infrastructure funding was provided by Cenex and 100,000 British Pound was provided by Centro (De Courcey, 2014). Travel de Courcey itself invested 400,000 British Pound at the start of the project (Optare, n.d.). According to De Courcey (2014), banks were reluctant to provide financial support due to the novelty of the project. After some efforts, Santadar and HSBC eventually provided funding to Travel de Courcey based on the encouraging fincial position of the bus operator[16] (De Courcey, 2014). De Courcey (2014) says the "project also required (us) [Travel de Courcey] to develop substantial financial expertise and financial modelling as the terms of the contract changed from a fully subsidised service to a commercial service with a de minimis payment from Centro. This meant that (we) [Travel de Courcey] had to model the feasibility of the project under various different scenarios, taking into account different levels of customer demand and battery lifetimes" (De Courcey, 2014).

As a next step, a technical and commercial partnership was formed with private sector organizations Optare, Valence Technologies (the battery supplier), and Epyon Power / ABB (charging- units and – infrstructure supplier). Due to the uniqueness and prestige of the Coventry project[17], investments were needed in research and development from all private partners. Travel de Courcey was engaged in technical and operational research, including changing the bus route to increase the opportunity for regenerative braking. The electric busses were extensively tested to make sure the technical operation would not lead to failures (Saint, 2014). Based on technical research and testing procedures, the electric bus system (e.g. the technical characteristics of the bus, the fast-charging units, and the charging infrastructur) was tailored to the situation in Conventry.

Unquestionable, the decision to implement electric busses was in this case made by the bus operator Travel de Courcey. By acquiring the busses themselves (with the help of subsidising schemes of public parties), the organization took full responsibility for the operation, maintenance, and ownership of the busses. Notably, the consent and support of the authorities was needed to operate the innovative busses on the public roads and to establish a complete electric bus system (including the charging infrastructure and electric grid adjustments). More specifically, the actual decision to implement electric busses was made by the senior directors of Travel de Courcey (i.e. the CEO, CFO, COO, Chief Engineer, and Chief Marketing). The departments that were involved in the decision process by conducting studies on the possible adoption of the innovation were the Finance, Engineering, Operations, and Marketing

[16] Adrian de Courcey (2014) explains on behave of the bus operator: "We are financially a very strong company for our size and are the fastest growing bus and coach company in the UK and as a strong local player we were able to persuade HSBC to fund the project. Eventually both HSBC and Santander banks were willing to fund the project.

[17] The Coventry project was the first in his kind with daily operating 11m-long Optare Versa EV busses (Optare, n.d.).

departments. Based on these facts, we could characterize the decision process as 'authoritarian'; the decision was made by a small group based on position, expertise, or status[18]. Relatively few people and hierarchical layers were involved in the decision making process (in terms of advisory and decision making). On the other hand, the number of involved departments (i.e. four) is reasonably high.

As a result of an established customer-supplier relationship, Optare was chosen by Travel de Courcey as their preferred electric bus supplier. In the case of Coventry, the supplier-buyer interaction was high due to the novelty of the project. Both parties were heavily involved in the R&D and test trajectory of the busses. Generally, Optare uses personal contacts, press releases, and pilot demonstrations in order to approach potential adopters. According to the bus supplier (Optare, 2014), it pursues several marketing strategies when establishing a relationship with customers: i.) By taking 100% technical risk on the electric bus. The operational risk is for the customer; ii.) By offering a maintenance and repair agreement; iii.) By offering the possibility to replace the electric drive system with a diesel drive system, in order to increase the flexibility of the bus and to work as a backup plan for the electric bus; iv.) By co-operating with suppliers of other electric devices to improve the company's knowledge; v.) By co-operating with infrastructure suppliers ABB (in Coventry) or APT (in other projects) based on a standardized charging system technique (Saint, 2014).

Current Situation

Three 11-meter long Optare Versa EV have been in operation as a park-and-ride service in Coventry since mid-2012. The vehicles are charged with the 'plug-in' AAB Terra 51 fast charging station to full capacity in two hours. Electric energy is stored in 56 Lithium Iron Magnesium Phosphate battery modules. During operation, an Enova Systems P120 electric drive system delivers a power of 120 kW and a torque of 650 Nm. Regenerative braking is used to increase the energy efficiency of the bus. The driving range on a full charge is approximately 120 to 150 km. The bus's maximum passenger capacity is approximately 50 persons (Optare, n.d.).

Travel de Courcey employs 318 people and operates 140 bus vehicles (De Courcey, 2014; Santander Corporate & Commercial, n.d.). The company recently tripled in size due to new contract wins and organic growth (De Courcey, 2014). The forecasted turnover for 2014 is 16 million British Pound (Santander Corporate & Commercial, n.d.). Travel de Courcey is family owned. The departments involved in the electric bus operation are Finance, Engineering, Operations, and Marketing. As mentioned before, especially the Finance and Engineering department specialized themselves in the trajectory towards the electric bus implementation. The departments were involved in compressive simulations and tests towards electric bus implementation. This results in a moderate diversity and number of specialists. Therefore the level of complexity, degree of specialization, and interconnectedness in this case has a diffuse effect on the implementation of the innovation.

The main advantage of the implementation of electric busses is the reduction in emissions. Electric bus operation reduces the emissions impact on the direct surroundings and the overall carbon foot print. Due to the fact that the Coventry project is one of the first 11-meter electric bus projects in the UK, it is seen as a prestige project. The high green innovative value of the project brought in media attention from local as well as national newspapers and television networks, which was beneficial for all projects' stakeholders. To the question if the implementation of an electric bus can lead to a competitive advantage, Adrian de Coucey (2014) answers: Yes, "… our business has tripled in size since we began

[18] More information about the different types of decisions is found in section 3.

with the electric bus project. Our main competitors in Coventry would be Stagecoach and National Express Coventry and they have not shown the same passion for innovation as we have done […] the electric buses product offering directly led to the growth in our business as we were able to leverage our innovation and experience in green transport to win three separate multimillion pound contracts. The Electric bus park-and-ride scheme in Coventry demonstrated our capabilities to a wider audience of customers and enabled us to secure more significant business contracts".

A disadvantage of the Coventry project is that the technology of larger-sized electric busses is still in an embryonic stage (De Courcey, 2014). The case of Coventry was the first project of the stakeholders regarding large-sized electric bus busses. This resulted in a delay of 18 months in the start of the daily bus service due to technical setbacks (e.g. overheating of the battery, problems with the fast charging system, problems with the charging- and electric grid-infrastructure) (De Courcey, 2014; Saint, 2014). According to Glenn Saint (2014), Deputy Chief Executive Officer and Chief Technology Officer of the bus supplier Optare, it was more important to deliver technical quality than to deliver on time due to the heavy media and public attention the project received. Another cause of the delay were organizational developments of multiple project stakeholders, as Adrian de Courcey (2014) states: "Between the start of the project and the final delivery Valence Technologies entered chapter 11 bankruptcy and Optare and Epyon Power underwent significant restructurings. Throughout this difficult period we remained the only consistent partner and had to carry the project forward and educate new staff within our partners". A second result of the uniqueness of the project was the need to convince the regional authorities of the sufficient reliability and safety of the electric bus (Saint, 2014). A third result was the initial rejection of financial funding by banks, because no guarantees of the stakeholders could be given on the novel technology[19][20] (De Courcey, 2014).

When talking about the economic viability of electric busses Travel de Courcey an Optare have contradictory perspectives. Adrian de Courcey (2014) states that current electric busses are not economical viable without subsidies. As described earlier, Travel de Courcey was compensated by a total subsidy scheme of 430,000 British Pound due to the innovations' green character and to compensate Travel de Courcey for their increased investment costs compared to conventional bus investments. Additionally, Travel de Courcey is subsidized directly by the national government with 0.06 £/km[21] for operating zero-emission busses (Saint, 2014). According to Adrian de Courcey (2014), the fundamental aspect of making a business case without subsidy schemes is a positive ratio charging/driving time. He adds "developments with for example BYD and Volvo [,electric/hybrid bus suppliers,] with vehicles that can operator longer between charges change the dynamics and increase the tipping point when these vehicles can compete effectively on a purely commercial basis with diesel vehicles" (De Courcey, 2014). On the other hand, Glenn Saint (2014) claims that current electric busses are economical viable when taking the complete lifecycle (i.e. 15 to 20 years) into account. Electric bus operations are not cost effective when accounting the bus costs as a capital expenditure or the lifecycle costs of a busses are

[19] The development of the project in a period of economic downturn might be another reason for the difficulty of receiving bank funds for the project.
[20] As mentioned earlier, eventually the banks Santadar and HSBC provided funding based on the fincial position of Travel de Courcey.
[21] This subsidizing scheme is a consequence from the 0.06 £/km rebate given on diesel taxes for low carbon (green) diesel busses. Evidently diesel taxes are not applicable on electric busses, so the 'tax rebate' can be distinguished as a direct subsidy (per kilometre) to electric bus operations (Saint, 2014).

based a lifetime equal to the concession time[22] (Saint, 2014). What can be an important factor for the ratio charging/driving time (and therefore the economic viability) is the adaption of the bus operating schedule to a different charging/refueling-time schedule. The operation schedule ought to be adapted to the passenger number over time by utilizing the number of busses in operation to the peaks and dips in passenger numbers.

In conclusion, the relative advantage of the innovation is positive. Due to its uniqueness and green innovative character the project is seen as a prestige project for the local government, bus operator, and bus supplier. Secondly, the electric bus operations lead to a reduction in emissions. However, a significant disadvantage of the project was the major delay in operation of the electric busses due to the novelty of the project and the restructurings/bankruptcy of some of the stakeholders. This disadvantage should be placed into perspective by acknowledging that successive project with 11-meter Optare Versa EV busses have had no experienced no delays (i.e. project in Nottingham, Dorchester, and York) (Kane, 2013; Stead, 2013; Saint, 2014) According to Glenn Saint (2014) of Optare, the current barriers are less technical and have more to do with commercial awareness of potential adopting organization. Still it remains questionable if the electric busses can currently compete on a commercial basis with conventional busses.

The compatibility of the electric busses to conventional bus systems is considered to be very low. Electric busses need a longer charging (refueling) time while its action radius is shorter. In addition, drivers and maintenance personal need additional training to cope with the operational and technical differences. Also, a modification in financial modeling is required due to the relatively high investment costs and low operational costs (De Courcey, 2014; Saint, 2014).

Prior to the decision to implement the electric busses the overall project risk was valued fairly high by Travel de Cource. The bus operator valued the legislative, public/media resistance, and operational risks low. However, the risks on financial and technical setbacks very valued very high due to the universal novelty of the project (De Courcey, 2014). According to De Courcey (2014), the expectations regarding the implementation and operation of the busses were very realistic. Nonetheless one important expectation was not fulfilled: the bus operator expected that the implementation of electric vehicles would lead a growth in customer volume. Evidently customers did not value the sustainability of the bus operations as a reason to switch bus operators (De Courcey, 2014).

After reviewing upon the project, it is notable that Travel de Courcey, has spoken out their intention to expand their electric bus fleet. Adrian de Courcey (2014) states that the final operation date of the current electric bus project is not known yet. If the concession to operate the park-and-ride service in Coventry is not prolonged by Travel de Courcey, the company is planning to operate their electric busses on other bus routes (De Courcey, 2014).

Table 7 shows an overview of the explaining variables as discussed in the case study analysis.

[22] The concession time is generally shorter than the lifetime.

Table 7. Valued explaining variables on the case study of Coventry.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	+	The relative advantage of the project (i.e. prestige and zero-emissions) is decreased by the project delays due to engineering setbacks and restructuring/bankruptcy of project stakeholders.
	Costs	+/-	When talking about the economic viability of the electric busses Travel de Courcey an Optare have contradictory perspectives.
	Compatibility	--	The implementation of electric busses requires many project changes.
	Testability	++	The electric busses were extensively tested to make sure the technical operation would not lead to failures (Saint, 2014).
	Observability	+	According to Adrian de Courcey (2014) the relative advantages of the electric busses are noticeable to the public.
	Political feasibility	n.a.	No data are available
	Uncertainty	+/-	Uncertainty aspect has a diffuse effect on the decision to implement electric busses. The risks are valued fairly high, however the expectations are valued realistic.
Potential adopting organization	Size	+/-	The organization is moderate sized with approximately 300 employees.
	Complexity, specialization, and interconnectedness	+/-	The organization holds moderate diversity and number of specialists, which results in a diffuse effect on the implementation of the innovation.
	Innovation decision	+	A small amount of people is involved in the decision making process. The process can be marked as 'authoritarian'.
Communication, information, and social system	Characteristics of the social system	+	The social system can be classified as supportive. The major stakeholders of the project as well as the media were extremely supportive. However competing bus operators and banks bared negative attitudes towards the start of the project.
	Availability of information	--	The major part of information on the innovation was directly supplied by the bus supplier. No substantial other media sources were used (De Courcey, 2014).
	Value and quality of information	+	The information value and quality that reached Travel de Courcey is valued 'good' to 'very good' (De Courcey, 2014).
	Degree of competiveness	++	As a result of the full privatized market, the degree of competiveness is high. According to De Courcey (2014), the implementation of electric busses brought a competitive advantage to the bus operator.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	+	There has been a relatively close connection between the Optare and Travel de Courcey, even before the electric bus project. In general, Optare uses multiple marketing strategies on the electric bus market (Saint, 2014).
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'[23].
	Subsidy schemes	++	The project is heavily subsidized (430,000 British Pound plus 0.06 £/km) by the regional and national government.

[23] The is valuation to this variable is substantiated in the sub-chapter 'Non-Case Specific Variables'

5.3.3 Turin

En route charging, Large project

Context

Turin is a large city with a population of 1.6 million citizens (Paonessa, 2012). Specifically in Turin, emissions result in strong air pollution, because of the calm climate (i.e. not windy) (Cavaglià, 2014). In order to fight air pollution the City of Turin decided to implement electric busses in its center city. The inner city's narrow streets constrains the use of small-sized busses. In 2002 23 7.5-meter slow-charged electric busses were introduced. Since 2005-2006, these electric busses are charged by inductive charging and slow charged overnight (Zazio, 2014).

The public transportation system in Turin is subdivided over three public transport networks: i.) an urban and suburban network, consisting of 100 bus lines (1,200 km in total), eight tram lines (200 km in total), and one metro line; ii.) an out-of-town network, consisting of 70 bus lines (3,600 km in total); iii.) a rail network, consisting of three rail lines. All three networks are managed and operated by the public company Gruppo Torinese Trasporti S.p.A., also known as GTT. GTT also manages the 50,000 'blue line'-, and 9,000 covered-parking spaces throughout the city. And GTT operates the specialized tourist transportation services in Turin. The urban and suburban surface network transports 640,000 passengers per day with the help of 1,200 busses and 230 trams (GTT, n.d.). These busses are run on diesel, except for 223 that run on CNG and 23 that are full electric (Taborelli, 2012). The electric vehicles operate on the STAR-1- and STAR-2-line as park-and-ride services (GTT, 2014). Each line is approximately seven km long (Taborelli, 2012).

GTT is completely owned by the City of Turin and has enjoyed a monopoly as the city's sole public transportation operator (GTT, 2014). In 2012, the first public tender of the urban and suburban network was held. A concession period of nine years was granted to GTT. Later, the concession period was extended to 14 years[24]. GTT completely owns its transportation-vehicles, -infrastructure (except the roads), and – real-estate(Cavaglià, 2014).

Decision

According to Bruna Cavaglià (2014), Head of the Mobility Service Department of the City of Turin, the main driver for implementing electric busses in the City of Turin was reducing the air pollution in the urban environment. The major barrier for the implementation of the innovation were the high investment costs[25] compared to conventional busses. Therefore, the City council requested funding from the regional government of Piemont and the state ministry. Both governmental bodies approved the request. The regional government of Piemont provided 4 million Euros and the state ministry provided 2.5 million euros as a direct subsidy. Subsequently the City Council approved the electric bus project in 2002. The actual decision to implement electric busses was made by a consultation between the City Council of Turin and GTT (Cavaglià, 2014). The public transportation organization GTT is defined as the potential adopting organization, because it owns and operates the electric busses.

During the decision period GTT received information on electric busses by bus suppliers, transport newspapers, and conferences. Also, the neighboring city of Genoa could provide firsthand information

[24] It is unknown why the concession period was prolonged.

[25] The infrastructure investment costs and bus purchase costs were assessed to be circa ten million Euros. The annual costs per bus line are 800,000 euros (Cavaglià, 2014).

on their experiences with a similar electric bus project that started in 2002. On average, the quality and value of information provided was valued 'good' (GTT, 2014).

The public tender procedure for the purchasing of the electric busses was managed by the Technical, Purchasing and Legislative department of GTT. A short testing period was included in the tender procedure: each proposed prototype vehicle was tested for one day (GTT, 2014). Paolo Zazio (2014), the co-founder and managing director of the Italian bus supplier Eco Power Technology (EPT) at the time of the procurement, states that its company was heavily involved in the testing period by enlarging test- and simulation-teams with EPT's employees. As a result of the tender procedure, EPT's bid was awarded[26] (GTT, 2014). Zazio (2014) claims that the reasons for winning the bid were EPT's high-quality product and proven experience with electric busses operating in Genoa. At the time of procurement no other charging technologies than 'slow charging' and 'battery exchange' were commercially available (GTT, 2014).

In 2003 EPT delivered the first electric busses for the Star-1-line (Cavaglià, 2014). The batteries were charged multiple times per day by slow, 'plug-in', charging (Zazio, 2014). According to Zazio (2014) this charging procedure resulted in an inefficient daily operation of the busses at hand. That is why a new charging technique was implemented by EPT in 2005-2006: static induction charging (Zazio, 2014). Subsequently, in 2007 EPT delivered the remaining busses for Star-2-line in 2007[27] (Cavaglià, 2014). All electric busses used Lead-acid gel batteries that had to be replaced every two years due to the depleting battery capacity (Lampe-Önnerud & Carlson, 2010; Taborelli, 2012). In 2011 extra funds were provided by the regional and national government to purchase Li-ion batteries that need replacement every five to six years (Cavaglià, 2014). The Li-ion batteries have been tested on two vehicles for three years. In 2014 the remaining electric bus fleet will receive these batteries permanently (Zazio, 2014).

Current situation

23 7.5-meter long ELFO electric busses operate every Monday till Friday as a park-and-ride service in Turin. The busses are divided over two different bus lines (i.e. the STAR-1- and STAR-2-line) (Cavaglià, 2014). GTT (2014) states that each run is approximately 6km up and 6km down the bus route. The runs take 35 minutes and 40 minutes of driving time respectively. At the end of each route the bus is inductively fast charged for a mean time of ten minutes (from eight to 12 minutes depending on the period of the day[28]); the amount of energy charged is 4-6%. The amount of discharge for every run is around 6-9%, therefore the bus is progressively discharged during the day. At the end of day, the state of charge of the bus is 40-50%. During the night the bus is slow 'plug-in' charged from 40-50% to 100%. According to Taborelli (2012) the inductive fast charging system "works with magnetic resonance couplings. It consists of two main components: a primary coil that is connected […] with the power grid, and a pickup coil, which is integrated in the underbody of the vehicle. The technology provides a non-contact and automated transfer". Regenerative braking is used to increase the energy efficiency of the bus. Per bus, the maximum passenger capacity is set to 37 passengers (Taborelli, 2012).

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[26] One of the competing bus suppliers was Iveco (Zazio, 2014).

[27] It is unknown why the busses for Star-2-line were delivered years after the first delivery of electric busses for the Star-1-line in 2003.

[28] The more the battery is discharged, the greater the amount of energy per time unit is 'accepted' by the battery. The battery is more and more discharged as the day goes by. Therefore, the charging time is reduced as the day goes by and the battery is more discharged.

GTT employs around 5,200 people of which approximately 2,900 are bus drivers (GTT, 2014; Taborelli, 2012). Currently the GTT's Maintenance and Operations Departments are involved in the electric bus project. Due to bankruptcy[29], the bus supplier EPT is not involved anymore in the project of Turin. Therefore, the Maintenance department has specialized itself so that it does not rely on external parties for technical knowledge on the ELFO-busses[30] (GTT, 2014). This results in a positive diversity and number of specialists. Therefore we consider the level of complexity, degree of specialization, and interconnectedness to have a positive effect on the implementation of the innovation.

As for many similar case studies, the main advantage of the implementation of electric busses is the reduction in emissions. According to GTT (2014) and Bruna Cavaglià (2014) this results in cleaner air in the inner city of Turin. Although the relative impact of 23 electric busses on the air quality of the city will not be high, the project is a starting point towards a cleaner urban environment. Therefore the project is in line with the overall air quality policy of the City of Turin (Taborelli, 2012). Other advantages of the electric busses are considered to be the reduction in noise pollution and the increase in travel comfort. To a lesser extent, the efficiency improvement in energy use is considered to be an advantage over conventional busses (Cavaglià, 2014; GTT, 2014).

The main disadvantage of the implementation of the electric busses are the increased life-cycle costs (Cavaglià, 2014). Higher investment-, operation-, and maintenance-costs result in a financial disadvantage. According to a study of Taborelli (2012), the purchase costs for an ELFO bus was circa 420,000 euro, a charging station circa 70,000 euro, and a charging rectifier 10,000 euro. GTT was compensated for 60% of the infrastructure-, and purchases-costs by the local government. A second group of disadvantages is the increased operational- and technical-risks due to the novelty and small-scale European implementation of the innovation at hand (GTT, 2014). A third disadvantage is the low energy- and power-density of the Lead-acid batteries. GTT has diminished this problem by replacing the current Lead-acid batteries with Lithium-ion batteries (with increased energy- and power-density rates). After receiving 70,000 euro in project funds from the regional government of Piemont, two Lithium-ion battery packages were tested by GTT since 2009,. After the successful testing period, the 21 remaining electric busses will receive Lithium-ion battery packages as well. The latter replacement costs amount 900,000 euro excluding VAT, of which 630,000 euros is funded by the State Ministry of Environment (Cavaglià, 2014).

In conclusion, the performance of the electric vehicles has a very positive impact on the implementation of the novelty. In addition to other advantages, the zero-emission principle of the busses is very important to the community. The actual impact on the air in the city of Turin is considered to be small, taking into account the number of vehicles: 23 electric busses compared to GTT's total bus fleet size of circa 1,200 busses plus the other internal combustion engine vehicles that drive around the city (Taborelli, 2012). There can only minor disadvantages in the performance of the electric busses be distinguished, such as an increase in operational risks compared to conventional busses. The higher costs of the electric busses negatively impact the decision to implement the innovation. This was explained by Cavaglià (2014) to be the biggest hurdle to adoption. The higher operational- and maintenance-costs of the electric busses can be placed in perspective when acknowledging that the

[29] Paolo Zazio, co-Founder and former Managing Director of EPT, claims that the main cause for the bankruptcy was that EPT could not grow due to a lack of funding from their financial partner.
[30] With the exception of Paolo Zazio, who is still cooperating with GTT as a consultant in managing the bus fleet and charging infrastructures (Zazio, 2014).

bus's higher life cycle costs are small compared to the company's turnover of circa 403 million euro[31] (Taborelli, 2012). As mentioned above, the investment costs of the STAR-1- and STAR-2-line were strongly subsidized by the regional- and national-government (GTT, 2014). Though, due to the economic downturn and therefore the lack of public money in Italy, the subsidizing schemes are diminishing. As a result, future comparable electric bus projects will be hard to realize, according to Cavaglià (2014).

The electric bus project of Turin is valued a moderate degree of uncertainty for the potential adopting organization (that is GTT in this case), which results in a diffuse impact on the decision to adopt the innovation. Prior to the decision to implement the electric busses in Turin, the project risk was valued moderate: the risks on technical failures and operational setbacks was valued very high, on the other hand the risks on financial setbacks, public/media resistance, and legislative setbacks were valued very low (GTT, 2014). Reviewing upon the project, GTT (2014) values it's average project expectation as moderate realistic. Apart from the bus operator GTT, the bus supplier EPT valued their risks on the project with different values. In particular the technical risks were valued less high (i.e. 'low' instead of 'very high') and the financial risks higher (i.e. 'high' instead of 'very low'). The financial risk was valued high because financial penalties were given to the bus supplier by the local government if product failures would arise (Zazio, 2014).

The final operation date of the current electric bus project is not planned yet. Initially, the planned project time was set from 2003 till 2017-2018 (Zazio, 2014). Then it was suggested that the electric busses would run till 2023 (GTT, 2014; Zazio, 2014). But currently no decision on the final operation date has been made (Cavaglià, 2014).

The compatibility of the electric busses to conventional bus systems is considered to be very low.
The driving/refueling-ratio is significantly different and the vehicle's action radius is decreased. In addition, bus-drivers and maintenance personal need additional training to cope with the operational and technical differences. A modification of financial modelling is required due to the relatively high investment costs and low operational costs. Also, the vehicles are dependent on a battery replacement every few years due to the battery capacity losses (Cavaglià, 2014; GTT, 2014).

After reviewing upon the project, it is notable that the Mobility Department of the City of Turin intends to expand the electric bus projects in the city (Cavaglià, 2014; Zazio, 2014). The main barrier to expansion is the city's is the lack of public money due to the economic downturn of the recent years. Secondly, Cavaglià (2014) notes that the length size of the current electric busses is too small to operate efficiently on existing standard bus routes. The current electric bus route operation is planned to be expanded by increasing the park-and-ride service from five to six days per week (Cavaglià, 2014).

Table 8 shows an overview of the explaining variables as discusses in the case study analysis.

[31] Based on data from 2005 (Taborelli, 2012).

Table 8. Valued explaining variables on the case study of Turin.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	++	The improved public perception and the reduced emissions have a very positive impact on the operations of electric busses.
	Costs	-	Although the higher life-cycle costs are expected to play a very negative role in the near future, this was not the case during the past trajectory of the electric bus project due to subsidy schemes and the relatively large overall budget (i.e. circa 403 million euros) of the bus operator.
	Compatibility	--	The compatibility of the electric bus is valued very low because of the many project modifications requires.
	Testability	-	The testing phases was short: each proposed prototype vehicle was tested for one day.
	Observability	+	The relative advantages of the electric busses are noticeable to the public. At the initiation of the project, the public was unaware of the electric busses due to bad advertisement (Cavaglià, 2014; GTT, 2014).
	Political feasibility	+	The perception of the public and media towards the implementation of electric busses is favorable (Cavaglià, 2014).
	Uncertainty	+/-	Prior to the decision to implement, the project risk was valued moderate by the potential adopting organization. Reviewing upon the project, the average project expectation was valued moderate realistic.
Potential adopting organization	Size	+	GTT employs circa 5,200 people of which approximately 2,900 are bus drivers (GTT, 2014; Taborelli, 2012)
	Complexity, specialization, and interconnectedness	+	The organization holds positive diversity and number of specialists, which results in a positive effect on the implementation of the innovation.
	Innovation decision	n.a.	Not enough data available.
Communication, information, and social system	Characteristics of the social system	++	The social system can be classified as relatively closed system with a willingness from the major stakeholders to implement the electric busses successful.
	Availability of information	-	A moderate amount of information was available in different media (i.e. company brochures and transport newspapers), though the major part was provided by the bus supplier.
	Value and quality of information	+	On average, the quality and value of information provided was valued 'good' (GTT, 2014).
	Degree of competiveness	-	Until 2011-2012 GTT had a monopoly on the public bus transportation within Turin. Since then, competition has increased due to the obligated public tender procedures. On the other hand, the embedded position of GTT in the public transport system of Turin and the protecting procurement procedures result in relatively low competitiveness[32].

[32] Instead of giving out concessions of a selection of transport lines, only one concession is given out for the complete public transportation network. This increases the investment costs-to-be-made by competing parties, thus enforces the embedded position of GTT in the public transportation sector in Turin.

Innovator/supplier	Supplier-buyer interactions and marketing strategy	+	EPT was heavily involved in the information supply and testing/simulation-procedures of GTT. The bus supplier also positioned the innovation in the market by taking 100% risk in on technical setbacks in the new project (Zazio, 2014).
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'[33].
	Subsidy schemes	++	More than 7 million euros was provided by the regional and national government as a direct subsidy for the investment costs and battery-replacement costs (Cavaglià, 2014).

5.3.4 Vienna

En route charging, Small project

Context

Vienna is a large city with approximately 1,750,000 inhabitants (Van der Pas, 2014). The winter climate is cold with temperatures far below freezing point. The past years the City Council has intended to decrease emissions in Vienna (Wiesinger, 2014). According to Clean Fleetss (2013b), an EU-funded non-profit organization, "Vienna is striving to be a leader in green transport. In its e-mobility strategy of 2012, it sets the aim to reduce personal motorised transport to less than 20% in 2025. […] Viennese buses, which all used to be powered by liquefied petroleum gas (LPG), are therefore gradually being substituted by diesel, hybrid and electric buses". In September 2012 several 7.7-meter flexible electric busses were introduced. The busses use the trams' overhead power grid to fast charge their batteries (Wiesinger, 2014)

Inner-city public transportation entails an extensive network of five metro-, 29 tram-, and 145 bus-lines, all operated by the Vienna's public transport company Wiener Linien (Wiener Linien, n.d.). The on-road vehicle Fleets of Wiener Linien currently consists of approximately 500 tramcars and 500 busses (Vienna City Administration, 2014). The public transportation business in Vienna has seen a steady increase of the number of customers over the past two decades, to an present amount of 500,000 regular customers today (Van der Pas, 2014). Clean Fleetss (2013b) states that Wiener Linien "decided to create a zero-emission zone in the historic centre with low emissions in the wider centre. Viennese buses, which all used to be powered by liquefied petroleum gas (LPG), are therefore gradually being substituted by diesel, hybrid and electric buses".

Wiener Linien is part of the 'Wiener Stadtwerke', a holding with companies responsible for the energy-supply, public transportation, and cemeteries in and around Vienna. Wiener Stadtwerke is 100 percent owned by the City of Vienna (Wiener Stadtwerke Holding AG, n.d.). Therefore the City of Vienna can directly influence the main strategies of Wiener Linien regarding public transportation. Evidently, the Vienna's management of the inner-city public bus transportation is not concession/tender based

Decision

Peter Wiesinger (2014),Wiener Linien's Head of Bus Technology, claims that the main driver to the electric bus project was the intention of the City Council of Vienna to decrease emissions in the city.

[33] The is valuation to this variable is substantiated in the sub-chapter 'Non-Case Specific Variables'

Also, Vienna is determined to be a leader in green transport. Wiener Linien was set to the task to investigate the opportunities to bring emissions in public transportation down. After a feasibility study, Wiener Linien concluded that changing from diesel Euro 6 busses to hybrid busses would not decrease emissions. Operating full-electric busses would be a more radical, but greener option. Upon this study, the City Council, decided to adopt electric busses[34]. The City Council agreed to warrant the extra costs that would be made when implementing several electric busses. A notable part of Vienna is its fifth largest tram infrastructure in the world (Gies, 2013). Wiener Linien decided to open up the possibility to use this existing infrastructure to opportunity charge their electric busses. This would lead to a reduction in infrastructure costs, however the option required a groundbreaking technology. Therefore a comprehensive market dialogue took place, resulting in four operating tests with four different bus suppliers. Ultimately, the technical and operational requirements were met by two bus suppliers (Clean Fleets, 2013b).

Subsequently an official tender was given out by Wiener Linien for the supply of the electric busses. The bus operator stated the following minimum procurement standards for the busses and management: i.) an electric vehicle that can be charged via overhead lines and induction; ii.) the maximum charging time (15 minutes); iii.) the minimum range (150 km); iv.) the minimum passenger capacity (30 passengers); v.) the maximum height, width, length and wheelbase regarding the relatively narrow inner city streets; vi.) the reliability of the bus (driving a minimum of 30,000 km before the bus endures a technical failure; vii.) a full warranty of two years for both batteries and the busses; viii.) the supplier covers the repairs to the busses, but the bus operator is responsible for maintenance (Clean Fleets, 2013b; Wiesinger, 2014). As a matter of the procurement policy, following weighed award criteria were drafted; "i.) 45% cost (including battery replacement cost, and operational overheads); ii.) 25% technology (e.g. vehicle dimensions, number of seats, door features such as low-floor and lowering ratio, range, charging time etc.); iii.) 20% reliability (e.g. downtime, maintenance time etc.); iv.) 10% charging process (e.g. charging time, charging cycle etc.)" (Clean Fleets, 2013b). In September 2011 the consortium of Siemens/Rampini received the procurement contract for 12 electric vehicles (Van der Pas, 2014). The busses gradually began daily operation: the first bus in September 2012 and the last one in July 2013 (Clean Fleets, 2013b; Wiesinger, 2014).

We define the 'potential adopting organization' as the bus operator Wiener Linien and the 'decision maker' as the City Council of Vienna. The bus operator is dependent on the City Council, as it is its strategic decision maker, financier, and 100 percent shareholder. According to Wiesinger (2014), the City Council of Vienna made the actual decision to implement electric busses in Vienna (Wiesinger, 2014). Wiener Linien is seen as the potential adopting organization, because it owns and operates the electric busses. The Wiener Linien employers involved tender award decision were the Managing Director, Vice President, and the Head of Bus Technology. The Construction department of Wiener Linien was involved in the construction/modification of the charging infrastructure[35] (Wiesinger, 2014).

[34] It is unknown how this decision process exactly evolved within the City Council of Vienna, due to the fact that no people with this knowledge could be contacted during our research.

[35] The construction/modification of the charging infrastructure was the divergence of the overhead tram line at the bus depot. The constructed 'supply line' is approximately 20 meters long and can be separated from the main tram line by a mechanical switch.

Current Situation
Since July 2013, 12 7.7m Rampini ALÉ EL busses operate on two inner-city bus lines in Vienna (Clean Fleets, 2013b; Wiesinger, 2014). According to Wiesinger (2014), the busses are being charged at the end station of each bus route for five to eight minutes using a pantograph to connect to the trams' overhead power grid. 30% of the battery energy is used during each bus round (Clean Fleets, 2013b) . As a result of the fast charges made after each bus round, smaller batteries can be used for daily operations: 96 kWh instead of 180 kWh. Which evidently decreases the extreme weight of the necessary batteries. The vehicles have the possibility to "shop" for electricity everywhere on the tram grid using a combined charger and inverter in the bus. The charging system in the bus is also compatible to induction charging in order to increase its flexibility. Though, in normal operation the busses are charged using the tram grids and plug-in slow charged during maintenance (Wiesinger, 2014). The energy efficiency of the bus is increased by the use of regenerative braking (Siemens, 2013). The driving range on a full charge is up to 150 km, consuming 85 kW (Clean Fleets, 2013b; Siemens, 2013). During winter the energy consumption is increased to approximately 92 kW due the heating system, resulting in a maximum driving distance of 120 km (Clean Fleets, 2013b). According to Clean Fleets (2013b), one technical setback arose during winter times: "the outer batteries got colder than the inner ones, which creates problems as electricity tends to be drawn from the warmer batteries. Special heaters for the outer batteries have therefore been installed. Costs had to be covered by the supplier". Due to the constantly recharging processes, the lithium-ferrite-battery lifetime is stimulated (Siemens, 2013). The expected total battery lifetime is four to five years (Wiesinger, 2014). Transport capacity of the busses is approximately 40 passengers (Siemens, 2013).

The main advantage of the implementation of electric busses is considered to be the reduction in emissions in the inner-city of Vienna (Wiesinger, 2014). The Technical University of Graz states that the implementation of the 12 electric busses "will reduce emissions of CO2 by 5.3t, of NO by 1.7t and of NO2 by 0.06t per year compared to the liquid gas buses which had been used before" (Clean Fleets, 2013b). Wiener Linien's mother-company Wiener Stadtwerke generates and supplies the electricity, which can be characterized as relatively clean electricity: 50% is generated by hydro-turbines, 15% is generated by wind-turbines, and 27% is generated by natural gas-turbines (Van der Pas, 2014). Another benefit of the electric bus operation is the improved public perception on public transportation (Wiesinger, 2014). The possibility to 'shop' for electricity using the overhead electricity grid results in an increased flexibility of the busses, compared to other electric busses. Minor advantages are considered to be the efficiency improvements in energy use and the reduction in noise pollution. The latter also leads to a minor disadvantage, which is the traffic danger arising from the low-noise vehicles (Wiesinger, 2014).

According to Peter Wiesinger (2014), the increased life time costs of electric busses compared to conventional busses is not a barrier for Wiener Linien, because the extra expenses are paid for by the national and local government. However, we will treat the increased costs as a barrier because the local government and the bus operator are strongly related to each other. Wiener Linien operates around 500 busses in total. So twelve electric busses cover around 2% of the Fleets. According to Clean Fleets (2013b), "Each electric bus cost 400,000 euro, double the cost of a comparable diesel bus. In addition, the additional charging infrastructure costs included a charging point at each end stations (each costing 90,000 euro), and charging point at the bus depot (costing 320,000 euro). [...] In terms of maintenance, electric buses will save about one third compared with diesel buses (with maintenance costs estimated at €8.000 per year) which themselves have lower maintenance costs than LPG buses". Replacement of the batteries will cost 30,000 euro for each bus every four-to-five years .The operating costs are significantly lower compared to conventional busses due to the lower fuel costs. Generally, electricity prices are much lower compared to diesel- or LPG-prices. The competitive fuel-price advantage is even higher in the case of Vienna, because the electricity is supplied by the mother-company Wiener Stadtwerke. Moreover, the operation of these particular electric busses is less expensive than for other electric (or hybrid) busses because an existing charging infrastructure was used and smaller batteries are being exploited due to the quick recharging procedure. The project is also subsidized by the National Government of Austria with 360,000 euro (Wiesinger, 2014).

In conclusion, the relative performance of the innovation is considered to be very positive. The electric bus operation decreases emissions, increases public perception and flexibility, and slightly increases energy efficiency and noise pollution. Only trivial disadvantages can be characterized ,such as the low noise operation could result in traffic danger and a minor technological setback which has currently been resolved. Electric bus expenses are high compared to conventional busses, but are not seen as decisive as the positive performance of the electric busses for the successfulness of the project (Wiesinger, 2014).

T The compatibility of the electric busses to conventional bus systems is considered to be very low. The electric bus needs a longer charging (refueling) time while its action radius is shorter. In addition, bus-drivers and maintenance personal require additional training to cope with the operational and technical differences. Also, the vehicles are dependent on a battery replacement every few years due to battery capacity losses (Wiesinger, 2014).

Peter Wiesinger (2014), Wiener Linien's Head of Bus Technology, claims that all risks on the electric bus project were valued 'very low', prior to the decision to implement the electric busses. He also claims that all expectations on the electric bus project were 'very realistic'. This very positive statement can be disputed. For instance the technical setback with the battery heating, by which the total battery power was reduced, can be characterized as an unexpected result. Due to the novelty of the project one would not be expected to value all risks as 'very low'. Therefore we determine the value of the explaining variable 'uncertainty' as unknown.

The final operation date of the current electric bus project is not known yet. Peter Wiesinger (2014) states that currently propositions are made within Wiener Linien to purchase and operate six new 12-meter electric busses in 2016. After a comprehensive internal evaluation of the current project, Wiener Linien will decide to expand their electric bus Fleets or not (Wiesinger, 2014). Furthermore, the bus supplier consortium of Siemens/Rampini are actively looking to expand their the distribution market of their "flexible trolley busses" by negotiating with other European and South American cities that have an existing tram infrastructure (Van der Pas, 2014).

Table 9 shows an overview of the explaining variables as discusses in the case study analysis.

Table 9. Valued explaining variables on the case study of Vienna.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	++	The main relative advantage of the electric bus in performance are considered to be the zero-emissions. No decisive disadvantages in performance can be distinguished.
	Costs	-	The electric bus expenses are high compared to conventional busses.
	Compatibility	-	Many project changes are required, however this project utilizes existing charging infrastructure that required few technical adjustments.
	Testability	n.a.	Prior to the decision to implement Rampini busses, four different electric vehicles were individually tested for one week. No data are available on the testing procedures after the bid was awarded.
	Observability	++	According to Wiesinger (2014) the innovation is very noticeable to the public.
	Political feasibility	n.a.	No data are available.
	Uncertainty	n.a.	Not enough data available.
Potential adopting organization	Size	+	Winier Linien employs around 8,000 people (Wiesinger, 2014)
	Complexity, specialization, and interconnectedness	n.a.	There is not enough data available on the diversity and number of specialists of Wiener Linien.
	Innovation decision	n.a.	The City Council made the actual decision to implement electric busses in Vienna, although the bus operator Wiener Linien is seen as the potential adopting organization. We are not aware of the characteristics of the decision process made within the City Council.
Communication, information, and social system	Characteristics of the social system	++	The social system can be classified as relatively closed system without much competition and with a willingness from the major stakeholders to implement the electric busses successful.
	Availability of information	-	The major part of information on the innovation was directly supplied by the bus supplier. The availability of information from professional magazines and the social/business network was substandard (Wiesinger, 2014).
	Value and quality of information	+	The value of information provided by the bus supplier was valued 'very good'. However, little amount of information from professional magazines and the social/business network was marked as 'poor' (Wiesinger, 2014).
	Degree of competiveness	--	Wiener Linien has a monopoly on all public transportation within the city of Vienna.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	n.a.	No data are available.
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'[36].
	Subsidy schemes	+	The project is financially supported by the National Government of Austria with € 360,000.

[36] The is valuation to this variable is substantiated in the sub-chapter 'Non-Case Specific Variables'

5.3.5 Rome

Overnight charging (used to be Battery Exchange), Large project

Context

Rome is a large city with a hot climate and a population size of 2.8 million people (Majo, 2011). The city has been pursuing to reduce the emissions caused by public transportation since the 1990s. A notable part of the city is the city center with its narrow streets and sharp corners. In this part of the city over 50 small-sized electric busses have operated since 1989. Till 2008 the electric busses were charged using 'battery exchange'. Since then the electric bus fleet has been renewed with 60 5.5-meter electric busses that are 'plug in' slow charged once per 24 hours (Spirito, 2014; Tecnobus, 2014).

Rome's public transportation consists out of an integrated metro-, tram-, and bus-network. The public transportation system is operated by the public company Atac SpA (also known as Atac Rome), which is owned by the City of Rome, and the private company Roma Tpl Scarl (also known as Roma Tpl), which is a consortium of private companies. Since 2000 Atac Rome is responsible for the activities and support of the city's rail- and road-public transportation, as well as the public parking system, and tourist- and school-transportation. Roma Tpl exists since 2011 and operates a small part of the city's bus system; 83 bus lines (mainly night busses lines) with 450 busses (Agenzia per la mobilità Roma, n.d.; Spirito, 2014). Atac Rome operates 334 bus lines with circa 2,000 busses (of which 400 CNG busses, 30 trolley busses, 60 electric mini-busses, and for the remainder diesel busses), five tram lines with 165 trams, two metro lines (with 49 stops), and three regional rail lines (with 47 stops in the urban area) (Calamante, 2005; Spirito, 2014; Agenzia della Mobilità Roma, n.d.).

The main strategies for public transportation (e.g. striving for cleaner road vehicles in the inner city but also deciding upon the specific bus routes and vehicle frequency on these routes) are set out by the City Council. Atac SpA has a monopoly on Rome's public transportation and realizes these strategies into services. Atac is 100 percent owned by the City of Rome and is its 'in house' operator . In order to outsource a part of the public transportation network, Atac gave out a tender for a concession to operate on some specific bus lines (amounting circa 10% of the total amount of bus lines). Roma TpL, a consortium of private companies, was awarded with this concession (Spirito, 2014)

Decision

According to the General Director of Atac SpA, Pietro Spirito (2014), the main reason for the City Council of Rome to decide[37] to implement electric busses in their city was the expected positive public perception of the electric bus project. Evidently, the political feasibility of the project had a positive effect on the implementation decision due to the positive public perception. After implementation, the electric busses have been "greatly appreciated by the users: besides being non pollutant, the most appreciated qualities are: comfort and silence" (Majo, 2011).

As a result of the City Council's decision, Atac Rome gave out an official tender for the delivery of the electric vehicles. The engineering department of Atac Rome[38] drafted the technical specifications of

[37] It is unknown how this decision process evolved, due to the fact that no people with this knowledge could be contacted during our research.

[38] The past decades, Atac Rome underwent several restructurings and held different trade names. For simplicity reasons we will converge these companies (all for 100 percent owned by the City of Rome) into 'Atac Rome' or 'Atac SpA'.

vehicles for the procurement procedure. Apart from information provided by the bus suppliers, information about the electric bus options was distributed to Atac Rome by media such as professional magazines, transport newspapers, (inter)national governmental agencies, and its social/business network. The value and quality of information is valued ‘good’, except from Atac’s business network is valued poor (Spirito, 2014). According to Stefano Strani (2014), Atac’s Head Maintenance of Electric Road Vehicles, before and after the tender procedure the engineering department tested prototypes of several bus suppliers for several months. In particular the IVECO Electro Daily and the Tecnobus prototype were extensively tested for several weeks during real operations.

Eventually Tecnobus won the tender procedure[39] and 55 Tecnobus Gulliver were adopted by Atac SpA in 1989 (Spirito, 2014). Although the City of Rome made the decision to implement electric busses in their city, the transportation operator Atac SpA is seen as the potential adopting organization, because it owns and operates the electric busses.

Since 1989 two different electric bus fleets have operated in Rome. Initially, the 55 Tecnobus Gulliver with Pb-acid batteries were charged by ‘battery exchange’ (Mannini, n.d.; Spirito, 2014). In 2005 Atac began testing two kind of electric busses: i.) two BredaMenarini ZEUS busses, in which the old lead acid battery was replaced with new ZEBRA NaCl-battery; ii.) one hybrid Altra Europolis, in which the old lead acid battery was also replaced with a ZEBRA NaCl-battery. Subsequently, from 2008 to 2010, the electric bus fleet was completely renewed with 60 new Tecnobus Gulliver busses with ZEBRA NaCl-batteries (Spirito, 2014). The battery charging technique changed from ‘battery exchange’ to ‘slow charging’, because the new batteries possess sufficient energy density to operate a full day of service on a single charge. Still, the possibility to replace batteries within a timeslot of three minutes remaines(Tecnobus, 2014). The tender- and award-criteria for the replacement of the electric bus fleet correspond to those in 1989. A five year full service contract starting from the last bus delivery onwards (expiring June 2015) was also included in the tender. Remarkably, the only company that made a bid for the new electric bus fleet was Tecnobus (Spirito, 2014).

Current Situation

The 60 5.3-meter Gulliver U530 ESP busses currently in operation in Rome are charged once per day for six to seven hours (Spirito, 2014; Tecnobus, 2014). During the day, half the bus fleet are being operated on the bus route while the other half is being recharged at the bus depot (Strani, 2014). According to Tecnobus (2014), a bus is operating along the bus route for circa 12 hours per day; driving approximately 120 km. The batteries used are Sodium Nickel Chloride ‘ZEBRA’ batteries (Meridian International Research, 2007; Spirito, 2014; Tecnobus, 2014). The carrying capacity of each bus is circa 25 passengers.

Nowadays, the ‘Divisione Superficie’ (also known as the ‘Surface Department’) of ATAC SpA is involved in the operation and maintenance of the electric busses (Spirito, 2014). In correspondence with the five year full service contract, parts of the technical staff involved in maintenance procedures are Tecnobus employees (Tecnobus, 2014).

The major advantage of the implementation of electric busses is the reduction of inner-city emissions, subsequently leading to the improved public perception on inner-city bus transport. Other advantages

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[39] It is unknown what the tender criteria were and on what grounds Tecnobus eventually won the tender procedure.

are the reduction in noise pollution, the increased travel comfort, and a growth in public transportation customer volume (Spirito, 2014).

The main disadvantage of the implementation of electric busses is the increased financial risk on the electric bus project due to the novelty and small-scale European implementation of the innovation at hand. Uncertainties about the battery lifetime of the busses is the major cause of the increased financial risk. A possible solution to this problem for the bus operator would be using a contract structure of leasing instead of buying the batteries. Another financial disadvantage is the higher life-cycle-cost of the electric bus compared to conventional busses. Although the fuel costs are reduced, there is an increase in the purchase- (of the bus and batteries) and infrastructure- (of the bus depot rebuilding and charging units) costs of the bus project. In operations, a disadvantage of the electric busses, is the small driving range in combination with the long charging times. Additionally, the creation and upkeep of the technical know-how of bus operating personnel on a small specialized fleet within a large traditional public transport company is a barrier to the implementation of electric busses. A legislative disadvantage is the non-existence of dedicated regulations for the safety of electric busses and charging units in Italy[40]. For the case of Rome, local safety rules have been introduced to manage the electric power lines and charging units at the bus depot (Spirito, 2014; Strani, 2014)

In conclusion, based on the fact that the project life time has been expanded and the electric bus fleet has been renewed since the project started in 1989, the electric busses implementation in Rome has a positive relative advantage compared to the implementation of internal combustion engine busses. Apparently, the bus operator weighs the advantages of the improved public perception and the reduced emissions heavier than the combination of higher financial risks, higher life-cycle-costs, and other disadvantages of the electric bus implementation. The burden of the financial disadvantages can be placed in perspective when acknowledging that the amount of electric busses (which is 60 vehicles) is tiny compared to Atac's total fleet size of circa 2,000 busses (Spirito, 2014). Therefore the negative financial result of the electric busses has a low impact on the total budget of Atac SpA. On the other hand, the financial disadvantages are currently evolving to more-and-more problematic barriers due to the bad financial situation of the Italian public sector (including Atac SpA) (Strani, 2014; Tecnobus, 2014; Zazio, 2014).

The compatibility of the electric busses to conventional bus systems is considered to be very low. The difference in driving/refueling-ratio requires many project changes (e.g. different time schedules and more resources). Secondly, modifications to the infrastructure are required. And third, drivers and maintenance personal need additional training to cope with the operational and technical differences (Spirito, 2014).

Table 10 shows an overview of the explaining variables as discusses in the case study analysis.

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[40] This not the case in all parts of Europe. According to Anlauf (2014), of the transportation authority TraffiQ in Frankfurt, there are strict German regulations on the charging operations of electric busses.

Table 10. Valued explaining variables on the case study of Rome.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	++	The improved public perception and the reduced emissions have a very positive impact on the implementation of the electric busses.
	Costs	--	The higher financial risks and higher life-cycle costs are currently evolving to more-and-more problematic barriers due to the bad financial situation of Atac SpA
	Compatibility	--	The implementation of electric busses requires many project changes.
	Testability	++	The electric busses were extensively tested for several months, prior and after the tender procedure (Strani, 2014)
	Observability	++	Spirito (2014) claims that the relative advantages of the electric busses are very noticeable to the public.
	Political feasibility	++	The perceived public opinion on the adoption of electric busses was positive and the main driver of the electric bus project (Spirito, 2014).
	Uncertainty	-	The financial-, operational-, technical-, and operational-risks have been valued high by the Atac SpA. The value of the expectations is unknown. Therefore we will value the explaining variable 'uncertainty' as moderate high, resulting in a negative impact on the adoption decision.
Potential adopting organization	Size	++	Atac SpA employs 11.850 people (Spirito, 2014).
	Complexity, specialization, and interconnectedness	n.a.	Not enough data are available.
	Innovation decision	n.a.	No data are available.
Communication, information, and social system	Characteristics of the social system	++	The social system can be classified as relatively closed system with a willingness from the major stakeholders to implement the electric busses successful.
	Availability of information	+/-	Although there were not many other electric bus projects in operation around the late 1990's, there was a moderate amount of information on electric busses available in different media (Spirito, 2014).
	Value and quality of information	+	On average, the value and quality of the information that reached Atac is valued 'good' by Spirito (2014).
	Degree of competiveness	--	Atac SpA has a monopoly on the public transportation system within Rome.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	n.a.	No data are available
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'[41].
	Subsidy schemes	n.a.	No data are available

[41] The is valuation to this variable is substantiated in the sub-chapter 'Non-Case Specific Variables'

5.3.6 Orleans

Overnight charging (used to be Battery Exchange), Small project

Context

Orleans is located in the center of France and inhabits 415,000 people (La mairie d'Orléans, n.d.). The City of Orleans proposed an all-electric public transportation system in its historic center. Subsequently, 7-meter 'Gépébus Oréos 2X' electric busses have been adopted and operate the in inner city of Orleans since July 2012 (L'AgglO, 2014; Keolis, 2014).

Orlean's city public transportation system consists of 33 modern trams and 220 busses that operate on two tram lines (in total 29km with 49 stops) and circa 30 bus lines(L'AgglO, n.d.; La mairie d'Orléans, n.d.). Eight of the 220 busses are full electric, the remainder are diesel powered (L'AgglO, 2014).

The regional body 'La Communauté d'agglomération Orléans Val de Loire' (also known as L'AgglO) is responsible for the public transportation system in Orleans by managing concessions, the transport plan (e.g. the routes and the frequency of busses and trams operating on these routes), pricing, and investments (L'AgglO, n.d.; L'AgglO, 2014). Once every seven years, the concession to operate the complete public transportation of Orleans is publically tendered. Currently, the private company Keolis is entrusted as the city's public transport operator. According to Benjamin Paillaud, Director of L'AgglO, Keolis follows the transportation strategies set by L'AgglO. Keolis is responsible for managing the vehicles (i.e. operations and maintenance) and human resources (L'AgglO, 2014).

Decision

The directors of the Department of Mobility and Urban Transport of Orleans together with the elected City Council of Orleans anticipated to implement electric busses in the inner-city of Orleans. The main driver was the electorate's favorable opinion on zero-emission bus operations. As a second driver, the local government anticipated to have an all-electric public transportation system in the city center to function as an exemplary part of town. As a result, L'AgglO was requested to launch a tender procedure with an important notice on the use of electric busses. Interestingly, the official tender criteria did not mention the electric busses, but the criteria did mention the focus on sustainable development. Subsequently, the French public transport operator Kéolis made a tender proposition and negotiated with l'AgglO (L'AgglO, 2014). Ultimately, Keolis was awarded a 7-year concession period on January 1 2012 (L'AgglO, n.d.).

We define the transport operator Keolis as the ultimate decision maker to operate the electri c busses, because the necessity to operate electric busses was not an official requirement in the tender procedure, as formulated by L'AgglO (L'AgglO, 2014). Keolis proposed to integrate electric busses in the tender bid (Keolis, 2014). Evidently the decision was strongly influenced by the local government that spoke out its anticipation to zero-emission public transport informally. In addition, we define Keolis as the adopting organization of the innovation, because Keolis purchased and operates the electr ic busses themselves.

The people involved in the decision to implement electric busses in Orleans were the Directors of Keolis and the Marketing/Sales-team. Based on these facts, we could characterize the decision process as 'authoritarian'; the decision was made by a relatively small group based on position, expertise, or status[42]. Relatively few departments and hierarchical layers were involved in the decision making process (in terms of advisory and decision making). On the other hand, we can only assume that the number of people was small. The fact that the project Orleans was not the first electric bus project for Keolis would suggest a relative ease to implement another electric bus.

External sources that provided Keolis with information on the specific electric busses were the bus supplier, a branch organization, and its own business network. The branch organization 'Transport Public' provided positive feedback on experience with other 'Gépébus Oréos 2X'-projects (Keolis, 2014).

The reason why specifically the electric bus type 'Gépébus Oréos 2X' was chosen, remains unexplained to us. It is evident that Keolis already was in contact with PVI and have had experiences with the electric busses of the same bus supplier (i.e. in the cities of Bordeaux and Tours) (Trans'bus, n.d.). Epvre Delquie, Commercial Director of the electric bus's supplier PVI, explains that his company is well known in France due to their long (i.e. more than 20 years) experience with electric busses. PVI's main marketing strategies are promoting itself as a reliable supplier, direct and indirect lobbying within the political establishment in favor of electric busses[43], cooperating in tests and pilot project, co-operating with infrastructure and IT suppliers by sharing innovative technology, and taking 100% technical risks on electric bus project[44] (Delquie, 2014).

After the tender was awarded Keolis executed four tests to measure the autonomy of the electric busses. The action radius target of every vehicle was 120 km, equal to the planned daily distance (Keolis, 2014). No extensive testing period was considered to be necessary due to Keolis's experience with the comparable types of electric busses in other public transportation projects (i.e. in the cities of Laval, Tours, Lyon, and Bordeaux) (Keolis, n.d.).

Current situation

Eight 7-meter 'Gépébus Oréos 2X' electric busses have been operating in the inner city of Orleans. PVI gradually supplied the busses between July 2012 and till December 2013. The busses are overnight 'plug in' slow charged (Delquie, 2014). A full charge (i.e. 85 kWh) of the Li-ion battery takes five to six hours. The motor power is rated on 47 kW. The maximum capacity of the vehicle is 22 passengers excluding the driver (Avere-France, n.d.; Trans'bus, n.d.).

As mentioned before, Keolis owns the busses. EDF-Sodetrel, PVI's technical and commercial Partner and EDF the national power supplier in France, owns the batteries and rents them to Keolis for 60 months (Delquie, 2014). At the end of the concession period in Orleans, Keolis has several options in relation to the ownership of the electric busses (as well as the diesel busses) in Orleans: i.) remain the owner and

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[42] More information about the different types of decisions is found in section 3.

[43] This method is inherent to public transportation sales, because the political establishment has a large influence on the general strategies in public transportation. However, the method's effect on the sales in Orleans is questionable because the governing body is in this case not the direct customer (Delqiue, 2014).

[44] Currently, PVI only offers 7-meter and 9-meter electric busses (PVI, n.d.). In June 2014 PVI will introduce their first 12-meter electric bus during a 6-to-12-month pilot project at the Airport of Nice. The bus's battery range is only 30-40km, but at every bus stop the bus's two supercapacitors will be fast charged in order to increase its range. PVI's corresponding principle is that large battery packs will decrease its number of passengers and therefore its economic benefit. PVI claims that currently: i.) mini-sized electric busses are not economical viable yet; ii.) mid-sized electric busses are more or less economical viable (i.e. break-even); iii.) large-sized electric busses (i.e. 12-meter or longer) are economical viable (Delquie, 2014).

operate the busses in a bus system where they granted a concession; ii.) sell the busses to a possible new bus operator in Orleans (Keolis, 2014).

French transport operator Keolis employs more than 55,000 people (Keolis, 2014). The company operates in 14 different countries, for the greater part in France (Keolis, n.d.). The department of Keolis Orleans consists of 750 employees including 500 drivers. 18 drivers are allocated to the electric vehicle operations (Keolis, 2014). Keolis Orleans is responsible for the regular maintenance of the Gépébus Oréos 2X electric busses, and therefore holds significant technical expertise over the vehicles (L'AgglO, 2014; Keolis, 2014).

According to Benjamin Paillaud (2014), the main advantage of the implementation of electric busses is the zero-emission principle and the resulting positive public opinion on the city's policy. A second important result of the zero-emissions is the 'green' exemplary function it portrays. Although, the impact of the eight zero-emission vehicles negligible given the total share of emissions in the City of Orleans, (L'AgglO, 2014). Lastly, the reduction in noise pollution due to the electric bus operations is seen as very positive as well (L'AgglO, 2014; Keolis, 2014).

Disadvantages are regarded to be the increased life cycle costs, increased technical risks, and decreased travel comfort (L'AgglO, 2014; Keolis, 2014). The increased life cycle costs compared to conventional busses are a result of an increase in bus purchase- as well as variable-costs. The latter is the case because the reduced fuel costs are negligible compared to the battery replacement costs[45] (Keolis, 2014). The extra costs do not weight heavily on the decision to implement electric busses, because the electric bus costs are embedded in the complete tender proposition, which includes the concession for the complete public transportation system (including 33 modern trams and 200 other busses) ((L'AgglO, n.d.; La mairie d'Orléans, n.d.; L'AgglO, 2014). The disadvantage of increased technical risks is a result of the innovation's reduced action radius compared to internal combustion engine busses (Keolis, 2014). And the decreased travel comfort (e.g. driving jerky and nervous) is the result of driver's lacking experience to operate electric vehicles. The latter disadvantage has currently been resolved with the help of training (L'AgglO, 2014).

The compatibility of the electric bus to a conventional bus system is valued very low. The action radius of the bus is shorter and the refueling time is lengthened. In addition, drivers and maintenance personal need additional training to cope with the operational and technical differences. A modification of financial modelling is required due to the relatively high investment costs and low operational costs.

The uncertainty of the project is considered to be diffuse. The risks were considered to be reasonably high, however the expectations on the implementation and operation are valued 'realistic' to 'very realistic'. Prior to the implementation of the busses, only the technical risks were valued moderate high by Keolis (2014). Once deployed, the concerns proved to appropriate: Some electronic problems were detected at the start of the commercial service (Keolis, 2014). After the initial technical problems were solved, no other technical setbacks were detected (L'AgglO, 2014; Keolis, 2014). After reviewing upon the project, the expectations regarding the implementation and operation of the electric busses (i.e. expectations on maintenance time, charging time, energy efficiency, and costs) are valued as 'realistic' to 'very realistic'.

[45] The batteries ought to be replaced every six to eight years (Keolis, 2014).

Table 11 shows an overview of the explaining variables as discusses in the case study analysis.

Table 11. Valued explaining variables on the case study of Orleans.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	++	Main advantages of the project are the increased public perception and the exemplary function, because of the zero-emissions principle. This results in a very positive impact on the implementation decision.
	Costs	-	There is an increase in the life cycle costs, which results in a negative impact on the decision to adopt.
	Compatibility	--	Many project changes are necessary for the electric bus's very low compatibility.
	Testability	+/-	Only four autonomy tests were performed. Though this does not result in a negative impact on the decision to implement electric busses, due to Keolis's existing experience with comparable types of electric busses.
	Observability	+	According to the L'AglIO (2014) as well as Keolis (2014), the relative advantage of the electric busses (i.e. zero-emissions) is 'noticeable' to 'very noticeable' to the public.
	Political feasibility	++	The opinion of the public and media was favorable towards electric bus operations. This very positively influenced the decision to implement electric busses (L'AgglO, 2014)
	Uncertainty	+/-	The uncertainty of the project is considered to be diffuse: The risks were considered to be reasonably high and the expectations on the implementation and operation are valued 'realistic' to 'very realistic'.
Potential adopting organization	Size	++	Keolis employs of 55,000 employees globally. 750 people work for Keolis Orleans.
	Complexity, specialization, and interconnectedness	+	The organization holds a substantial amount of diversity and number of specialists due to its great size and its great amount of activities as a transport operator, which results in a positive effect on the implementation of the innovation.
	Innovation decision	+	The process can be marked as 'authoritarian'. It is assumed that a relatively small amount of people is involved in the decision making process.
Communication, information, and social system	Characteristics of the social system	++	The social system can be classified as relatively closed system with a willingness from the major stakeholders to implement the electric busses successful.
	Availability of information	-	The mass media information on electric busses that was used was feedback from branch organization. The major part of the information was received from the by supplier.
	Value and quality of information	+	The value and quality of information provided was rated on average as 'good' (L'AgglO, 2014; Keolis, 2014)
	Degree of competiveness	+	The public tender procedure results in a high degree of competiveness.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	+	The supplier-buyer interactions during the project of Orleans were constructive and based on earlier electric bus projects in which both parties were involved. In addition, the bus supplier positioned itself pro-actively in the market.
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'[46].
	Subsidy schemes	-	No subsidies were granted (Keolis, 2014)

[46] The is valuation to this variable is substantiated in the sub-chapter 'Non-Case Specific Variables'

5.3.7 Frankfurt

Failed case

Context

The German city of Frankfurt am Main (also known as Frankfurt) inhabits circa 700,000 people, of which only two thirds have a German passport (City of Frankfurt am Main, n.d.; TraffiQ, n.d.). The City of Frankfurt portrays itself as a financial center, traffic hub, and a "very green city" (City of Frankfurt am Main, n.d.). In line with the latter statement, the City of Frankfurt signed a letter of intent in 2011 to introduce three 12-meter electric BYD busses (Anlauf, 2014; BYD, 2011; Geen Car Congress, 2011). But a year later the project was publically aborted and the electric busses never reached Frankfurt (Anlauf, 2014; Muller, 2012).

The urban public transportation system in Frankfurt consist of metro-, tram-, and bus-lines. Especially the metro-network is extensive with nine metro lines (109.6 km and 87 stops) and 203 metros in operation during peak hours, transporting 117.3 million passengers per year. In addition 89 trams operate on 10 tram-lines (111.0 km with 139 stops) transporting 49.9 million passengers per year. And 278 busses operate on 63 bus lines (567.6 km with 703 stops) transporting 53.3 million passengers per year (TraffiQ, 2012). On an average day 300,000 people use the public transportation system (City of Frankfurt am Main, n.d.; TraffiQ, n.d.).

The City of Frankfurt sets out the main strategies for public transportation (e.g. striving for cleaner road vehicles in the inner city). The managing body for public transportation, TraffiQ, is responsible for the concessions, networks, information, and investments for the urban public transportation. The City of Frankfurt is 100 percent shareholder of TraffiQ, Concessions for urban public transportation lines are individually tendered (Anlauf, 2014;TraffiQ, 2012). The bus operators that currently operate the Frankfurt bus lines are ICB, Nachtbus Frankfurt, RKH, Sippel, Urberachter Busbetriebe long, and Veolia Transport (TraffiQ, n.d.). The Rhine Main Transport Association (RMV) is the sister-organization of TraffiQ and manages the regional public transport surrounding Frankfurt am Main (RMV, 2013).

Decision

Starting point of the electric bus project was the letter of intent to implement three 12-meter electric BYD busses Frankfurt, written and signed by the mayor of Frankfurt Petra Roth, the head of Frankfurt's Department of Economics, Personnel and Sport Frank Markus, and the Chinese bus supplier Build Your Dreams (also known as BYD) in 2011 (Anlauf, 2014; BYD 2011; Green Car Congress, 2011). Next, BYD (2011) published: "The City of Frankfurt announced that it was working towards a plan to implement an integrated electric mobility system aligned with public transportation and the utilities companies. BYD will supply three (3) all-electric buses eBUS-12, two (2) DC charging stations and technical support in the first quarter of 2012. These electric buses will be used as shuttles at Frankfurt's Airport and Public transportation routes to the Gateway Gardens in Frankfurt".

A major driver for the electric bus project in Frankfurt was the stimulation of innovations in its city (Anlauf, 2014). The major Petra Roth stated at the signing ceremony of the letter of intent: "This electric bus project shows the tremendous innovation of our city and will expand our leading position in the electric vehicle development. With BYD, we are implementing a project with high technological standard that will bring both sides new insights for the design of electric vehicle in the future" (BYD, 2011). Other drivers for Frankfurt's intention to introduce electric busses was the reduced air- and noise-pollution. Moreover the implementation of the novel technology would have a sustainable character, because it copes with the global depletion of fossil fuels. The city was also in the running for the 'green city award' -

competition, which would be positively stimulated by the introduction of electric busses (Anlauf, 2014). Lastly, the upcoming mayor elections in Frankfurt could have influenced the decision to press for electric busses and publically sign a letter of intent with the electric bus supplier (Anlauf, 2014; Yin, 2014).

Conforming the European Directive on "the procurement procedures of entities operating in the water, energy, transport and postal services sectors" (European Parliament & European Council, 2004), an official public tender procedure is obliged for the implementation of electric busses in Frankfurt's public transportation system. The subjected bus lines ought to be operated by bus operators that have been granted the concession through a public tender procedure. In the case of Frankfurt, the bus operator purchases the to-be-operated busses themselves; the bus operator, not the local government, is the potential adopting organization (Anlauf, 2014). Therefore, the signed letter of intent by the City of Frankfurt and BYD is premature and does not hold value, according to Kirsten Anlauf (2014) of the Tender Management department of TraffiQ. These facts underline the potential political motive of the signed letter of intent by the major of Frankfurt. Also, at the time of the signing of the letter of intent and the several months after, no homologation was yet granted by the German government for driving the particular BYD busses on the German roads. Which also makes the letter of intent premature and of less value (Anlauf, 2014).

As a result of the City's intention to implement electric busses, TraffiQ was ordered to open up the concession tender procedures for the use of alternative technologies (e.g. electric busses). Tender criteria and legislation were changed to cope with possible bids with busses running on alternative fuels. Though no obligations or incentives to use alternative fuels were set (Anlauf, 2014). According to Alois Rautschka (2014), Managing Director of the bus operator ICB, the only award criteria was the lowest price.

Current situation

Ultimately, the concession was awarded to a bus operator driving internal combustion engine busses (Anlauf, 2014). No bus operator submitted a bid involving electric busses. Given the award criterion in combination with the bus's high investment costs and high risks, the electric bus option was inferior to a diesel bus option for bus operators who bid (Rautschka, 2014). According to the German bus operator ICB electric busses have not yet progressed beyond an experimental stage yet which result in high exploitation risks (Rautschka, 2014).

Financial similarity between investment costs of electric- and conventional-busses would be a driver in favor of electric bus implementation in Frankfurt, according to the bus operator ICB (Rautschka, 2014). Also, an increased scale of successful electric bus implementation and an increase in long term experience with the electric busses in Europe would increase the technical reliability of the innovation and would decrease its risk (Rautschka, 2014).

Nevertheless, the implementation of electric busses could also be seen as a political choice: changes to the tender- and award-criteria (e.g. adding an obligation to operate zero-emission busses) can lead to structural changes to the bus system (e.g. operating electric busses instead of conventional busses) (Rautschka, 2014). The barrier to this choice would be the lack of public money. Electric busses together with their charging infrastructure are costly and their implementation would result in spending more public money on public transportation (Anlaus, 2014).

The social system of the project in Frankfurt is considered to have a fairly negative impact on the possible implement electric busses. Apart from the negative bus operators and the fairly positive local government, the influence of interest groups, branch organizations, consultants, and researchers was diffuse (some had a negative-, some had a positive-attitude). Also the media had a diffuse point of view; positive on the major drivers of the electric bus project, but negative on the past experiences with electric busses (i.e. the failed electric bus project of Offenbach). The national- and European government did not grand any subsidies to the project, which can be regarded as a negative impact on an innovation project in Europe[47]. And the bus suppliers are regarded to have had a negative influence, because to their little or no experience with electric bus projects in Europe (Anlauf, 2014).

Currently, the City of Frankfurt still has a positive political motivation to implement electric busses, according to Kirsten Anlauf (2014). The main barrier for the city are the projects higher concession- and investment-costs (Anlauf, 2014).

Table 12 shows an overview of the explaining variables as discusses in the case study analysis.

[47] Innovative technology projects in Europe are generally granted with financial subsidy schemes from the EU or national government(s). Therefore I value the fact that no subsidies have been granted to this project as a negative influence on the decision to implement the innovation.

Table 12. Valued explaining variables on the case study of Frankfurt.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	+	As a first impression, the electric bus's performance is regarded positive. The electric bus implementation would result in a stimulation of innovation, as well as a reduction in emissions and noise.
	Costs	--	The electric bus option was more expensive than diesel bus operations (Rautschka, 2014). The only award criteria for the concession was set to be the price. Therefore the higher costs have a very negative impact on the electric bus implementation.
	Compatibility	n.a.	Not enough data are available.
	Testability	--	No electric busses were tested.
	Observability	n.a.	No data available.
	Political feasibility	+	The upcoming mayor elections in Frankfurt could have influenced the initial decision to press for electric busses. Subsequently, the appointment of a new major resulted in a less strong political driving force in favor of electric busses (Yin, 2014)
	Uncertainty	-	The risks on the innovation were valued high (Anlauf, 2014; Rautschka, 2014)
Potential adopting organization	Size	n.a.	It is unknown which particular bus operators considered electric bus operations in Frankfurt.
	Complexity, specialization, and interconnectedness	n.a.	It is unknown which particular bus operators considered electric bus operations in Frankfurt.
	Innovation decision	n.a.	It is unknown which particular bus operators considered electric bus operations in Frankfurt.
Communication, information, and social system	Characteristics of the social system	-	Apart from the local government, the major players (i.e. the bus operators and the bus suppliers) negatively influenced the decision to adopt the innovation.
	Availability of information	n.a.	Not enough information are available.
	Value and quality of information	+	Non-case specific variable.
	Degree of competiveness	+	There is a high competiveness in the public tender procedures for the bus operation concessions in Frankfurt.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	n.a.	No data are available.
National/EU government	Active outreach programs	n.a.	No electric busses are used.
	Subsidy schemes	-	No subsidies were granted (Anlauf, 2014).

5.3.8 Offenbach

Failed Project

Context

Offenbach is a small city with 177,000 residents and located near the city of Frankfurt am Main in the region of Rhine-Main(City of Offenbach, n.d.). Since 2009 the project "Elektromobilität Rhein-Main" funds electric mobility projects in the region. One of these projects was "Line 103", which entails electric mobility along a specific transport route. Part of this project was a demonstration project with an electric bus in 2011. After ten days in operation, the electric bus project was aborted due to technical setbacks. Since then, no electric bus has operated in Offenbach.

Public transport in Offenbach consists of the S-bahn and an integrated bus system. The S-bahn functions as a rapid transit commuter train system for the Frankfurt- and Rhin-Main region, (City of Offenbach, 2011). The S-bahn holds six train stops in Offenbach and is managed by the Rhine Main Transport Association (RMV), the regional public transport organization (NiO & Stadtwerke Offenbach Holding, 2013; RMV, 2013). The bus system consists of eight urban bus lines and four regional bus lines (OVB, 2011; RMV, n.d.). The bus system is operated by the Offenbacher Verkehrs-Betriebe (OVB) with a bus fleet of 60 diesel busses (OVB, 2014). Since 2007 the OVB has renewed its diesel bus fleet consistently to meet the highest European emission standards (City of Offenbach, 2011; OVB, 2011).

Next to the OVB, the Nahverkehr in Offenbach (NiO) manages the public transportation network in Offenbach by financial controlling and route planning (OVB, 2014). Both organization are subsidiaries of the Stadtwerke Offenbach Holding, which is for 100 percent owned by the City of Offenbach (City of Offenbach, n.d.). The Rhine Main Transport Association (RMV) is the sister-organization of NiO and manages the regional public transport surrounding Offenbach (RMV, 2013).

Decision

In order to stimulate the research and development of electric mobility in its country, the German national government has provided a 500 million euro subsidy scheme between 2009 and 2011. Part of this program is the "Modellregionen Elektromobilität"-project (translated to English as "Electromobility Model Regions"), which entails eight regions that participate in electric mobility pilot projects. The regions received a subsidy of 130 million euros in total (BMVI, n.d.).

One of the "Model Regions" is Rhine-Main. With the help of the governmental subsidy scheme Stadtwerke Offenbach Holding has been managing the "Elektromobilität Rhein-Main" project since 2009 (NiO & Stadtwerke Offenbach Holding, 2013; Lampmann, 2014). According to the German State Ministry of Transport and Digital Infrastructure (also known as BMVI) (n.d.) the project consist of three modules: i.) Module 1, also known as "Line 103" connects Frankfurt, Mulheim, and Offenbach with an "Ecostyle" bus line named. Along the bus line different demonstration project will show how renewable energy in transport, housing, and work can be used; ii.) Module 2 stimulates the electric vehicle use on the Rhine-Main airport; ii.) Module 3 will stimulate inner-city electric vehicle transport. In addition, the e-mobility infrastructure in the region will be developed.

Initially, the "Line 103" would only provide electric cars and electric bicycles as a mean to the development of e-mobility. In a later stage, Volker Lampmann, the Managing Director of OVB at that time, and the Rhine-Main Transport Association decided to operate an electric bus on Line 103 (Lampmann, 2014). Subsequently, the electric bus project was prepared by stating the specific technical, operational, and organizational project requirements. One of the requirements was the operation of a large-sized bus in order to transport a significant amount of people on its way (OVB, 2011).

Current situation
Due to the unavailability of suitable large-sized electric busses (i.e. with a length of 12- or 18-meter) in Germany, the decision was made to rent a 12-meter standard bus of the company Contrac GmbH (OVB, 2011). The bus was designed and build in Portugal (OVB, 2011; Lampmann, 2014). The bus used seven Lithium iron phosphate battery packs with a total capacity of 150 kWh. The batteries could be slow charged in seven hours, or quick charged in three hours (Bulut, 2011b; OVB, 2011). With a range of about 100 km on a full charged battery, the electric bus would only cover one-third of the day's required distance. Due to the limited project lifetime (i.e. approximately two and a half month) no large charging infrastructure investments were made. The bus was to be fully charged at the bus depot using a DC fast charge station that was used for another e-mobility demonstration project in Offenbach. As a safety margin the battery state of charge would not go below 40% during weekdays, and 20-30% in the weekends. As a result, the bus could be charged multiple times per day and finish two-thirds of the day's required distance for bus line 103. During charging, a conventional bus operated as a back-up vehicle. Contrac GmbH provided a maintenance procedures and the German technical inspection association TÜV Süd provided training to OVB's staff. (OVB, 2011).

The electric bus was supposed to be operational in Offenbach in March 2011, but due to delays in the technical development the electric bus was delivered late (OVB, 2011). Subsequently, after extensive technical tests by TÜV Süd the bus was granted an official approval to operate on the German roads (Bulut, 2011a). Its first regular operation was started on October 31 2011 and was planned to end on December 15 2011 (Bulut, 2011a; OVB, 2011).

Only after ten days of operation, it was decided to withdraw the bus from operations (Lampmann, 2014). For the reason that the electric bus's integrated heating system could not withstand Offenbach's winter temperatures (Bulut, 2011b; Lampmann, 2014). The remainder of the bus operated successfully these ten days. A modification to the bus's technical system could not be realized in the winter of 2011-2012, therefore the modified bus could not be tested with the similar winter temperatures at a moderate notice. As a result, Offenbach's electric bus project was aborted (Lampmann, 2014).

The compatibility of the electric busses to conventional bus systems is considered to be very low. The electric bus needs a longer charging (refueling) time while its action radius is shorter. Also a novel charging infrastructure is required. All increasing the required resources for the same operation (OVB, 2014; Lampmann, 2014)

Despite the continuation of other electric mobility activities for the project "Elektromobilität Rhein-Main", a follow up of the electric bus project in Offenbach never got off the ground (BMVI, n.d.; Lampmann, 2014). Volker Lampmann (2014) states that the main reason for this is the lack of financial resources for the City of Offenbach. Another reason for OVB would be the incompatibility of an electric bus with current bus operations: the electric bus's constricting range and the required charging time during which the bus cannot be operated (Lampann, 2014).

Table 13 shows an overview of the explaining variables as discusses in the case study analysis.

Table 13. Valued explaining variables on the case study of Offenbach.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage		
	Performance	--	The reason for the failure of the electric bus project are the technical setbacks of the electric bus.
	Costs	--	The project was part of a pilot project that was completely funded by the national government, therefore the bus costs would have no significant impact on the implementation decision. But Lampmann (2014) claims that the main barrier for not operating an electric bus in the near future are its high costs. Therefore we value the costs to have a very negative impact on the decision to implement electric busses.
	Compatibility	--	The implementation of electric busses requires many project changes. Therefore the compatibility is valued very low.
	Testability	n.a.	The electric bus project was part of a pilot project.
	Observability	n.a.	Not enough data are available.
	Political feasibility	n.a.	The electric bus project was part of a government funded pilot project.
	Uncertainty	n.a.	No data are available.
Potential adopting organization	Size	n.a.	No data are available.
	Complexity, specialization, and interconnectedness	n.a.	No data are available.
	Innovation decision	n.a.	Not enough data are available.
Communication, information, and social system	Characteristics of the social system	n.a.	Not enough data are available.
	Availability of information	n.a.	Not enough data are available.
	Value and quality of information	n.a.	No data are available.
	Degree of competiveness	n.a.	The electric bus project was part of a government funded pilot project.
Innovator/supplier	Supplier-buyer interactions and marketing strategy	n.a.	No data are available.
National/EU government	Active outreach programs	++	The electric bus project was part of a nation-wide electric mobility project from the national government
	Subsidy schemes	++	The subsidy scheme from the national government made the electric bus project possible.

5.3.9 Non-Case Specific Variables

The cases show similarities with respect to variables underneath.

Perceived characteristics of the innovation

- **Compatibility** :
  The driving operations of the electric bus are similar to ordinary bus operations (i.e. operations with internal combustion engines). The main difference in operations is the charging compared to refueling procedure. Depending on the charging technique (i.e. slow charging, fast charging, opportunity charging, or battery exchange) the electric bus operation calls for a different refueling/charging-time schedule. Secondly, the range of an electric bus is generally lower than that of a conventional bus, which results in less operational flexibility. In order to cope with these differences, specific organizational and operational concepts (e.g. timetables and service planning) need to be redesigned. Additionally, drivers and maintenance personnel require extra training in order to operate the innovation[48].

  From a technical point of view, the battery of the bus needs to be replaced regularly due to periodic battery capacity losses (i.e. circa every two years for Pb-acid batteries (Taborelli, 2012) and every four to six years for Li-ion batteries (Cavaglià, 2014; Wiesinger, 2014)) (Lampe-Önnerud & Carlson, 2010). Also, additional technical expertise is needed for employees of the engineering- and maintenance-team in order to cope with the radical new drive- and charging-system.

  A modification to financial modelling is required due to the relatively high purchase costs and low operational costs of an electric bus. Also, additional investments are required for the charging-infrastructure. The different cost models and the additional risks the novel technologies bring with (mainly due to the fact that the technology has not been implemented at a large scale in Europe), result in difficulties to receive sufficient funding for electric bus projects.

  In conclusion, the implementation of electric busses requires many project changes. On the other hand, the similarity in driving operations between the electric bus and an existing bus should be acknowledged.

Characteristics of the communication process, the information that is communicated, and the social system

- **Value and quality of information**:
  It is apparent that the major information source on the implementation of electric busses to the potential adopting organization is the bus supplier. The information provided is mostly delivered by a personal channel. Involvement of research institutes and consultants was not distinguished in the case studies[49]. Prior to the decision to implement electric busses information is gathered/received from mass media channels (e.g. professional magazines and company brochures of the supplier) and personal channels (e.g. other potential adopting organizations and bus suppliers). The bus supplier(s) is/are heavily involved in the information exchange by clarifyi ng the bus implementation. Often prototypes are demonstrated to the potential adopting organization. At the end of

[48] Note that with the implementation of new internal combustion engine busses the drivers and maintenance need training of comparable magnitude.

[49] With the exception of the case study of Offenbach, in which the RWTH Aachen University was involved in measuring the electric bus's performance (OVB, 2011).

preparation stage, the potential adopting organization critically studies the operational-, economical-, and risk-conditions and consequences of an adoption procedure. These conditions and consequences are semi-case specific; based on general terms and somewhat customized to the new situation. If this 'cost-benefit'-analysis concludes that electric busses are favourable, the decision to adopt an electric bus is made by the potential adopting organization. In case of a tender procedure, the final decision to implement electric busses depends on the concession outcome.

After the decision to adopt, a customized electric bus system is designed and implemented in close cooperation between the potential adopting organization, bus supplier, and the charging infrastructure supplier. Bus- and infrastructure-suppliers use personal channels for communication with the potential adopting organization depending on the contractual maintenance- and service-procedures. The value and quality of information exchange between the latter three actors is case-specific.

In conclusion, the value and quality of information is depended on the particular project stage. But overall, the value and quality of information is expressed in terms of 'good' by the different case study actors.

The role of the national and European government:

- **Active outreach programs**:
  Based on online search results and interviews with experts[50], few EU programs on specific electric urban bus stimulation can be acknowledged: i.) A R&D project for electric mini-busses between 1991 and 1994, in which electric bus and battery operations were tested. The EU commission funded circa 320,000 euros of the approximately 800,000 project costs (CORDIS, 1991); ii.)The ZeEUS (also known as Zero Emission Urban bus Systems) project that functions as a knowledge platform and a demonstration project for electric busses (Guida, 2014). ZeEUS "is the main EU activity for following experiences and developments of electric urban bus systems, ZeEUS aims to encourage collaboration beyond boundaries by establishing key relationships between similar projects and initiatives in the field of electromobility" (UITP, 2014). The project was launched January 23 2014 and its 13.5 million budget is partially funded by the EU (Guida, 2014; UITP, 2014). The coming years, ZeEUS will demonstrate innovative electric bus solutions in eight different cities (Guida, 2014). Only one national outreach program specifically focusses on electric busses can be distinguished: In France, the Agency for Environment and Energy Management (ADEME) in cooperation with other organizations, established the '100 bus électriques' project. The stakeholders refund 20% of the extra investment costs made on electric busses compared to conventional busses (ADEME, n.d.; Trans'bus, n.d.; Cornet, 2011).

  Other than stimulation programs that specifically focus on electric busses, electric mobility- and green transportation-stimulation programs are widely deployed in Europe and indirectly influence development of electric bus innovations. Examples of national policy measures are the 'The Green Bus Fund' in the UK, 'RVO' in The Netherlands, and 'Modellregionen Elektromobilität' in Germany. European measures on electric mobility exist of a wide range of indirect and direct R&D fundings, demonstration projects, electric vehicle congresses and seminars in order to enhance its social

[50] No unique repository of information exists on funding tools for R&D and procurement of electric urban busses. Also, experts from UITP and the European Commission could not give an overview the active outreach programs in the European Union (Debachy, 2014; Guida, 2014).

system, and knowledge institutes (such as the European Electro-mobility Observatory) (CORDIS, n.d.; EIB, n.d.; EEO, 2013). Green transportation projects related to electric bus innovation are funded by the EU programs ‘Horizon 2020’ and ‘Seventh Framework Programme (FP7)’ (CORDIS, 2014; European Commission, 2014). Electric bus innovation development is also indirectly stimulated by outreach programs on public transportation and climate innovation (Climate-Kic, n.d.; European Commission on Mobility and Transport, n.d.).

In conclusion, few outreach programs specifically focused on electric bus transport can be distinguished. On the other hand, national and European programs on climate innovation, public transportation, green transportation, and more specifically electric mobility are extensively developed. Electric bus transport is very much interrelated with these, more general, fields. And these general programs generate several projects specifically aimed at electric bus innovations. Therefore, the indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as ‘diffuse’ because we think more focused outreach programs can be developed to stimulate electric bus innovations.

Table 14Table 14 shows an overview of the non-case specific explaining variables as discusses in the analysis above.

Table 14. Valued non-case specific explaining variables.

	Explaining variable	Value	Remark
Perception of the innovation	Relative advantage	n.a.	Case specific variable
	Performance	n.a.	Case specific variable
	Costs	n.a.	Case specific variable
	Compatibility	--	The implementation of electric busses requires many project changes.
	Testability	n.a.	Case specific variable
	Observability	n.a.	Case specific variable
	Political feasibility	n.a.	Case specific variable
	Uncertainty	n.a.	Case specific variable
Potential adopting organization	Size	n.a.	Case specific variable
	Complexity, specialization, and interconnectedness	n.a.	Case specific variable
	Innovation decision	n.a.	Case specific variable
Communication, information, and social system	Characteristics of the social system	n.a.	Case specific variable
	Availability of information	n.a.	Case specific variable
	Value and quality of information	+	The value and quality of information is depended on the particular project stage. But overall, the value and quality of information are expressed in terms of 'good' by the different case study actors.
	Degree of competiveness	n.a.	Case specific variable
Innovator/supplier	Supplier-buyer interactions and marketing strategy	n.a.	Case specific variable
National/EU government	Active outreach programs	+/-	Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, we value the explaining variable as 'diffuse'.
	Subsidy schemes	n.a.	Case specific variable

5.3.10 Identification of the drivers and barriers

In this subchapter an overview of the explaining values of each variable per case study is presented. Based on this analyses the case studies, the influence on the implementation of the innovation is valued in Table 15 with '++' (i.e. strongly positive), '+' (i.e. normal positive), '+/-' (i.e. neutral), '-' (i.e. negative), or '--' (i.e. strongly negative). Some variables that could not be valued are indicated with 'n.a.', meaning 'not available'. Variables that have a 'negative' or 'strongly negative' effect can be identified as potential obstacles to the implementation of electric busses. Variables that have a 'positive' or 'strongly positive' effect can be identified as potential drivers to the implementation of electric busses. As mentioned before, the values in Table 15 render the researcher's impression on the explaining variables. Based on the analyses and values or the variables, the 'perceived critical factors' for the successful implementation of electric busses can be derived.

Table 15. Overview of the valued explaining variables per case study.

	Explaining variable	Madrid	Coventry	Turin	Vienna	Rome	Orleans	Frankfurt	Offenbach
Perception of the innovation	Relative advantage								
	Performance	+	+	++	++	++	++	+	--
	Costs	-	-	-	-	--	-	--	--
	Compatibility	--	--	--	-	--	--	n.a.	--
	Testability	+	++	-	n.a.	++	+/-	--	n.a.
	Observability	+	+	+	++	++	+	n.a.	n.a.
	Political feasibility	n.a.	n.a.	+	n.a.	++	++	+	n.a.
	Uncertainty	+/-	+/-	+/-	n.a.	-	+/-	-	n.a.
Potential adopting organization	Size	+	+/-	+	+	++	++	n.a.	n.a.
	Complexity, specialization, and interconnectedness	+/-	+/-	+	n.a.	n.a.	+	n.a.	n.a.
	Innovation decision	--	+	n.a.	n.a.	n.a.	+	n.a.	n.a.
Communication, information, and social system	Characteristics of the social system	++	+	++	++	++	++	-	n.a.
	Availability of information	+	--	-	-	+/-	-	n.a.	n.a.
	Value and quality of information	+	+	+	+	+	+	n.a.	n.a.
	Degree of competiveness	--	++	-	--	--	+	+	n.a.
Innovator/ supplier	Supplier-buyer interactions and marketing strategy	n.a.	+	+	n.a.	n.a.	+	n.a.	n.a.
National/EU government	Active outreach programs	+/-	+/-	+/-	+/-	+/-	+/-	n.a.	++
	Subsidy schemes	+	++	++	+	n.a.	-	-	++

Based on Table 15 we can distinguish similarities as well as differences in the values of explaining variables between the case studies. Where applicable, we try to explain significant differences between the values of the variables on the basis of the case studies. Based on the values of the variables we will suggest their general impact on the decision to implement electric busses (i.e. a positive impact; a driver, a negative impact; a barrier, or a diffuse impact).

Perception of the innovation
The variable *'performance'* of the innovation is for most cases marked as 'positive' or 'very positive', which indicates the successful technical- and operational-features of the innovation. Only in the case of Offenbach the 'performance' is valued poor because of the major technical failure of the electric bus. We might distinguish the 'performance' of the innovation as a driver. The influence of the variable *'costs'* on the implementation decision is for all cases marked as 'negative' to 'very negative'. It seems that higher costs can be distinguished as a barrier. The same applies to the variable '*compatibility'*, which is valued as a 'very negative' influence on the decision to adopt. There can be great differences distinguished between the case studies regarding the *'testability'* of the busses. In the case of Frankfurt the potential busses were not tested at all. For the cases of Turin and Orleans the novel busses were tested very briefly, due to existing knowledge based previous experiences with the same type of electric busses. Only for the cases of Coventry and Rome, and to a lesser extend the case of Madrid, the electric busses were extensively tested, resulting in a 'positive' to 'very positive' influence on the decision to adopt. *'Observability'* and *'political feasibility'* of electric bus implementation are in all cases, where available, 'positively' to 'very positively' valued. Thus, both variables could be distinguished as drivers. For the case of Coventry 'political feasibility' was not applicable, because governmental bodies were not involved in the decision to adopt. The cases of Madrid, Vienna, Frankfurt, and Offenbach lacked information on the 'observability' and 'political feasibility' of the electric bus implementation. The influence of the variable *'uncertainty'* on the implementation decision is for most cases marked as 'diffuse' to 'negative'. This variable can be differentiated in a component 'expectations' and a component 'risks'. The 'expectations' were valued as 'positively' (i.e. realistic) in the cases of Orleans, Coventry and Turin. In the case of Frankfurt the 'expectations' were valued 'diffuse'. Only in the case of Madrid they were valued 'negatively' (i.e. unrealistic), because of the increased investment- and maintenance-costs, and decreased technical reliability of the electric busses. On the other hand, the 'risks' were for most cases (i.e. in the cases of Coventry, Rome, Orleans, and Frankfurt) valued 'high', due to relatively high costs and the novelty of the electric bus. Only in the cases of Madrid and Turin the risks were valued 'diffuse', probably because of the relatively high total transportation budget of the adopters compared to the electric bus costs to be made. Overall, it seems that not the variable of 'uncertainty', but the variable component of 'risks' can be marked as a potential barrier to the implementation of electric busses.

Potential adopting organization
The *'size'* of the potential adopting organizations is for most cases marked as 'positive' or 'very positive'. Only in the case of Coventry the organization's 'size' is valued as diffuse, due to its relatively small size. The *'complexity, specialization, and interconnectedness'* of the potential adopting organization is for Madrid and Coventry valued as 'diffuse', because both organizations hold moderate diversified and large sized group of specialists. For Turin and Orleans the variable is valued as 'positive', because both organizations have a high diversity and high number of specialists due to their great size and their great amount of activities as transport operators. Overall, the effect of the 'complexity, specialization, and interconnectedness' of the organizations on the decision to implement the innovation is hard to distinguish. However, the fact that this variable is not a barrier can be acknowledged. On the last explaining variable, the '*innovation decision'*, there is relatively little known due to a lack of information.

In accordance with the variable 'complexity, specialization, and interconnectedness', its overall influence on the decision to implement the innovation is hard to distinguish. The influence is marked as 'very negative' for the case in Madrid, because many hierarchical levels and departments were involved in the decision to adopt. This is inherent to the bureaucratic structure of the large public organization (i.e. EMT) and the involved local government. For the cases of Coventry and Orleans, the influence of the '*innovation decision'* is marked as 'positive', because of the lean decision structure (i.e. a relatively small amount of people is involved in the decision making process), inherent to small private organizations (i.e. in the case of Coventry) or well experienced private organization (i.e. in the case of Orleans).

Communication, information, and social system

The influence of the *'characteristics of the social system'* is valued as 'positive' to 'very positive' for all successful cases, due to a willingness from the major stakeholders to implement the electric busses successful. For the failed case of Frankfurt, the variable is valued as 'negative', because the major players (i.e. the bus operators and bus suppliers) negatively influenced the decision to adopt the innovation. Therefore we could value the 'characteristics of the social system' as a factor that directly influences the implementation decision of an electric bus, evidently the social system affected successful projects 'positively' and failed projects 'negatively'. It is difficult to distinguish the variable as an overall driver or barrier. The *'availability of information'* is in Madrid valued as 'positive' and in Rome as 'diffuse'. However, in most cases (i.e. Turin, Vienna, Orleans, and Rome) the explaining variable is valued as a 'negative' to 'very negative' influence on the decision to adopt. Based on the valuation, we perceive the 'availability of information' as a barrier to the implementation of electric busses. Though the valuation of this variable is dependent on the subjectivity of the interviewees, because of a lack of measurable indicators. The valuation is subject to the interpretation and assessment of past events by one or two individuals per case study. The *'value and quality of information'* is a non-case specific variable and is in all successful case studies valued as positive. Therefore, based on Table 15, this variable can be noted as a driver to electric bus implementation. The *'degree of competiveness'* is 'positively' valued in privatized public transportation markets such as in Orleans, Frankfurt, and Coventry. In the latter case, the variable is even valued as 'very positively' due to the real-time competition bus operators encounter on overlapping bus schedules. In the case of Turin the 'degree of competiveness' is valued 'negatively' due to the partially 'in-house'[51] operations. In the cases of Madrid, Rome, and Vienna the variable is valued 'very negatively' due to the completely 'in-house' operations, which means the bus operator is completely owned by the local government and possesses a monopoly on the bus operations within the city. We perceive a high degree of competiveness as a driver and a low degree of competiveness as a barrier.

Innovator/supplier

In correspondence to the variable 'innovation decision', there is little known on the variable *'supplier-buyer interactions and marketing strategy'* due to a lack of information. Only for the cases of Coventry, Turin, and Orleans its impact is valued as 'positive', due to the heavy involvement of the bus suppliers in the bus projects. Therefore the explaining variable could be noted as a driver.

National/EU Government

The impact of *'active outreach programs'* is in most cases valued as 'diffuse'. Few outreach programs specifically focussed on electric bus transport can be distinguished. The indirect effect of the overarching programs can be acclaimed as positive. Ultimately, the explaining variable has been valued

[51] With partially 'in house' operations we mean that the bus operations are publically tendered, but in a protective manner so that the penetration grade of other bus operators – than the existing public bus operator –is negligible.

as ‘diffuse’. Except for the case of Offenbach, in which an active outreach program was a driving factor behind the electric bus project and was therefore valued as ‘very positive’. Finally, the variable *‘subsidy schemes’* is for most cases (i.e. Madrid, Vienna, Coventry, Turin, and Offenbach) valued as ‘positive’ to ‘very positive’, due to the high amounts of financial support provided by national and European governmental bodies. On the other hand, the variable is valued ‘negative’ in the cases of Orleans and Frankfurt, due to the lack of financial support of national and European governmental bodies. All in all, one could distinguish ‘subsidy schemes’ as a driver to electric bus projects, but not a necessity to successfully implement electric busses (e.g. in the case of Orleans).

5.4 Identification of the major drivers and major barriers

Based on the interpretation of the above suggested drivers and barriers, the major drivers and major barriers to electric bus implementation are identified.

Major drivers

A major driver for all case studies is the reduced environmental impact by electric bus operations. In particular the reduced local emissions. For most case studies (i.e. Madrid, Turin, Vienna, and Rome) the city’s contaminated air is a problem that negatively affect the environment and human health. The cities’ local governments choose to mitigate this problem by adopting electric bus innovations. The indefinite cleaner at close distance of the electric bus lines will surely result in great advantages regarding the environment and human health. However, the greater effects of the operation of a relative small bus fleet on air pollution in big urban environments will not be significant. Other sustainability characteristics that also work as drivers to the adoption of electric busses are the reduction in noise pollution and a more sustainable energy conversion process. The latter is the case because electricity can be generated by: i.) renewable energy sources, or by ii.) centralized fossil fuel power plants, that have a higher energy conversion efficiency than internal combustion engine vehicles (excluding the energy- transportation and –storage losses).

The sustainability aspect of electric busses results in maybe the major driver for electric bus projects: the improved perception of electorates and media. Often the local government, and therefore the political feasibility of the project, plays a crucial factor in the decision process on possible adoption. Especially when a relative small electric bus fleet compared to the adopter’s complete bus fleet is in operation, the reduced negative effect on the environment in terms of emissions is negligible. Therefore we can assume that the political feasibility, as a result of the positive public perception, plays a major role on the decision to adopt electric busses. The decisions made in Frankfurt, Orleans, and Rome (and to a lesser extend in Turin) were politically motivated. The case study of Coventry is an exception in which the public bus operator solely decided to implement electric busses. The influence of the political feasibility on the projects in Madrid, Vienna, and Offenbach is unknown due to a lack of information.
In conclusion, the green character of the electric bus can be presented as a means to reach a sustainable future as well as being a popular ‘image’ for a city. Nevertheless, in both manners the green character of the bus positively influences electric bus adoption.

Another driver to electric bus adoption is innovation policy. Stimulation of electric bus innovations can be part of a wider innovation policy of a city or company. A higher degree of innovation can lead to economic growth and/or an improvement on people’s well-being. The electric vehicle sector specifically can be stimulated by increased experiences with electric bus operations. Large scale adoption of electric busses can lead to a reduction in production costs and a reduction in risks. In the cases of Coventry, Frankfurt, and Offenbach innovation policy is marked a direct driver.

Lastly, a visionary leader could act as a driver to an electric bus project. The bus operator Travel de Courcey (in the case of Coventry) as well as the city of Frankfurt, both held individual people who instilled their ideas on their environment and decided to implement electric busses.

Major barriers

A major obstacle to electric bus adoption is the low degree of compatibility between electric and conventional busses. The fact that electric busses cannot be put into service on the same criteria as conventional busses is often a result of the differences in driving/refuelling (charging is considered to be a type of refuelling) ratio and the reduced range. This could lead to an increase in the required resources (vehicles, personnel) and eventually leads to a negative business result. The issues regarding compatibility are mostly related to differences in operations, but one must also acknowledge the disparity in financial modelling. Because of the increased investment costs and often lower operations costs, the business model of an electric bus is benefits from a longer devaluation time. In conclusion, due to the unfavourable compatibility the complete operation system (i.e. the bus technique, the operation schedule, and the infrastructure) needs to be completely customized to the electric bus operation to effectively make use of the battery and charging technique. This negatively affects the deployment flexibility of the electric bus after a concession period.

A second major barrier to electric bus adoption is the perceived (by the decision maker and potential adopting organization) increased life cycle costs compared to conventional busses. The increased life cycle costs would be mainly a result of the increased investment costs consisting of: i.) the battery purchase and replacement costs; ii.) the infrastructure investment costs. Electric busses have often not been implemented, because decision makers (which directly or otherwise indirectly pay for the bus operations) have a shortage in money or have an emphasis of making profit. Especially in the cases of Frankfurt, Offenbach, and Turin the main barrier to adoption of (extra) electric busses are the higher costs. For the successful cases studies at hand, we must acknowledge the often small electric bus fleet compared to the total bus fleet (20 electric busses compared to 1,964 busses in total in the case of Madrid; 23 electric busses compared to circa 1,200 busses in total in the case of Turin; 12 electric busses compared to circa 500 busses in total in the case of Vienna; 60 electric busses compared to circa 2,000 busses in total in the case of Rome). Therefore the financial impact of the higher life cycle costs of these relatively small electric bus fleets should be put into perspective. One can imagine that a large increase in the electric bus fleets in these cities might impact the decision maker's budget on a completely different scale. The higher life cycle costs might therefore be a major barrier. However, the fact that large-sized electric busses have higher life cycle costs is also disputed. The Chinese bus supplier BYD claims that their busses are economic viable with a lifespan of 8-10 years. The latter statement is assured by the bus operator Travel de Courcey. The bus supplier Optare states that their bus is economic viable with a lifespan of 15-20 years (Saint, 2014). Interestingly the French bus supplier PVI claims that and large-busses are economical viable with a lifespan of 12 years. PVI adds that mini-busses are not economical viable and midi-busses are more or less economical viable.

Another major barrier to large scale electric bus implementation are the high risks it bears, as perceived by the potential adopting organization. The electric bus, particularly the large-sized electric bus, is still in its embryonic phase. It is evident that electric busses have only been implemented on a small scale in Europe. High technical risks are the result of the little experience with electric busses. Strongly related to the technical risks are the high financial risks on electric bus implementation. Due to the fact that there is little known about the influence of electric bus operations on the battery's behaviour, the exact battery lifetime for each electric bus project is still a big question mark. This significantly influences the financial risks, because battery replacement costs are relatively expensive. Furthermore, the financial risks are increased by, the already mentioned, higher investment costs. For the adopter, high risks can lead to i.) project delays (in case of technical problems; in the case of Coventry); ii.) a need to convince the authorities to implement the innovation (in the cases of Coventry and Frankfurt); iii.) an increased need to convince the financiers for funding (in the case of Coventry).

Bus suppliers claim that decision makers and potential adopting organizations lack education on financial- as well as technical-knowledge on electric busses. This brings us to another obstacle: a low availability of information. Most information on electric busses is confined to information provided by bus suppliers, often not believed or at least suspiciously read by decision makers and potential adopting organizations. The one-sided information, and therefore the perceived lack in objectivity, prevents adoption. The bus suppliers BYD and Optare claim there is an ignorance over the electric bus opportunities and challenges. Saint (2014) claims that low compatibility on operating- and financial-characteristics and the perceived higher costs of electric busses compared to conventional busses are not are not barriers. Merely the incorrect perception on these features ought to be the barrier. According to Saint (2014) this would be solved by 'education' on customizing the bus operations system and financial modelling procedures. Changing the financial modelling procedures can be done by accounting the life cycle costs over its complete lifespan, instead of accounting the accounting the costs as a capital expenditure or accounting the life cycle costs over the concession period.

From a liberal point of view, a possible barrier to electric bus adoption is a low degree of competition in the organization of public transportation, resulting in risk-averse management with often a low degree of innovation adoption. We can acknowledge that there are great differences in the degree of competitiveness between the case studies. The immediate cause is the difference in an open or closed organization structure. A low degree of competitiveness correlates with 'in-house' operations (in the case of Madrid, Rome, and Vienna) or partially 'in-house' operations (in the case of Turin). In these cases the bus operator is completely owned by the local government and possesses a monopoly on the bus operations within the city. A high degree of competitiveness correlates with a privatized public transportation market (in the cases of Coventry, Orleans, and Frankfurt) by which concessions for bus operations are publically tendered. In the case of Coventry we even value a very high degree of competiveness, because bus lines are separately publically tendered over private companies, who can even compete with each other by operating on overlapping bus lines.

6 REVIEW ON CASE STUDY FINDINGS

In this section the findings based on the case study analyses will be reviewed. By means of a survey, recipients are asked to rate the impact of the major drivers and barriers (as distinguished in the previous section) on the implementation of electric busses in Europe. In addition, the recipients are asked about their profession and experience within the electric bus sector. The main survey characteristics and results are discussed below. Following, we will discuss the impact of the survey results in correspondents with the findings of the previous section.

A survey link was emailed to 212 stakeholders of the European electric bus market. Email contacts were collected with the help of (in)direct personal contacts, internet websites, and an extensive conference contact list of the 'VDV-Akademie Konferenz: Elektrobusse – Markt der Zukunft!' (Berlin, 2014). The latter culminated in the fact that most recipients are located in Germany and surrounding countries (e.g. The Netherlands, Finland, Poland, Czech Republic). In addition, a web link was posted on two LinkedIn-groups related to the electric bus industry: i.) 'Electric Vehicles and Hybrid Electric vehicles test - EV/HEV test', with 3,842 members; ii.) Fast Charged Electric Bus Group, with 202 members.

Survey results

In the end, 70 recipients answered the survey; 66 email contacts and 4 LinkedIn group-members. Figure 8 shows a graph with an overview of the representation of the population's jobs within the electric bus sector. Evidently bus operators, bus suppliers/manufacturers, and researchers individually have a high representation. Appendix VII shows an overview of the response percentage and response count regarding the answers to this question.

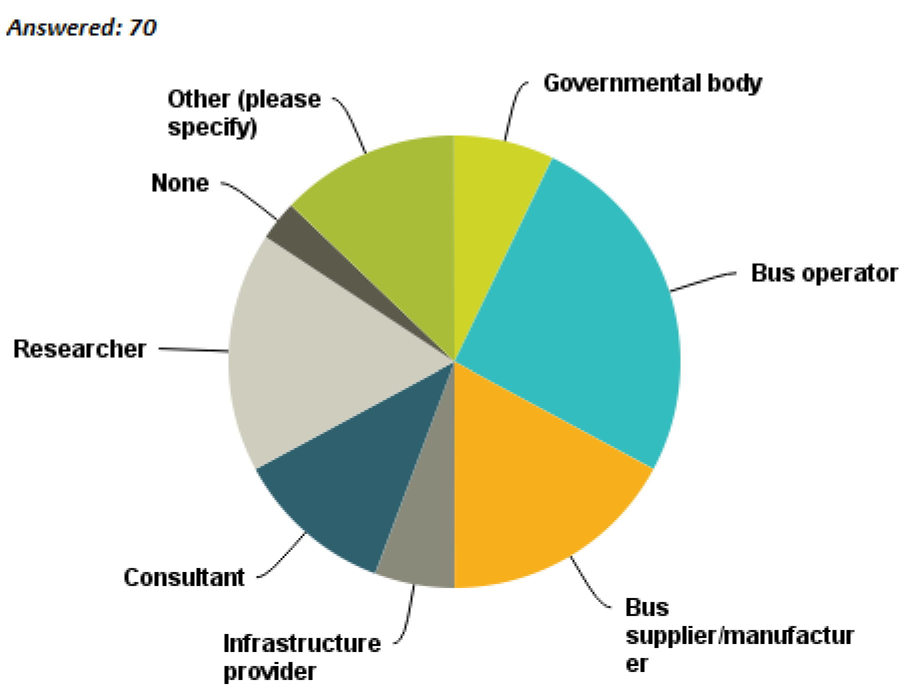

Figure 8. Representation of the survey population's answer to the question "What is your job within the electric bus sector?"

Figure 9 shows a graph with an overview of the representation of the population's experience regarding electric bus projects. Recipients were allowed to give multiple answers. Evidently over 70% of all recipients are -- or have been -- involved in an electric bus pilot- or demo-project. And more than 90% of all correspondents have been involved in electric vehicle- or bus-projects. Appendix VII shows an overview of the response percentage and response count regarding the answers to this question.

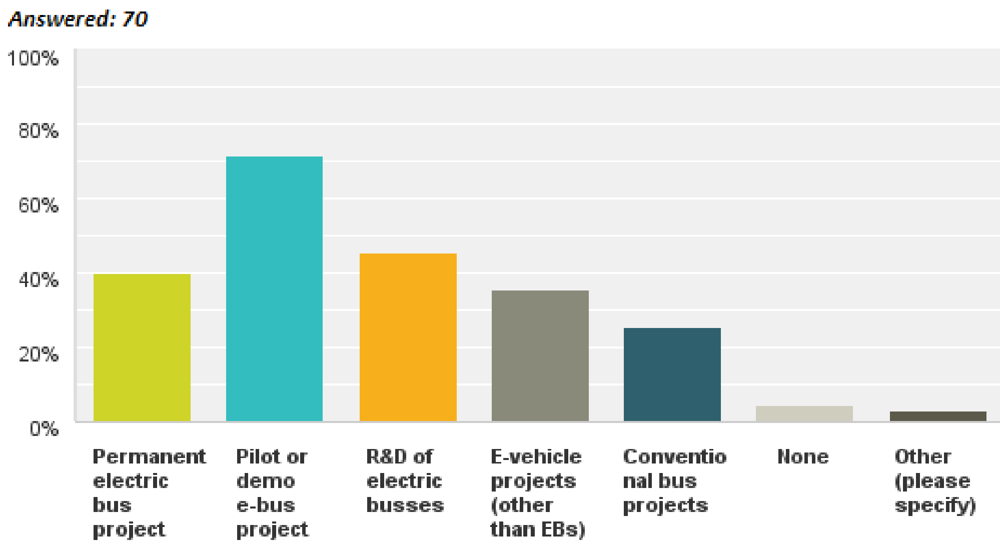

Figure 9. Representation of the survey population's answer to the question "What is your experience regarding electric bus projects? (multiple answers are allowed)"

Figure 10 shows a graph with an overview recipient's mean valuation of the barrier's impact on the implementation of electric busses in Europe. The recipients were asked to value each barrier's impact on a scale from 1 to 5; 1 for a very low impact, 5 for a very high impact. An explanation of each barrier was posted next to the survey question:

- Low compatibility: adverse compatibility between electric and conventional busses, due to differences in operation (e.g. driving/refuelling and reduced range) and the disparity in financial modelling (as a result of increased investment costs and lower operations costs).
- Perceived higher LCC: increased life cycle costs compared to conventional busses mainly as a result of the increased investment costs consisting of: i.) the battery purchase and replacement costs; ii.) the infrastructure investment costs. Note that the possible higher life cycle costs is also disputed by stakeholders.
- Higher risks: High technical risks are the result of the little experience with electric busses. High technical risks are a result of technical uncertainties (in particular on battery lifetime) and the high investment costs.
- Low avlb. of information: decision makers and potential adopting organizations would lack sufficient education on financial- as well as technical-knowledge on electric busses as a result of a low availability and mostly one-sided information. Coping with this barrier would mitigate barriers such as 'low compatibility' and 'perceived higher life cycle costs'.
- Low degree of competition in the organization of public transportation: low degree of competition in the organization of public transportation, resulting in risk-averse management with often a low

degree of innovation adoption. A high degree of competitiveness correlates with a privatized public transportation market. A low degree of competitiveness correlates with 'in-house' operations.

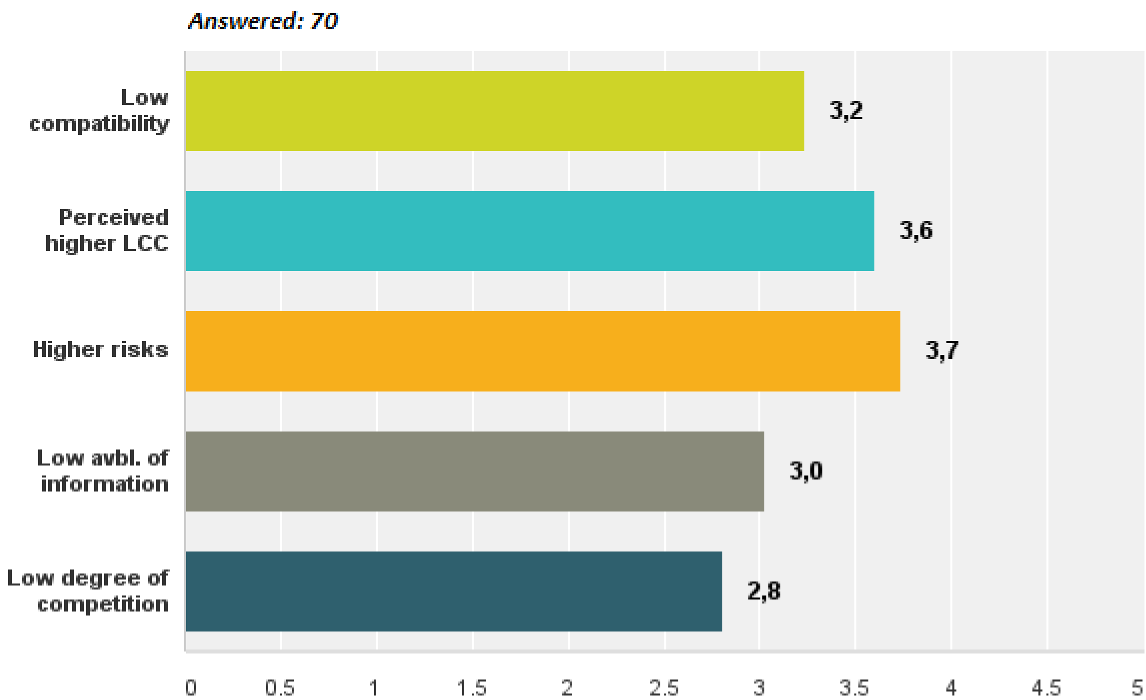

Figure 10. The mean impact of barriers on electric bus implementation in Europe according to the survey population, by answering the survey question "What are the barriers to electric bus implementation in public transportation in Europe?".

Appendix VII shows an overview of the response percentage and response count regarding the answers to this question. Also the distribution of the answers to the question is presented.

Figure 11 shows a graph with an overview of the recipient's mean valuation of the drivers' impact on the implementation of electric busses in Europe. The recipients were asked to value each drivers' impact on a scale from 1 to 5; 1 for a very low impact, 5 for a very high impact. An explanation of each driver was posted next to the survey question:

- Red. Impact on environment: Regarding reduced local emissions, but also reduced noise and a more sustainable energy conversion process
- Impr. public perception: possible electric bus implementation is often seen as a political decision. In a representative democracy, a political decision is often fueled by the opinion of electorates and the media.
- Innovation policy: Stimulation of electric bus innovations can be part of a wider innovation policy of a city or company. A higher degree of innovation can lead to economic growth or an improvement on people's well-being.
- Visionary leader: Radical changes in public transportation can result from individual people (i.e. leaders) who instilled their ideas on their environment.

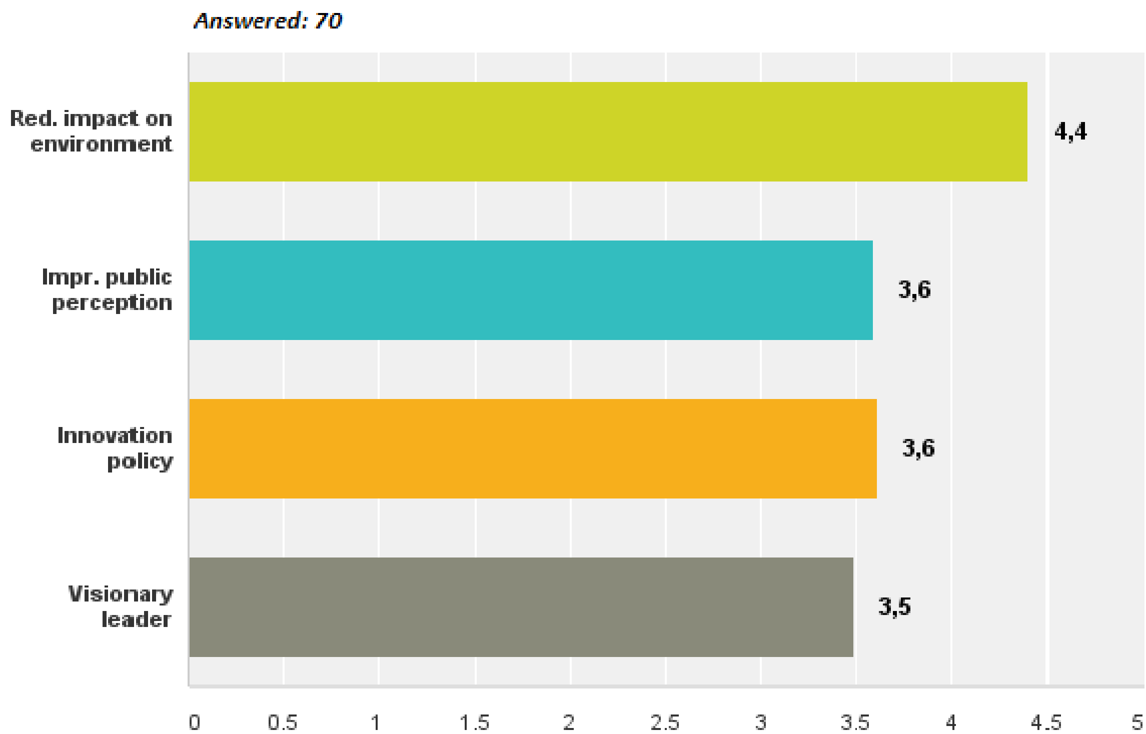

Figure 11. The mean impact of drivers on electric bus implementation in Europe according to the survey population, by answering the survey question "What are the drivers to electric bus implementation in public transportation in Europe?".

Appendix VII shows an overview of the response percentage and response count regarding the answers to this question. Also the distribution of the answers to the question is presented.

Survey findings

Based on Figure 10 we can conclude that the two barriers that have the highest impact on successful electric bus adoption in Europe are: i.) the perceived high life cycle costs of electric bus adoption; ii.) the higher technical- and financial-risks that are associated with electric bus adoption. The low compatibility, low availability of information, and possible low degree of competition in the public transportation sector, also negatively impact the successful adoption of electric busses in Europe, yet to a lesser extent.

Based on Figure 11 we can conclude that the biggest driver to electric bus adoption in Europe is the reduced impact on the environment. The improved public perception, innovation policy, and a visionary leader, also positively impact the successful adoption of electric busses in Europe, yet to a lesser extent.

Appendix VIII shows a Chi-square analysis of the relation between a selection of the dependent and independent variables of the survey.

The conclusions in this section are based on the results of the researched sample, which does not represent the stakeholders of the complete European electric bus sector. Most survey recipients were located in Germany and surrounding countries (e.g. The Netherlands, Finland, Poland, Czech Republic). Southern Europe, which accommodates a large part of the European electric bus projects, was underrepresented. Therefore we are mindful of making firm conclusions on the survey results in relation to the complete European electric bus sector.

7 CONCLUSION

By answering the sub-questions of this thesis, this section will gradually lead up to answering the main research question. Subsequently a reflection upon the research is presented, including research limitations and contributions. And eventually, recommendations for stakeholders of the electric bus industry and the academic world are given.

7.1 Answers to the sub-questions

Three sub-questions, considering the different aspects of the research, are answered below.

7.1.1 What current electric bus projects can be found across Europe?

Table 4 in section 5 shows an overview of European electric bus projects as of December 2013. All projects are commissioned by local governments and include full electric busses (defined as a five-metre autonomous public transportation road vehicle driving along a fixed route, using solely on-board battery- or supercapacitor-stored electricity to drive). Project types that are included are demonstrations, pilot projects, and permanent projects that have been or still are in progress. For some projects that are included, the electric busses will be operational in the near future. For each project, information is given on the geological location, charging technique, project type, begin- and end-date of operation (i.e. the date on which the busses are operated on the road), and references. Several projects lack information, which is illustrated by an empty box in the overview.

7.1.2 Which major drivers and barriers to the successful adoption of electric busses can be derived from a selection of electric bus projects in Europe?

Major drivers of electric bus adoption compared to conventional bus adoption are the innovation's reduced environmental impact, the improved public perception of the decision maker and/or potential adopting organization, the innovation policy of the decision maker, and the presence of a visionary leader.

The reduced environmental impact is a result of reduced local emission, reduction in noise pollution and a more sustainable energy conversion process. For most case studies (i.e. Madrid, Turin, Vienna, and Rome) the city's local government chooses to mitigate their city's contaminated air by adopting electric bus innovations.

Stimulation of electric bus innovations (i.e. electric bus adoption) can be part of a wider innovation policy of a city or company. A higher degree of innovation can lead to economic growth and/or an improvement on people's well-being. In the cases of Coventry, Frankfurt, and Offenbach innovation policy is marked as a direct driver.

The improved public perception regarding the decision maker and/or potential adopting organization can be a result of the implementation of sustainable and innovative solutions (i.e. electric bus implementation). This prospect positively influence the political motivation to adopt electric busses. In particular the adoption decisions made in Frankfurt, Orleans, and Rome (and to a lesser extend in Turin) were politically motivated.

A visionary leader can act as a strong driver by instilling his or her ideas on the environment and deciding to implement electric busses (i.e. in the cases of Coventry and Frankfurt).

Major barriers of electric bus adoption compared to conventional bus adoption are the low degree of compatibility, the perception of higher life cycle costs, and the higher associated risks. Also the low availability of information and the possible low degree of competition in the organization of public transportation are distinguished as barriers.

The low degree of compatibility between electric and conventional busses is often a result of the differences in driving/refuelling ratio (charging is considered to be a type of refuelling), the reduced range, and the disparity in financial modelling because of the increased investment costs and often lower operations costs. This results in required project- and system-changes, which negatively affect the deployment flexibility of the electric bus after a concession period.

The perceived (by the decision maker and potential adopting organization) increased life cycle costs compared to conventional busses would be mainly a result of the increased investment costs consisting of: i.) the battery purchase and replacement costs; ii.) the infrastructure investment costs. Electric busses have often not been implemented, because decision makers (which directly or otherwise indirectly pay for the bus operations) have a shortage in money or have an emphasis on making profit. Especially in the cases of Frankfurt, Offenbach, and Turin the main barrier to adoption of (extra) electric busses are the higher costs. However, the fact that large-sized electric busses have higher life cycle costs is also disputed by several bus suppliers.

The high risks, endured by the adopting organization when adopting electric busses, can be divided in technical- and financial-risks. Both are a result of the limited experience with electric bus implementation; electric busses have not been implemented on a large scale in Europe. Additionally, the high investment costs enhance financial risks. For the adopter, high risks can lead to i.) project delays (in case of technical problems; in the case of Coventry); ii.) a need to convince the authorities to implement the innovation (in the cases of Coventry and Frankfurt); iii.) an increased need to convince the financiers for funding (in the case of Coventry).

The low availability of information is the result of one-sided information sources for decision makers and/or potential adopting organizations. Most information on electric busses is confined to information provided by bus suppliers. The one-sided information, and therefore the perceived lack in objectivity, prevents adoption. According to bus suppliers, the mistrust of decision makers and potential adopting organization, leads to an ignorance over the electric bus opportunities and challenges.

The possible low degree of competition in the organization of public transportation is a result of 'in-house' operations (in the case of Madrid, Rome, and Vienna) or partially 'in-house' operations(in the case of Turin). A high degree of competitiveness correlates with a privatized public transportation market (in the cases of Coventry, Orleans, and Frankfurt) by which concessions for bus operations are publically tendered. This possible barrier can result in risk-averse management, often with a low degree of innovation adoption.

7.1.3 Which major drivers and barriers to the successful adoption of electric busses in Europe can be derived from a review by stakeholders from the electric bus sector in Europe ?

Based on the review by stakeholders from the electric bus sector, it is concluded that the biggest driver to electric bus adoption in Europe is the reduced environmental impact. The improved public perception, innovation policy, and a visionary leader, also positively impact the successful adoption of electric busses in Europe, yet to a lesser extent.

Additionally, the two barriers that have the highest impact on successful electric bus adoption in Europe are: i.) the perceived high life cycle costs of electric bus adoption; ii.) the higher technical- and financial-risks that are associated with electric bus adoption. Low compatibility, low availability of information, and possible low degree of competition in the public transportation sector, also negatively impact the successful adoption of electric busses in Europe, yet to a lesser extent.

7.2 Answer to the main research question

Based on the answers to the sub-questions the main research question is answered:

What are major drivers and barriers to the successful adoption of electric busses in Europe?

The major driver to successful adoption of electric busses are the innovation's reduced environmental impact. Other major drivers, that have slightly less impact on the decision to adopt, are the improved public perception of the decision maker and/or potential adopting organization, the innovation policy of the decision maker, and the presence of a visionary leader.

The reduced environmental impact of electric bus operation is valued as the biggest driver. Especially in large urban environments traffic emissions result in problematic air pollution. Electric bus adoption is a solution to mitigate the air pollution. Unlike conventional busses, electric busses do not produce local emissions. Moreover, electric bus operation leads to reduced noise pollution and a potential sustainable energy conversion process. The latter is the case for the use of renewable energy sources and/or an increased conversion efficiency. Larger scale implementation of electric busses will result in a significant reduced impact on the local environment. Baring in mind that in urban areas the greatest sources of NO_x-pollution is freight- and bus-transportation. And by acknowledging that a public transportation bus is on average in service for more than 16 hours per day – in comparison a private car operates for 45 minutes per day on average (Glotz-Richter, 2014). Regardless of the positive environmental effects, one should be mindful of negative environmental effects caused by the production of batteries (Clean Fleet, 2013; Van der Pas, 2014).

Innovation policy functions as major driver for electric bus adoption. This is reflected in subsidy schemes, active outreach programs, and simply imposing decisions to adopt electric busses. The fact that a higher degree of innovation can lead to economic growth and/or an improvement on human well-being motivates organizations to be involved in innovation policy.

The improved public perception of the decision maker and/or potential adopting organization also functions as a driver in European electric bus adoption. It is an anticipated result of the implementation of sustainable and innovative solutions (i.e. electric bus implementation). The improved public perception is not only a driver for governmental bodies, but also for corporations which might increase their corporate value as a return.

Visionary leaders are also drivers to electric bus implementation. Multiple electric bus projects (e.g. Coventry and Frankfurt), as well as many other public transportation projects (e.g. Los Angeles's America Fast Forward plan) had individual people who imposed their ideas and functioned as a major driver to change (MacKechnie, n.d.; Cervero, 1998).

Five major barriers to successful adoption of electric busses can be distinguished. The two barriers that have the highest impact on successful electric bus adoption in Europe are: i.) the higher technical- and financial-risks that are associated with electric bus adoption; ii.) the perceived high life cycle costs of electric bus adoption. Other major barriers, that have slightly less impact on the decision to adopt, are the low degree of compatibility, low availability of information, and possible low degree of competition in the public transportation sector.

High technical- and financial risks are a result of the limited experience with electric bus implementation, which reduces its reliabilities. High financial risks are a result of high technical risks as well as the high investment costs. Charging techniques, other than overnight charging, often result in even higher risks due to the higher investment costs and fewer experience. The fact that the exact battery lifetime in electric busses is often unknown plus the fact that battery costs are a critical factor in the investment costs, significantly increases the financial risks. The potential adopting organization can overcome the latter when the batteries are leased instead of bought. As a result, the organization that leases the batteries will be inflicted with these risks. For the adopter, high risks can lead to i.) project delays (in case of technical setbacks); ii.) a need to convince the authorities to implement the innovation; iii.) an increased need to convince the financiers for funding. In general, electric bus suppliers take 100 percent risk on technical setbacks of a bus (excluding technical failures caused by excessive operations). Though, they cannot always guarantee a certain bus quality over a period of 10-20 years (bus lifetime). This results in high financial risks due to possible fines from the local government or bus operator. For small stakeholders, risks are often too high to bear due to the high investment costs, the long time period (a concession runs for multiple years and the bus lifetime is 10-20 years), and the current embryonic phase of the innovation. It is evident that additional space is needed for failure in order to push competition and activity in the electric bus market.

The perceived higher life cycle costs of electric busses function as a major barrier. The increased life cycle costs would be mainly a result of the increased investment costs consisting of: i.) the battery purchase and replacement costs; ii.) the infrastructure investment costs. In several cases, decision makers declare that electric busses were not adopted due to a lack of money or the emphasis of making profit. According to these stakeholders, electric bus adoption is simply not viable without subsidising schemes (e.g. direct subsidies or taxation policies) from the local, national, or European government. Nonetheless, the fact that large-sized electric busses have higher life cycle costs compared to conventional busses, is disputed by several bus suppliers. And the current economic viability of electric busses is unknown to academic literature (Lajunen, 2014). Therefore, this research uses the term 'perceived' higher life cycle costs, as perceived by decision makers. Evidently, there is more research needed on financial modelling in order to conclude on the current economic viability of the innovation. It is assumed that electric bus projects will become economically viable without governmental support as a result of technological advances and a fall in the investment cost due to wider economies of scale. Miller (2010) states that high-power battery costs are expected to drop circa 50 percent between 2010 and 2020. This will greatly influence the life cycle costs of electric busses due to the fact that mainly battery costs are accountable for the bus's high purchase price. Also, the operational costs of electric vehicles are assumed to decrease in relation to conventional vehicles, due to an expected increase in fossil fuel prices.

The low degree of compatibility of electric busses to conventional bus transportation systems is a moderate high obstacle to successful implementation of electric busses. This barrier stems from differences in the driving/refuelling ratio (charging is considered to be a type of refuelling), the reduced range, and the disparity in financial modelling (as a result of increased investment costs and often lower operations costs). Low compatibility of electric busses could lead to an increase in the required resources (vehicles, personnel) and eventually to a negative business result. Also, it reduces the flexibility of electric bus operations: because the bus's complete operation system (i.e. the bus technique, the operation/charging schedule, and the infrastructure) needs to be completely customized to effectively make use of the battery and charging technique. The low degree of compatibility results in required project- and system-changes, which negatively affects the adoption rate.

The low availability of information also functions as a moderate high obstacle to successful implementation of electric busses. Most information on electric busses is confined to information provided by bus suppliers. The one-sided information, and therefore the perceived lack in objectivity by decision makers and/or potential adopting organizations, prevents adoption. According to bus suppliers, the mistrust of decision makers and potential adopting organization, leads to an ignorance over the electric bus opportunities and challenges. Merely the incorrect perception on technical- and financial-features would be the barrier. This barrier would be solved by increasing the availability of information, and therefore knowledge, by educating stakeholders (e.g. by enlarging knowledge platforms, tests and demonstrations). In addition, knowledge ought to be magnified through research on technical- and financial-aspects (e.g. on battery lifetime and life cycle costs) of electric busses. The lack in reliable information is amplified by the fact that the electric bus industry is seen as 'one brand'. Technical failures of any electric bus affects all electric bus suppliers in the market, although this is not always justified; A problem which is also acknowledged with electric cars or other radical innovations implemented in conservative markets.

The possible low degree of competition in the public transportation market functions as a moderate high obstacle to successful implementation of electric busses. A low degree of competition results in risk-averse management with often a low degree of innovation adoption. Conservative decision makers (inherent to the public transportation market), often operating in a market with a low degree of competition, are cautious for technological change. They often wait with adopting novel technologies, assuming the technology will greatly improve over time. There are great differences between European public transportation systems regarding the degree of competitiveness. There are systems that are managed by 'in-house' operators (e.g. in the cases of Madrid, Rome, and Vienna) or partially 'in-house' operators (e.g. in the case of Turin), which both corresponds to a low degree of competition. On the contrary, there are systems with a privatized public transportation market (e.g. in the cases of Coventry, Orleans, and Frankfurt), which corresponds to a high degree of competition. Accordingly the denomination 'possible' is added to the notion 'low degree of competition'.

To conclude this section, it is acknowledged that the electric public bus market is a network of various actors with different interests, which makes it a complex market. It is not a simple buyer-supplier market. For instance the political establishment, infrastructure companies, electricity companies, and the public are heavily involved as well. Also, the great differences (e.g. in institutional embedding or environmental characteristics) between public transportation systems in Europe result in a demand for tailored strategies in order to cope with the barriers to successful implementation of electric busses.

7.3 Reflection

Are the main research results a surprise? Based on the literature study on the current electric bus market, as show in section 1, it was expected that the high investment costs and high risks would be major barriers - and the reduced environmental impact of electric busses would be a major driver - to the successful adoption of electric busses. Based on innovation literature, the need for sufficient i.) knowledge-development, ii.) knowledge–diffusion, and iii.) stimulation programs through governmental bodies for successful innovation diffusion and utilization, was expected. Though, what can be indicated as a surprise is the fact that the driver of 'improved public perception' has not constituted as the number one driver of electric bus adoption in Europe. Based on literature of Feitelson & Salomon (2004), it was expected that the political decision making process of a representative government would be greatly impacted by the perception of the electorates and media, acknowledging that the adoption of innovations in the public transportation sector has usually been subject to a political decision. It is suspected that this unexpected outcome is the result of the low involvement of electorates in the political establishment nowadays, because the overall public's awareness of the pollution problems and conviction in the solution of zero-emission vehicles are regarded to be 'positive' (according to the case study findings).

The remainder of this sub-chapter reflects upon this study by discussing the research limitations and research contributions as follows.

7.3.1 Research Limitations

This research provides an overview of electric bus projects in Europe, for the greater part based on project-, company- and government-websites. In addition, some electric bus projects were identified based on one source only. Therefore, the reliability of this overview is very much dependent on the reference assessment of the thesis researcher. The reliability of the overview of electric bus projects in Europe could be improved by expanding its number of unique sources and by utilizing an increased number of solid reference sources such as project's stakeholders and academic papers. For all that, we recognize that it is highly probable that this overview of electric bus projects in Europe does not incorporate all current electric bus projects in Europe due to a lack of information.

With the help of case study analyses the field of electric bus projects was explored and its major drivers and barriers were identified. Case study analyses are perceived to deliver several research limitations:

- First of all, the subjectivity in case study analyses is high. According to McCutcheon and Meredith (1993), the data analysis exploits two basic sets of tool that are conditional to subjectivity and therefore the assessment of the researcher at hand: i.) data reduction methods, in this case the summarization and characterization of project's information supplemented by interviewees, websites, and academic papers; ii.) logical analysis, in this case the interpretation, valuation, and explanation of the characterized and summarized data towards the identification of the major drivers and barriers. McCutcheon and Meredith (1993) state that the "case study's reader must judge the researcher's reasoning, based on the provided data. In fact this subjectivity is a property shared with virtually all forms of empirical research. However the case's subjective portion tends to be very obvious, while other empirical methods may have similarly subjective elements (such as a survey respondent's interpretation of questionnaire items) that are cloaked in objectivity through their reduction to numerical data". The latter statement results in a favourable utilization of case study research, due to its easy-to-recognize subjectivity, case study research is more transparent. Moreover, the correcting feedback on researcher's falsely interpreted- or summarized-data by study objects is more extensive than for many other research methods, because of the more closely studied study objects (Ragin, 1992, from Flyvbjerg, 2006).
- Second, the internal and external validity of a case study analysis remains subject to discussion. The fact that the major drivers and barriers were identified based on a qualitative analysis of a 'sample' (i.e. case study), does not necessarily indicate that these are the major drivers and barriers to the implementation of electric busses in Europe. Certainly, an attempt was made to enhance the degree of internal and external validity by maximum varying case studies and relying on a survey as a review method. Overall, the research method chosen (e.g. large samples compared to single cases) was strongly linked to the research objectives (as shown in section 2). Flyvbjerg (2006) states that

the "difference between large samples and single cases can be understood in terms of the phenomenology for human learning (..). If one, thus, assumes that the goal of the researcher's work is to understand and learn about the phenomena being studied, then research is simply a form of learning. If one assumes that research, like other learning processes, can be described by the phenomenology for human learning, it then becomes clear that the most advanced form of understanding is achieved when researchers place themselves within the context being studied. Only in this way can researchers understand the viewpoints and the behavior, which characterizes social actors". Especially in this research on electric bus adoption, human behaviour is analysed (i.e. the adoption of a novelty by an organization is inherent to human-perception, -decision-making, and -interactions, for instance as presented in politics) and therefore this study is interrelated to social sciences. According to Flyvbjerg (2006), context-independent theory does not exist in social sciences because of his view "that human behavior cannot be meaningfully understood as simply the rulegoverned acts found at the lowest levels of the learning process and in much theory". Accordingly, the strong context-related method of case-study research is justified. As mentioned in section 4, the addition of quantitative research (i.e. survey research) to qualitative research (i.e. case study research) has resulted in an enhancement of the external validity. With the help of the survey research the degree of impact of certain phenomena (i.e. the major drivers and barriers to electric bus adoption that were distinguished and analysed in the case study analyses) over different population groups was measured. And the differences in impact of these phenomena according to different population groups could be measured (as shown in Appendix VIII).

- Third, the reliability of the case study findings is subject to discussion due to the analysis' high dependency on the findings of the study objects (i.e. interviewees), the limited amount of study objects (i.e. interviewees), and possible language barriers during interviews. The researcher's assessment of the reliability of interviewee's findings is based on comparison between other interview's findings. Also possible bias attitudes of stakeholders are considered. The reliability of the case study findings could be enhanced by using more and different shareholders as interviewees. As a result, answers of study objects can be compared and false findings can be corrected. Although the research design in section 4 featured the utilization of at least three interviews per case study, this could not always be achieved in practice. Four case study analyses (i.e. Madrid, Coventry, Rome, and Offenbach) entailed only two interviews. And one case study analysis was based on only one interview (in the case of Vienna) [52], which significantly reduced the analysis's reliability. Lastly, Additionally, the language barrier in several interviews could have reduced the reliability of the case study findings. Some interviewees did not acquire a full professional proficiency in English which results in possible communication errors . Some interviews answers were provided in German or French and had to be translated using https://translate.google.com/.

The adapted model of Bontekoning (2002) has provided us with an extensive guideline in order to analyse complex case studies of current electric bus projects. Through the guidance of this model the i.) information collection, ii.) structuring of the information analyses, and ii.) the presentation of the research finding, could be fixated in a comprehensive style. The relatively great amount of variables (compared to other conceptual models) taken into account was helpful in simplifying the complexity of the adoption of the innovations in the different case studies. A significant reduction of the measured characteristics would dismiss the closeness of the case study to the real-life situation. Based on research of Flyvbjerg (2006) the scope of case study analysis and its high degree of detail is important in two respects: "First, it is important for the development of a nuanced view of reality, including the view that

[52] Three case study analyses were based to three interviews (i.e. Turin, Orleans, and Frankfurt).

human behavior cannot be meaningfully understood as simply the rulegoverned acts found at the lowest levels of the learning process and in much theory. Second, […] (if) researchers wish to develop their own skills to a high level, then concrete, context-dependent experience is just as central for them as to professionals learning any other specific skills".

The addition of 'political feasibility' (including the perceived characteristics of electorates) to the adaption model of Bontekoning (2002) results in the incorporation of a fundamental aspect of decision making in public transportation systems (Feitelson & Salomon, 2004). However, the collection of reliable data on political decision making (and therefore seemingly political feasibility) has deemed to be a research limitation. City councils were mostly unfavourable towards providing information on their actions. Moreover, political decision making is subject to a complex and dynamic environment in which facts are often not registered. In order to properly analyse political complexity, a more reliable amount of data is necessary. Also, the data collection on the characteristics of electorates, as perceived by the potential adopting organization, ought to be enhanced to investigate the impact of the perceived public opinion on the decision to adopt electric busses.

An additional limitation to the utilization of the conceptual adoption model is the subjectivity of the valuation of each explaining variable during the case study analyses, and therefore identifying the drivers and barriers. As a result, the degree of reproducibility of the research at hand is reduced. However, the valuation of the explaining variables holds a significant degree of transparency and consistency by extensive and coherent reasoning on each variable per case study. As mentioned before, ultimately the "case study's reader must judge the researcher's reasoning, based on the provided data" (McCutcheon & Meredith, 1993). For possible future operationalization of the adapted conceptual model of Bontekoning (2002), a 'benchmark case study' prior the researched case studies is recommended. The 'benchmark case study' is the analysis of a simple and recognized case study, including a valuation of the different explaining variables. As a result, the valuation of the explaining variables of the to-be-researched case studies can be benchmarked, thus reducing the subjectivity in the valuation of the explaining variables, therefore increasing reproductively of the research.

The survey and subsequent statistical analysis that was performed, to review the distinguished drivers and barriers from section 6, holds several limitations. First of all, the multiple-choice-answer 'N/A' was not explained in the survey. This could have led to different perceptions on its meaning while answering the survey questions. It is expected that impact of this limitation on the research findings is negligible because 'N/A' was only answered 13 times on an amount of 630 responses in the survey (and a maximum of 4 times 'N/A' on an amount of 70 responses per question). Second, the survey sample does not represent the stakeholders of the European electric bus sector. Most recipients were located in Germany and surrounding countries (e.g. The Netherlands, Finland, Poland, Czech Republic). Southern Europe, which accommodates a large part of the European electric bus projects, was underrepresented. Third, the variance in survey answers was not taken into account. The latter results in a non-observation of possible outliers (population wise as well as empirical) (Rossiter, 2006), which reduces the external viability of the statistical analysis.

7.3.2 Research contributions

This research tried to identify the main drivers and barriers to the adoption of a novelty, which can help exploit drivers and/or overcome or mitigate barriers. The contributions of this research are specified underneath.

Scientific contributions
Existing work in the field of innovation- and adoption-literature was discussed in section 2. This discussion revealed that current literature holds shortcomings for providing us with an analytical conceptual model conforming the criteria of this study (e.g. taking into account the characteristics of the public transportation sector). Therefore an analytical conceptual model was designed, that takes into account the characteristics of the public transportation sector.

To contribute to existing literature on electric public transportation busses, an in-depth overview of the current electric bus market was provided. First, an overview of the current electric bus projects in Europe was presented. Second, eight unique case study analyses of electric bus projects in Europe were elaborated upon. Third, the impact of several drivers and barriers on the implementation of electric bus projects was measured, based on a survey answered by stakeholders from the European electric bus sector. Fourth, the major drivers and barriers to the implementation of electric bus projects in Europe were identified. Overall, this study provides an unique socio-political analyses of the current status of electric bus projects in Europe.

Societal Contributions
It is evident that society will benefit from zero-emission vehicle operations by significantly reducing the damage to the environment and human health caused by transportation. Adoption of electric vehicles is one of the roadmaps to a zero-emission transportation system. This thesis provides an overview and a discussion on the current condition of electric bus implementation in Europe. Based on this information, private as well as public organizations can construct or modify their strategy favouring the introduction of zero-emission vehicles.

From a broader perspective, this thesis contributes to the field of innovation policy by providing a unique review on the adoption of a particular innovation (i.e. the full electric bus) on a firm-level. Future potential adoption of innovations in the public transportation sector could benefit from the lessons learned from the introduction of electric public transportation busses. In this research, the involvement of the political establishment gave insights in the significance of political feasibility in the decision process on innovation adoption in the public transportation market. In particular the environmental benefits, public perception, innovation stimulation, and economics, directly or indirectly influence this decision. The significance of the technical feasibility of an innovation, more particularly the technical-reliability and –risks, is demonstrated in their high influence on the decision to adopt. Policymakers that pursue an enhancement of social awareness, the creation of economies of scale, stimulation of knowledge-development and –distribution, are expected to utilize drivers and cope with barriers to implementation of high cost, radical innovations in the public transportation market. Therefore enhancing the political- and technical-feasibility of the innovation adoption, thus improving the successfulness of innovation adoption.

7.4 Recommendations

This subchapter elaborates on the study's recommendations for stakeholders of the electric bus market and recommendations for further research.

7.4.1 Recommendations for stakeholders of the electric bus market

Based on this thesis, multiple recommendations can be made. By exploiting the identified drivers and coping with barriers, a resulting cost benefit analysis could positively impact the decision to implement electric busses in Europe. Increased electric bus adoption could lead to a more sustainable future with enhanced human wellbeing. Concrete recommendations for stakeholders in the electric bus sector:

1. *Customize the complete operation system of an electric bus*: Bus operators should customize the electric bus's complete operation system (i.e. the bus technique, the operation/charging schedule, the driving plan, and the infrastructure) to effectively make use of the battery and charging technique. Therefore, the major barrier of the electric bus's low degree of flexibility is reduced. The latter is a result of the innovation's relatively short range and unfavourable charging/driving ratio.
2. *Enhance battery technology*: Battery manufacturers and researchers should enhance battery technology in order to mitigate major barriers on the electric bus's low degree of flexibility and high risk. Based on literature, this study identifies battery technology as a the limiting factor to the latter two barriers. The battery's power- and energy-density results in a relatively short range and unfavourable charging/driving ratio. And the fact that the exact battery lifetime in electric busses is often unknown plus the fact that battery costs are a critical factor in the investment costs, significantly increases the financial risks. Additionally, bus operators could lease the battery component of the bus, therefore diminishing the impact of the high financial risks of battery technology.
3. *Educate stakeholders and develop additional knowledge*: The low availability in information on electric bus implementation should be overcome or mitigated by educating stakeholders (e.g. by enlarging knowledge platforms, tests and demonstrations). In addition knowledge ought to be magnified through research on technical- and financial-aspects (e.g. on battery lifetime and life cycle costs) of electric busses. As a result, uncertainty on the economic viability of electric bus implementation (i.e. bus suppliers state that electric busses are economical viable, though bus operators state they are not) is reduced.
4. *Liberalize public transportation sector*: It is recommended that the public transportation market in Europe should be liberalized, in order to cope with the low degree of competitiveness in several public transportation systems throughout Europe. By increasing the competiveness, stakeholders' innovation adoption (e.g. of electric busses) would be enhanced. Note, that possible unwanted secondary effects of these policies should be studied before incorporating this measure.

7.4.2 Recommendations for future research

During the course of this study several uncertainties could not be eliminated. Therefore recommendations for future research are provided underneath:

1. *Research the current economic viability of electric busses*: Independent research on the current economic viability of electric busses in Europe is needed in order to cope with the lack of objective information sources on this matter. Decision makers and potential adopting organizations in the electric bus sector find the information currently available biased and one-sided, because bus suppliers are the main information sources. Additionally, due to vast technological- as well as economical-changes (e.g. subsidy schemes and fuel costs), older financial analyses are outdated.
2. *Research the existence and influence of outreach programs and subsidy schemes regarding European electric bus projects*: Today, no unique repository of information about outreach programs and subsidy schemes in regarding the European electric bus sector exists. The existence and influence of these programs and schemes ought to be investigated, so that they can be aligned to work effectively to stimulate the development of the electric bus market.
3. *Research the professional opinion of a representative sample of the complete European electric bus market on the impact of the identified drivers and barriers on the implementation of electric busses in Europe*: As discussed earlier, the survey and statistical analyses incorporated in this thesis hold

several limitations. It is recommended that the stakeholders in the European electric bus sector would be represented in the survey population accordingly. Subsequently, the variance in answers should be included in the statistical analysis. The latter would increase the external viability of the statistical analysis and could lead to contributing insights in the drivers and barriers to the implementation of electric busses in Europe. Therefore leading to possibly exploitation of drivers and mitigation of barriers, thus positively impacting the adoption of electric busses in Europe.

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LIST OF INTERVIEWEES

Madrid
Juan Angel Terrón Alonso, Director of Engineering of Bus Operator EMT.
Mauro Cecchini, former Engineer of Bus Supplier Tecnobus.

Coventry
Adrian De Courcey, CEO of Bus Operator Travel de Courcey.
Glenn Saint, Deputy Chief Executive Officer and Chief Technology Officer of of Bus Supplier Optare.

Turin
Bruna Cavaglià, Head Mobility Service of the City of Turin.
Gruppo Torinese Trasporti (GTT), Bus Operator.
Paolo Zazio, co-Founder and former Managing Director of Bus Supplier EPT

Vienna
Peter Wiesinger, Head of Bus Technology of Bus Operator Wiener Linien

Rome
Mauro Cecchini, former Engineer of Bus Supplier Tecnobus.
Pietro Spirito, General Director of ATAC SpA Rome.
Stefano Strani, Head Maintenance of Electric Road Vehicles of Bus Operator ATAC SpA Rome.

Orleans
Benjamin Paillaud, Director of Mobility and Urban Transport of Public Tansportation Manager L'AgglO
Epvre Delquie, Commercial Director of Bus Supplier PVI.
Keolis, Bus Operator.

Frankfurt
Alois Rautschka, Managing Director of Bus Operator ICB.
Edison Yin, Business Development Manager of Bus Supplier BYD Europe.
Kirsten Anlauf, Tender Manager of Public Transportation Manager TraffiQ.

Offenbach
Anja Georgi, Managing Director of Bus Operator OVB
Volker Lampmann, former Managing Director of Bus Operator OVB

APPENDICES

Appendix I Innovation- and adoption-literature

This appendix elaborates on the development of innovation- and adoption-literature.

Innovation theories

Innovation theory is rooted in several science disciplines, such as sociology, organizational studies, management studies, economics, policy studies (Martin, 2012). It tries to analyse and/or influence the emergence and development of innovations.

Early innovation theory

Innovation theories between the 1930s and 1970s advocate a simple 'linear model' of innovation development. This model can be based on technology-push, which says R&D advances directly determine the innovation advances. Or demand-pull, which means the market-demand directly determines the innovation rate and direction. Both linear models have been criticized as too simple to be used effectively. Though both definitions of technology-push and demand-pull are still widely recognized today (Leger & Swaminathan, 2007; ICEPT, 2012).

Additional concepts

Between the 1970s and 1990s, three fundamental approaches were added to innovation theory: induced innovation, the evolutionary economics approach, and path-dependency. These additions advanced the 'linear models' to a more general systems theory of innovation. Induced innovation is based on the aspect of demand-pull and recognizes the strong influence of economic activity on the innovation advances (Nordhaus, 2002). According to ICEPT (2012) a "key insight is that a change in the relative prices of factors of production motivates innovation directed at economising the use of the factor that has become relatively expensive". The evolutionary economics approach and path-dependency indicate the influence on the rate and direction of present innovation development by past decisions and events. Evolutionary economics suggests decision makers only have limited abilities to control innovation development and favour incremental over radical innovations, due to the concepts of 'bounded rationality' and 'uncertainty'. 'Bounded rationality' stands for the inability of actors to collect and process all information. 'Uncertainty' includes the unknown opportunities and future trajectory of a technology, resource, policy, supplier, competitor, or consumer (Meijer et al., 2007). The fundamental approach of 'path-dependency' suggests that the more an innovation has been adopted, the more it will be adopted in the future. Learning by doing and scale effects can result in incremental improvements and cost reductions. Finally this can lead to a dominant design resulting in a 'lock-in' effect, possibly 'locking-out' more optimal technologies (Walker, 2000; ICEPT, 2012).

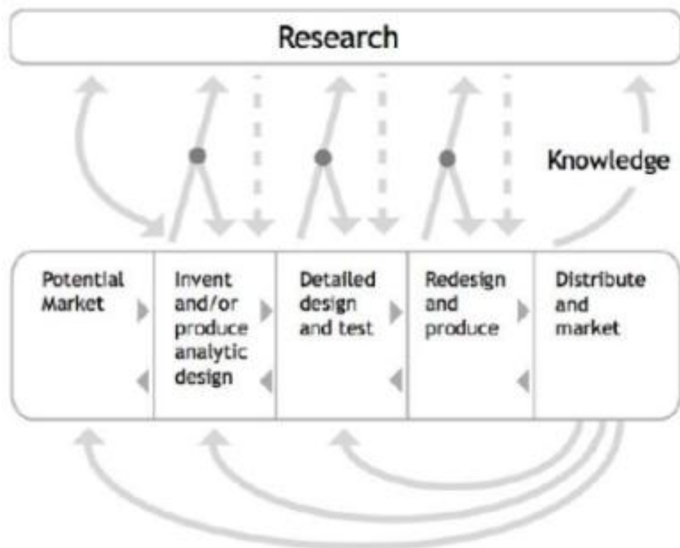

Figure 12. The chain-linked model (Kline, 1986, from ICEPT, 2012)

The chain-linked model by Kline (1986), as shown in Figure 12, represents an early conceptual model of the more general systems theory of innovation. It shows that development of innovations is not linear, but holds feedback loops. The model combines two types of interaction within the visualized system. First, the interaction within the firm or network of firms itself (as shown in the lower part of the figure). And second, the interaction between the firm or network of firms and the wider technology and science system (as shown in the upper part of the figure). The system as described by the chain-linked model can be seen a narrow definition considering the inclusion of political, social, economic, and cultural characteristics in later system definitions (Leger & Swaminathan, 2007; ICEPT, 2012).

Innovation systems

Between the 1980s and 2000s, innovation literature emphasised on the perception that innovation is a complex activity with many interacting mechanisms. Additions such as the Innovation System Frame, as well as the National Innovation Systems (NIS) were proposed.

As shown in Figure 13, the Innovation System Frame marks four main domains of the innovation capacity of an economy; framework condition, science and engineering base, transfer factors, and innovation dynamo. The innovation dynamo represents the dynamic factors that determine the innovativeness of a firm or entrepreneur. Placing the innovation dynamo in the middle of the frame, shows the reliance of an economy on firms and/or entrepreneurs in order to have a certain degree of innovation capacity (OECD, 2005; ICEPT, 2012).

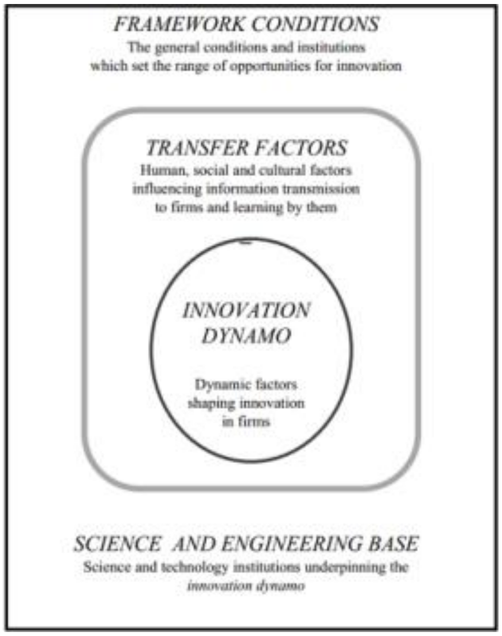

Figure 13. The Innovation System Frame (OECD, 2005)

The National Innovation Systems adds a fundament to innovation literature by focusing on the interactions between all actors within the system. The approach holds the notion that public and private sectors at the national level result in key institutional drivers (in science and engineering) for the development of innovations. Building upon this theory comes forward a generic model of innovation as shown in Figure 14. It represents several innovative entity clusters that interact with each other under certain framework conditions. Three different interactions between the entities are defined: i.) competition, ii.) transaction, or iii.) knowledge transfer or networking (Speirs et al., 2008).

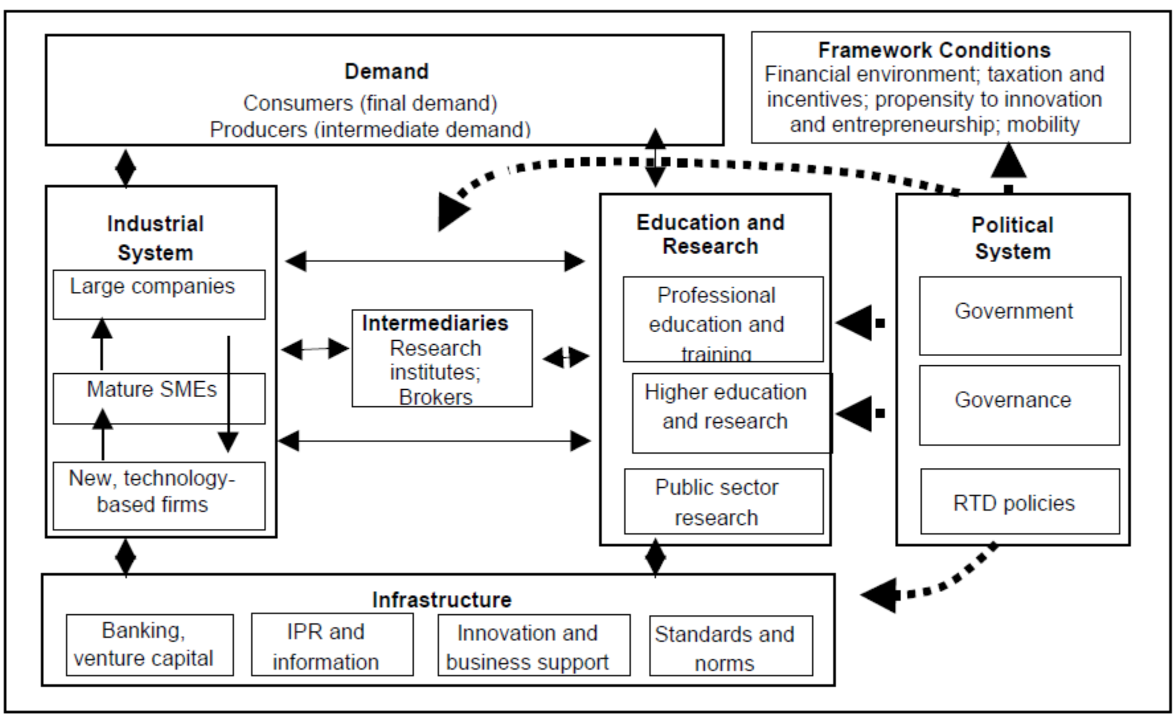

Figure 14. National Innovation System generic model (Arnold & Kulman, 2001; from Speirs et al., 2008)

Systems perspective of innovation

From the 1990s to present day the innovation theory developed perspectives of a more dynamic, non-linear innovation system, also known as systematic innovation. The systems perspective "emphasis the expectations, knowledge flows between actors; expectations about future technology, market and policy developments; political and regulatory risk; and the institutional structures that affect incentives and barriers" (ICEPT, 2012). The 'system' consists of organizational networks and interactions, rather than supreme actors or unidirectional knowledge flows. Interactions between different parts of the system are inherent to the close relationship between institutional and technological change.

Within the systems perspective of innovation, institutions have a broad definition. According to Ruttan (2001) "Institutions are the social rules that facilitate co-ordination among people by helping them form expectations for dealing with each other. They reflect the conventions that have evolved in different societies regarding the behaviour of individuals and groups". Institutions play an important role in empowering incentives and barriers of incremental and radical technological change.

The systematic innovation process is still perceived as a process of stages, but than in a wider context including changes in wider socio-economic structures such as consumer perceptions and the political environment. An example is shown in Figure 15. Influential theories on systematic innovation are 'technological innovation systems' and 'transition theory' (ICEPT, 2012).

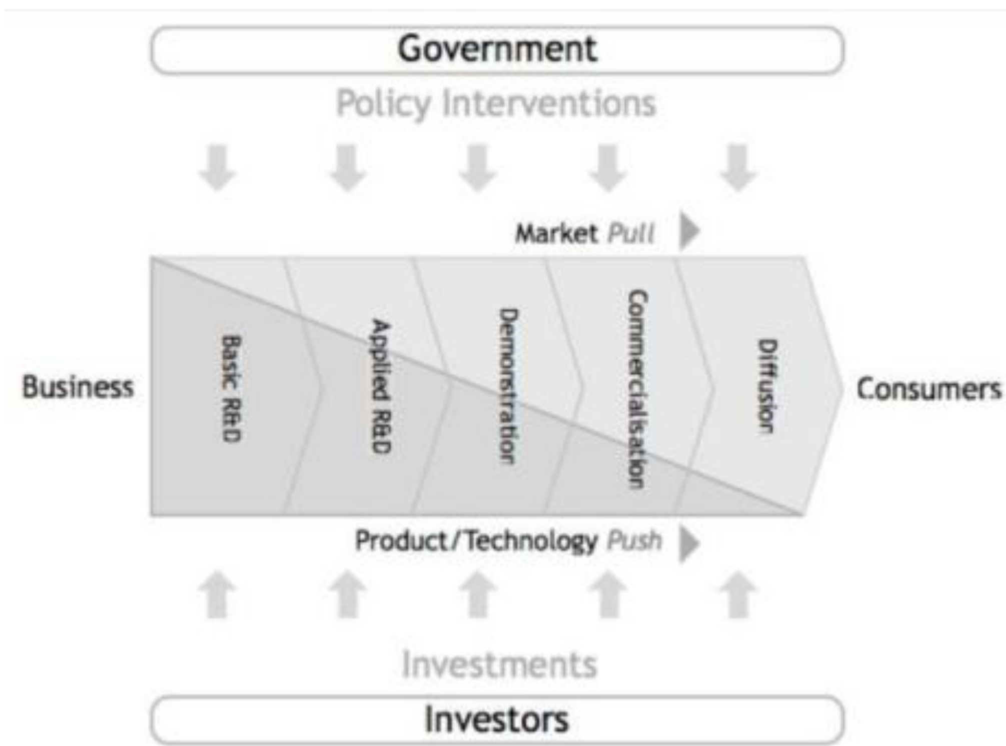

Figure 15. Stages of technology development from a systems perspective (Carbon Trust, 2002, from ICEPT, 2012)

The research of technological innovation systems (TIS), also known as the functions of innovation systems (FIS), emphasis on the fundamental processes in successful innovation system. According to Speirs et al. (2008) the approach is considered to be a form of history event analysis. The success of an innovation system is determined by analysing seven important innovation processes defined as 'functions of the innovation system'; 'entrepreneurial activities', 'knowledge development', 'knowledge diffusion', 'guidance of the search', 'market formation', 'resource mobilization', and 'creation of legitimacy'. At the moment of emergence of an innovation often a limited amount of functions pull the other systems functions. Such mobilizing patterns are called the motors of change and are the drivers behind the early phases of innovation development (Hekkert et al., 2007; Kamp & Quist, 2012). TIS theory perceives government policy as essential to aid the creation and development of the functions. At the same time, established technologies and actors can block the advancement of such functions (especially) in the early stages of innovation development (ICEPT, 2012). Compared to the national innovation systems approach, TIS theory usually analysis a smaller system of agents, networks, and institutions. Generally an early innovation only needs a limited amount of institutions and agents aligned in order to emerge successfully. The decreased complexity in the analysis results in a better understanding of the most important dynamics in an innovation system (Hekkert & Negrom 2009).

'Transitions theory' focusses on radical or disruptive technological change. Radical innovations result in significant technological change in an existing market. Disruptive innovations similarly fulfil existing market needs, but result beyond radical change; even overturning existing dominant technologies, processes and knowledge bases. Incremental innovation on the other hand, built and develop existing technologies and processes without resulting in significant changes. Established firms prefer to invest in incremental innovation due to its low risk and its preservation of the current system.

The main goal of transition theory is predicting and managing future transitions. Three approaches of this research have been developed: i.) the multi-level perspective that helps understand historical sociotechnical change and its dynamics in different levels of the sociotechnical system; ii.) strategic niche management conceptualizes and helps guide the emergence and development of innovations based on the multi-level perspective; iii.) socio-technical scenarios that built upon the multi-level perspective by exploring possible future system settings for the development of innovations and investigates how these system settings affect and are affected by the various strategies and actors (Foxon et al., 2010; ICEPT, 2012).

The theoretical approach of this thesis research is based on transitions, because the emergence and development of electric busses is seen as radical or disruptive technological change. The established technology of internal combustion engine and its specific activities hold significantly differences to the electric engine, thus the introduction of electric busses results in a major technical change.

Adoption theories

Adoption research emphases on the factors that influence the adoption of innovations by social actors in a system. In literature there exists confusion in the relationship between acceptance and adoption. According to a study of Nabih et al. (1997) acceptance is a mental concept and often precedes the actual usage of an innovation. Adoption is the actual use (and continuous use) of a physical innovation. Note that innovations are always an idea (mentally) and only sometimes a material (physical). In the case of electric busses, a technological innovation, the research is focussed on adoption of instead of merely acceptance.

As mentioned before, two schools of innovation theory can be distinguished. Each school has this own definition of the process to adoption that it propagates. The school of Rogers (1995) indicates innovations are adopted through a process of persuasion and communication by the use of marketing principles (i.e. product, price, promotion, and place). The theory is focussed on the behaviour of the potential adopter. The school of Schumpeter, Barnett, and others contrarily states that the adoption is a rational process rather than persuasive. Important aspects are the ability of the promoter and the ability to adopt (EPAT, 1999).

There have many different adoption models developed over the years, most of them focussing on the adoption on an individual level (Oliveira & Martins, 2011) (e.g. the 'technology acceptance model (TAM and TAM2) (Davis, 1986; Venkatesh & Davis, 2000), the 'theory of planned behaviour' (TPB) (Ajzen, 1985), 'combined TAM and TPB' (C-TAM-TPB) (Taylor & Todd, 1995), 'unified theory of acceptance and use of technology' (UTAUT) (Venkatesh et al. 2003), 'social cognitive theory' (SCT) (Bandura, 1986; from Venkatesh, 2003), and the 'motivational model' (MM)(Davis et al., 1992). In the case for electric bus projects we focus on the adoption of by local governments and/or bus operators. Therefore we are interested in adoption models on a firm or government level. Two widely used models to be elaborated upon are the 'innovation diffusion theory' (IDT) (Rogers, 1995) and the 'technology, organization, and environment' (TOE) framework ((Tornatzky & Fleischer 1990, from Oliveira & Martins, 2011).

Innovation diffusion theory

IDT, also known as 'diffusion of innovation' theory, comes forward out of the school of Rogers (1995) which sees diffusion as the process in which an innovation is communicated through channels, over time, and among social actors. Rogers (1995) says the innovation adoption process is "the process through which an individual or other decisions making unit passes from first knowledge of an innovation, to forming an attitude towards the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision". In principal, diffusion comprehends the adoption processes by several members of a social system over time. The population of individuals adopting a novelty is roughly normally distributed over time and can be divided up into segments that segregate individuals into five adopter categories as shown in Figure 16. The graph explains the change in actor categories adopting the innovation over time (starting with 'innovators' and ending with 'laggards'.

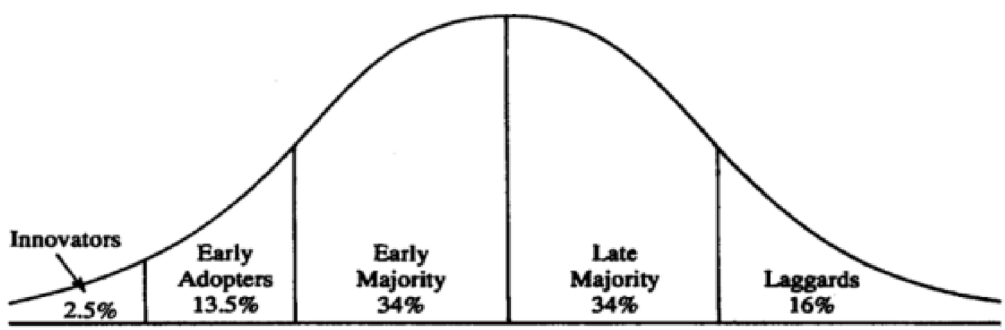

Figure 16. Adopter categorization (Rogers, 1995)

Rogers (1995) states that the adoption process of organizations is more complex than for individuals. The innovation process by organizations is mostly subjective to multiple individuals that influence the innovation-decisions. Moreover, after accepting an innovation the actual implementation process is regularly not put into action. As shown in Figure 17, the innovation-decision process in an organization can be divided into two main processes: i.) *initiation*, includes the process preceding to the decision to adopt (e.g. information gathering, lobbying, planning), and ii.) *implementation*, includes the process after the decision to adopt (e.g. decisions, actions and events putting an innovation into use) (Rogers, 1995).

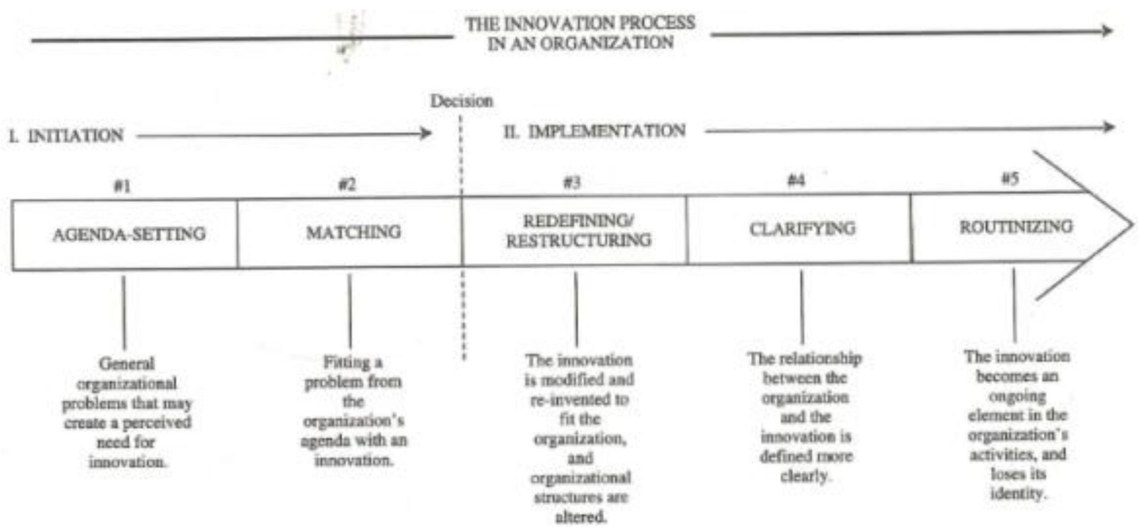

Figure 17. Five stages in the innovation process of organization (Rogers, 1995)

The IDT at organization level distinguishes three contexts that influence the organizational innovativeness, which is directly related to the organizational adoption process: i.) *individual characteristics*, meaning the leadership style considering change; ii.) *internal characteristics of organizational structure*, whereby the characteristics are defined as "centralization is the degree to which power and control in a system are concentrated in the hands of a relatively few individuals"; "complexity is the degree to which an organization's members possess a relatively high level of knowledge and expertise"; "formalization is the degree to which an organization emphasizes its members' following rules and procedures"; "interconnectedness is the degree to which the units in a social system are linked by interpersonal networks"; "organizational slack is the degree to which uncommitted resources are available to an organization"; "size is the number of employees of the organization"; and iii.) *external characteristics of organizational structure*, which emphasising on the openness of the system (Rogers, 1995; Oliveira & Martins, 2011). Figure 18 gives an schematic overview of the model.

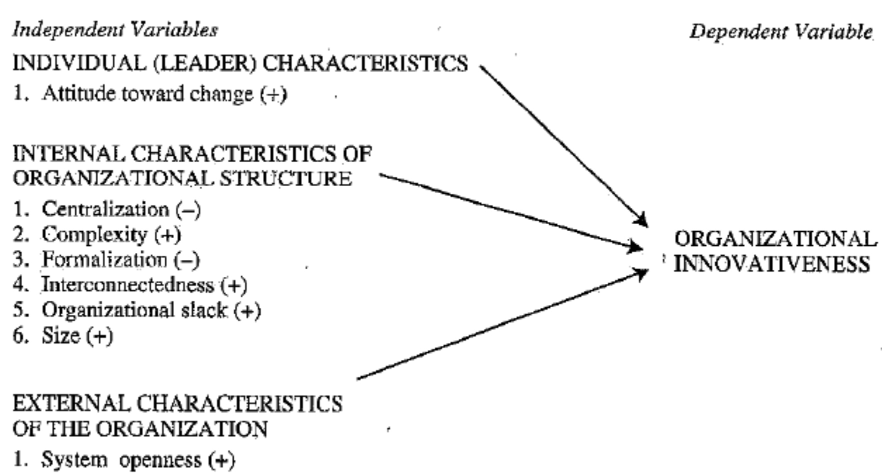

Figure 18. Independent variables related to organizational innovativeness (Rogers, 1995)

Technology, organization, and environment framework

The TOE framework represents how the context of an enterprise effects the adoption process of technical innovations. The TOE framework is similar to the IDT model of Rogers (1995), but also elaborates on the environmental context of an organization. According to Hsu et al. (2006, from Oliveira & Martins, 2011), TOE would better explain innovation diffusion between organizations. As shown in Figure 19 the model divides an enterprise into three elements: i.) *technological context*; international and external technologies relevant to the enterprise, ii.) *organizational context*; organizational characteristics such as size, scope, and hierarchy, and iii.) *environmental*; the surroundings in which the enterprise performs such as relevant external actors, infrastructure and policies. TOE theory provides explanations a firm's technological innovation capacity. It is widely used in numerous sectorial and technological settings and innovations. Though for each setting and innovation there is unique set of characteristics and factors that play a role in the decision making process to adopt. Figure 19 shows a schematic overview of the framework (Tornatzky & Fleischer, 1990, from Oliveira & Martins, 2011; Baker, 2002).

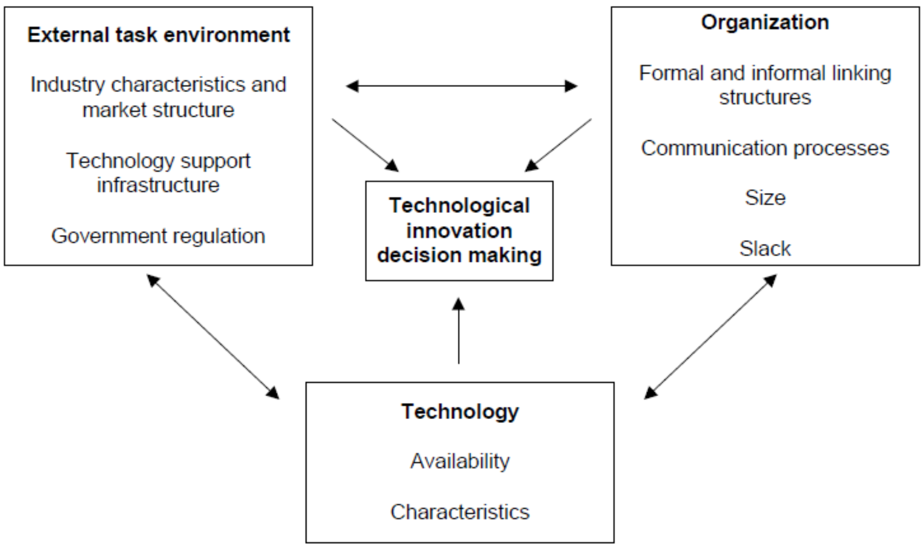

Figure 19. Technology, organization, and environment framework (Tornatzky & Fleischer, 1990, from Oliveira & Martins, 2011)

Appendix II Selection of electric bus projects

Table 16. Electric bus projects after the first selection round

First selection round	Possible case studies	Project size (#busses)	Bus type	Begin date daily operation	End date daily operation	Remark
Slow charging	Nottingham (GB)	28	9.5m and 11.1m Optares			Slow charging 2-4x per 24 hours
	Florence (IT)	26	5.3m Tecnobus Gulliver and possibly Zeus M200-E			Slow charging 1x per 24 hours
	Madrid (ES)	20	5.2/5.3m Tecnobus Gulliver	2007		Slow charging 1x per 24 hours
	Schiermonninkoog (NL)	6	12m BYD	Jul-13		Slow charging 1x per 24 hours
	Klagenfurt (DE)	1	8.9m Solaris Urbino electric	Jul-13		Slow charging 1x per 24 hours
	Heusden-Zolder (BE)	1	Tecnobus	Q1-13		Slow charging 1x per 24 hours
	Segovia (ES)	1	9m Gépébus Oréos 4X	2007		Slow charging 1x per 24 hours
	Arcachon (FR)	1	5.9m Zeus M200E			Slow charging 1x per 24 hours
	Coulommiers (FR)	1	9m Gépébus Oréos 4X	2011		Slow charging 1x per 24 hours
	Coulsdon (FR)	1	9m Gépébus Oréos 4X			Slow charging 1x per 24 hours
	Faure (FR)	1	9m Gépébus Oréos 4X			Slow charging 1x per 24 hours
	Laval (FR)	1	5.5m Bluebus			Slow charging 1x per 24 hours
	Le Mont-Saint-Michel (FR)	1	5.5m Bluebus			Slow charging 1x per 24 hours
	Orleans (FR)	1	7m Gépébus Oréos 2X			Slow charging 1x per 24 hours
	Périgueux (FR)	1	7m Gépébus Oréos 2X			Slow charging 1x per 24 hours
	Rambouillet (FR)	1	5.5m Bluebus			Slow charging 1x per 24 hours
	Rochefort (FR)	1	5.2/5.3m Tecnobus Gulliver			Slow charging 1x per 24 hours
	Coventry (GB)	1	11m Optare	Jul-12		Slow charging 2-4x per 24 hours
	Ayr (GB)	1	7-10m Optare Solo SR			Slow charging 2-4x per 24 hours
	Debrecen (HU)	1	Coulomb-bus			Slow charging 1x per 24 hours
	Rotterdam (NL)	1	5.9m Zeus M200E	2006		Slow charging 1x per 24 hours
	Rennesse (NL)	1	Spijkstaal Eco-bus	1995		Slow charging 1x per 24 hours
En route charging	Turin (IT)	23	7.5m ELFO	2003		Static induction
	Vienna (AT)	12	7.7m Rampini ALÉ EL	Sep-12		Fast charging using trolley grids, when within the coverage area
	Genoa (IT)	7	7.5m ELFO	2002		Static induction
	Eberswalde (DE)	1	Solaris/Cegelec	Sep-12		Fast charging using trolley grids, when within the coverage area

Battery exchange	Rome (IT)	52	5.3m Tecnobus Gulliver	1989		Since 2008 the electric bus fleet has been renewed with slow-charged electric busses (slow charging 1x per 24 hours)
	Orleans (FR)	8	7m Gépébus Oréos 2X			
	Bordeaux(FR)	6	7m Gépébus Oréos 22			
	Gravelines (FR)	1	7m Gépébus Oréos 22			
Failed	Frankfurt (DE)	3	12m BYD eBus	2011		Slow charging 1x per 24 hours
	Offenbach (DE)	1	12m Contrac E.Cobus 2500	2011		Slow charging 2-4x per 24 hours

Appendix III Exceptions in data collection

Each exception with respect to the ordinary data collection procedure of the different case studies is discussed in this appendix

Madrid

- According to the local government, they are not involved in any decisions regarding public transportation busses. The local government refers to the bus operator EMT as the organization involved in the decision to implement electric busses. No local government representative is interviewed.
- The bus operator wants to answer questions solely by email. A digital interview document together with the questionnaire was send.
- The bus supplier Tecnobus wants to answer questions solely by email. A digital interview document together with the questionnaire was send.

Coventry

- The authorities are not involved in the decision to implement electric busses. No local government representative is interviewed.
- The bus supplier answered the questionnaire questions during the telephone interview.

Turin

- The bus supplier Eco Power Technology (EPT) is bankrupt. No current bus supplier representative could be contacted. A former EPT employee is contacted for an interview.

Vienna

- The local government refers to the bus operator Wiener Linien as the organization to-be-interviewed on the decision to implement electric busses. No local government representative is interviewed.
- A translated-to-German questionnaire is answered by the bus operator after the interview.
- The bus supplier did not participate in a questionnaire or interview.

Rome

- The local government refers to the bus operator ATAC Rome as the organization to-be-interviewed on the decision to implement electric busses. No local government representative is interviewed.
- The bus supplier Tecnobus preferred to answer questions solely by email. A digital interview document together with the questionnaire was send.

Orleans

- The local government preferred to answer questions solely by email. A digital interview document was send.
- Answers of the local government were provided in French and had to be translated to English with the help of https://translate.google.com/.
- The bus operator Keolis preferred to answer questions solely by email. A digital interview document together with the questionnaire was send.
- The bus supplier answered the questionnaire during the telephone interview.

Frankfurt am Main

- No bus operator was directly involved in a decision or the procedure to implement electric busses, though the bus operator ICB was interviewed as a potential adopting organization of electric busses in Frankfurt am Main.
- Answers of the bus operator were provided in German and had to be translated to English with the help of https://translate.google.com/.
- The bus supplier answered the questionnaire during the telephone interview.

Offenbach

- The local government was involved in the decision and operation of the electric bus project in the appearance of the bus operator.
- The current- as well as former- Managing Director of the bus operator OVB preferred to answer questions solely by email. A digital interview document was send.
- Answers of the former- Managing Director of the bus operator OVB were provided in German and had to be translated to English with the help of https://translate.google.com/.
- The bus supplier did not participate in a questionnaire or interview.

Appendix IV Template questionnaire for local government

I. GENERAL QUESTIONS

Could you confirm, correct, or add to your project information in the table underneath?

#busses	Bus type	Begin date operation	End date operation	Remarks

II. QUESTIONS ON SITUATION AFTER THE DECSISION TO IMPLEMENT ELECTRIC BUSSES

– *Compatibility, after the decision to implement electric busses*
To what extent were organizational, technical, legislative, and financial changes necessary to implement electric busses successfully (on a scale from 1 to 5. 1 is no changes, 5 is many changes). In other words, how are electric buses different from conventional Diesel buses? Please mention the most important specific changes that were made?

Changes	Value of the change	Specific example
☐ *Organizational*	1 – 2 – 3 – 4 – 5	....
☐ *Technical*	1 – 2 – 3 – 4 – 5	....
☐ *Legislative*	1 – 2 – 3 – 4 – 5	....
☐ *Financial*	1 – 2 – 3 – 4 – 5	....

– *Testability, after the decision to implement electric busses*
To what extend did your organization test the new electric busses prior to the decision to adopt (please indicate the type of tests, number of tests, and time periods)? ....
....

– *Observability, after the decision to implement electric busses*
How noticeable are the relative advantages of electric busses to the public?
- ☐ Very noticeable
- ☐ Noticeable
- ☐ Unnoticeable
- ☐ Very unnoticeable

– *Political feasibility, after the decision to implement electric busses*
How would you value the opinion of the public on the adoption of electric busses by your government?
- ☐ Very favourable
- ☐ Favourable
- ☐ Unfavourable
- ☐ Very unfavourable

How would you value the opinion of the media on the adoption of electric busses by your government?

- ☐ Very favourable
- ☐ Favourable
- ☐ Unfavourable
- ☐ Very unfavourable

- *Uncertainty, after the decision to implement electric busses*

  Looking back, how realistic were your expectations regarding the implementation and operation of an electric bus prior to the decision to adopt (on a scale from 1 to 5. 1 is very unrealistic, 5 is very realistic, N/A means not applicable)?

Expectations	Value of the expectation
Investment costs	1 – 2 – 3 – 4 – 5 – N/A
Maintenance costs	1 – 2 – 3 – 4 – 5 – N/A
Maintenance time	1 – 2 – 3 – 4 – 5 – N/A
Refuel time	1 – 2 – 3 – 4 – 5 – N/A
Reliability	1 – 2 – 3 – 4 – 5 – N/A
Energy use	1 – 2 – 3 – 4 – 5 – N/A
Increased use of public busses (growth in customer volume)	1 – 2 – 3 – 4 – 5 – N/A
Improved public perception	1 – 2 – 3 – 4 – 5 – N/A
Increased travel comfort	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A

III. QUESTIONS ON SITUATION PRIOR TO THE DECSISION TO IMPLEMENT ELECTRIC BUSSES

- *Relative advantage, prior to the decision to implement electric busses*

  What did you expect from electric busses (on a scale from 1 to 5. 1 for very negative expectations, 5 for very positive expectations, N/A means not applicable)?

Possible benefit	Value of expectation
Cleaner air	1 – 2 – 3 – 4 – 5 – N/A
Reduction in emissions	1 – 2 – 3 – 4 – 5 – N/A
Reduction in noise pollution	1 – 2 – 3 – 4 – 5 – N/A
Efficiency improvement in energy use	1 – 2 – 3 – 4 – 5 – N/A
Reduction in operation costs	1 – 2 – 3 – 4 – 5 – N/A
Reduction in maintenance costs	1 – 2 – 3 – 4 – 5 – N/A
Increased travel comfort	1 – 2 – 3 – 4 – 5 – N/A
Increased use of public busses (growth in customer volume)	1 – 2 – 3 – 4 – 5 – N/A
Improved public perception	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A

Possible barrier	Value of expectation
Increased technical, operational, legislative of financial risks	1 – 2 – 3 – 4 – 5 – N/A
Efficiency loss in energy use	1 – 2 – 3 – 4 – 5 – N/A
Increased operation costs	1 – 2 – 3 – 4 – 5 – N/A
Increased maintenance costs	1 – 2 – 3 – 4 – 5 – N/A
Reduced travel comfort	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A

- *Uncertainty, prior to the decision to implement electric busses*
  Which risks did you value prior to the decision to implement electric busses? And how did you assess each of these risks (on a scale from 1 to 5. 1 is very low risk, 5 is very high risk, N/A means not applicable)?

Risk	Value of the risk
Technical failures	1 – 2 – 3 – 4 – 5 – N/A
Operational setbacks	1 – 2 – 3 – 4 – 5 – N/A
Legislative setbacks	1 – 2 – 3 – 4 – 5 – N/A
Financial setbacks	1 – 2 – 3 – 4 – 5 – N/A
Public/media resistance	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………	1 – 2 – 3 – 4 – 5 – N/A

IV. VARIOUS QUESTIONS

- *Characteristics of the potential adopting organization*
  How many people are employed at your organization? ……………………………………………………………….

  Who were involved in the decision process to implement electric busses and what was their role? Which departments were involved in the decision process? ………………………………………………………………
  ……
  ……

  Who are **currently** involved in the electric bus project and what is their role? Which departments are involved in the public transport bus project? ………………………………………………………………………………
  ……
  ……

- *Characteristics of the communication process, the information that is communicated, and the social system*
  How were you informed about electric busses (Check each box that is of the source that is applicable, more than one answer is possible)? And how do you judge the quality of that information (on a scale from 1 to 5. 1 is very poor, 5 is very good)?

Means of information	Quality of information
☐ *Professional magazine*	1 – 2 – 3 – 4 – 5
☐ *Transport news paper*	1 – 2 – 3 – 4 – 5
☐ *Company brochure of the supplier*	1 – 2 – 3 – 4 – 5
☐ *Congress / Conference*	1 – 2 – 3 – 4 – 5
☐ *Consultant*	1 – 2 – 3 – 4 – 5
☐ *Employee(s)*	1 – 2 – 3 – 4 – 5
☐ *Clients*	1 – 2 – 3 – 4 – 5
☐ *Innovation centre*	1 – 2 – 3 – 4 – 5
☐ *National/European government*	1 – 2 – 3 – 4 – 5
☐ *Researchers*	1 – 2 – 3 – 4 – 5
☐ *Personal approach of supplier*	1 – 2 – 3 – 4 – 5
☐ *Social / business network*	1 – 2 – 3 – 4 – 5
☐ *Branch organization*	1 – 2 – 3 – 4 – 5
☐ *Other, namely ……………………………*	1 – 2 – 3 – 4 – 5

Which stakeholders have had an impact on your implementation decision? Please add if this influence had a positive or negative impact on the decision to adopt an electric bus and please add briefly what their role was.

Actors in the business arena	Impact on implementation decision	Role
☐ *Other local governments*	Positive / Negative	……………………………………………
☐ *National/European government*	Positive / Negative	……………………………………………
☐ *Suppliers of busses*	Positive / Negative	……………………………………………
☐ *Suppliers of infrastructure*	Positive / Negative	……………………………………………
☐ *Suppliers of IT*	Positive / Negative	……………………………………………
☐ *Electric energy suppliers*	Positive / Negative	……………………………………………
☐ *Grid operators*	Positive / Negative	……………………………………………
☐ *Media*	Positive / Negative	……………………………………………
☐ *Electorates*	Positive / Negative	……………………………………………
☐ *Interest groups*	Positive / Negative	……………………………………………
☐ *Unions*	Positive / Negative	……………………………………………
☐ *Branch organizations*	Positive / Negative	……………………………………………
☐ *Banks/financiers*	Positive / Negative	……………………………………………
☐ *Shareholders*	Positive / Negative	……………………………………………
☐ *Consultants*	Positive / Negative	……………………………………………
☐ *Researchers*	Positive / Negative	……………………………………………
☐ *Other, namely …*	Positive / Negative	……………………………………………

Can the implementation of an electric bus lead to an competitive advantage? And if so, who would be your competitors? ………

- *The role of the national and European government*
  What activities and measures (including funding or other resources) by regional, national and international governmental organizations **did you make use of** in order to stimulate the development and use of electric busses in the public transportation sector? ....
  ....
  ....

  What activities and measures (including funding or other resources) by regional, national and international governmental organizations **would you recommend** in order to stimulate the development and use of electric busses in the public transportation sector? ....
  ....
  ....

- *Other questions*
  Are you aware of any attempts to implement electric buses in your country/region which did not succeed (i.e. no buses were implemented or where the project was ended earlier than planned)?...
  ....

Appendix V Template questionnaire for bus operator

I. GENERAL QUESTIONS

Could you confirm, correct, or add to your project information in the table underneath?

#busses	Bus type	Begin date operation	End date operation	Remarks

II. QUESTIONS ON SITUATION AFTER THE DECSISION TO IMPLEMENT ELECTRIC BUSSES

- *Compatibility, after the decision to implement electric busses*
  To what extent were organizational, technical, legislative, and financial changes necessary to implement electric busses successfully (on a scale from 1 to 5. 1 is no changes, 5 is many changes). In other words, how are electric buses different from conventional Diesel buses? Please mention the most important specific changes that were made?

Changes	Value of the change	Specific example
☐ *Organizational*	1 – 2 – 3 – 4 – 5	....
☐ *Technical*	1 – 2 – 3 – 4 – 5	....
☐ *Legislative*	1 – 2 – 3 – 4 – 5	....
☐ *Financial*	1 – 2 – 3 – 4 – 5	....

- *Testability, after the decision to implement electric busses*
  To what extend did your organization test the new electric busses prior to the decision to adopt (please indicate the type of tests, number of tests, and time periods)? ....
  ....

- *Observability, after the decision to implement electric busses*
  How noticeable are the relative advantages of electric busses to the public?
  ☐ Very noticeable
  ☐ Noticeable
  ☐ Unnoticeable
  ☐ Very unnoticeable

- *Uncertainty, after the decision to implement electric busses*
  Looking back, how realistic were your expectations regarding the implementation and operation of an electric bus prior to the decision to adopt (on a scale from 1 to 5. 1 is very unrealistic, 5 is very realistic, N/A means not applicable)?

Expectations	Value of the expectation
Investment costs	1 – 2 – 3 – 4 – 5 – N/A
Maintenance costs	1 – 2 – 3 – 4 – 5 – N/A
Maintenance time	1 – 2 – 3 – 4 – 5 – N/A
Refuel time	1 – 2 – 3 – 4 – 5 – N/A
Reliability	1 – 2 – 3 – 4 – 5 – N/A
Energy use	1 – 2 – 3 – 4 – 5 – N/A
Increased use of public busses (growth in customer volume)	1 – 2 – 3 – 4 – 5 – N/A
Improved public perception	1 – 2 – 3 – 4 – 5 – N/A
Reduction in explanation time the way daily operations are carried out	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A

III. QUESTIONS ON SITUATION PRIOR TO THE DECSISION TO IMPLEMENT ELECTRIC BUSSES

– *Relative advantage, prior to the decision to implement electric busses*
What did you expect from electric busses (on a scale from 1 to 5. 1 for very negative expectations, 5 for very positive expectations, N/A means not applicable)?

Possible benefit	Value of expectation
Cleaner air	1 – 2 – 3 – 4 – 5 – N/A
Reduction in emissions	1 – 2 – 3 – 4 – 5 – N/A
Reduction in noise pollution	1 – 2 – 3 – 4 – 5 – N/A
Efficiency improvement in energy use	1 – 2 – 3 – 4 – 5 – N/A
Reduction in operation costs	1 – 2 – 3 – 4 – 5 – N/A
Reduction in maintenance costs	1 – 2 – 3 – 4 – 5 – N/A
Increased travel comfort	1 – 2 – 3 – 4 – 5 – N/A
Increased use of public busses (growth in customer volume)	1 – 2 – 3 – 4 – 5 – N/A
Improved public perception	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A

Possible barrier	Value of expectation
Increased technical, operational, legislative of financial risks	1 – 2 – 3 – 4 – 5 – N/A
Efficiency loss in energy use	1 – 2 – 3 – 4 – 5 – N/A
Increased operation costs	1 – 2 – 3 – 4 – 5 – N/A
Increased maintenance costs	1 – 2 – 3 – 4 – 5 – N/A
Reduced travel comfort	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………………………………………	1 – 2 – 3 – 4 – 5 – N/A

- *Uncertainty, prior to the decision to implement electric busses*
  Which risks did you value prior to the decision to implement electric busses? And how did you assess each of these risks (on a scale from 1 to 5. 1 is very low risk, 5 is very high risk, N/A means not applicable)?

Risk	Value of the risk
Technical failures	1 – 2 – 3 – 4 – 5 – N/A
Operational setbacks	1 – 2 – 3 – 4 – 5 – N/A
Legislative setbacks	1 – 2 – 3 – 4 – 5 – N/A
Financial setbacks	1 – 2 – 3 – 4 – 5 – N/A
Public/media resistance	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ………………………………	1 – 2 – 3 – 4 – 5 – N/A

IV. VARIOUS QUESTIONS

- *Characteristics of the potential adopting organization*
  How many people are employed at your organization? ……………………………………………………………………

  Who were involved in the decision process to implement electric busses and what was their role? Which departments were involved in the decision process? ………………………………………………………………
  ………
  ………

  Who are **currently** involved in the electric bus project and what is their role? Which departments are involved in the public transport bus project?………………………………………………………………………………
  ………
  ………

- *Characteristics of the communication process, the information that is communicated, and the social system*
  How were you informed about electric busses (Check each box that is of the source that is applicable, more than one answer is possible)? And how do you judge the quality of that information (on a scale from 1 to 5. 1 is very poor, 5 is very good)?

Means of information	Quality of information
☐ *Professional magazine*	1 – 2 – 3 – 4 – 5
☐ *Transport news paper*	1 – 2 – 3 – 4 – 5
☐ *Company brochure of the supplier*	1 – 2 – 3 – 4 – 5
☐ *Congress / Conference*	1 – 2 – 3 – 4 – 5
☐ *Consultant*	1 – 2 – 3 – 4 – 5
☐ *Employee(s)*	1 – 2 – 3 – 4 – 5
☐ *Clients*	1 – 2 – 3 – 4 – 5
☐ *Innovation centre*	1 – 2 – 3 – 4 – 5
☐ *National/European government*	1 – 2 – 3 – 4 – 5
☐ *Researchers*	1 – 2 – 3 – 4 – 5
☐ *Personal approach of supplier*	1 – 2 – 3 – 4 – 5
☐ *Social / business network*	1 – 2 – 3 – 4 – 5
☐ *Branch organization*	1 – 2 – 3 – 4 – 5
☐ *Other, namely ……………………………*	1 – 2 – 3 – 4 – 5

Which stakeholders have had an impact on your implementation decision? Please add if this influence had a positive or negative impact on the decision to adopt an electric bus and please add briefly what their role was.

Actors in the business arena	Impact on implementation decision	Role
☐ *Other bus operators*	Positive / Negative	……………………………………………
☐ *Local/national/European government*	Positive / Negative	……………………………………………
☐ *Suppliers of busses*	Positive / Negative	……………………………………………
☐ *Suppliers of infrastructure*	Positive / Negative	……………………………………………
☐ *Suppliers of IT*	Positive / Negative	……………………………………………
☐ *Electric energy suppliers*	Positive / Negative	……………………………………………
☐ *Grid operators*	Positive / Negative	……………………………………………
☐ *Media*	Positive / Negative	……………………………………………
☐ *Electorates*	Positive / Negative	……………………………………………
☐ *Interest groups*	Positive / Negative	……………………………………………
☐ *Unions*	Positive / Negative	……………………………………………
☐ *Branch organizations*	Positive / Negative	……………………………………………
☐ *Banks/financiers*	Positive / Negative	……………………………………………
☐ *Shareholders*	Positive / Negative	……………………………………………
☐ *Consultants*	Positive / Negative	……………………………………………
☐ *Researchers*	Positive / Negative	……………………………………………
☐ *Other, namely …*	Positive / Negative	……………………………………………

Can the implementation of an electric bus lead to an competitive advantage? And if so, who would be your competitors? ……

- *The role of the national and European government*
  What activities and measures (including funding or other resources) by regional, national and international governmental organizations **did you make use of** in order to stimulate the development and use of electric busses in the public transportation sector? ....
  ....
  ....

  What activities and measures (including funding or other resources) by regional, national and international governmental organizations **would you recommend** in order to stimulate the development and use of electric busses in the public transportation sector? ....
  ....
  ....

- *Other questions*
  Are you aware of any attempts to implement electric buses in your country/region which did not succeed (i.e. no buses were implemented or where the project was ended earlier than planned)?..
  ....

Appendix VI Template questionnaire for bus supplier

- Could you confirm, correct, or add to your project information in the table underneath?

#busses	Bus type	Begin date operation	End date operation	Remarks

- *Uncertainty, prior to the decision to implement electric busses*
  Which risks did you value prior to the decision to adopt electric busses? Check each box that is of the source that is applicable, more than one answer is possible. And how did you assess each of these risks (on a scale from 1 to 5. 1 is very low risk, 5 is very high risk, N/A means not applicable)?

Risk	Value of the risk
Technical failures	1 – 2 – 3 – 4 – 5 – N/A
Operational setbacks	1 – 2 – 3 – 4 – 5 – N/A
Legislative setbacks	1 – 2 – 3 – 4 – 5 – N/A
Financial setbacks	1 – 2 – 3 – 4 – 5 – N/A
Public/media resistance	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A
Other, namely ……………………………	1 – 2 – 3 – 4 – 5 – N/A

- *Characteristics of the innovator/supplier*
  Which types of potential adopters' approach strategies have you used for this specific electric bus project:

  - ☐ Press releases
  - ☐ Mailings
  - ☐ Personal contacts
  - ☐ Pilot demonstrations
  - ☐ Development co-operation
  - ☐ Co-financing
  - ☐ Other, namely ……..

Which marketing strategy did you use for this specific electric bus project? And could you indicate what was the impact of this strategy on the decision to adopt electric busses (on a scale from 1 to 5. 1 no impact, 5 is very much positive impact)

Marketing strategy	Impact
□ *Positioning the innovation in the market by setting a penetration price*	1 – 2 – 3 – 4 – 5
□ *Reducing the risk of adoption by absorbing all the additional financial costs involved for the potential adopter in the implementation phase*	1 – 2 – 3 – 4 – 5
□ *Erect a joint venture with an adopter and share the financial risks*	1 – 2 – 3 – 4 – 5
□ *Positioning the innovation in the market by taking 100% risk in a new project and own exploitation*	1 – 2 – 3 – 4 – 5
□ *Financing the back-up strategy which the adopter will need during the start-up of new electric bus operations*	1 – 2 – 3 – 4 – 5
□ *Enlarge test teams with employees of the potential adopters and other stakeholders in order to test different scenario's during the pilot project*	1 – 2 – 3 – 4 – 5
□ *Enlarge test teams with employees of the potential adopters and other stakeholders in order to test different scenario's with a simulation/animation tool*	1 – 2 – 3 – 4 – 5
□ *Co-operation with other bus suppliers by sharing the innovative technology*	1 – 2 – 3 – 4 – 5
□ *Co-operation with infrastructure suppliers and/or IT suppliers by sharing the innovative technology*	1 – 2 – 3 – 4 – 5
□ *Another strategy, namely ……………………………………………………………………………………………… ……….*	1 – 2 – 3 – 4 – 5
□ *Another strategy, namely ……………………………………………………………………………………………… ……….*	1 – 2 – 3 – 4 – 5

– *The role of the national and European government*
  What activities and measures (including funding or other resources) by regional, national and international governmental organizations **did you make use of** in order to stimulate the development and use of electric busses in the public transportation sector? ……………………………………
  ……
  ……

  What activities and measures (including funding or other resources) by regional, national and international governmental organizations **would you recommend** in order to stimulate the development and use of electric busses in the public transportation sector? ……………………………………
  ……
  ……

– *Other questions*
  Are you aware of any attempts to implement electric buses in your country/region which did not succeed (i.e. no buses were implemented or where the project was ended earlier than planned)?………
  ……

Table 17. Survey results on "What is your job within the electric bus sector?"

What is your job within the electric bus sector?		
Answer Options	Response Percent	Response Count
Governmental body	7.1%	5
Bus operator	25.7%	18
Bus supplier/manufacturer	17.1%	12
Infrastructure provider	5.7%	4
Consultant	11.4%	8
Researcher	17.1%	12
None	2.9%	2
Other (please specify)	12.9%	9
	answered question	70
	skipped question	0

Table 18. Survey results on "What is your experience regarding electric bus projects?"

What is your experience regarding electric bus projects? (multiple answers are allowed)		
Answer Options	Response Percent	Response Count
Permanent electric bus project(s)	40.0%	28
Pilot/demo electric bus project(s)	71.4%	50
R&D of electric busses	45.7%	32
Electric vehicle projects (other than electric busses)	35.7%	25
Conventional bus projects	25.7%	18
None	4.3%	3
Other (please specify)	2.9%	2
	answered question	70
	skipped question	0

Table 19. Survey results on "What are the barriers to electric bus implementation in public transportation projects in Europe?"

What are the barriers to electric bus implementation in public transportation projects in Europe? (on a scale from 1 to 5. 1 for a very low impact, 5 for a very high impact, N/A means not applicable)							
Answer Options	1	2	3	4	5	N/A	Response Count
Low compatibility	3	21	17	16	11	2	70
Perceived higher LLC	3	11	17	21	16	2	70
Higher risks	2	6	18	26	18	0	70
Low avbl. of information	10	18	15	15	11	1	70
Low degree of competition	15	18	15	13	5	4	70
Comment (if desirable):							10
						answered question	70
						skipped question	0

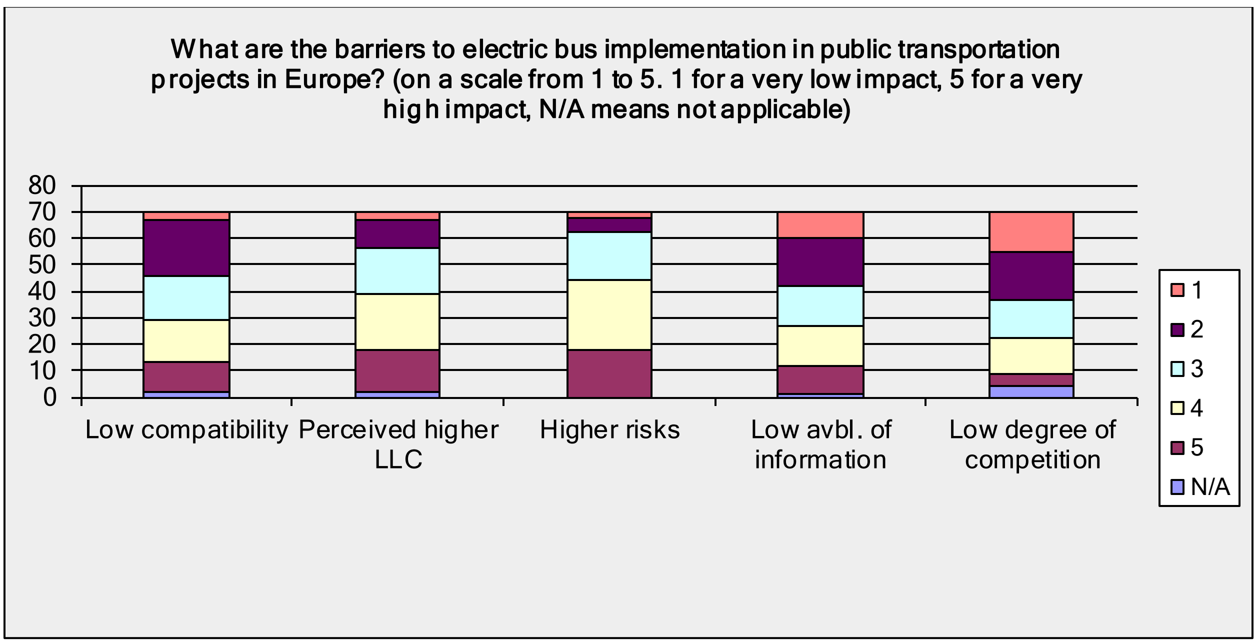

Figure 20. Survey results on "What are the barriers to electric bus implementation in public transportation projects in Europe" in a graph.

Table 20. Survey results on "What are the drivers to electric bus implementation in public transportation projects in Europe?"

What are the drivers to electric bus implementation in public transportation projects in Europe? (on a scale from 1 to 5. 1 for a very low impact, 5 for a very high impact, N/A means not applicable)							
Answer Options	1	2	3	4	5	N/A	Response Count
Red. Impact on environmental	1	3	4	20	42	0	70
Impr. public perception	3	6	25	20	15	1	70
Innovation policy	1	7	25	23	13	1	70
Visionary leader	5	9	20	21	13	2	70
Comment (if desirable):							7
						answered question	70

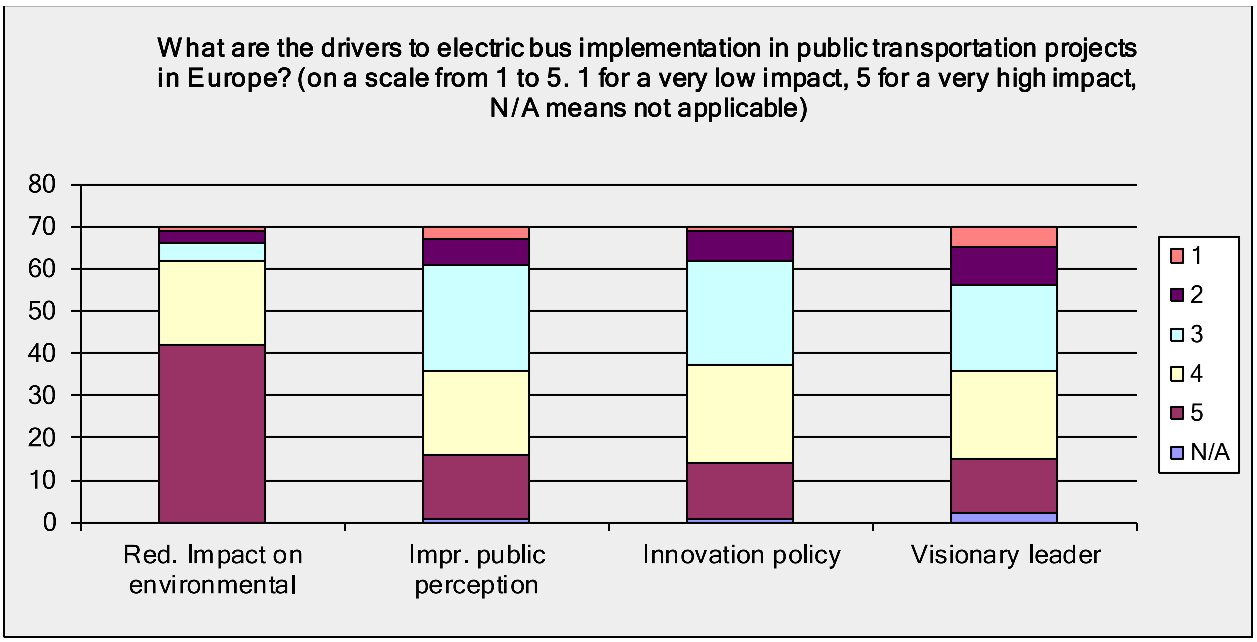

Figure 21. Survey results on "What are the drivers to electric bus implementation in public transportation projects in Europe" in a graph.

Appendix VIII Chi-square analysis

In order to increase the external validity, the relation between a selection of dependent and independent variables is analysed with the help of a Chi-square analysis. The independent variables of the potential adopting organizations (i.e. the governmental bodies and bus operators taken together) and the suppliers (i.e. the bus suppliers and infrastructure providers taken together) are considered as variables that could have significant differences in opinion on the major drivers and barriers to electric bus implementation. The dependent variables that are considered are the major drivers and barriers that have been identified in the case study analyses. In order to generate an unambiguous analysis, the survey answers with the values '3' (i.e. diffuse impact) and 'N/A' (i.e. not applicable) have been discarded from the analysis. Additionally, the frequencies of the values '1' and '2' have been combined, as well as the values '4' and '5'. Appendix VIII shows an overview of the Chi-squared tests performed.

The observed frequencies of the independent and dependent are calculated and indicated as actual data. The expected frequencies of the independent and dependent are calculated and indentified as expected data. The Chi-square analysis is performed in Microsoft Excel 2010 using the syntax "CHITEST(actual_range,expected_range)". The syntax uses the Chi-square distribution with the number of degrees of freedom to calculate the probability level (i.e. p-value). The Chi-square (i.e. $\varkappa^2$) is calculated with the equation:

$$\varkappa^2 = \sum_i \sum_j \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}}$$

The degrees of freedom are calculated as the number of independent variables in the problem minus one, times the number of dependent variables in the problem minus one. When the p-value is higher than the significance level of 0,05 there is no statistical significant difference between the independent variables (i.e. potential adopting organization and supplier) regarding the valuation of the major driver or barrier (De Vocht, 2008). In order to perform the Chi-square test, two conditions ahve to be met: i.) All expected frequencies need to be larger or equal to one; ii.) A maximum of 20% of the expected frequencies are between one and five (De Vocht, 2008).

Based on the tests we can conclude that there is a significant relation between the potential adopting organizations (i.e. the independent variables in this test) and the valuation of the barrier 'low availability of information'. As shown in Table 22, potential adopting organizations have a significantly different perception than suppliers. The potential adopting organizations value the barrier's negative impact on the successful implementation of electric busses significantly lower in comparison to the valuation by the suppliers. The Chi-square tests could not be performed on other dependent variables, because the test-conditions were not met (as shown in Table 21, Table 22, and Table 23).

Table 21. Chi-squared test of the survey results on the barriers 'Low compatibility', 'Perceived higher LCC', and 'Higher risks'.

Low compatibility

	Low impact	High impact	Total*
Potential adopting organization	10	11	21
Supplier	3	6	9
Total	13	17	30

Expected
Low compatibility

	Low impact	High impact	Total*
Potential adopting organization	9.1	11.9	21
Supplier	3.9	5.1	9
Total	13	17	30

Significant?

p	0.47
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	Yes
Max 20% of all expected cell frequencies between 1 and 5?	No

Perceived higher LCC

	Low impact	High impact	Total*
Potential adopting organization	3	15	18
Supplier	6	5	11
Total	9	20	29

Expected
Perceived higher LCC

	Low impact	High impact	Total*
Potential adopting organization	5.6	12.4	18
Supplier	3.4	7.6	11
Total	9	20	29

Significant?

p	0.03
If p < 0.05	Yes

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	yes
Max 20% of all expected cell frequencies between 1 and 5?	No

Higher risks

	Low impact	High impact	Total*
Potential adopting organization	3	12	15
Supplier	3	10	13
Total	6	22	28

Expected
Higher risks

	Low impact	High impact	Total*
Potential adopting organization	3.2	11.8	15
Supplier	2.8	10.2	13
Total	6	22	28

Significant?

p	0.84
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	yes
Max 20% of all expected cell frequencies between 1 and 5?	No

Table 22. Chi-squared test of the survey results on the barriers 'Low availability of information' and 'Low degree of competition', and the driver 'Reduced environmental impact'.

Low availability of information

	Low impact	High impact	Total
Potential adopting organization	13	4	17
Supplier	4	9	13
Total	17	13	30

Expected
Low availability of information

	Low impact	High impact	Total
Potential adopting organization	9.6	7.4	17
Supplier	7.4	5.6	13
Total	17	13	30

Significant?

p	0.01
If p < 0.05	Yes

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	Yes
Max 20% of all expected cell frequencies between 1 and 5?	Yes

Low degree of competition

	Low impact	High impact	Total*
Potential adopting organization	11	5	16
Supplier	7	5	12
Total	18	10	28

Expected
Low degree of competition

	Low impact	High impact	Total*
Potential adopting organization	10.3	5.7	16
Supplier	7.7	4.3	12
Total	18	10	28

Significant?

p	0.57
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	Yes
Max 20% of all expected cell frequencies between 1 and 5?	No

Reduced environmental impact

	Low impact	High impact	Total*
Potential adopting organization	0	22	22
Supplier	1	15	16
Total	1	37	38

Expected
Reduced environmental impact

	Low impact	High impact	Total*
Potential adopting organization	0.6	21.4	22
Supplier	0.4	15.6	16
Total	1	37	38

Significant?

p	0.23
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	No
Max 20% of all expected cell frequencies between 1 and 5?	No

Table 23. Chi-squared test of the survey results on the drivers 'Improved public perception', 'Innovation policy', and 'Visionary leader'.

Improved public perception

	Low impact	High impact	Total*
Potential adopting organization	4	10	14
Supplier	1	8	9
Total	5	18	23

Expected
Improved public perception

	Low impact	High impact	Total*
Potential adopting organization	3	11	14
Supplier	2	7	9
Total	5	18	23

Significant?

p	0.32
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	Yes
Max 20% of all expected cell frequencies between 1 and 5?	No

Innovation policy

	Low impact	High impact	Total*
Potential adopting organization	2	13	15
Supplier	2	8	10
Total	4	21	25

Expected
Innovation policy

	Low impact	High impact	Total*
Potential adopting organization	2.4	12.6	15
Supplier	1.6	8.4	10
Total	4	21	25

Significant?

p	0.66
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	yes
Max 20% of all expected cell frequencies between 1 and 5?	No

Visionary leader

	Low impact	High impact	Total*
Potential adopting organization	7	9	16
Supplier	4	6	10
Total	11	15	26

Expected
Visionary leader

	Low impact	High impact	Total*
Potential adopting organization	6.8	9.2	16
Supplier	4.2	5.8	10
Total	11	15	26

Significant?

p	0.85
If p < 0.05	No

Conditions Chi-square Test

All expected cell frequencies are larger or equal to 1?	yes
Max 20% of all expected cell frequencies between 1 and 5?	No