A systems approach to designing new mobility and smart grid services: The World's Smartest Grid showcase

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The World's Smartest Grid showcase

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Abstract	This report focuses on concepts and ideas that make use of big data extracted from vehicles. Activities related specifically to EVs are facilitated by designing mobile applications. The first steps of the design process of smart charging application are presented.
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Foreword

Energy and automotive are embarking on a quest to get their energy from renewable sources, and electric vehicles show that both industries are becoming more closely intertwined. In order to use renewable energy in the most economical way we need smart grids and vehicle to grid technology that balances supply and demand using modern information technology. In this report, Marinos sketches not only the problem but also possible solutions in the form of multiple smart phone applications.

This report is part of the world's smartest grid project that is creating a very advanced smart grid on what is sometimes called "the smartest square km" on earth (hence the name). The project has also realized – Marinos more than anyone – that extended bi-directional communication to cars based on open standards is vital if you want to create the world's smartest grid. Since this project is one of the first to move on this I have high expectations of its impact, especially since the entire region around it is a hotbed of automotive and energy technology, including a university "next door" that has energy and smart mobility as two of its three strategic areas. So I hope this report is heralding great things to come!

I've come to know Marinos as smart, hardworking, honest to a fault and much too modest for his own good. He was not an expert in this field when he started this assignment but then again: nobody is because this topic simply spans too many technologies, disciplines and domains. Still, I think Marinos has done a commendable job in quickly coming to terms with this broad field and in coming up with fresh ideas for applications that might help to tackle the enormous challenge we have before us. I hope this report will lead to follow up efforts with which we will create the infrastructure facilitating the applications he has outlined and then I hope we will actually build them. I can hardly wait!

Auke Hoekstra
EV Researcher at Eindhoven University of Technology and the E-laad foundation

September 19th 2014

Preface

The transition to a smart grid has become an essential prerequisite for a sustainable future. The penetration of Electric Vehicles (EVs) into the modern automotive society inserts one more variable into the set of problems that needs to be solved in order to achieve the transition.

The number of EVs sold in the Netherlands recently increased significantly, and therefore a large growth in charging infrastructure is required and expected. Power issues associated with the grid's limited capacity will be created during peak-load in future. Smart charging offers the solution to this limitation by establishing a bidirectional communication channel between the grid operator and the EV driver and manipulating the time of the energy consumption (i.e. charging). Besides the grid operator and the consumer, new market roles are envisioned and created such as the Charge Point Operator (CPO) and Mobility Service Provider (MSP) in order to facilitate smart charging.

The virtual platforms that will provide the multidirectional communication between the entities will also create multiple channels of data streaming. Business cases are built based on the exploitation of the data extracted from vehicles. This opens up new markets that target the driver, the traveler or the commuter. The key requirements for these platforms are real-time information and the interface to achieve mass distribution of services.

Mobile applications enable the mass distribution of automotive-related services to the world. Operation Systems that host apps in devices of various manufacturers are already being integrated inside the vehicle's Human Machine Interface (HMI) by the automotive Original Equipment Manufacturers (OEMs).

The main objective of the World's Smartest Grid project is to develop a smart charging infrastructure, using a communication platform that can comprise the test lab for developing, testing and validating automotive services for the EV drivers, for the commuters, for the application developers and for the entrepreneurs.

This was the motivation that drove this project into investigating concepts and ideas of mainly mobile applications. The key question was how vehicle data can serve the end user starting from the smart charging service.

This report is part of the final project of the Professional Doctorate in Engineering program in Automotive System Design and it was made under the umbrella of both the Eindhoven University of Technology and Vehicle Innovation Brabant electric.

Marinos Aspragkathos

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Acknowledgements

Executive Summary

The World's Smartest Grid (WSG) is a project funded by the TKI Switch to Smart Grids headed by a consortium of companies named after Vehicle Innovation Brabant electric (VIBe). Enexis and the site management of the High Tech Campus (HTC) are involved as well. The main goals of the WSG project is the establishment of the elements that can realize smart charging. One of the elements is the deployment of Electric Vehicles (EVs) to employees in the working areas of the HTC, the Automotive campus and the TU/e campus. The installation of Charging Points (CPs) in this region is the second important element. A communication platform that will connect the components mentioned above with the grid operator (Distribution System Operator - DSO) and the Charging Point Operators (CPO) is the key element of the infrastructure (i.e. virtual and physical).

The stakeholder analysis of the WSG project revealed a complex web of companies associated. Besides VIBe that consists of six organizations (TU/e, NXP, Automotive NL, BOM, Daut Milieu and Autogroep Driessen), there were companies currently involved in smart mobility services such as SycadaGreen, Vtron, Greenflux and Alliander Mobility Services (AMS). Autogroep Driessen is the company in charge of the deployment of EVs. GreenFlux provides the HTC management with the CPs. Vtron and Sycada Green install communication boxes in the vehicles and can provide alternative solutions for the communication platform that VIBe has planned. These were only few examples of the ongoing interrelations in the project.

Automotive services regarding the electric mobility and transportation was the main focus of this report. The stakeholders' requirement was to expand the range of applications regardless of the electric factor. Almost twenty mobile applications were investigated divided in two main categories of smart mobility and energy management. Smart mobility was divided into car management, fleet management, chain mobility and traffic management. Energy management was divided into the load management and green energy management. Other research areas that mass data from vehicles can be used were investigated. Examples are research institutes, governmental authorities and insurance companies.

The next step was to focus on the commercial added value of a limited number of applications that fulfilled a variety of criteria. The CP Reservation & Smart Charging application is investigated and presented in that perspective. The business case has been constructed to support the potential of the commercial value. The CP Reservation & Smart Charging bases its success on the national deployment of EVs along with the respective installation of CP infrastructure. Currently there are approximately 38000 EVs including Plugin Hybrid Electric Vehicles (PHEVs) and Fully Electric Vehicles (FEVs) according to the Dutch government. FEVs were only 5100 (i.e. 13% of the total fleet) until July 2014 which is the base market that the CP Reserve & SM can target. The average estimated projections of the EV deployment reach the 200000 by 2020 and assuming that the battery technology will develop, the percentage of FEVs will increase as well. So the EV market is expected to grow by 400 – 600 % in six years, creating various opportunities around it. The CP infrastructure (currently 8000 CPs) is expected to follow the EV deployment creating excessive demand in charging during the process. For instance only in April 2014 there were 40000 charging transactions operated by one CPO (i.e. e-Laad).
The design process continued until the requirement elicitation of the same applications. The CP Reserve & SM application will include features such as CP locator displaying a map with charging stations available in the user's region. The reservation of CPs will be enabled and that will be the Unique Selling Point (USP) of this application. The app will be able to set the radius of interest based on the host's location. Reliable update of CP status in the frequency of few minutes is a hard requirement as well. The user could filter the CP map based on the vehicle type and also set the desired target of SoC or the time of arrival and the duration. Communication with the DSO through the CPO or other intermediate is mandatory to facilitate smart charging. Futuristically the selection of the source of the energy mix could be provided as an option. Similar conceptual processes have been developed for the EV path planner, the Seat market manager and the HTC EV parking solution. Use cases, flow charts that display the functionality of the apps and list with the main requirements have been drawn.

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1.Introduction

Smart grid technologies comprise a field of endeavor where the multidirectional communication in the energy market is facilitated. At the same time the quality and quantity of services for energy consumers is going to be improved. So far many pilot projects have been initiated. They are focused on the benefits of smartening the electricity grid, of replacing the world's transportation fleet with electric vehicles and of integrating renewable energy into the ecosystem.

1.1   Towards sustainable energy

Worldwide, we need to make our energy ecosystem more sustainable. While energy consumption is rising continuously, the dependency on fossil fuel has not dropped, despite the fact that the dead-end has been recognized for nearly 30 years now. Coal, oil and natural gas are the sources for approximately 85 percent of the total primary energy supply. Energy security has been identified as the main challenge to achieve sustainability due to the finite resources of fossil fuels. Climate change is the second problem that needs to be addressed due to its irreparable harm to the environment.

In the past years there have been quite a few European regulations and directives dealing with energy matters, emphasizing electricity as a crucial enabler of economic growth. The three European energy policy pillars are security of supply, sustainability and market efficiency. One of the most important European directives is the "20-20-20" energy policy that sets three key objectives for 2020:

- a 20% reduction in EU greenhouse gas emissions from 1990 levels,
- a 20% increase of the share of EU energy consumption produced from renewable resources,
- a 20% improvement in the EU's energy efficiency.

Energy security and reduction of CO2 emissions are tackled by confronting the major oil consumers and by changing the traditional methods for producing electrical energy. The transportation sector contains some of the biggest oil consumers overall with passenger vehicles depending on petroleum and gasoline for more than one century (Table 1) [1]. The electrification of transportation has become an indispensable part of a sustainable future.

Table 1 World energy consumption by end-use sector and shares of total energy use*				
	Energy End Use[2]	Electricity Losses[3]	Total Energy Use[4]	Share of Total Energy Use
End-Use Sectors				
Commercial	29	34	62	12%
Industrial	200	66	266	51%
Residential	52	40	92	18%
Transportation	101	2	103	20%
Total End-Use Sectors	382		524	
Electric Power Sector[4]	204			39%
Total Electricity Losses[3]	142	*quadrillion Btu	[1] This is the most recent year for which data are available at the time of update. [2] Energy end-use includes end-use of electricity but excludes losses.	[3] Electricity losses includes losses in generation, transmission, and distribution. [4] Total energy use includes electricity losses.

A specific group of measures and actions leading to an electrified energy-dependent society is discussed below.

The building units are required to be micro-plants of Renewable Energy (RE) production, which feed their surplus to the grid.

The slow integration of the intermittent RE production to the grid should be accelerated.

The energy storage technologies are an essential factor for the desired sustainable future with primary focus on improving battery technology for RE applications and Electric Vehicles (EVs). The electrification of the global means of transportation, especially of passenger vehicles, is the ultimate stake of the scientific community, the manufacturers and the society. Efficiency is the key element that characterizes the previous technological efforts for breakthrough. That is also why full electrification of the energy systems is extremely important for roadmaps of a sustainable energy-dependent society. Electricity is more easily distributed and can be consumed with minor losses and without pollution.

1.1.1. The electricity grid system

The electricity ecosystem consists of three basic layers. The first layer is the electrical-energy production from fossil fuels such as coal and natural gas, and from nuclear. Additionally electrical energy is produced from Renewable Energy Sources (RES) such as solar, wind, wave and hydropower. The energy transportation is the second and primer layer of the electricity grid defined by the transmission and distribution processes. The grid's borders extend to both the energy production and the energy-demand layer which is the third part of the ecosystem. The increased demand was the trigger that made the transition to a sustainable intelligent solution a necessity. Major contributors to the energy demand are the industrial and commercial consumers as well as the households that over the years became more and more energy intensive.

1.1.2. The EV factor

One new (or very old) consumer was re-introduced in the past decade. EVs are evolving rapidly to the new trend in transportation. Along with the technological explosion of smartphones in the past decade, a need was created for smart applications integrated in the vehicle.

Smart mobility addresses problems such as managing traffic, increasing road safety, designing an infrastructure with lower operational costs and making the transportation of people and goods efficient and sustainable. The common denominator of these results is information and the means to share it almost in real-time between the driver, the vehicle and the operators. It is also a prerequisite in order to integrate the new key elements that the energy transition requires. One of the most important elements for EVs is the charging infrastructure.

There are not many times in recent history that mankind thought ahead and actually initiated strategies in order to avoid upcoming problems. These strategies require innovation and one characteristic example is smart charging. While many realize that EVs are going to be a robust pillar of the energy solution, there is some skepticism around the downsides that EVs could actualize; their impact on the electricity grid being the topmost one. However it has been argued that it will require an enormous number of EVs to create capacity issues to the electricity grid and that number may not even be reached.

The majority of pilot developments towards the smartening of the electricity grid have been made already without taking into account the EV factor. These projects are focusing on the other large consumer of the energy demand layer, the households. The scientific and industrial community zoom in on the energy consumption of households and EVs because they offer more flexibility in terms of time-shifting demand than industrial and commercial consumption.

The need for load flexibility is expressed mainly by the Distribution System Operators (DSOs) that are concerned about the grid investments that will be required to meet the increased electricity demand. Studies have shown that the investment cost would be much greater than the actual realization cost of the smart grid.

1.2   The Smart Grid

The smart grid is the evolution of the electricity grid that realizes the bidirectional communication from the energy producer through the grid operator and energy supplier to the consumer. Smart grids utilize information and communications technology to monitor and actively control supply and demand in near real-time. This provides a more reliable and cost effective system for transporting electricity from the energy production layer to households, commercial customers and industry. Furthermore, it integrates decentralized RE production into the grid. Some examples of the capabilities of the smart grid technology are the integration of real time pricing and smart sensors connected to the cloud (such as thermostats). These electronic devices can be controlled remotely either by the user or the energy supplier.

Smart grid technologies such as smart metering and smart charging are applied to both household appliances and EVs.

The main features and goals of the smart grid transition are presented in Table 2 [2].

Table 2 Smart features & goals

Features
- Smart appliances
- Supply balancing
- Smart meters
- Control electric devices (e.g. thermostats)
- Critical peak pricing

Goals
- Enable active participation by consumers
- Reducing greenhouse gas emissions
- Accomodate generation and storage options
- Anticipate and respond to system disturbances
- Enable new products, services and markets
- Facilitate the EV deployment

Smart grids can benefit EV deployment in various ways:
- Reducing range anxiety
- Creating or enhancing a "green community" image
- Supporting early EV adopters within the community
- Provide charging for municipal and private fleets
- Removing any regulatory barriers for EV charging

Smart charging is the connective process between the energy transportation and the energy demand of EVs. On one hand smart charging turns the disadvantages of EVs into advantages. On the other hand, smart charging is effective enough to stall the power reinforcement of the grid. If the number of EVs increases in the same scale as of conventional vehicles now, eventually the upgrade of the grid capacity will be inevitable. While the role of the demand layer is pretty clear, the transportation layer has a more complicated role especially referring to the smart grid transition.

1.2.1. European efforts towards Smart Charging

The existing European electricity system already provides end-users with a very efficient infrastructure for generation, transmission, distribution and commercialization of electricity. The equilibrium of this very complex system is managed in real time, across all borders of Europe [1]. There are also more than 200 smart grid and smart metering projects from EU27 Member States, Switzerland and Norway. The overall investment until 2011 amounted to over €5 billion (Figure 1). However most of the projects developed do not include EV deployment and smart charging. A brief analysis of the current market reports that Germany, France, UK and Netherlands are the leading countries at building charging infrastructure.
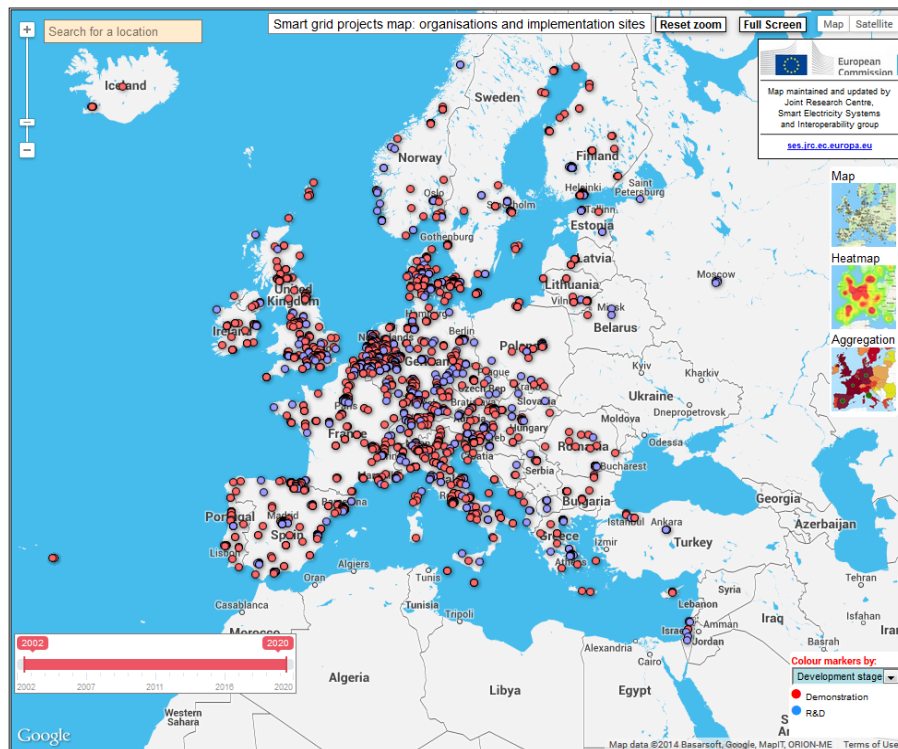
Figure 1 Smart Grid project maps

1.2.2. The Netherlands

One unique characteristic of the Netherlands compared to the rest of the Europe is the role of the grid operators. The largest grid operators Alliander, Enexis and Stedin and most of the smaller ones united themselves in a foundation, E-Laad, and started to implement a national charging infrastructure.

The number of EVs in the Netherlands is also increasing steadily. On July 13, 2013 when the WSG project was in its first stages, there were 10,000 Electric Vehicles (EVs) registered in the Netherlands. Currently (July 2014) there are approximately 38000 EVs including 5100 Fully Electric Vehicles (FEVs). This steady increase is caused by the financial incentives that the Dutch government provides to EV customers. So far, similar tactics have not been applied for the charging infrastructure.

Another unique characteristic is that the Netherlands granted a concession for fast chargers along the highways. These chargers are not hosted by semi-public businesses such as restaurants or gas stations and will be installed on public property (i.e. parking spots).

Furthermore, the type of chargers in the Netherlands are three-phase AC power chargers that are quite popular. "This may be a result of these countries' decision in an early stage to adopt the Type 2 plug standard which enables semi-fast charging. Another reason may be that these countries also aim for relatively early commercialization of the infrastructure and the related need to install smart chargers which are capable of identifying the user and of metering the power use" [2]. (A/N: In the quote Germany is included)

Many projects on smart grid and smart charging specifically are in progress throughout the Netherlands.

The **Amsterdam** New West district contains approximately 40.000 households, of which around 10.000 are served by Alliander's new Smart Grid. New West has a high penetration of smart meters and contains the largest amount of solar panels in Amsterdam. To align current developments and further ambitions in the field of sustainable power supply in New West, this district has been chosen for the construction of the first smart grid in the Netherlands.

In 2009, the municipality of **Rotterdam**, Stedin and Eneco applied to Agentschap NL for a subsidy for the Rotterdam Tests Electric Vehicles project. Different electric vehicles (75) and charging points (129) have been monitored from 1 April 2012 to 1 April 2013. 100 drivers have

participated in this project driving 711.494 electric kilometers resulting in a 67 percent CO_2 reduction, and a reduction of 10 percent of PM and 100% of NOx compared to driving with conventional vehicles. In this year more than 270 million measurements have been registered.

Since 2009 a demonstration project has taken place in **Hoogkerk** near Groningen called PowerMatching City. It was a pioneering pilot project and also a European field trial to connect supply and demand of electricity and heat in an intelligent way. The purpose of the ongoing project is to fully profit and benefit from the characteristics of both centralized and renewable energy systems. During the first phase 25 households participated. At the end of 2011 the second phase took off with 42 households participating in the initiative. The developed IT systems include market models for Charging Points (CPs) and EVs.

Eindhoven

In November of 2013, the World's Smartest Grid project was initiated, aiming at the transition to a smart grid at the High Tech Campus (HTCE) in Eindhoven. The HTCE is an office location where around 10,000 employees work. The imminent cause for the project was that increasing demand threatened to surpass the power limitations of the local grid. Enexis, the regional grid operator, became aware of the upcoming problem and has been involved in the project. But the project will do more than provide a smart grid that alleviates local power limitations. It will also provide a test facility and Living Lab.

In the test facility, stakeholders can apply and test standards, communication protocols, and pilot policies. Of course with a focus on smart grid technologies and especially smart charging. In the Living Lab, innovators and entrepreneurs can apply, test and validate their products and services in real-life environment. Both functions of the same platform profit from the many users and from the massive data flows coming from the vehicles and charging processes. They need those in order to achieve product qualities, like scalability and extendibility. Furthermore, the independent developers need scale to achieve return on investment, break even milestones and profits. The end result will be applications that solve the daily problems of EV drivers and some solutions might even be beneficial for most transportation users.

1.3   Outline

In Chapter 2 the author's contribution to the overall project is stated. The problem's framework was formed after a series of meetings with key stakeholders of the WSG project. Chapter 3 describes the systems approach that was followed using the CAFCR method and how the customers' high level requirements have been elicited.
The stakeholders involved in the WSG project by August 2014 are stated in Chapter 4. Their role, their contribution and the after-project-completion agenda is documented. A graphical representation of the project's stakeholders is shown in Appendix A.
Chapter 5 contains a description of the system architecture of the communication platform that is going to be established to connect EVs with the end users and third-party developers. Furthermore a Charging Point (CP) management solution that is under development is presented. The reason for this chapter is to properly position the layer of automotive application services, which the author is going to investigate, in the overall system architecture.
The conceptual design of the applications that comprise the application layer is illustrated in Chapter 6 and in Chapter 7 the functional view of the application design is discussed. Chapter 8 includes the project management and the work breakdown throughout the past eight months. Chapter 9 encompass the essence of this report through its conclusions and the recommendations for the realization of the application development. Chapter 10 attempts a retrospective of the project and describes the lessons learned.

2.Problem Analysis

The description of the World's Smartest Grid project is presented. The motivation that initiated the project is explained and the main research questions and upcoming challenges are stated. A top-level course of action is presented in a four-year plan. Moreover the scope of the PDEng project is defined and the main problem is analyzed based on the conceptual design, the technology and the business aspect. Finally, possible design opportunities are reported.

2.1   The World's Smartest Grid

The World's Smartest Grid (WSG) is a recently started project on smart grid located in the High Tech Campus Eindhoven (HTCE) in the Brabant region.

This project will be the guiding showcase for larger scale smart grid projects across the whole of the Netherlands. It will establish a Living Lab for entrepreneurs and/or innovative companies to test their applications (products & services). The group responsible for this initiative is the Vehicle Innovation Brabant electric (VIBe).

The WSG project's main objective is to introduce a small-scale smart grid infrastructure in order to investigate in real conditions related innovative technologies that can be developed. The key objectives are:

1. Balancing supply and demand. Because of the large-scale deployment of Electric Vehicles (EVs), the HTCE and the grid operator were facing large investments. Balancing reduces the costs related to infrastructure at the campus and its parking spots (existing and future). Furthermore, upgrading the electricity grid can be postponed.
2. Applying Smart Grid technologies, such as smart meters and sensors, remote controllable switches and applications of telecommunication can lead to smart integrated solutions and reduction of costs of the components.
3. Reduction of fossil energy consumption by balancing with renewable sources (later phase).

A dealership company will be responsible for deploying 150 – 200 (initial target) EVs with communication boxes installed. They will be provided at attractive terms to employees of companies located at the HTCE. The site management of the HTCE will install Charging Points (CPs) (including fast charging in a second phase) throughout the HTCE.

The Living Lab will be based on an open-source virtual infrastructure that will connect every system component (i.e. EVs, CPs). The open-source platform will facilitate an information flow between the deployed fleet of EVs, the charging stations and their operators, the backoffice of Distribution System operators (DSOs) and in the future the decentralized energy micro-plants.

The platform-to-be-designed will focus on the application and validation of the Open Smart Charging Protocol (OSCP) that will eventually be able to provide a 24 hour forecast of the required power capacity. The OSCP standardizes and establishes the bi-directional communication between the DSO and the Charging Point Operator (CPO).

Furthermore, business cases are going to be introduced to convince EV drivers to participate in smart charging. One business case is based on the fact that vehicles, including EVs, stand still 95% of the time. The EV driver will communicate with the DSO through the CPO using the already developed Open Charging Point Protocol (OCPP). This will enable so called peak shaving using charging pattern algorithms. An analytical explanation of the communication architecture will follow in Chapter 5.

The following challenges were included in the initial project proposal:

- How can parameters and data of an EV fleet be extracted smart and inexpensively by standardization, and how can they be uploaded into the cloud based on available technologies and while avoiding lock-in by one supplier or service provider?
- What is the optimum algorithm for learning and predicting charging behavior of EVs 24 hours in advance?

- How can user privacy be ensured when smart charging is based on their data?
- What are the consequences of a scalable EV energy demand in the public domain?
- What market can deliver the required, according to the set specifications, compatible components for in-vehicle technology?
- What is the role of the DSO in the local smart grid and what not?
- What is the overall business case for the smart grid?

The project is funded by the Top consortium for Knowledge and Innovation – Switch to Smart Grids (TKIS2SG).
The WSG project started on November 2013 and will last till November 2017.

Table 3 World's Smartest Grid Project timeline	
2014	Development of the open innovation platform version 0.1. A part of the hardware will be installed, tested and there will be a fleet of EVs deployed. Two additional smart grid innovation projects will be planned in the collaboration environment in HTCE.
2015	The first major test of OSCP will be conducted using the open platform. The EV fleet and CP infrastructure will be expanded.
2016	Business case for smart charging on the High Tech Campus will be developed. EV fleet and CP infrastructure will be expanded.
2017	A number of parties will provide smart charging as a service to EV drivers. • The role of the DSO with respect to smart charging is crystallized within the legal framework • National standard of the OSCP, in-vehicle data exchange communication and overall business case (including the benefits of the DSO)

During the four-year time plan the WSG project will be extended to at least two additional smart grid projects. These projects will use the open-innovation infrastructure and will demonstrate its functionality to attract additional investments for projects that will run outside the TKI context. The challenge of this project is essentially to introduce the collaboration environment, standardize the smart and safe use of personal data, and develop innovative appliances in the Brainport region [3].

2.2   *Delimiting the scope*

Examples of typical research on problems related to smart charging technologies are presented in Figure 2. Some of these problems are addressed by available resources from companies involved in the WSG project. The contribution of each separate stakeholder will be discussed in the stakeholder analysis in Chapter 4. The primary implementation of the overall project is undoubtedly smart charging and its main feature is the indirect peak shaving using real-time pricing as incentive for the EV drivers.

However many of the stakeholders also acknowledge the huge added value in the data that can be extracted from the EVs. The benefit of serving the EV driver and attracting third-party developers is the dual goal of this effort. These two potential customers define the point of view of this assignment. Smart mobility concepts are being developed already and are included in the process of EV manufacturing by OEMs.

Due to the limited deployment of EVs at the moment and due to the huge potential that the communication platform can offer there is a great interest in developing applications using data extracted from conventional vehicles as well.
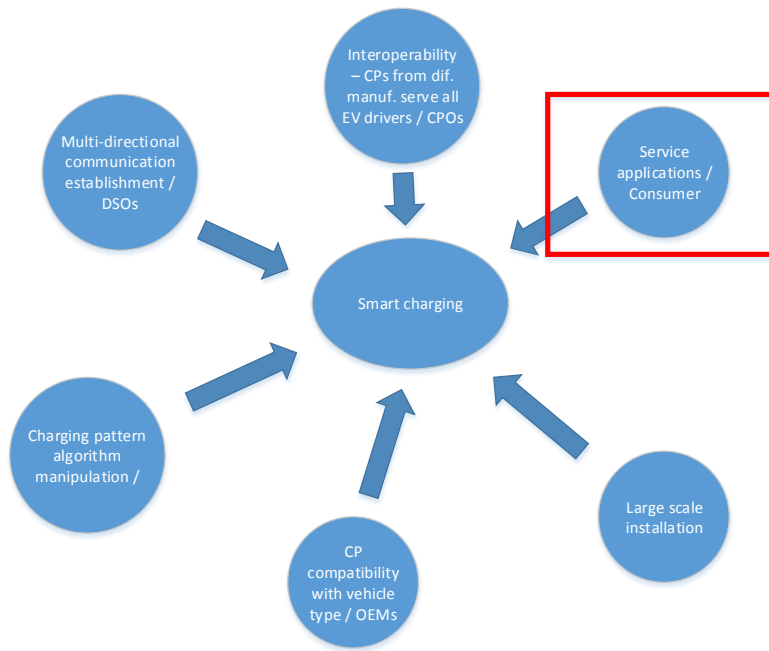
Figure 2 Multiple research angles on smart charging

The stakeholders' considerations for utilizing data value, after the main project is completed, are addressed through the following question:

If the objectives are met what kind of potential lies at the World's Smartest Grid for future applications?

2.2.1. EV-oriented framework

The WSG project's goal is to deploy 200 EVs at the HTCE during the four-year time plan. Nevertheless, according to the stakeholders that run the project, this target will be achieved much sooner. The plan is to expand the project goals regarding EV deployment and CP infrastructure to the TU/e science campus and the Automotive campus in Helmond. Communication boxes are going to be installed after-market inside the vehicles creating a large fleet of mobile data sources. Great opportunities are being created based on an expanding group of customers that soon won't limit their needs to mobile applications which target only to the reduction of EV-range anxiety or the overview of the charging process.

Currently, mobile applications for EVs are quite limited. Most of the applications that have a significant amount of users globally are dedicated for a specific EV model or brand (e.g. the Nissan leaf carwings app). Applications that work across brands are usually limited to mapping the CP stations across the country or in a broader region.

There are markets such as travel and navigation that prove the substantial value in the research of conceptual design of EV mobile applications. These markets are based on the concepts of the Internet of Things (IoT) and big data and channeled through smartphones and other electronic devices. Additionally those markets have shown that apps themselves could facilitate the rapid growth of EVs to the general public.

Therefore, the main goal of the current report and the PDEng's overall project is to investigate mobile applications that satisfy existing needs and anticipate satisfying new ones concerning activities around the EV.

2.2.2. Expansion to conventional vehicles

There is a great stakeholder interest in developing applications that will use data from connected cars independent of their powertrain. While the market for mobile EV applications is still in its infancy there is already a large market for automotive services to regular cars. But what is still lacking in this market is a platform that can provide near real-time information. This is of course exactly what the communications platform of the WSG project can offer.

Three factors indicate the significance of including applications and services on conventional vehicles in the scope:

- benefits the business of service providers due to the numbers of end users,
- serves a great number of customers with additional advantages for the society,
- tests qualities of scalability and extendibility of the platform directly.

Business Roadmap

Research questions were also addressed in this assignment regarding the business aspect of these applications.

What business cases with potential can be derived and what markets can be addressed?

A preliminary business case for the development of mobile applications (i.e. app for CP reservation & smart charging) is included in Appendix B.

Technical development aspect

Which are the functional specifications of the mobile applications with respect to the communication platform?

Important qualities of interest are scalability, flexibility and security. A systems approach that can show the roadmap of the development is going to be presented.

2.3 Design Opportunities

In the initial phase, the user interface will be provided by smartphones and tablets, so the project can immediately reach a large community of potential users. In a later phase when the OEMs open the in-vehicle Human Machine Interface (HMI) platform (e.g. Open Automotive Alliance) to third-party developers these applications will also be part of the in-vehicle services.

The described framework and the scope of the project limited the design to a high level of abstraction process with respect to the design opportunities that could be encountered. Main attention was paid to the conceptual point of view, the structure of the problems of this project and not in the implementation of apps.

The specific steps of the design process, which were described by the CAFCR method until the functional view, will be analyzed in the next chapter.

3. Systems Approach

In the previous chapter the framework of the problem was analyzed. The next step is to describe the method that was used to approach the problem and outline the process throughout three to-be-defined phases. The definition of CAFCR method and its application to this project is addressed. The selection of the specific method is reasoned. A top view of the key drivers, the value chain as well as the requirement elicitation is presented.

3.1   Introduction

The Living Lab consists of four system units being the EVs, the CPs, the interface devices of end users and developers, and finally the communication platform that connects the subsystems together. On top of that multiple stakeholders with different views and objectives are involved constructing a quite complex ecosystem that can be approached using a system thinking process. In every layer of the ecosystem, either it is the stakeholders or components, there are intricate interrelations in both business and technical level that need to be investigated and analyzed. The structure of this process is going to be expounded by the CAFCR method.

3.1.1. CAFCR Method

CAFCR is a method that describes the high-level approach of a system designer towards the process of a project and it consists of five stages [4].

Customer objectives is the first part of the analysis of the stakeholders. It contains the key drivers that make the stakeholders involved in a project in the first place. It includes the value chain of the stakeholders starting from the initiators of the project to OEMs, suppliers and indirectly-involved companies to ultimately the end users and consumers.

Application view is the second part of the stakeholder analysis. It further analyzes the stakeholders and their concerns. The boundaries between the customer objectives and the application step are not clear. The application view contains the entity relationship models which shows what are the key elements that these companies exchange with each other (e.g. information, money, and energy). The context diagram assists to understand the field; for instance to define the keywords that express and characterize the domain.

Functional view contains basically the translation of the application key drivers and of the top-level requirements into functional requirements. Use cases are the ideal way to convey the main functionality of the product and eventually to produce the technical functional map which includes the required information, components and interfaces in an abstract level.

Conceptual and Realization views are the stages of the project's process that describe the implementation phase. Conceptual view is used to convey how the service fulfills the specification that were defined. The main difference is that conceptual phase can be reusable in contrast to realization. Conceptual phase includes the construction decomposition and the functional decomposition of the system under development.

The realization view consists of the budget-based design flow that makes the design explicit and specify the requirements for the detailed designs. During the realization view qualities such as security and functionality are tested and validated.

The method provides a structure to the process, it has the advantage of still being usable even if it is not applied entirely. Although it cannot be characterized as modular mainly because its boundaries between the steps are not strictly defined, it is still a flexible method that offers the helicopter view which is mandatory for such an assignment. The second advantage is that the qualities attributes, can be treated as integrating needles through the five CAFCR views. Quality attributes are taken into consideration in the process of the conceptual design and requirement elicitation which is critical for their integration in the implementation phase.

3.1.2. Application of the CAFCR method

The process was divided into three phases based on the CAF model (Figure 3). The first phase was the stakeholder analysis that was required to identify the companies involved and their roles. The analysis was quite important to mirror the companies' contribution to the overall project. It was also used to identify their needs and their business agenda during and after the completion of the project. The key drivers of each company and of the overall project were then identified. The stakeholder analysis was part of the customer objectives and part of the application view mapping the stakeholders' affiliations into an entity relationship model (Appendix A). The main reasons that indicated the importance of the stakeholder analysis for the project are:

- mapping the current stakeholders provides a concise top view of the companies involved and facilitates the interrelation flows of the system and speed up the progress,
- exploration of their main interests and their business agenda was used as input for applications of interest,
- stakeholder analysis can highlight the conflicting requirements especially in a collaboration environment that combine the public and the private sector.
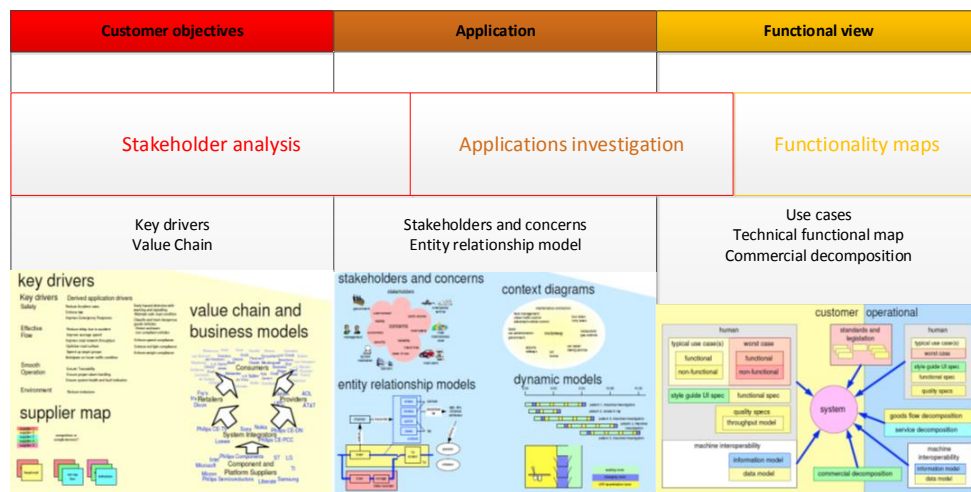
Figure 3 CAF approach followed during this project

The second phase of the process was the application investigation, which was the core requirement of the internal stakeholders. The mobile applications, which were considered, were divided into specific categories of mobility services and they will be presented in Chapter 6. Prior to that, the description of the system architecture of the communication platform is given as the stakeholders have envisioned it. The current status of the development is still under implementation, therefore only the most important features will be discussed. The generation and examination of applications will be the proof of the added value of the vehicle's data.

The third and last phase contains the functional requirements of the apps. The procedure begun with building use cases for a number of scenarios that describes how the functionality of the apps was conceived. Then full operational maps are constructed using flowchart diagrams. Additionally, the commercial decomposition takes place by building business cases for applications in order to explore the potential benefit from a monetization point of view. The business cases capture the potential of consequent projects and can attract more companies to extend the collaboration environment (Business case of CP reservation & Smart charging app can be found in Appendix B).

The main quality attributes of the applications are scalability, extendibility, security, privacy, performance and functionality. These qualities will concern software developers in the implementation phase and express the integration of the communication platform with the service applications layer. On the other hand, there are different qualities that appeal the end user and influence the design process such as usability, privacy, simplicity and price (i.e. free of charge).

3.2   Key drivers and value chain

There is a common understanding that the electricity grid will have to be upgraded in the fore-
seeable future. Notably in the Netherlands EVs were introduced and spread fast, therefore the
electric energy demand is going to grow. The Dutch government, the Distribution System Op-
erators (DSOs) as well as the scientific and high tech community recognized the need to take
action through pilot projects. The main objective is to evolve the electricity grid avoiding the
investment cost of a possible capacity upgrade. Other key drivers are strongly related to the
High Tech Campus and to an extent also to the Brabant region (Figure 4). Moreover the vision
includes the attraction of more companies at the HTCE. These companies develop innovative
smart grid services and products and can increase the technologic impact of the region world-
wide.
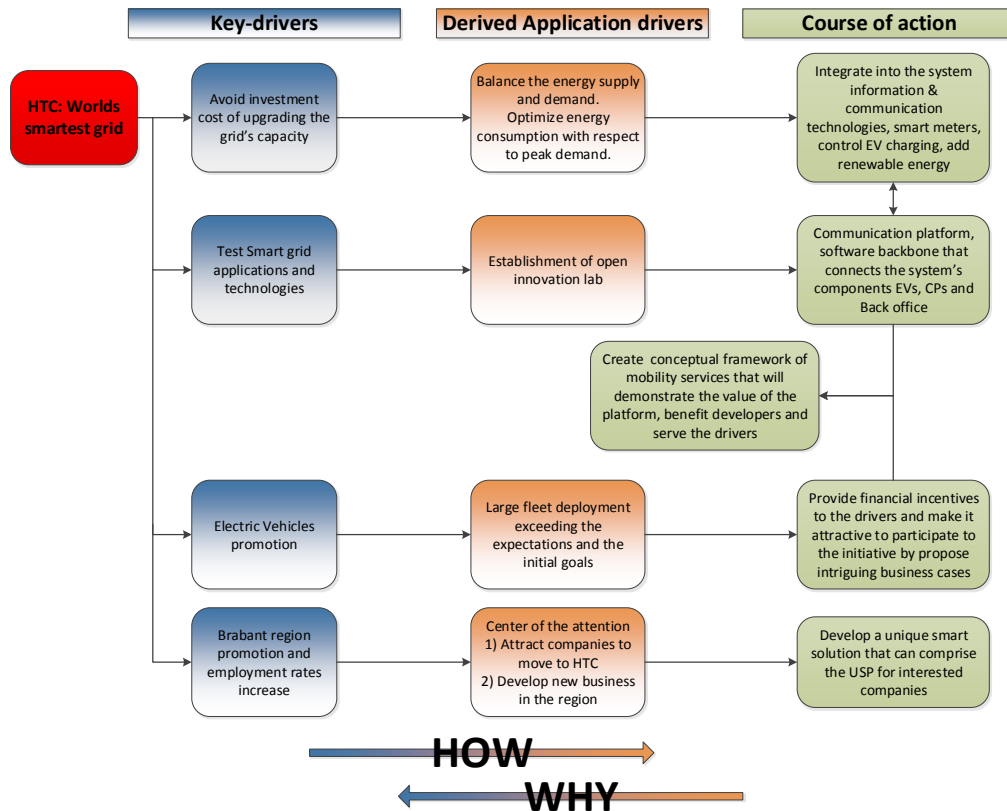
Figure 4 Key drivers translated into applications drivers

The value chain (Figure 5) exhibits a series of activities that were commenced by the VIBe
initiative through various types of stakeholders to the end user. VIBe now creates added value
by extracting the in-vehicle information and offering it as input to third-party applications using
open standards and user-friendly web services.
The chain accentuates the necessity of a unified communication platform between the multiple
stakeholders working in the collaboration environment of mobility services. Every party has to
comply with the same standards and communication languages, instead of each regional part-
nership building their own. In that way huge business case can be created considering that cur-
rently there are more than 1 billion vehicles globally (more than 8 million in the Netherlands)
on the roads. One common platform reduces the complexity of the interrelations of entities,
facilitates the flow of data and capital and optimizes the benefit for the end user and the devel-
oper.
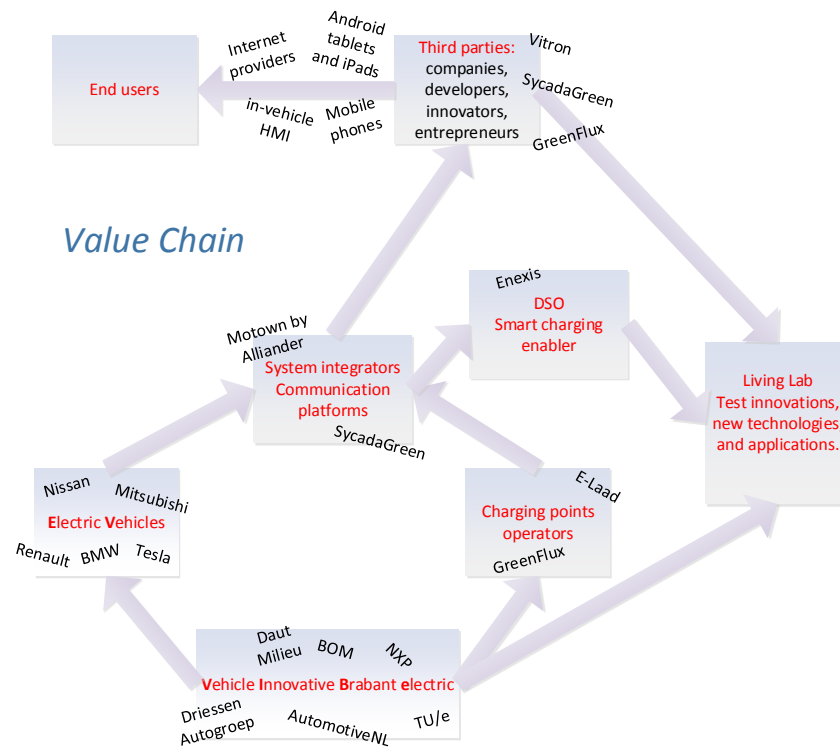
Figure 5 Value chain of the entities that are or could be involved

3.3   Customer wishes and relevant Stakeholders

The customer's (members of VIBe) desire was the exploration of services and applications related firstly to smart charging technology, then with the EVs and finally with mobility services in general.

Initial directions by the customer have been given regarding fleet management. Fleet management is one of the most promising and directly feasible group of applications that use combination of data extracted from the EVs. Key elements of the monitoring can be battery health and EV range (state of charge).
Other business cases on fleet management can be derived with respect to fuel saving and CO_2 reduction, regardless of the type of the powertrain of the vehicle.

According to individual stakeholders, seat market or shared mobility will become the absolute trend and will monopolize the chain mobility management. Chain mobility applications offer the user a variety of options when it comes to traveling by a combination of different means of transportation (e.g. cars, train, buses).

Elicitation process
The requirement elicitation that was performed consisted of the following steps:
1. identify different problems and challenges based on the majority of the directly involved stakeholders (VIBe, Enexis, HTCE),
2. define the research problem based on the requests of key stakeholders (i.e. VIBe and TU/e ASD PDEng requirements) and the author's competences,
3. retain a strong core of key stakeholders during the project to process iterations of the requirements validation,
4. integrate the feedback on each deliverable (i.e. stakeholder analysis, application investigation and business cases and functional specifications) at the end of every phase.

4.Stakeholder Analysis

The World's Smartest Grid (WSG) project involves many stakeholders from different fields with disparate agenda and requirements. The stakeholders focus on the question of how this project can become beneficial for each side. In this chapter VIBe along with Enexis and HTCE will be introduced in relation to the WSG project which is funded by the TKI Switch2SmartGrid. Each one of the six companies that comprise the VIBe initiative is presented separately. Stakeholders that are interested in the WSG as the first innovators will be presented. Appendix A includes a representative relationship model of the stakeholders involved in the project as well as graphic diagrams of the individual contribution.

4.1   TKI Switch to Smart Grid

TKI stands for Topconsortium Kennis & Innovatie and it is a public-private partnership in line with each of the nine top sectors of the Dutch government. The Top consortium Smart Grids Knowledge and Innovation is formed within the top sector of Energy and it is one of the seven existing TKIs. The TKI Switch2SmartGrid contributes to the six goals of the top sector of Energy [5]:

- producing 20% less CO2 emissions in 2020,
- reaching 14% renewable energy in 2020,
- exploiting the potential for energy saving,
- turning competitive energy prices in the short and long term,
- strengthening position of Netherlands in key sectors,
- making renewable energy options more competitive faster.

TKI Switch2SmartGrids is responsible for funding eleven projects which started in 2013. The total budget for these projects is over 12 million € (Figure 6). The total amount of the subsidy is 5.28 million €. The rest of the budget is covered by own contributions.

100% = 12.034.802 euro

Figure 6 Projects funded by TKIS2SG divided to four sources of absorption
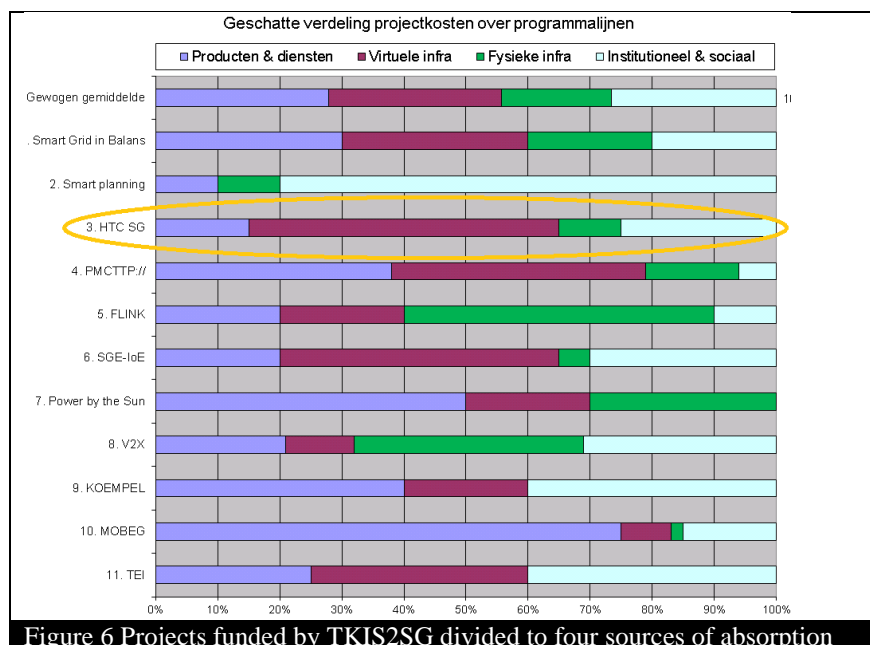
TKI Switch2SmartGrid is the main sponsor of the WSG project funding the partners of the project (i.e. Enexis, HTCE, TU/e, Sustainable Growth Capital/Daut Milieu, Driessen Autolease, BOM) and recognizing NXP and AutomotiveNL as participants of the initiative [6] (Figure 7). The other sponsor is the Rijksdienst voor Ondernemend Nederland (RVO.nl) which channels subsidies from the government to encourage innovative entrepreneurship.

Enexis is the second, Alliander being the first, major grid operator that handles over 2.6 million electricity connections mainly in the Brabant region.
The site management of the High Tech Campus Eindhoven (HTCE) is the administration company that facilitates the operational systems of the campus (e.g. transportation, parking lots, power grid). Enexis and HTCE are involved in the WSG and they are funded by the TKI Switch 2 Smart Grids center along with the members of VIBe except for NXP and AutomotiveNL.

Figure 7 Parties involved in the WSG project

4.2 Vehicle Innovation Brabant electric (VIBe)

The VIBe consortium was inaugurated in the early 2013 and consists of six parties with (inter)national reputation in their field. Particularly TU/e and NXP have the social and technological magnitude to propagate the WSG to the rest of the world. Autogroep Driessen is a nationwide car dealership and AutomotiveNL a knowledge center focused on smart mobility located at the Automotive Campus in Eindhoven. Brabantse Ontwikkelings Maatschappij (BOM) is a development agency with strong relationship with the government (Province of N-Brabant). BOM investigates potential business cases in various fields and invests in them. Sustainable Growth Capital is a corporate advisory company that manages projects of sustainable and innovative genre.

The inception of VIBe as well as the roadmap of a variety of technical projects was intuitu personae. VIBe was founded by a group of people, who are employed by essential players in the region. These people share the vision of an innovation platform and the fact that only through a collaboration environment is possible to accomplish a swift establishment of new, smart technologies in the automotive and energy sector.
The VIBe partnership is responsible for the standardization of the Information Technology (IT) infrastructure and for the additional growth of electric mobility at the HTCE, with the ambition to export these ideas toward the TU/e Science Campus, and the Automotive Campus in Helmond.

The initial objective of VIBe was to design and develop an open platform in the format of a Living Laboratory. The rationale behind this objective was to stimulate entrepreneurs and companies to develop and test their innovative products and services in a real-condition environment. These developers will be able to apply their ideas and produce results faster and cheaper. Vehicle energy management, smart mobility applications, fleet management and car sharing applications are typical examples of projects and applications of interest. The platform will be the virtual foundation for follow-up projects that could be of individual interest of the companies that comprise VIBe as well.

VIBe's structure is characterized by flexibility. Besides the core objective of the innovation platform, VIBe was created initially to focus on projects related to EVs. The current distribution of different vehicle types limits the vision of the consortium and activates them to expand the zone of their activities to the whole automotive workspace. However it is anticipated that EVs will start replacing conventional vehicles, thus in order to prepare the technologic ground projects on ICT systems are developed and later on can be applied with minor modifications to EVs.

The communication platform will be the software 'glue' between the physical world of the vehicles and the infrastructure units, and the virtual world of the cloud server, the databases of information. Therefore the added value, which VIBe is willing to invest in discovering, is the data that can be extracted from the vehicles and the infrastructure. The ways of exploitation of those data is the focus of this report and the author's contribution to the overall project as it was analyzed in Chapter 3 (Problem Analysis).

In summary, VIBe introduces a Living Laboratory that consists of four conceptual layers:

- Connected cars
- Information flow
- Applications and services
- Innovative technologies

4.3   Individual contribution and objectives

The individual contribution to the WSG along with the objectives of each company involved are stated. The stakeholders map is presented graphically on an entity relationship model and with individual company diagrams (Appendix A).

Eindhoven University of Technology

TU/e is a co-founder and a member of VIBe's steering group and offers to the project scientific support, advanced theoretical and practical know-how in the area of smart mobility with focus on Electric Vehicles (EVs) and comprehensive expertise in the area of smart charging. TU/e is able to provide a flow of resources through bachelor and master thesis, PDEng final projects, PhD thesis to ensure the continuation of the support to the project. The university serves the project as an objective pillar of integrity and assurance to the various stakeholders of the project.

The main beneficial business for the university that arises consists of the following aspects:

- a Living Lab where the academic research can be applied, tested and validated,
- attracting program research funding, EU sponsorship and subsidies, more students (tuition fees),
- sponsored Master thesis, PDEng final projects, PhD thesis by the current stakeholders (VIBe, Enexis etc) and the future stakeholders.

Externally, if the collaboration environment (University and industry) succeeds its goals subsequently there would be more EU and governmental subsidies available for more projects in a larger scale of smart charging infrastructure in order to ensure the continuation of the research and development and eventually the establishment of the Smart Grid in the Netherlands. It will be a small confident step to achieve the strategic goals in the areas of smart mobility and energy.

NXP

NXP is a co-founder of the VIBe initiative, a member of the steering group committee and of VIBe solution systems. NXP is actively co-designing the architecture for the communication platform and exhibits currently considerable activation relating to the progress of the project, specifically in matching VIBe's requirements with the selected middleware solution design specifications.

NXP interests lie on two categories of applications that they offer as a company. In the area of automotive there is development in in-vehicle networking, car entertainment, and telematics. In the area of identification there is huge interest in secure identity, secure transactions and tagging & authentication.

The development of security systems can be extended to the Smart Grid cyber security market if NXP chooses to expand their business to the side of smart charging between the transportation layer and the platform; the grid's transmission and distribution parties.

There are many examples that makes the security layer a necessity to the system such as [7]:

- loss of grid control resulting in complete disruption of electricity supply over a wide area can occur as a result of errors or tampering with data communication among control equipment and central offices,
- consumer-level problems ranging from incorrect billing to interruption in electric service can be introduced via smart meter tampering,
- commuting disruptions for electric vehicle operators can occur if recharging stations have been modified to incorrectly charge batteries,
- data confidentiality breaches, both personal and corporate, can provide information for identity theft, corporate espionage, physical security threats (e.g. through knowing which homes are vacant), and terrorist activities (e.g. through knowing which power lines are most important in electric distribution).

Sustainable Growth Capital (SGC)

SGC is a corporate advisory company that targets to introduce innovative technologies for a sustainable future. One of the partner companies is the **DAUT Milieu** (Enviromental sector), which is a consulting and engineering company specialized in the field of sustainable technologies.

DAUT Milieu is also a member of VIBe's steering group and VIBe solution systems. The overview of the project's development is the main task of DAUT Milieu side.

- Project management
- Project time planning (deadlines, deliverables, milestones)
- Financial management
- Decision making and agreements monitoring

Their objective is to accomplish the goals of the WSG project, to fulfill the requirements of the agreements between the signed parties and to satisfy as many stakeholders as possible. The TKI Switch2SmartGrids remains the primary stakeholder that needs to be satisfied as it is the major sponsor of the project.

DAUT Milieu can become a knowledge frontier and benefit even without participating actively in projects. Consultation to the companies that are involved in smart charging infrastructure projects can be part of the services that Daut Milieu offers.

Finally, DAUT Milieu will expand the VIBe's business agenda to other innovation projects (e.g. CP reservation application, Traffic management).

Autogroep Driessen.

Driessen targets through this project markets such as the three tech areas in the Eindhoven region namely the High Tech Campus, the TU/e science campus and the Automotive Campus. The overall goal is to strengthen the company's position in the Brabant region and in a national spectrum. Other markets that could be addressed are in suburban areas, other universities or industrial campuses, municipalities and governmental agencies.

The potential benefits for the Autogroep Driessen are:

1) Sales: Participation in the WSG project leads to an increase of the car sales (and not EVs exclusively).

2) Car leasing: Leasing is already a profitable business model for Autogroep Driessen and appears as an advisable business model in the case of EVs. The flexibility that leasing offers is attractive to many people. EVs is a technology that is evolving. Leasing a vehicle, which can be obsolete in a few years, can be more beneficial than owning one (e.g. Tesla already announced an affordable EV for the broader public). Additionally the promotion of the cost-effective transportation can be included in the marketing campaign to advertise car leasing. Car-leasing strategy is strongly recommended also because the customer-loyalty rate is three times as strong as it is with buyers.

The need of owning or leasing fleets of cars by major private parties could be enhanced by creating an even greater business out of the vehicle data that could lead to mass vehicle sales. Although that maintenance and repair are services with less appliance in EVs, they create higher dependability of the customer on the specific service provider than before with the gasoline-powered cars. Dealers could benefit by providing a larger product variety to their customers. That requires higher component compatibility adapted to the specific EV model. Diagnostic and repair services requires strong collaboration with OEMs or other manufacturers at this stage of the EV technology. Especially the diagnostic part requires additional competence.

Brabantse Ontwikkelings Maatschappij

The mission of the Brabantse Ontwikkelings Maatschappij (BOM) is to create, improve, maintain and develop the industrial and economic structure in the region of Brabant by offering a range of professional services. BOM invests in a business idea and supports the development until completion. It offers four core activities:

- BOM Foreign Investments
- BOM Venture Capital
- BOM New Business Development
- BOM Business parks

BOM's goal is to strengthen the regional economy and in that sense any entrepreneur that has an idea that meets certain standards and requirements, such as early Return on Investment (ROI), is a potential partner. A percentage of the ROI and shares of the new-coming company (if it is possible) is the form of revenue for BOM. BOM is interested in funding financial schemes that serve the technological upgrade of the area as a long-term investment with the expectation of achieving profit indirectly through future companies and individual entrepreneurs.

One more consequence of concentrating many companies of the same field in one place is the increase of the competition. VIBe can be the example of a successful collaboration in making decisions and exchanging information and resources, thus this competition could turn into an advantage for the region.
The support and fortification of the technological breakthrough with its future benefits in the region can impel the development and the evolution on a national or continental scale.

AutomotiveNL

AutomotiveNL main role is to boost the Dutch Automotive industry through national and international promotion. Additionally the foundation holds the role of representation the Dutch Automotive industry to foreign companies. The main focus areas are Smart Mobility and the Future Powertrain. Being a member of VIBe allows AutomotiveNL to follow the upcoming projects (after the completion of WSG project) and in combination with the technological knowhow can be a strong player in the area of smart grid applications. They are also the company that links VIBe and the project with the Automotive Campus.

The showcase of the WSG can define one of the future technological directions of AutomotiveNL. Traffic management could be a potential application of interest. Future applications in Advanced Driving Assistance Systems (ADAS) and in Car to Car (C2C) communication tested at the innovation lab can be a potential business agenda for the institute., However, this kind of applications requires real-time information with frequency of (mili-) seconds which is not part of the design specifications of the communication platform at this state.

HTCE Site management

High Tech Campus Eindhoven is known as the smartest km² in the Netherlands with more than 125 companies and institutes, and 10,000 employees, researchers, developers and entrepreneurs working on the development of future technologies and products.

The site management of the HTCE is responsible for the charging infrastructure inside the campus. Specifically HTCE installed CPs at the parking spots of the High Tech Campus. The HTCE is the owner of the charging stations.

One point of interest for the HTCE is to make a regulation framework for the users on how to smart charge.

An additional small percentage of the EV charging cost, will go to the HTCE as a repayment revenue model for the purchase of the CPs and their maintenance.

A second point in the agenda is the attraction of technology companies to the High Tech Campus in the long term. In the short term the key driver is to attract companies related to the Smart Grid technology field.

Enexis

Enexis and in an extent HTCE acknowledge that they may face a problem with the capacity of the network and therefore they are willing to invest in smart grid technologies. Currently Enexis sees the WSG as a showcase project that will be used to push the developed standards (e.g. OSCP) to the rest of the stakeholders and "force" them to share the knowledge and the developed technology.

The main objectives of Enexis are listed below:

- tests their Open-source Smart Charging Protocol (OSCP) in a real-life conditions (Living Lab) at the High Tech Campus
- avoids investment cost of upgrading the grid capacity through peak shaving.

4.4 Rest of the current stakeholders involved

The rest of the companies, which are interested in the project, are smart-mobility oriented companies that expand to the EV field. Up to this point there weren't many parties that started their business model exclusively on FEV/PHEV-related application services.

GreenFlux is a company that develops services and products for charging infrastructure and works on a nationwide charging network for EVs. They provide Charging Points (CPs) for businesses and homes, so that everyone can recharge their EVs.

One more point of interest about Greenflux is their green energy contract with Green Choice. The customers are able to charge their EVs using Renewable Energy (RE) through CPs of Greenflux. In this way the driver achieves zero indirect emissions of CO_2, nitrogen or other pollutants.

The ongoing projects regarding charging network are held:
- along the road by ANWB & Green Flux,
- charging infrastructure at Van der Valk,
- charging infrastructure at La Place,
- charging infrastructure at RWS institutes.

Greenflux is the current CP provider of the WSG project holding an agreement with the site management of the HTCE. Also they are co-developers (together with Enexis) of the Open source Smart Charging Protocol (OSCP), therefore they are indirectly involved also from the side of the grid operators.

The main objectives of Greenflux are:
- to develop a charging network and make charging as accessible as possible,
- to expand their company with sustainable partnerships.

The current agenda of Greenflux, regarding the CP network development, includes:

- CPs sales,
- charging passes (badges),
- customized charging components for different EVs.

Vtron's main business is based on hardware components and application development. The Track and Trace System is an online tracking system of vehicles that offers unique advantages for fleet managers concerned with the planning and management of the vehicles and their drivers (staff).
- The system encourages more conscious behavior. As soon as the behavior of drivers can be registered, it makes it possible to influence this behavior. This will lead to: safer driving, lower fuel consumption, less damage and less maintenance costs.
- The new business line "Car Sharing", is specially designed for the business market, to help drivers park in the easiest and most efficient way. Also with Car Sharing, each vehicle will be used much more efficiently by employees who can access easily and quickly a "flexible" transport.
- Being involved at an early phase in this project can benefit Vtron to position themselves in a market at the beginning of its growth. Contracts with other companies can bring profitable deals due to the low competition at the moment. That means parties that are involved now may have to update the pricing of their services because of the rising competition. That could be even more complicated if a private party tries to monopolize the data streaming through exclusive contracts.

Potentially they can also include:
- commercialization of data streaming through the CPO backoffice,
- applications for EV drivers related to CPs,
- applications for DSOs regarding monitoring and managing charging behavior.

The goal of **Alliander** is to avoid the huge investment costs for upgrading the grid capacity in the near future. The goal of **Alliander Mobility Services (AMS – currently Allego)** is to encourage the electric mobility. Technological research and financial investments are required. The four business propositions of AMS are [8]:
- different charging services (ensures that EV-drivers can charge their vehicles, anywhere and at any time, trouble-free and independently of supplier, service provider or charging technology),
- business & retail locations (fleet management, facility and parking solutions),
- mobility service providers & automotive,
- collaboration with local & regional governments to achieve environmental targets.

One of the initiatives supported by AMS (and E-laad, iHomer, NewMotion) is Motown. This is a free open-source platform that assists AMS or another Charge Point Operator (CPO) to share CP data with other stakeholders, e.g. with DSOs to enable smart charging or with third party developers and car manufacturers to enable new services using these data.

Motown is an initiative to set-up a worldwide collaborative community for developing an open-source CP management solution with standardized interfaces for all market actors. Motown stands for MObility Transition Open source Webservices iNterface.

Sycada.Green is an initiative of Sycada Mobile Solutions and develops wireless Machine to Machine (M2M) solutions to cope with climate change. Sycada.Green uses innovative telematics technologies to help corporations make drastic and lasting reductions in fuel consumption and CO_2 emissions, while simultaneously reducing costs and improving the operational efficiency.

Sycada.Green also facilitates the introduction of EVs in corporate fleets by providing a 'plug & play' telematics infrastructure that reduces 'range anxiety' of drivers. Furthermore it catalyzes finance leasing through battery health and residual value assessments. The driver's support tools are state-of-the-art in the automotive industry and can be used with any EV. Sycada.Green also enables corporate e-car sharing programs with web-based planning and reservation tools.

5. System Architecture

This section presents the solutions which the stakeholders are promoting towards the establishment of an open communication platform. The architecture of Motown (focused on CP management) is examined. The VIBe required solution that focuses more on the vehicle domain is discussed. The layer of the overall architecture, where the current report and the PDEng project focus, is analyzed. Finally an explanation of the most highlighted features of VIBe's platform is attempted.

5.1   Establishment of the Living Laboratory

The basic concept of the communication platform is the establishment of an open multi-directional information-flow network between several entities in order to enable at a first phase smart charging for EVs. The key characteristic of the platform is the almost real-time dissemination of data from transmitters to receivers. Data streaming is channeled from the sources (i.e. EVs and CPs) to the service providers and to the end users.

Additionally the features of the communication platform illustrate the potential value of the platform beyond the smart charging application to the realization of the Internet of Cars (IoC) concept and the monetization of the data extracted from the vehicles. Communication boxes are installed in the cars after market by hardware and service providers. Other providers are using in-vehicle existing components to achieve communication with the outer world. VIBe focuses on standardization activities to identify and apply an integration protocol of in-vehicle technology to the middleware. In this phase it will be only allowed to extract information from the vehicle and not send information to it. In-vehicle useful information (e.g. for peak shaving) can be redirected from the platform to mobiles or tablets.
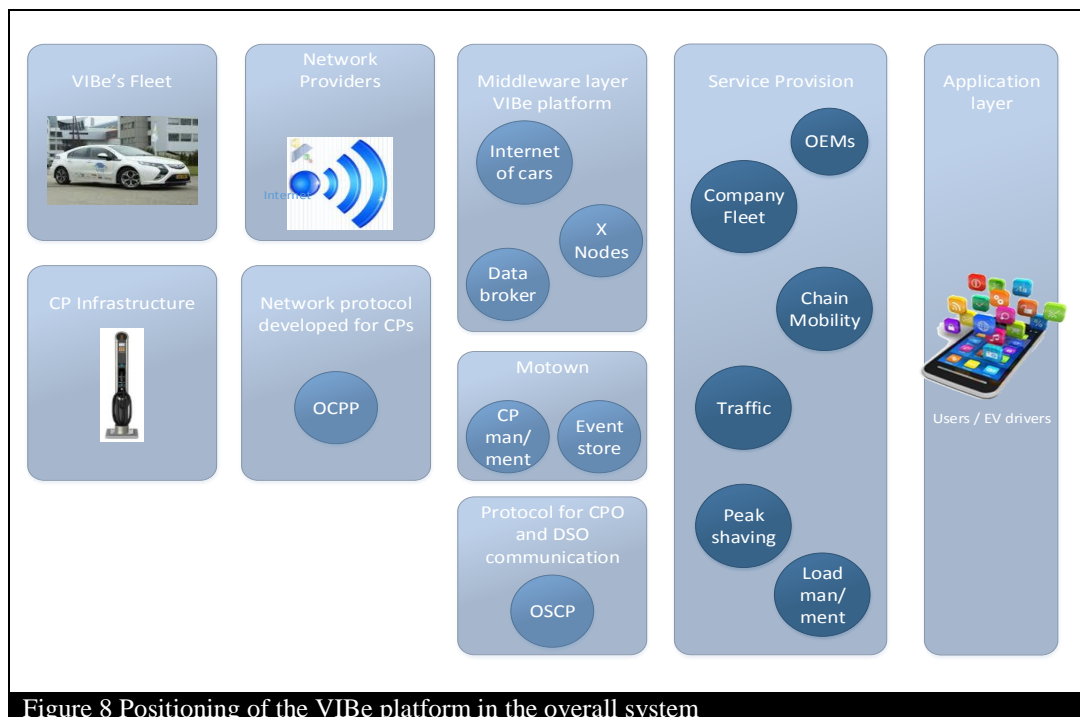
Figure 8 Positioning of the VIBe platform in the overall system

The platform can be described as the middleware layer between the Operation System (OS) and the user applications. A software platform is classified as middleware when it [9]:

1. offers service that provides transparent application-to-application interaction across the network,
2. acts as a service provider for distributed applications.

The VIBe platform focuses mainly on the standardization of the communication with the vehicles. Together with Motown, which focuses on the CP management, it can assemble a complete solution that will serve the EV market.

5.2 Motown Solution.

Motown is an open-source, industry-supported CP management solution. Motown handles the bidirectional communication between the CP infrastructure in the field and the services that want to interact with it (such as the back-office of a Charging Point Operator or CPO). It creates a standardized web-services layer on top of e.g. the Open Charge Point Protocol (OCPP). This creates a smart, responsive and easy to work with interface for services that interact with CP infrastructure [10]. In combination with the Open Smart Charging Protocol (OSCP) it can realize smart charging applications developed for or by the DSOs.

Third-party applications, new technologies and innovative solutions that are able to connect to Motown will be able to offer services to a large audience without worrying about the hardware implementation of the CP infrastructure. The mechanism is developed in such a form that integrating competing products or services is simplified. The top level functional architecture is presented in Figure 9.
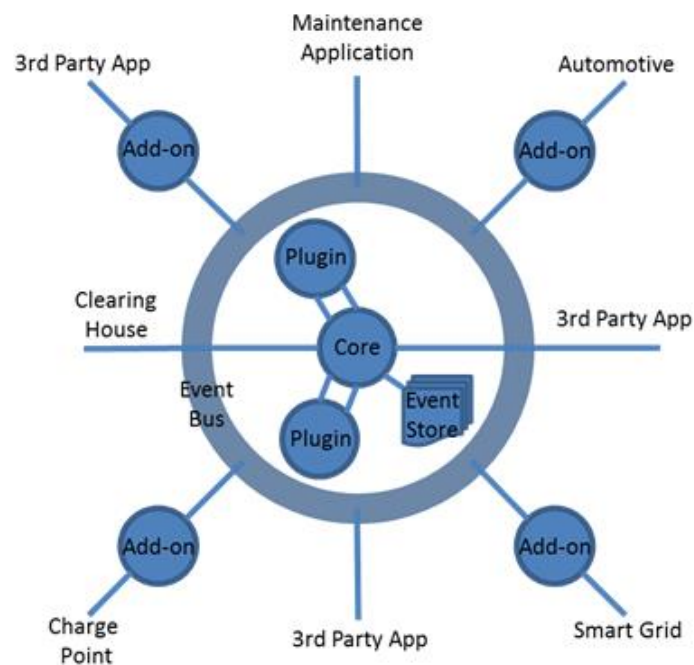
Figure 9 Motown solution

5.3 VIBe Solution

There is a huge added value to the unified solution because of the fact that the platform will not belong to a specific party. All parties involved will be able to take advantage of the opportunities created by each other's attached technologies (e.g. communication boxes suppliers, secure connections services). Significant business cases can be developed using standard components that could be provided cheap and at high volume.

VIBe initiative wish to build the innovation Living Lab based on the middleware layer concept. It aims to combine different technologies that can apply and plug-in at the unified platform. The main integration will occur through the software middleware. This platform is not yet standardized (e.g. multiple communication boxes installed to each vehicle for each purpose to satisfy each stakeholder's requirements is not feasible and efficient).

The Real-Time Push Middleware (RTPM) will serve four main functions:

1) collects data from an array of sources using a variety of protocols,
2) stores collected data in a local database,
3) provides data on request through a web service,
4) provides a publish/subscribe "push" interface to clients who require low latency near real-time data.

A client may require pricing, demand, and sensor data from many sources including the utility provider, the micro grid operator, EV users, chargers, and sensors and actuators using communication protocols (e.g. Zigbee, Bluetooth and others) [11].
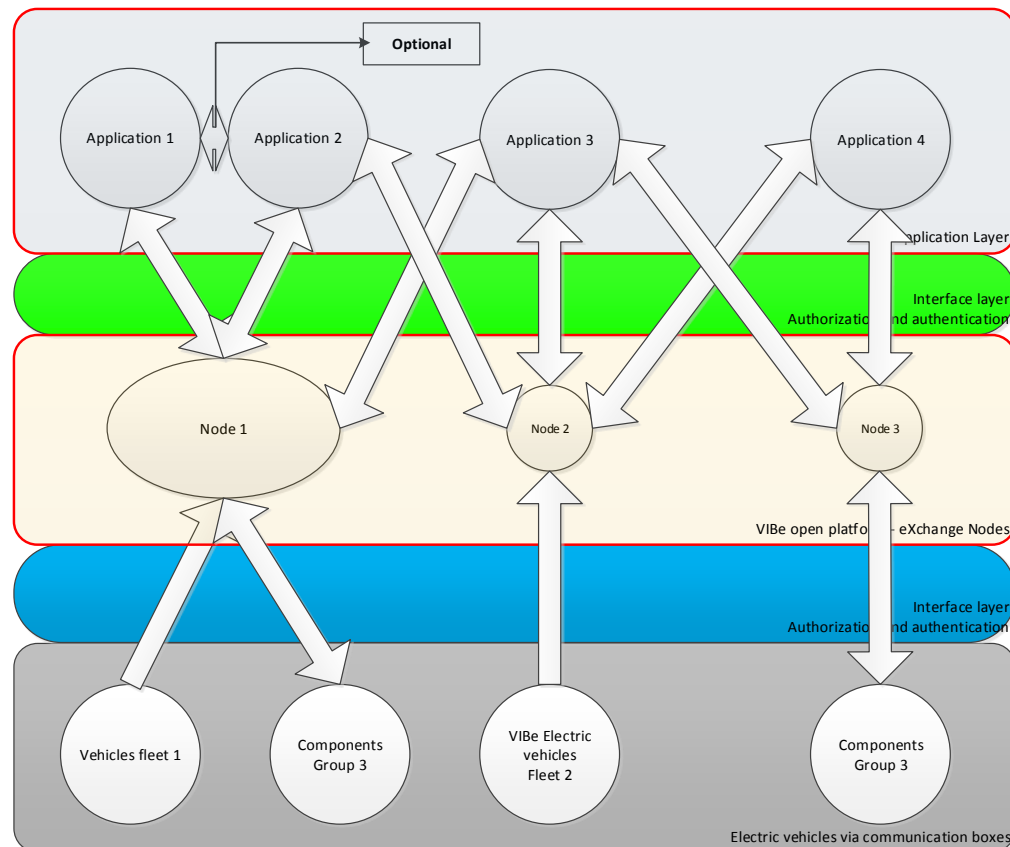
Figure 10 VIBe's middleware solution

5.3.1. VIBe eXchange nodes

X Nodes will be the open-source platform that developers of in-vehicle technology (hardware and software) and OEMs will have to work with in order to be part of the VIBe initiative. A node is software that securely initiates and responds to requests for information. Partners connect their Nodes to databases so that they can securely share their environmental information. Nodes can facilitate exchanges of information between partner databases or publish data that can then be consumed in a number of ways (e.g. on websites, mobile apps, etc.). With properly configured Nodes, network partners can seamlessly exchange data regardless of hardware, operating system, or programming environment. [12]

Multiple applications will be able to connect to an individual node that will retrieve data from various sources (e.g. EVs, CPs through other platforms). The communication between the nodes at the first phase will be avoided due to high complexity in implementation. Moreover at the

first version one unique eXchange node will correspond with one fleet of vehicles operated by one manager (Figure 10).

5.3.2. Interface layer

There are two interface layers that surround the VIBe platform. The interface between the in-vehicle communication technology and the platform is essential for the owners that manages the usage of the data. The data owner is going to be the individual end user that will be requested to share the data with various stakeholders. Privacy issues in data ownership are raised. Their analysis is outside the scope of this project.

The interface between the application layer and the platform will also include an authorization and authentication process to protect end users from malicious software. Separate communication protocols for both interfaces will be developed and standardized by the VIBe initiative.

5.3.3. VIBe data broker

A typical data broker is responsible for collecting, analyzing and packaging personal user information in order to redistribute it to various parties such as consumer marketing analysts. The volume and the nature of the data is varied by the type of the customer. This type of data broker can be part of the application server.

VIBe's data broker will only facilitate the streaming and the real-time access of the data without storing any of those at least in a mass scale for commercial reasons such as a big data history database. In case VIBe manages to increase the deployment of EVs or generally the installation of communication boxes in vehicles then it can create a high demand by different parties. Agencies or institutes that are interested in big data from vehicles are listed in the application category in Chapter 6.

6. Application Investigation

This chapter documents concepts and ideas that pertain to the World's Smartest Grid project and the prospective of developing and applying them in the Living Lab. The intention is to concentrate original, innovative and already implemented applications that can be of monetary or research value with respect to vehicles' data exploitation and utilization. The focal point of this report and of this project is the smart charging of Electric Vehicles (EVs), nevertheless it is beneficial to the stakeholders to include applications of other technologic processes.

6.1 Introduction

The applications were divided into two main categories, smart mobility and energy management. There is a third category consisting of various non-indexed areas of interest where the data streaming of a vast fleet of vehicles can be profitable.

Furthermore, the initial categorization was analyzed into types of management depending on whom they address to. Basically there are the Business to Business (B2B), Business to Customers (B2C) and Customer to Customer (C2C) applications. B2B addresses to fleet managers and owners, private companies, research institutes, official authorities and other governmental agencies, insurance companies etc. The B2C addresses mainly to the end user to the general public (e.g. car management, chain mobility). Most of the B2B applications, previously mentioned, are also addressing to the end user eventually. The C2C market facilitates the exchange of services between the customers themselves for a price.

The following classification shows the applications that are in scope (Figure 11). Other groups of applications such as safety management in Smart Mobility category are considered out of scope of the current project. Groups that can be interested in general in big data from vehicles are stated at the non-indexed category.
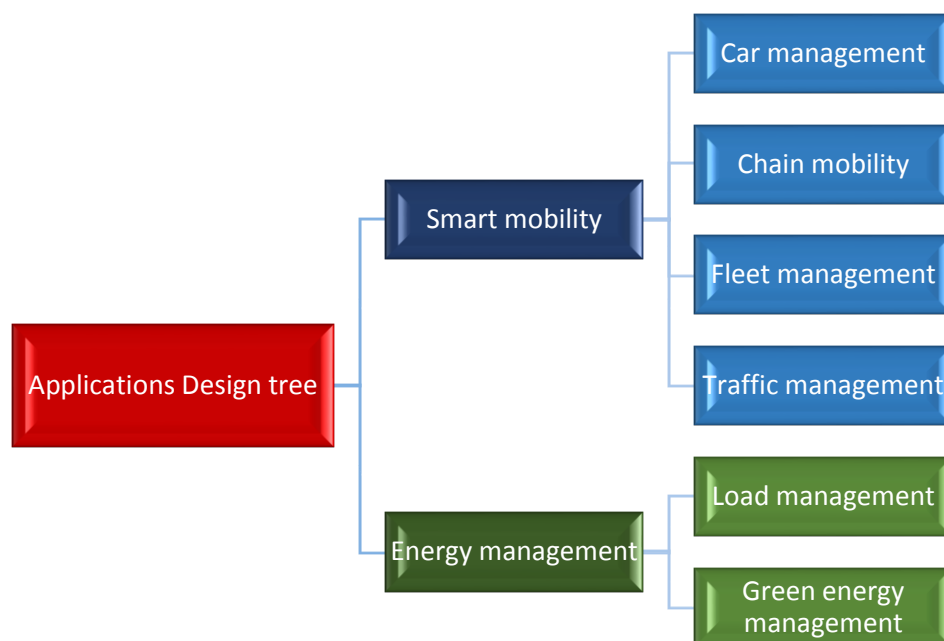
Figure 11 Categorization of mobile applications for the WSG project

■

The Critical Success Factors (CSFs) define the current framework as well as the roadmap of the follow up (i.e. spin-off) projects/applications to result to a well-structured business case. The following CSFs were defined:

- User control and personalization
- Business model subjected to user benefit
- Functionality credibility
- Connected EVs & Charging Points (CPs) & drivers
- Functional relevance
- Architectural consideration
  - Almost real-time update of information
  - Scalable software development (both core platform and application)
- Mass EV deployment along with CP infrastructure
- Transparent privacy security layer
- Full alignment with the concept of Internet of Things (IoT)
  - Internet of Cars as the subsystem
- Community management.

Most of the hereinafter applications are decomposed into a short description of the concept of the application, the fundamental features and significant issues that could be encountered as a preliminary risk identification. The purpose of the app is explained where needed. The elementary prerequisites of a favorable plan are stated.

6.2   *Car management*

Car management services consist of the business to customer applications, which are handled by an operating center that is either the development team or its customer. These services target the individual end user or EV driver to facilitate specific activities regarding long-distance trips, parking with available CP, targeted infotainment etc.

EV Path Planner

EV Path Planner is the evolution of the classic service application of Global Positioning System (GPS). The gas stations are replaced with charging stations. One of the most common demotivation factors when it comes to long EV trips is range anxiety. The purpose of this app is to reduce range anxiety and enhance driver's willingness to take an EV even for longer trips. However in due course it comes to the availability of fast chargers along the way. The path planner is a trip-advisor application where the concept is based on finding the optimum route for an EV based on available CPs. The driver is able to set the departure and destination location. The added features rely mostly on the charging process:

- sets the departure and destination location. Route converted into energy consumption estimation based on average highway speed (history), temperature, wind direction,
  - Optional: Sets the desired available range where he reaches the destination.
- sets the initial state of charge. A route algorithm calculates the optimum route based on the shortest or quickest path and also based on the available CPs (fast chargers including),
- includes an almost real-time update of current CP availability together with automated rerouting possibilities especially because the reserving feature will not be included at a first phase,
- asks to connect to an infotainment application or other suggestions of leisure during the charging stop, asks to connect with the services to the parking/charging nearby facilities. (The car is already connected to the internet or the smartphone).

Figure 12 Visualization of the EV Path Planner functionality

HTCE EV parking solution

HTCE EV parking is an informative app that is developed and operated by the site management of the High Tech Campus Eindhoven (HTCE) to facilitate the EV mobility and the charging process. The main functionality focus on informing EV drivers about the status of their EV charging.

The purpose of this app is to facilitate the EV mobility and its users, optimize the pattern of their charging behavior, and issue the technological evolution in the micro-environment of the HTCE (i.e. publicity).

- Reservation option with limitations.
    - First limitation: not all CPs will be able to be reserved.
    - Second limitation: user is not able to reserve multiple CPs.
    - Third limitation: user is able to reserve for a specific number of days and hours.
- The user has an overview of the charging process at any time he chooses. The frequency of data update is yet to be defined.
- The user is able to set target of the State of Charge (SoC), due to different pricing. Also he can set the ETA and ETD (Estimated Time of Arrival and Departure).
- Smart charging is facilitated through this app
- Guidance to the free parking/charging spot

EVPolis

EVPolis is an online multiplayer strategy game that uses the map of the HTCE as the playing field for the EV users. It will combine real and imaginary actions. Some of the principles of the game is similar to Monopoly. It can be connected to the EV parking solution app and give

playful incentives to the EV drivers to move their EVs after charging target is accomplished (EV bonus points).

The user's goal is to control the charging infrastructure of the HTCE and the electricity transaction flow. The key drivers for the implementation are:

- app game that will make the WSG project known to HTCE employees,
- communication with real apps and incentives to achieve third party goals,
- the subsystems of the WSG project are introduced (e.g. EV vehicles, types of CPs).

Key features of this application are:

- the game management holds the role of the "bank". The user can sell EVs, sell and upgrade CPs etc,
- the user with enough smart points can enlarge his/her fleet, buy his own CPs from the game management or from other users, or install new ones,
- at some point the EV users will have to become also energy producers by selecting/buying/installing a Renewable Energy Source (RES),
- the additional energy that the individuals do not use they can sell it "real-time", by defining the price once or twice per day,
- the grid's power capacity is finite. It can be reached with simultaneously charging with the increase of EVs and the CPs.

CP Reservation & Smart Charging solution

An application that is developed to facilitate the charging process, reduce the range anxiety and establish a bidirectional communication between the consumer and the Distribution System Operator (DSO) through the back office of the Charging Point Operator (CPO).

It provides a user interface for EV drivers with:

- reliable information of CPs,
- ability to reserve in advance charging hours from a specific unit,
- user profile building that provides an overview of the EV user charging pattern and suggestions of improvement or time-shifting,
- provides DSOs with the means to communicate with users and influence the load demand.

Typical charging app with main characteristic the spatial placement of CPs on a map for the EV drivers that will require real time information on CP availability in the region that the user is currently located. The key drivers for the implementation are:

- facilitates the charging process for EV drivers,
- ensures the charging process at the requested or needed time of the user,
- CP traffic (history available),
- DSO: Manipulates massively the load demand in the future,
- DSO: Overview of EV user charging pattern and suggestions of improvement or time-shifting.

Key features of this application are:

- typical CP locator displaying a map with charging stations available in your region,
- reservation option with limitations*,
- radius of interest in combination with host locator,
- reliable update of CP status: availability, in use, under service,
- CP map filtered based on vehicle type,
- SoC target or the time of arrival and the duration settings.
- individual CP history available with relating user reviews,
- peer to peer communication through a share button connecting to a EV social medium,
- futuristic: Selection of the source of the energy mix.

Electrifying Infotainment app

EV drivers or other users that are interested in information related to EV technology along with other more broad updates, for instance on new models of Tesla or BMW. Of course other type of information like weather forecast and news will be provided.

People want to be informed about activities during charging stops like eating, shopping, Wi-Fi options along with other type of news. EV users are usually interested in the technology they acquired. Additionally EV drivers are usually people devoted to constant feed of information. Therefore this app is targeting information in the field filtered by the specific user based on his search history.

Related advertisements on products or services concerning smart grid transition are displayed. E-shops or nearby stores where the user can find products based on his recent searches are suggested.

Key features

- Assuming that the user has a conventional vehicle connected to the network, based on his statistical data, recommendations on the next suitable EV model can be given. Suitability is defined based on the current driving habits.
- Internet radio is tuned to favorite stations focused on popularized technology associated to sustainability, EVs, CP infrastructure.
- Targeted news & articles on new EV models, CPs, standards.
- Connected to EV social media, personalized profile with EV statistics like total energy consumption, updated contribution to CO_2 reduction
- Location-based services
- Other common information such as weather forecast

Significant issues

The category of such apps is one of the most populated and highly invested in. The competition in this market require additional effort in the appearance of the layout such as smart buttons and switches than the contents themselves.

Maintenance monitor app

The maintenance app monitors specific components of the vehicle and alarms the driver for possible malfunction and service issues.

- makes the driver constantly aware of the current condition of his/her car,
- ensures that the driver keeps the regular services,
- displays an approximate cost of maintenance service dependent on the current measure levels and the expense history.

Purpose

The fundamental key drivers of this application is the reduction of road calls, the reduction of the time needed for trouble shooting, the improvement of the service capacity, of the efficiency of maintenance and operations, and finally of the fuel economy.

Key features

- Monitors fuel consumption and tracks various other fluid levels
- Monitors temperatures
- Monitors tire pressure
- Displays maintenance status (motor management, air-condition function, status of the bakes, etc.)
- Sends status report distributed in a regular basis

6.3   Fleet management

Fleet management is the category of applications that comprises the Business to Business (B2B) services and includes company's cars, distribution vans, taxis etc. Ultimately these applications are developed to serve the end user, however the core structure involves the development party, the fleet manager and the fleet owner. In many cases these roles are overlapping.

EVTaxi

A renewed application based on the taxi concept. A sophisticated car-service renting app that addresses two parties. The first party is the users that they need a taxi as soon as possible and the second is taxi drivers that they want to facilitate the taxi ride process from the moment of the call until the time that they leave the customer at the requested place. In summary the application,

- optimizes the taxi experience based on waiting time minimization, comfort and environmental footprint,
- facilitates the taxi hiring process,
- clarifies in advance the total cost of the ride compared to the competition,
- adjusts the type of the ride with the customer.

Key features

- Locates in the map the closest taxi either at a station or in motion.
- Selects the type of the vehicle based on comfort, driver, and user reviews.
- Secures transactions between client and service (e.g. google wallet), cash can be exchanged in case of tip.
- Connected to EV social media
  - Find people that could/want to share a ride
  - Find taxi drivers that you could share interests with based on social profiles
- Provides also other means of transportation (i.e. motorcycles, concept cars) that could increase the fun criterion in expense to the comfort.
- Futuristic: Selects the source of energy that the EVTaxi consumes (maybe the user is also a local energy producer (solar) and actually he ends up paying himself).

Significant issues

1) Battery technology limitations. The application manager makes use of specific models that allows battery replacement or invests in high-range EVs and/or DC fast chargers.
2) Competition. Multiple applications can lead to many groups of taxi drivers that are in different 'app agreements' in the same city and that eventually can work against the whole concept.

Company-cars sharing app

The company(-ies) owns one small fleet of EVs in order to offer services such as group commuting from home to work and back and car sharing for business meetings. Also it is possible for a group of companies to own a small EV fleet and manage the car sharing and the drive monitoring all together using a shared employee agenda.
The purpose of this app is to facilitate the Company Car sharing by introducing known interfaces such us an outlook look-alike environment and by minimizing the daily commuting expenses for business meeting, conferences, professional events etc..
The user is not forced to own a car for their regular commuting or other working obligations.
A seat planner can be integrated displaying location and availability especially when there is a group of companies that use the fleet.

Key features

- Outlook layout for reserving an EV. (Selective shared employee agenda in case of multiple companies)

- Multiple filtering - Specific models are excluded the moment that you select a short trip (e.g. only electric Scooter available)
- Status of vehicle (reserved, away, service) and current SoC overview
- An overview of statistic information for each vehicle is available
  - Total mileage (average per day/week)
  - Vehicle Maintenance history

Driving behavior monitoring

This app monitors the driving behavior of users in a fleet of vehicles (e.g. company-ies). Moreover, it prolongs the battery's health, it reduces the range anxiety and it also significantly adjusts the driving style of users to reduce energy consumption.

This driving monitoring app is attached (i.e. is a continuation) to the Company-car sharing application. The main issue is the very sensitive matter of privacy.

Key features
- Observes the availability and the use of the company cars.
- Monitors max speed, excessive acceleration, heavy braking
- Sends an alarm notification to fleet manager
- Gives compliance advice to driver
  - Indirectly: If the entire group of data are available for anyone to monitor there can be a sort of monitoring of each other.
  - Directly: A message can be sent with the appropriate driving style for speeding and accelerating.

Significant issues

Although that the company has every right to protect its property and of course the lives of its employees, privacy intrusion is a matter that must be addressed.

Compliant advice for driving styles especially to experienced drivers is challenging.

There is no profit in the form of revenue. However, in the long term there are concrete benefits in proper driving styles.

OEM Monitoring

A frequent overview of a fleet of car models by the OEMs assists them promptly in fault diagnosis. Vehicle monitoring is vital for the OEM to have a real-time overview of the fleet of a specific EV model that they have sold. The driver also benefits having a personalized expert opinion focused on his/her vehicle.

Key features
- Direct communication with the customer.
- Access to information about the status of the vehicle and use it to prevent mass recalls informing the production line rapidly.
- All-around communication with driver, dealership and repair shop for optimizing the maintenance and repair process.

Significant issues

Privacy issues compel the filtering of the type of the data that the OEM can receive. Possible misuse by the driver under the OEM monitoring can lead to conflicts concerning guarantee issues even if the possible incident is not proven as the direct cause of malfunction.

6.4   Chain mobility services

Chain mobility services facilitate the peer-to-peer communication in order to provide car sharing solutions. These applications target users that travel without owing any transportation mean and users that own a vehicle but they don't use it most of its lifetime.

Borrow my car

Owners of one or more vehicles are willing to dispose their vehicle(s) for a certain amount of hours in a regular basis. The app connects this service with the commuting need of people without a car.

This can be developed as an individual app or as a feature in other applications. A variety of choices are offered to the user including the "EV experience" (i.e. the option to choose an EV to support energy sustainability) for the environmental sensitive individuals.

The owner provides a service for extra revenue and covers partially expenses of a property that costs money even if it stands still. Then he can estimate the time that actually the vehicle is used in a daily basis and calculate the expenses yearly. Finally he deduces the cost per hour and charges accordingly.

The renter avoids the expenses of proprietary vehicle and rents one only when is necessary.

Key features
- Sets time, location and availability
- Filters the renters based on their age
- Provides Seat Market Manager option checkbox
- Views periodically the location of the vehicle
- Regulates the insurance policy
- Rents the rest of the empty seats to other passengers after the acceptance of primary renter

Significant issues
Each ride will be able to be shared with other clients after the acceptance of the first client/driver (connected to Seat Market Manager app). In that case a reduced price will be applied per individual but increased in total.

Except from the fact that an EV is an attractive option for a notable group of people the current numbers in the Netherlands does not allow to introduce this app in an EV strictly-related manner.

Seat market manager

Seat market is a shared mobility application that offers the user a variety of options for traveling using a variety of mobile mediums (e.g. different types of vehicles including EVs). The key feature of this app is that the user is able to rent a seat throughout a journey selecting for instance the type of the car that will be related to the price of the seat rental.

There are two markets that will be addressed. The daily commuting is the 'structural' market that is based on providing seats in big volumes to meet the demand. The incidental traveling is the market that requires more complex mobility solutions although in a lower scale. In both cases private negotiations are allowed and options dependent on type of vehicle, luxury, and performance are offered.

The principal basis of Seat market app, which operates in a user benefit perspective, is composed of two key drivers regarding expenses:
- reduces the regular commuting expenses,
- eliminates the fixed year expenses of car ownership.

A unified solution that gives the user a combination of transportation options from point A to point B. This app handles every detail like medium, transitions, unified price (no separate bills). Furthermore it contains a map of scheduled trips that have empty seats based on vehicle data transmission.

Key features
- Sets time, place of departure and destination
- Researches the possible solutions based on driver reviews, vehicle, price
- Selects the desired combinations of seats optimizing the duration of transition

Figure 13 Combinations of means of transportation of the Seat market manager

Significant issues
Seat market at this point is not possible to be limited only to EVs.

EVSpace

A social network offers information about several EV and/or CP related matters even faster than the communication platform. Also it can provide the platform for discussion about EVs, trips with EVs and optimal routes.
A mass scale association can promote a paradigm shift in the scientific community. The dominant power of social media is the ability to spread news throughout the global community of EV owners and technology supporters. Additionally it can operate regardless interoperability issues between different CP and EV manufacturers

Key features
- Communicates real-time with other EV drivers (e.g. CP malfunction, parking spot)
- Locates EV charging stations and add new ones
- Reviews the status of specific CPs in the station, upload photos
- Arranges EV rides with specific routes to promote EVs and introduce the EVClub

Significant issues
The most important factor for a social medium is the continuous internet connection. The second factor is the competition with Facebook or other social networks. EV drivers believe they belong in a special group of pioneers but until now there is no medium that can express this class.

6.5   Traffic management

Traffic management is responsible for monitoring the flow of vehicles on the roads in order to ensure safety and as fast circulation as possible.

Congestion Avoider

The main target of the Congestion Avoider is to help the driver to steer clear of traffic. It can be included as a separate feature in the social media EVSpace and/or in the EVTaxi app. A fast re-

routing algorithm is included taking into account the CP mapping in the area of interest. Basically this application comprises the mitigation strategy against traffic congestion. The main key drivers of this service are:

- enhances situational awareness to the end user,
- solves congestion problems as they occur,
- reduces commuting time and EV range anxiety,
- minimizes energy consumption,
- proposes alternative EV routes.

Key features
- Collects battery data (e.g. SoC, temperature, battery management, aux systems)
- Collects weather and road conditions data
- Predicts precisely the range of an EV and determine what charging stations to use.

Significant issues
1) Multiple driving routes that can be time-effective is usually difficult to find.
2) Congestion avoider cannot be an EV standalone app.
3) It is an application that demands high volumes of data as input.

Traffic management complete solution

A complete traffic solution manages and regulates congestions in a national scale. Information from connected cars to the network utilize the prediction of the current traffic in a daily basis and broadcasts its status to the involved parties (fleet managers, traffic control authorities and drivers). The presented solution catalyzes the prevention strategies of management and control authorities.

Certain prerequisites are required:
- every vehicle is equipped with a GPS and transmits in advance the scheduled route,
- the driving speed limits (and statistical data - history) are taken into account to predict the velocity,
- bidirectional communication platform that is able to operate almost real-time.

The purpose of this application:
- tackles congestions problems in advance,
- reduces CO_2 emissions,
- minimizes energy/fuel consumption,
- improves driver's comfort and reduce commuting time.

Key features
- Accurate drivecycles are predicted almost real time
- Input to energy management controllers
- Alternative routes are provided
- Departure timing suggestions to flexible drivers

Significant issues
The road infrastructure is not sufficient to provide multiple driving routes that can be time-effective.
The vehicle energy management algorithm runs internally. The calculations concerning the drivecycles (dc) as input will run in the cloud and only the finalized dc will be sent to reduce the required processing power of the vehicle thus its cost. That means that it could operate also partially offline after the vehicle receives the data from the cloud.

6.6   Load management

Load management aims at balancing the supply of electricity provided by the grid operator with the demand that is set by the various consumers. The main principle is to reduce the energy demand during the peak hours by integrating a load control system. Data from the EVs regarding the power and charging behavior can be of use to many peak manipulating applications.

Grid operator controller

This service will empower the grid operator to avoid power outages or to confine peak loads (e.g. in communication with a fleet owner/manager), assuming that the Vehicle to Grid (V2G) technology will be available in everyday life conditions. EVs can be in a large scale of deployment the spinning reserves of the electricity system.

This feature presupposes and necessitates the notification and the approval of EV users. The possibility of the driver signing an agreement in advance, which authorizes the grid operator to use the EV stored energy to handle grid emergency conditions, is investigated.

Grid operator:
- Minimizes grid capacity upgrade expenditure
- Reduces power outages, increase comfort level of consumers
- Expedites the replacement of spinning reserves

Customer:
- Minor energy traders for financial profit
- Charges at low cost hours and sells during peak demand
- Supports the grid when needed and benefit from less blackouts

Key features
- Communication with a fleet owner/manager and indirect overview of mobile energy storages
- Ability to shut down the charging process of a requested number EVs
- Ability to request V2G energy feed from EVs
- Suggestion to use a CP from a power line that is not overloaded
- Under discussion: Control of the output power of CP and advise driver accordingly

Significant issues
Reliability: A dependency relation with a high-uncertainty factor is created because EVs have to be in the right place at the right time to rely on them as regional spinning reserves.
Approval: In addition, widespread acceptance by EV drivers is imperative.
Modifiability: The app requires sophisticated real-time power management with numerous parameters controlled (Grid operator and EV).
Availability: Current energy storage and battery technology status is not sufficient. Reduction of battery lifetime due to limited charge cycles is at stake.
Performance: Efficiency of transferring energy is a minor intercepting factor (i.e. converters are highly efficient).

Energy Balancer

Energy balancer is an application for grid operators that are able to manage and balance the energy supply and demand of their system by manipulating the peak demand and using features as real-time pricing. The primary feature is peak shaving which is the technique of reducing the energy demand during the peak hours and redistributing it to the rest of the day. Real-time load measurement can be dealt with by using Advanced Metering Infrastructure (AMI) systems to inform customers and enable them to make energy-use decisions.

Grid operator:
- Avoids investment costs of electricity grid capacity upgrade
- Improves grid reliability & ensure a more stable network
- Integrates intermittent energy from renewable sources

Customer:
- More energy self-sufficient
- Savings from lower electricity distribution and retail prices
- Reduced duration and frequency of power outages
- Home automation services

Key features
- Household smart metering
- EV charging monitoring & control
- Balance the energy supply and demand of their system
- Demand response mechanism
    - Electricity use optimization
    - Real-time pricing
- Remote building energy management

6.7   Green Charging management

Green charging refers to applications that in the future will monopolize the smart energy consumption based on the selected energy mix by the households and the EVs.

Green charging app

Green Charging application operates charging management of EVs by green energy. EV users can select the desired RES that his/her vehicle can charge from in a user interface (UI) of either the CP or their own device. Display of the green CP infrastructure is provided to the user. In the present time that fully green charging cannot be secured, CPs can be mapped according to their momentary energy mix. Suggestions of shifting the charging process to "greener" hours (i.e. time in the day that it is sunnier and/or windier) are provided.

There is an ongoing increased demand from consumers to use green energy in their daily consumption habits. This shift will be extended progressively to EVs. Autonomous charging stations are already installed with solar panels on their roof or connected to a nearby wind turbine. Smart grid technologies qualifies this type of charging pattern to stations connected to the grid. It is possible to be aware of the energy mix that each driver is using to charge his EV. That energy could be even 100% renewable if the weather conditions (e.g. solar, wind) allow it.

Key features
- Selects the source of energy that the EV can charge from.
- Provides other options of selection such as country of origin, producer, and green certificate.
- Reserves specific amount of kWh per month for E V charging from specific green energy producer.
- Locates CPs that are able to charge EVs with clean energy
- First phase: If RES intermittency does not permit 100% green energy provision, then the current energy mix of charging will be presented.

Significant issues
A business model being dependent on intermittent RES exclusively cannot be successful in the long-term. However it is a futuristic application that could under technological circumstances be effective. The most important challenge is that the energy storage medium will have to be sufficient (i.e. optimized with respect to cost) to manage a continuous flow of EV charging.

6.8   *Non-indexed data-exploitation applications*

Most of the following applications are areas of research that consider real information as extremely valuable input in a broad spectrum of automotive services. Except for the privacy intrusion logger that is a mobile application the rest are potential business models or scientific research fields.

In-city Solar Parking

The main point of interest in this business case is to take advantage of the empty spaces in the parking floors of big buildings, especially in the city center, during specific periods of the week. One more Unique Selling Point (USP) will be that the charging system that will be offered is going to be completely autonomous using solar power installed on the roof of the building. The app will offer information about the available solar power translated into range for the EV users. A proper autonomous micro-grid will be established. Charging stations can be introduced inside the city and EVs can be promoted with installation of more CPs. RES can be added in the system and make the business case independent on the DSO. There are three categories of parking space.

- i)   Public (with permission you can park regularly in front of your home)
- ii)   Semi-private - e.g. in commercial centers
- iii)   Private - in companies parking floor.

The average commuting in the Netherlands is about 35 km/day. Usually there is no space for public charging stations in homes. That makes the idea of a charging/parking station a necessity. In-city Solar Parking is a business case that addresses the problem of in-city parking by exploiting the many empty spaces that the companies have in their parking lots. Especially this phenomenon is magnified during the evenings and the weekends.

Key features

- Reserve or rent a CP on a regular basis
- CP availability, status (used, reserved, malfunction)
- Overview of the available green energy capacity translated into range after entering the model of the EV

Significant issues

This application requires an investment because of the solar panels installation. Besides the company that owns or rents the building, an employee or a group of employees could invest on this application. In any case the provision of the capital can be a deterrent to interested parties.

Privacy Intrusion Logger

The privacy intrusion logger displays an overview of personal information requests (legal or not) to the end user at a regular basis. Examples of provided information are:

- what type of personal information is requested,
- how many times per day data were requested,
- which app have requested it for what service.

The option for instantaneous permission approval can be also available. Privacy agreements, which most of the previous applications require, need a transparent mechanism to be demonstrated to the end user. Therefore an app that monitors the rest of the apps and notifies the user when personal information is shared (and what) is suggested to be developed.

Key features

- App that visualize to the user the exposure of sensitive information and runs on the background monitoring other apps
- Overview of sharing information based on type, frequency, receiver in a form of a log
- Option to be notified real-time for data sharing and allow or reject the action for
- Report apps to the user that do not comply with their own policy

Significant issues

It should be stated that the level of intrusion is not compared to internet providers and mobile operators' privacy policy. Nonetheless even this application entails considerable privacy issues concerning the persuasion of the user that the app manager or developer will not able to access and commercialize the data. In any case the user has to be informed in a crystal way about any process and exploitation of personal information. Notifying and enlightening the user is the right foundation to develop the concept of internet of cars.

Research institutes data feeding

There is an apparent value of mass vehicle data to research institutes across the broad field of automotive. There are currently thousands of active researches that require large scale data extracted real time from vehicles. A cursory list of the research fields that use mass vehicle data:

Table 4 Research fields of potential interest	
Research field	Energy demand prediction algorithms for Smart Grid (EV case)
	Vehicle to Vehicle communication
	Vehicle to Infrastructure communication
	Safety platforms development
	Automated driving
	Traffic management - congestion models
	Reliable drivecycles building for numerous appliances of modeling and simulations
	Road infrastructure
	Road weather conditions & local forecast
	....

Insurance policy business case

Car insurance companies aspire to have a real-time flow of incoming data from the vehicles of their customers (i.e. drivers) and be able to offer more usage-based insurance products. The current insurance system base mainly the profiling of the drivers on fines from official authorities and the declared annual mileage. Now a dynamic driving style can be defined by the regular commuting and charges can be set by the insurer accordingly.

Repetitive speed limit violation or excessive acceleration can provide with reasons of increasing the insurance cost for aggressive drivers and reduce it for the compliant ones. This way the insurance system can become unprejudiced and fair in terms of pricing.

Fair: The current argument of insurance companies for high costs is accidents, and a significant percentage of accidents are related to speeding. This system achieves a cost distribution to drivers based on real data and not on statistical criteria or assumptions.

Unprejudiced: The constant conjecture that younger drivers should be charged more because of higher chance of irresponsible driving behavior or inexperience will be resolved.

Key features

An insurance company applies a plentiful of features to attract new customers:

- common account system with extra features at each level,
- faster to be promoted in case of EV insurance,
- option to "buy your way up",

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- communication with Maintenance monitor application,
- equitable pricing system.

EV drivers can have special treatment due to the limited numbers with extra benefits to promote the transition without being excluded from the insurance policy.

Significant issues
VIBe's platform can ensure that the privacy intrusion will be limited to the data that the two parties (i.e. insurance company and customer) have agreed to share.
However this system can be quite strict and unrealistic in the future. Example: Assuming that the distance from preceding vehicle is among the information that is sent, many times is almost impossible to keep the legal distance in traffic conditions. This is a pitfall for the next case that is investigated as well. On the other hand an adaptive cruise control integrated in every vehicle in the future can solve this issue.

Governmental authorities business case

Governmental official authorities monitor specific data of vehicles to optimize cost-effectively taxing or fining. Monitoring driver's compliance to driving regulations costs annually millions of euros, mainly on installation and maintenance of surveillance equipment and working man-hours of traffic regulatory authorities.
For example, the speed of connected cars across the country compared to the speed limits is monitored. There are two possible scenarios:
   a) in the first scenario the sportive drivers do not comply (at least the majority) and the government earns continuous revenue by fining the transgressors,
   b) in the second scenario the majority complies with the regulations due to the constant monitoring (initial agreement of all involved parties is required) and the government manages to reduce the accidents related to speed and in a pragmatic extent to reduce health expenses. It will require though a significant investment of acquiring the data.

The distance covered in an annual basis will be measured. That feature will accelerate the government's plan to charge drivers based on every driven km (or per time unit) and not based on an annual fixed road tax for every vehicle owner. The measure is based on other parameters of the vehicle such as:
- type of the vehicle (Powertrain),
- age of the vehicle,
- current emissions levels,
- type of the road
    o Recently constructed roads are more expensive
    o Driver's compliance to take alternative routes and assist to congestions reduction should be rewarded

This strategy will create a just and legitimate system for the majority of the drivers. There is a significant percentage of drivers that will financially benefit from these measure. Extra benefits for potential EV buyers will be created.
The prime affair is to create a method that the outcome would be transparent and legal without uncontrolled private data collection by the government.

Significant issues
1. Governmental vehicle monitoring requires enormous privacy intrusion. Even if the data that could be extracted from the vehicle would have been limited to speed (and not location for instance) the opposition will be strong.
2. The billing information will be disclosed outside the automated system for security reasons.

7. Information exchange requirements

The applications under investigation correlate with the communication platform as they have specific requirements. The procedure of the requirement management and decomposition is described. The functional and non-functional requirements of the Reservation and Smart Charging application with respect to the communication platform are presented as an example. A top-level overview of the dependencies of the applications on the external virtual environment is attempted. A description of the communication interface between the application layer and the platform is given.

7.1 Requirement decomposition process

The functional view of the CAFCR describes the requirement elicitation process as the method where the generic requirements are going to be decomposed to functional, non-functional and interface requirements branched in sub-specifications.

This process conveys the method how to define the interactions of the application with the communication platform through the interface layer. The decomposition of the requirements was part of the third phase of the project. This was the final step of the conceptual design of these applications until the functional view. The process of the functional analysis consisted of:

- uses cases regarding the main operations of each app,
- diagrams mapping the operational flow of the app,
- requirements of applications and where is needed a decomposition into more explicit ones.

Use cases facilitate the understanding of the main operations of the application in order to assess the qualities of the design. Use Case Diagrams (UCD) can show the available functionality via graphical examples. UCDs consist of four basic elements:

- the actors who are either the user and/or the system administrator and/or third-party entities,
- the system that usually contains everything except the actors,
- the use case including the main scenario and the extensions as well,
- the relationship between the actors and the actions.

After the uses cases, a flow diagram was constructed to show the main activities and actions in a workflow. The dependencies on external entities are more explicit in this type of diagram. Also the sequence of actions that are described presents the application as a system of functions with input and output variables.

The final step is to extract the functional requirements based on the primary operation of the application. One of the most important type of functional requirements in these applications are the data requirements. Data requirements establish how information is stored and administrated by the application.

The non-functional requirements are definitions of the quality attributes that specify criteria to assess the operations of the system.

In the next section the Reservation & Smart charging application is presented as a practical example of the design process. Its functional and non-functional requirements are presented in Appendix C. Four applications in total followed the same process to identify the requirements and their dependencies from the communication platform.

7.2   Application's requirements from the platform

The Reservation and Smart Charging application is a multi-purpose mobile application with two main functionalities:
1. Reserves a CP after the request of an EV driver for specific duration
2. Facilitates smart charging by providing an interface where the communication of the grid operator and the user is established

Table 5 Use case of the CP reservation & Smart Charging app	
Use Case:	**RSC 001**
Name:	Reserve a CP and charge the EV
Brief Description:	Reserve in advance a specific CP for a specific duration, complete the charging of the EV and pay for it
Scope:	First CP reservation system demonstrating VIBe platform
Level:	Summary
Actor(s):	EV driver (EVD), Reserve Smart Charging System (RSCS)
Stakeholders & Interests:	VIBe, Enexis, CPOs
Pre-Conditions	
Title	**Description**
Middleware layer	VIBe platform with bidirectional communication is established
Internet of Cars	Every EV is registered in the same database
Motown	A communication platform that manages and includes every single CP
Create account	An EV profile is already made (EPP 001) and desired duration of stops have been set.
Guarantees	
Minimal	Charge the EV and attain the billing transaction
Success guarantees	Reserve the CP, charge the EV for the selected duration and attain the billing transaction
Trigger	EV's SoC is low and forces the driver to ensure an available CP
Main Success Scenario	

          \<1\> EVD: Presses the RSC launch icon on his smartphone

          \<2\> EVD: Inserts the username and password to log in

          \<3\> EVD: Chooses from a map the available CP on his way inside the radius of max EV range

          \<4\> EVD: Reserves the CP and sets the ETA and the duration (or sets desired target SoC)

          \<5\> EVD: Confirms the service and completes the billing transaction

          \<6\> EVD: Reaches the CP station through navigation, finds it available and plugs in the EV

          \<7\> EVD: Views the charging process in his smartphone

          \<8\> RSCS: Pushes a notification that the charging is over

Extensions	
Title	**Description**
Not registered	<2a> EVD: Subscribes, makes a profile and edits it <2b> EVD: Erases the profile
Reservation is out of service	<4a> EVD: Selects a currently available CP <4b> Reaches the destination of CP and finds unavailable <4c> Connects to the EV social to find the other EV driver that charges at the moment and either he charges afterwards or he goes to the next closest CP
Post-Conditions	
Title	**Description**
Success	The CP map must be accurate
Real-time	The billing transaction is completed
Related information	
Filtering CP / Vehicle Compatibility Plug Type and CP selection based on power output. If the driver doesn't plug in his EV before the ETD the transaction is cancelled and is charged only for the reservation option.	

Top Level Use Case Diagram: RSC 001
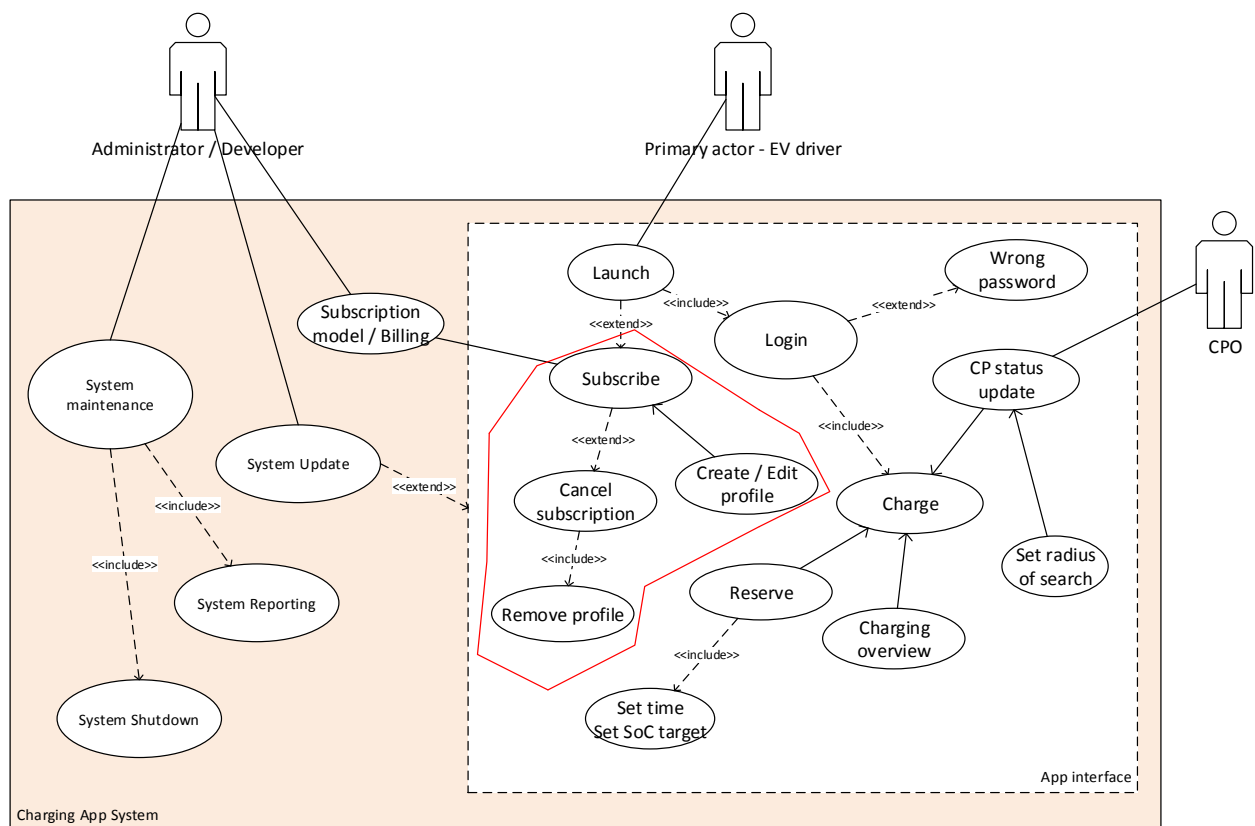
Figure 14 Use case diagram for the reservation and the smart charging application.

The functionality of the application in terms of commands and features are displayed in

Figure 15. The user's subscription and login are mandatory for accessing the full functionality of the application. Otherwise the user can access only the CP map and view the status of each CP without being able to reserve.

Most importantly, the application is not independent from its external virtual environment. There are two external sources that provide the end-user with critical information:

- Back office CPO: for CP status update
- Back office DSO/Grid Operator: for real-time pricing of charging process

The status of the CPs is updated via a CP management solution such as Motown that was presented briefly in Chapter 5. The communication of the user with the DSO includes one intermediate. Firstly the DSO contacts the CPO using the Open Smart Charging Protocol (OSCP). Then the CPO reports to the EV driver using Motown.
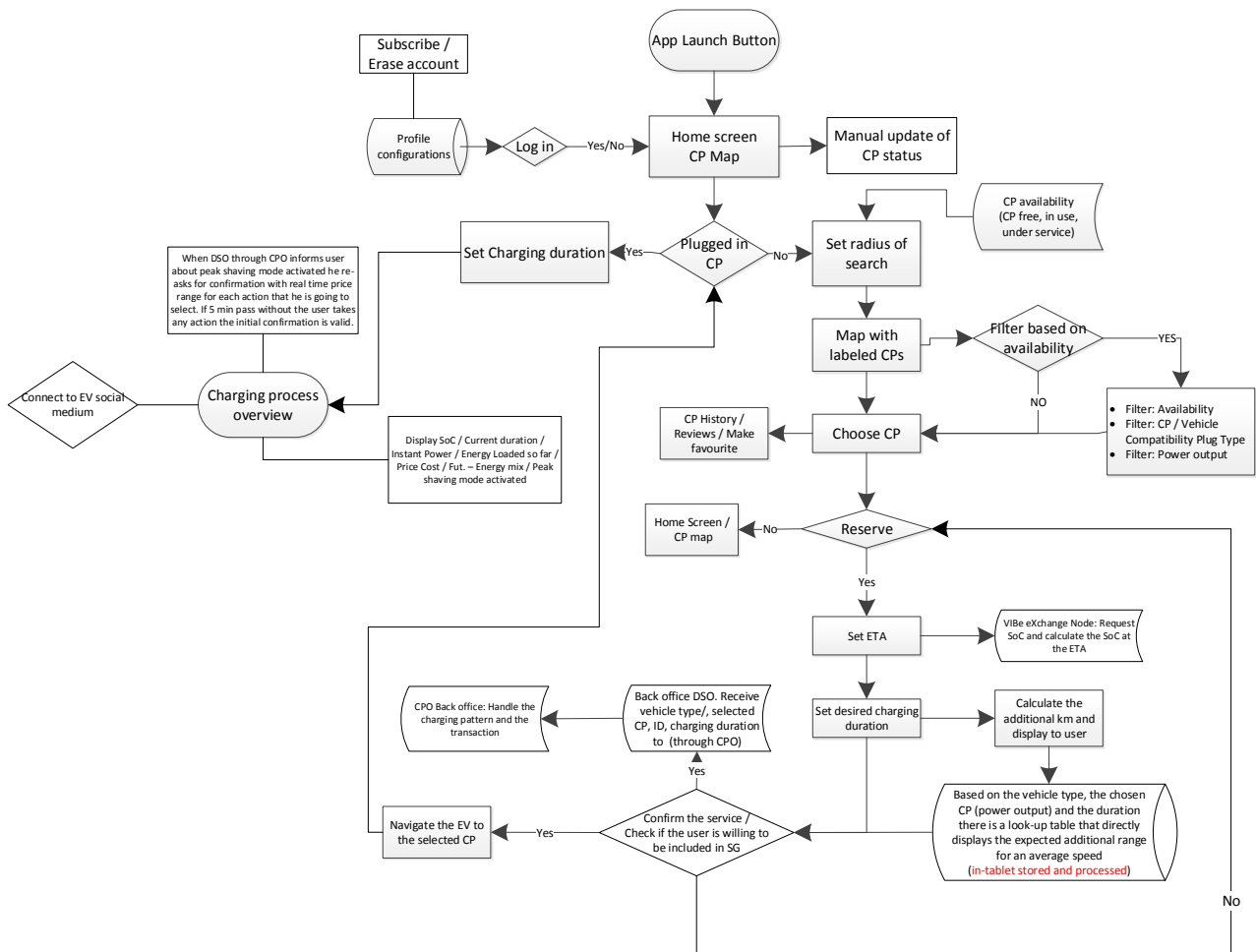
Figure 15 Operational flow chart of the Reservation & Smart Charging App

The applications that are related to smart charging and CP reservation require data from a CP management solution. The two platforms (i.e. the one that handles vehicle data and the other that handles CP data) could share a common interface to facilitate the simultaneous communication between all layers of the system.

7.3   Interface with application layer

The applications are going to be plugged-in on an interface connected to the VIBe platform and the eXchange Nodes as shown in Chapter 5. The platform will be able to feed continuously the application layer with data from vehicles. The interface between the platform and the application layer will include an authorization and authentication process not only for the end user but for the administrator of the application. It will provide security that determines which app administrators have access to which services. The interface protocol should have to validate external network service requests and responses.

Applications that have to operate online at a 24-hour basis require a constant online connection with the platform. If it is not possible then the platform should store some of the data in its own database. At the moment the main design principles of the VIBe platform do not include storage of information but only streaming.

Real-time information is another requirement of the majority of the applications and that has to be allowed by the platform. A log will have to be implemented that will store events and incidents such as determining if a request had been correctly submitted by an administrator or if a data service is being used with inappropriate parameters. The communication platform should be able to monitor each application's activities such as frequency of access by the app administrator. Also the platform should be able to hold statistical data regarding the services that are mostly or least used either by implementing a feature in the core of the platform or by developing a proprietary app in the application layer.
The platform should have the ability to communicate through the interface with an app administrator in case the requested data are so large that can only be supported at a time with low demand in terms of bandwidth.

The basic network service interactions with the application layer should:
- authenticate the administrator of the application to access data,
- submit a request from the platform to an application (e.g. request more authorization information or request status of an application if there is no automated notification),
- execute orders for large exchange of data,
- notify the application for an event in the platform (e.g. dropped signal, malfunction),
- download registry information and statistical data for the application services.

8.Project Management

In this chapter the project's project management is presented. The Work-Breakdown Structure of the project consisted of two work packages and the documentation process. The deliverables of each work package are stated with respect to the time that was spent for each one. The milestones are positioned in the timeline of the project. The month-to-month plan is presented along with the day-to-day working activities. A brief comparison between the initial project plan and the actual final one is given.

8.1 Work packages

In Systems Approach (Chapter 3) the steps towards the completion of this project were analyzed. The finalization of each step was defined by a deliverable. These deliverables comprised the milestones of the project, which were set from beginning to end. The timeline of the project started from mid-January of 2014 until the end of August of the same year.

Two Work Packages (WP) were defined along with the documentation WP. The first WP comprised the foundation of the project's background divided into the literature study and the problem definition. The first WP lasted from 15th of January until the end of February. The problem definition required several meetings with the internal stakeholders and three iterations to finalize the problem's framework. The second WP included the main workload based on the requirements that were identified in the first one. The requirements were defined by the university supervisor, the company supervisor, the project mentor and the program manager, who comprise the steering group committee.

8.2 Work-Breakdown Structure (WBS)

The project's work breakdown was the first task that was made after the problem definition. The breakdown was structured in two ways based on the details of the activity. The first breakdown was a month-to-month division of general tasks, which were serving the implementation of the deliverable at each milestone. The second structure was based on a week-to-week basis that facilitated the daily working process and gave a better overview of the general task completion. Additionally the week-to-week decomposition of tasks helped to quantify the total completion of the project as well as the coverage of the milestones. The dynamic nature of the project resulted to monthly minor adjustments of the project plan. More important adjustments were made at the final months of the project due to the documentation WP.

8.2.1. Activity-Cost Estimations

The main singularity of this PDEng project was the absence of an initial project framework. The definition of the general research problem and its details caused the reduction of the total project's duration.

The first WP was dependent on the availability of the various stakeholders of the project and resulted to be spread over a month. The iterations of the project's proposal were included in the first WP and they were reviewed by the steering group committee. In the second WP the conceptual design of applications was dependent on the availability of resources for brainstorming that were proved limited. Also the business cases that were built took eventually much more time than expected and planned.

8.2.2. Initial

The initial estimation of the activity-cost was made after the definition of the project's framework (i.e. end of February 2014). That was mandatory due to the initial opacity of the scope of the project. The overall timeline of the project's plan can be seen in Table 6.

Table 6 Project plan		
Stage	Activity	Period
Introductory meetings		15 Jan – 31 Jan
Project framework		1 Feb – 28 Feb
	Problem definition	
	Stakeholder meetings	
	Literature study	
	High level requirements' management	
Stakeholder analysis		1 Mar – 31 Mar
	Companies involved listing	
	Key drives and value chains	
	Entity relationship model	
	Individual company involvement analysis	
Application's conceptual design		1 April – 31 May
Divergence phase		1 April – 30 April
	Categories of automotive services	
	Concepts and ideas catalogue	
	Analytical features and individual CAF	
Convergence phase		1 May – 30 May
	Merging ideas	
	Feature integration	
	Data requirements	
	Criteria identification to introduce filtering mechanism	
	Business cases for a limited number of apps	
Functionality identification		1 June – 31 July
	Business cases for a limited number of apps	
	Use cases	
	Functionality maps and flow charts	
	Functional and nonfunctional requirement decomposition	
University requirements		
	Final report	1 May – 20 Aug
	Final defense preparation	1 Sep - 8 Sep

8.2.3. Final

Modifications in the project plan were started in early June. Two main reasons caused delays to the initial project plan. The first one was the construction of the business cases for a number of applications. The miscalculation of the total time needed was originated to the lack of experience in making business cases and plans. The second reason of delay was the iterations that the final report needed to reach the desired standards.

8.3   *Project Planning and Scheduling*

The milestones of the project's time schedule were pinpointed based on the deliverables that the trainee set and promised to the stakeholders. As an outcome of the first WP four milestones were defined. The four milestones that constructed the time plan of the project were:

1. stakeholder analysis of the WSG project by the 31st of March,
2. conceptual design of applications of mobility services by the 31st of May
3. functional and non-functional requirements for specific applications by the 31st of July
4. final defense on the 9th of September
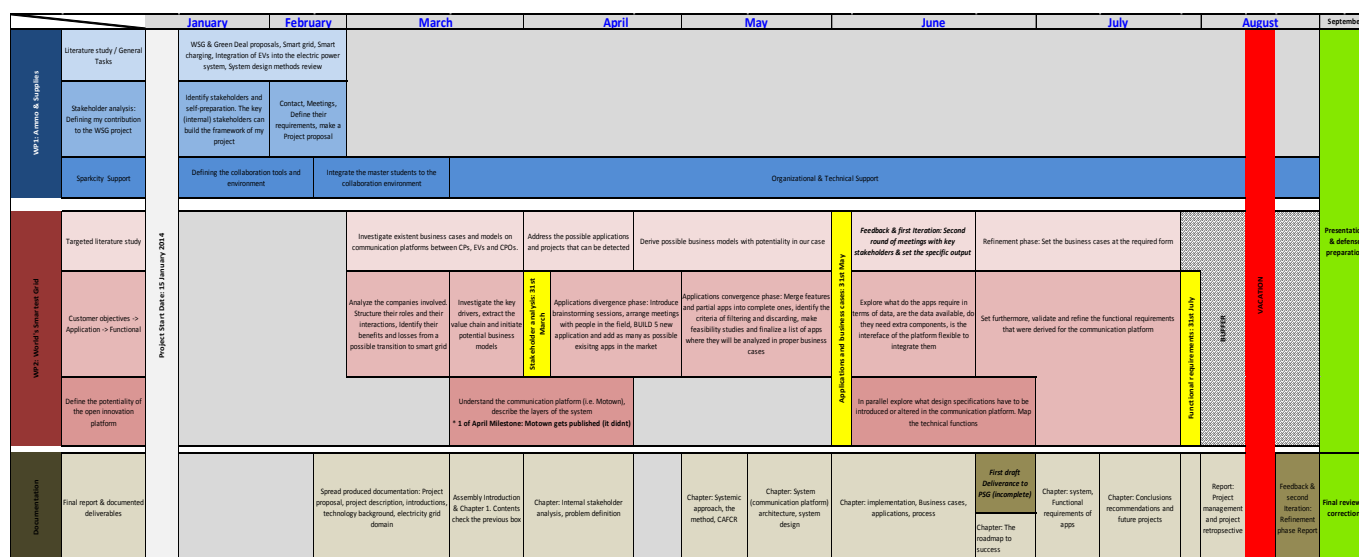
Figure 16. Month-to-month project plan

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Accuracy of the time estimation for each deliverable was achieved for most of the project. Due to the two reasons that were mentioned previously the deliverable of the application's requirements was postponed for mid-August. Additional processes regarding preparation for meetings, travelling and post-work were difficult to be estimated in advance. Project Steering Group (PSG) meetings were arranged in a monthly basis to update the supervisors on the progress of the project, and to receive and integrate their feedback. The amount of stakeholders, who were involved actively in the trainee's project, was reduced during the project. That caused a reduced impact of the consequences related to meetings and feedback integration. In general the project management facilitated the progress through monitoring and controlling the factors that were causing delays.

9. Conclusions

The essence of the current report regarding transportation and mobility services is presented. This project has been based on four interdependent pillars. The conclusions have been derived from the stakeholder analysis of the WSG project, the applications of (electric) mobility services, their business cases and their requirements. Future work and recommendations for the further exploitation of the potentiality of the platform are suggested.

9.1 Findings and results

The technological trend of Electric Vehicles dictated the need for smart charging. Smart grid technologies are being implemented and applied currently through pilot projects. Pilot projects like the World's Smartest Grid create opportunities for technological breakthrough and innovation that goes beyond smart charging. The information infrastructure that is going to be established will facilitate the development of mobility services.

9.1.1. Stakeholder analysis

1. VIBe's vision for standardization of communication between the vehicle, the service providers and the end users is based on its people. There is no unified support by the companies themselves.

2. Multiple-stakeholder projects might have the advantage of a unified solution that can be applied universally but on the other hand the progress is slow due to parallel individual activities, incompatible interests and requirements and limited communication.

3. The VIBe initiative not only can lead the transition to smart grid in the region but also show the path for more and larger collaborations in other regions (e.g. national and multinational).

4. HTCE Site Management main objective is to reduce the cars in HTC. On the other hand Autogroep Driessen is involved to increase the sales of EVs and cars in general having the HTC employees as their target group.

5. The fact that the project takes place in a private territory facilitates the project's development in terms of legislation and regulations.

9.1.2. Applications of mobility services

Smart mobility and energy management offer a variety of services. Fleet management is currently one of the most promising and feasible applications with immediate effect concerning EVs. One of the main business cases of Vitron and Sycada.Green is on fleet management with respect to fuel saving and CO_2 reduction.
Currently there is not a profitable application that targets to individual EV drivers especially in global scale or mass distribution. Current applications with mass distribution are focused on fleets of conventional vehicles (e.g. UBER – taxi app with more than 1 million installations) in USA and Europe.

The site management of the HTC will develop an application that will inform the EV drivers about the charging process of their vehicles. The features and ideas in the HTC EV Parking solution can be a guide towards its implementation.

Reservation of CP (especially of fast chargers) is at the moment the most requested feature by the EV drivers. It is now the only way to reduce range anxiety of the drivers and facilitate their daily commuting. The CP reservation combined with the smart charging application offers a complete solution that serves multiple sides such as the EV driver, the grid operator (DSO), the CPO and the app administrators and/or developers. The charging process can provide the base for more applications considering though a more complete system including the household.

The EV path planner has already been integrated in many navigation systems in the market. The communication platform by VIBe can offer a more reliable and responsive solution to the needs of the EV driver. A direct connection with a CP management solution can give regular updates of the CP availability. Additionally the platform can provide the EV driver with almost real time location of other EVs at charging stations and internal peer-to-peer communication for CP status.

Seat market manager reduces the regular commuting expenses and eliminates the fixed year expenses of car ownership. Combined with other means of transportation such as buses and trains it can provide a comprehensive service for the commuter and the traveler. If the VIBe platform integrates a large volume of vehicles and manages to connect the application layer with other services of mass transportation then a complete travel solution can be achieved.

9.1.3. Business cases

The commercial value of the applications that were investigated shows positive signs for the future. Undoubtedly EVs are a growing market that promise opportunities to various aspects.

The business cases were based on a few assumptions regarding the EV path planner and the CP reservation & smart charging. The current percentage of the base market (i.e. FEVs) to the total market (nr. of EVs) is 13%. The base market was assumed to be increased up to 20% of the total market raising the number of FEVs to 40.000 in 2020.
Profit projections have been made based on three scenarios of user downloads. Profit can be made only in the best case scenario for the CP reservation application. For third party developers it is not feasible to rely on a single mobile application and make their company sustainable.

The future business case of HTC Site management for the charging infrastructure relies on the continuous charging of EVs at full output power. On the contrary Enexis (i.e. grid operator) wants to manipulate the charging process reducing the transferred power when is needed.

9.1.4. Requirement management

The requirements of the applications are limited to the high-level primary functions and operations. The goal was to provide a starting point to potential developers that would like to proceed to implementation. It was also intended to display the dependencies from external source of information such as the communication platform that handles data of vehicles.
From the CP reservation & Smart Charging app it is understood that it is rather complicated to establish multidirectional communication between the DSO, CPO and the EV driver. The functionality credibility is crucial to be fulfilled by providing the EV driver with prompt and accurate information regarding CP status. A peer to peer communication to reduce range anxiety can be facilitated.

9.2   Recommendations and future work

9.2.1. Collaboration progress

The current work's value can be shown through the implementation of the proposed applications. However the real value lies in the architecture of the communication between the sources of information (i.e. EVs, CPs, CPOs, DSOs, service providers, internet providers).
In general the steps that should be followed to establish a national standardization in all layers of communication for smart mobility services are:

1) Collaboration willingness between the CPOs, the service providers and VIBe should be established
2) Common Cloud platform with real-update information is under development
3) Standardization of the communication protocol between the platform and the drivers' interfaces is under design
4) Project funding for the multi-interaction layer between the entities is under planning

9.2.2. Application development

A series of steps can be done to continue the current work.
1) A team of application developers should be assembled
2) A team of EV drivers and a team of app experts should be chosen
3) The requirements that are elicited in the current project can be validated by the personas or typical EV drivers
4) Development phase should follow the V-modelling approach
5) Testing phase has to include app experts that can assess the functionality of the applications (e.g. minimum learning iterations)

The following suggestions are short roadmaps for the successful deployment of the applications that were investigated closer in this project.

Reservation and smart charging application.
As the numbers (EVs and CPs) are growing and the demand for new features based on user feedback is expanding, it is important for the app developers to keep focus on the core functionality as the primary feature. It is common for mobile applications to be enriched with multiple features until the time that they lose their original purpose
One of the big problems is the physical infrastructure and the simultaneous installation of CPs proportional to the deployment of EVs. The number of EVs grows faster than the number of CPs and this increases the need for CP reservation.
Until now there is no app that offers a reservation module neither that facilitates multidirectional communication.

High Tech Campus EV parking solution must provide the full amplitude of the theoretical functionality to the driver as simple as possible. That requires at the first level that each car is equipped with a communication box that collects the data through the can bus and transfer them to the server.
The cloud server part of the middleware layer has to be established. The plug & play specification should be integrated and the application is going to be connected and provide almost real-time feed of information.
B2C apps concentrate on the personalization of the features. The success of an application is dependent most of the cases on designating the uniqueness and the individuality of the user.
It is very important for the cloud server but also for the app to be able to handle many users without failures because of unavailable resources or limited processing power.

EV path planner
A detailed and thorough CP map displayed as a web of stations throughout Europe is a strong requirement for the application and the EV deployment. The B2C applications target connected people together with connected cars. Exchange of user opinions on CP status along with parallel activities during charging is possible due to the application's intercommunication and multi-purpose charging stations respectively.

Mass EV deployment will necessitate an establishment of a complete CP infrastructure. That designates the reservation feature into the EV Path Planner app as the time window margin will be acceptable. Nonetheless a massive installation of CPs, along the highway, could engender the alternative route calculation as pointless. If there are enough CPs then there is no need for secondary routes. On the other hand an even distribution (limited due to expense through many international routes) of DC fast chargers makes the rerouting feature important again and regulates international EV traffic. If the EVs reach the volumes of conventional vehicles then alternatives routes (with CP infrastructure) will be required to reduce traffic.

For the **seat market manager** the mechanism to collect data from different parties has to be established. This application can base its success on four Unique Selling Points (USPs):

- offer a door to door solution,
- include other means of transportation such as buses and trains,
- persuade different parties to outsource their billing process to this unified application,
- it is essential for the success of the application that there will be large scale participation in order for multiple solutions and offers to be provided.

10. Project Retrospective

The development of the project over the past eight months is shown. A brief summary of the steps that were followed is provided. A list of factors that influenced the project's progress positively or negatively is presented. Design opportunities that were encountered during the project are revisited. A summary with proper insight about the lessons learned is attempted.

10.1   Backward-looking to the project

The majority of the working time in the beginning of the project (February 2014) was invested in becoming aware of the broad technological field of smart charging. Three main tasks were scheduled in parallel to facilitate the **identification of the problem and the establishment of the related technical background**:

- a literature study was conducted on smart charging, smart grid technologies, Charging Points (CP) and infrastructure and Electric Vehicles (EVs). The integration of EVs into the electric power system was investigated. Automotive services that facilitate the electric mobility were explored,
- arrangement and holding of meetings with the various stakeholders,
- organizational support of the research program of Sparkcity (trainee's supervisor/project mentor Auke Hoekstra).

The second WP included the main objectives of the project. The **stakeholder analysis** of the World's Smartest Grid (WSG) project was performed during March. The information that was gathered from multiple sources was analyzed and formed into the first deliverable. Stakeholders from companies that are involved in the project were identified. The analysis was derived from the companies' background and the meetings of the stakeholders.

The investigation of applications for mobility services that are related to EVs was the topmost task. Information and suggestions from various sources were received conducting brainstorming sessions and meetings. The conceptual phase resulted to a **booklet of applications** and areas of research that data from vehicles could be of use.

The following step was to proceed to the next phase of the conceptual design of applications. Since it was impossible to map the full functionality of almost twenty applications, a filtering procedure had to be introduced. The procedure was based on four sets of criteria (i.e. end-user perspective, third-party developer perspective, VIBe's stakeholders and the trainee's perspective – Appendix B) that resulted to four applications based on their ranking. The list of the four applications was the EV path planner, the Seat market manager, the HTC EV parking solution and the Reservation & smart charging app.

The **business cases of** these applications were built. Additional effort was given to support and argue on the reasons why these applications had development and commercial value to third-party companies and end-users.

The final step of the process (CAF – see Chapter 4) was the design of the full functionality of the application. The process of the **functional analysis** consisted of:

- uses cases regarding the main operations of each app,
- a diagram mapping the operational flow of the app,
- main requirements and where is needed a decomposition of a requirement into more explicit ones

10.2 Important factors that affected the project

10.2.1. Factors that worked well

One requirement for the success of this project was the suitable network. Fortunately an extensive network of professionals in the Dutch field of smart grid technologies was provided thanks to the trainee's supervisors, and the project manager and mentor.

Moreover the university is an institution where it is possible to find people of different level of education willing to assist in any direction needed. Especially for the first part of the project regarding the stakeholder analysis a broad network was activated to represent as best as possible the current status of the interrelations in the overall project.■

10.2.2. Factors that were problematic

The framework of the part of the project that the trainee was going to work on was not existent. The technical field of smart grid and smart charging was unfamiliar to the trainee. Also the overall system architecture (i.e. VIBe's middleware layer) where the application layer is going to attach was completely unknown territory to the trainee. The general unfamiliarity with the technical background of the project didn't only cause loss of time but it was also an obstacle for further development of the design process towards implementation of at least one application.

10.3 Lessons Learned

An abstract project is not always an easy one. The technical field that had to be conveyed, even superficially, was so broad that it took quite a lot of time and effort to be accomplished at a satisfactory level.

Certainly the lack of implementation phase lowers relatively the level of the general difficulty. However it also grants a constant dynamic perspective to the project increasing the uncertainty of the outcome.

A project that is not in the highest priorities of the stakeholders issues less feedback and interest in frequency and depth. Techniques to trigger the interest of the stakeholders in a regular basis must be planned in the initial project plan as well as in the mitigation strategy.

The systems approach based on the CAFCR method, even partially used, gave a top view perspective of the design process. Especially for a project that doesn't reach the implementation phase and mostly focuses on the concepts of the system(s), CAFCR provided with useful tools to understand and convey the elements of the project.

10.4 Design opportunities revisited

The design opportunities in this project were indeed limited. The design process was followed until the functional view of the CAFCR method. The implementation phase and furthermore the validation and testing phase of the application development was absent. The objective of the project though was not the development of one application but to exhibit a variety of ideas of added value, which take advantage the potentialities of the VIBe's platform. On the other hand one application used as a demonstrator could have added an additional value to the project even if the platform is still under development. The software development of one application as an additional task outside the agreed scope was avoided by the trainee.

Although the in-depth technical aspect of the design was missing, the creative aspect was quite strong and apparent throughout the whole project. Especially during the two months of investigating and generating ideas for such applications the effort for original, innovative, imaginative but also practical concepts was notable.

Glossary

Big data	An all-encompassing term for any collection of data sets so large and complex that it becomes difficult to process using on-hand data management tools or traditional data processing applications.
Carbitrage	The capability for an EV or PHEV (Plugin Hybrid EV) or charging station to communicate with the electrical grid to schedule charge/discharge activities based on conditions including pricing signals, tariff agreements, TOU (Time Of Use), DR (Demand Response) programs, and manual overrides by car owners.
Demand response	Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments de- signed to induce lower electricity use at times of high whole- sale market prices or when system reliability is jeopardized.
Distribution System Operator	The DSO redistributes power in lower voltages to households, commercial and industrial customers through the grid.
Flat rate	An electric utility that charges a flat rate for electricity does not charge different rates based upon the demand that the customer places on the system.
IEC 62196	It is an international standard for set of electrical connectors and charging modes for electric vehicles and is maintained by the International Electrotechnical Commission (IEC).
Internet of Things	
Islanding mode	During disturbances, the generation and corresponding loads can autonomously disconnect from the distribution system to isolate the load of the micro grid from the disturbance without damaging the integrity of the transmission grid.
Lock-in	It means that a particular technology or product is dominant, not because its inherent cost is low or performance is good, but because it enjoys the benefits of increasing returns to scale. As a result, decision makers are greatly influenced by the dominance (large market share) of a product rather than by their preferences for its inherent properties. The wider system can therefore not easily escape the dominant entity.
OCPP Open Charging Point Protocol	Application protocol that establishes the communication between CP and centralized management station. It is developed by E-Laad (CPO) in the Netherlands.
OSCP: Open Smart Charging Protocol	Currently Enexis (together with Greenflux) is building this protocol. It determines very precisely which messages can be sent by the Distribution System Operator to the operator and what form these messages should take
Peak shaving	Reducing a user's effective peak load by using storage discharge to augment power delivered by the grid. The reduction of the amount of electricity drawn from a power utility during utility designated peak time periods. Peak shaving methods may include the installation of generators or energy saving devices, or may simply involve reducing usage during peak hours
Push, or server push	It describes a style of Internet-based communication where the request for a given transaction is initiated by the publisher or central server. It is contrasted with pull, where the request for the transmission of information is initiated by the receiver or client. Push services are often based on information preferences expressed in advance.
Spinning reserve	Generation capacity that is on-line but unloaded and that can respond within 10 minutes to compensate for generation or transmission outages. "Frequency

	responsive" spinning reserve responds within 10 seconds to maintain system frequency. Spinning reserves are the first type used when shortfalls occur.
Transmission System Operator	The responsibility of a TSO is to carry electric power over long distances from the energy production units to the DSO.
Valley filling	The addition of loads to an electric power system in off-peak periods.

References

[1] Eurelectric, "European electricity industry views on charging Electric Vehicles," Eurelectric, 2011.

[2] J. J. Sjoerd Bakker, "Stakeholder strategies regarding the realization of an electric vehicle recharging infrastructure," E-Mobility NSR Interreg IVB project , Delft, December 2013.

[3] J. Willems 2013, "Project plan. High Tech Campus: The world's smartest grid!," Eindhoven, 2013.

[4] G. Muller, "CAFCR: A Multi-view Method for Embedded Systems Architecting," Technische Universiteit Delft, Delft, 2013.

[5] IA Special Netherlands office for Science and Technology, "Smart Grids and Energy storage," NL Agency Ministry of economic affairs, Den Haag, November 2012.

[6] TKI Switch2SmartGrids, "tki-switch2smartgrids.nl/over/," 2014. [Online]. Available: http://tki-switch2smartgrids.nl. [Accessed March 2014].

[7] An Interdisciplinary MIT study, "The Future of the Electric Grid," MIT Energy Initiative, Cambridge, MA, 2011.

[8] Allego, "Allego," 2014. [Online]. Available: http://www.allego.eu/. [Accessed 30 August 2014].

[9] M. Mathew, "Derivation of the required elements for a definition of the term middleware," Rochester Institute of Technology, Rochester, 2002.

[10] A. Hoekstra and O. Warnier, *Motown proposal,* 2013.

[11] S. Mal and R. Gadh, "Real-Time Push Middleware and Mobile Application for Electric Vehicle Smart Charging," *International Journal of Communication Networks and Distributed Systems (IJCNDS),* p. 32, June 15, 2011.

[12] Exchange Network, "http://www.exchangenetwork.net/node-basics/," 2013. [Online]. [Accessed June 2014].

[13] O. Ongkiehong, "Electricity grids: Description of the state under the Dutch energy research program EOS (Energie Onderzoek Strategie)," SenterNovem Agentschap NL, 2006.

[14] Greenflux, "Over Greenflux," 2014. [Online]. Available: http://www.greenflux.nl/. [Accessed 17 March 2014].

[15] Vtron, "About us: V tron," [Online]. Available: http://www.v-tron.nl/en/. [Accessed 18 March 2014].

Additional Reading

Rifkin, Jeremy, The third industrial revolution: How Lateral Power is Transforming Energy, the Economy, and the World. Palgrave MacMillan, 2011. (978-0230341975)

Appendix A

Stakeholder analysis – Entity relationship model
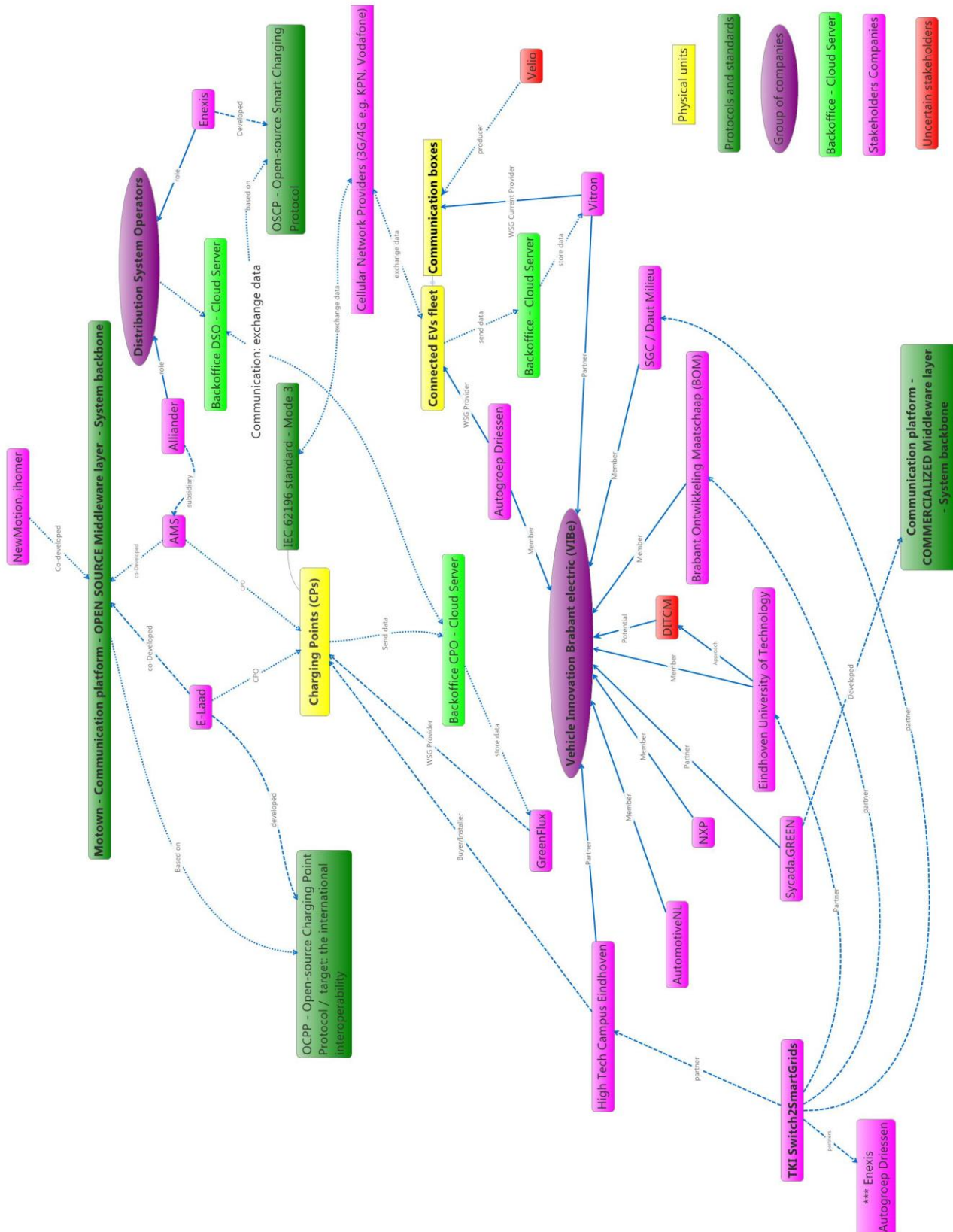
Value flow of individual stakeholders
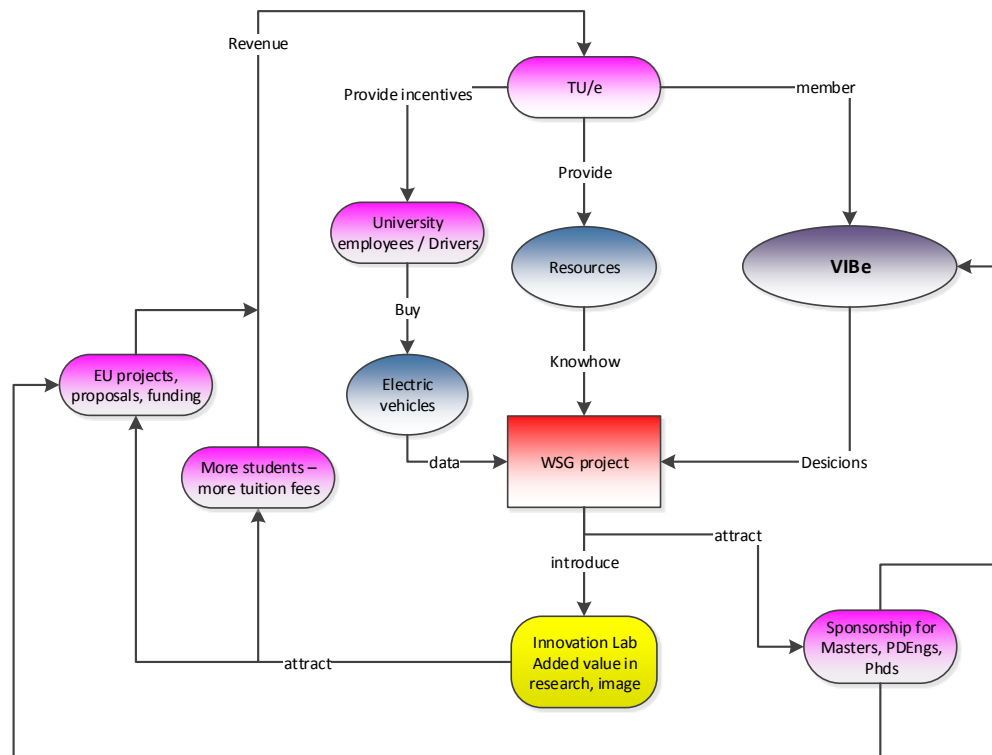
Figure 17 TU/e value chain
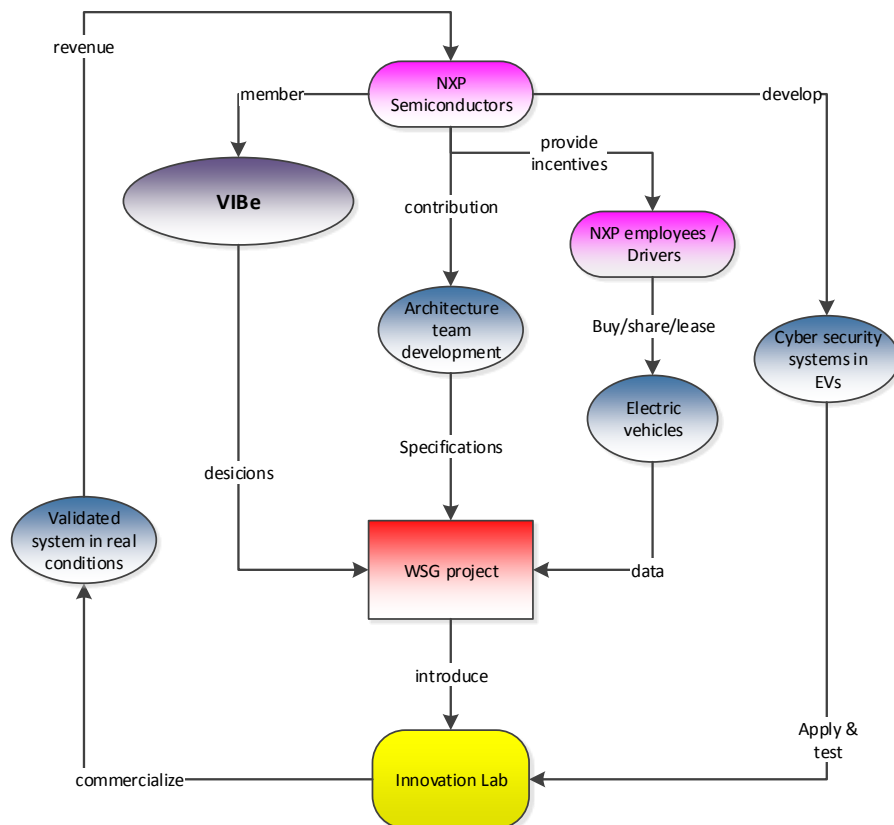
Figure 18 NXP value chain
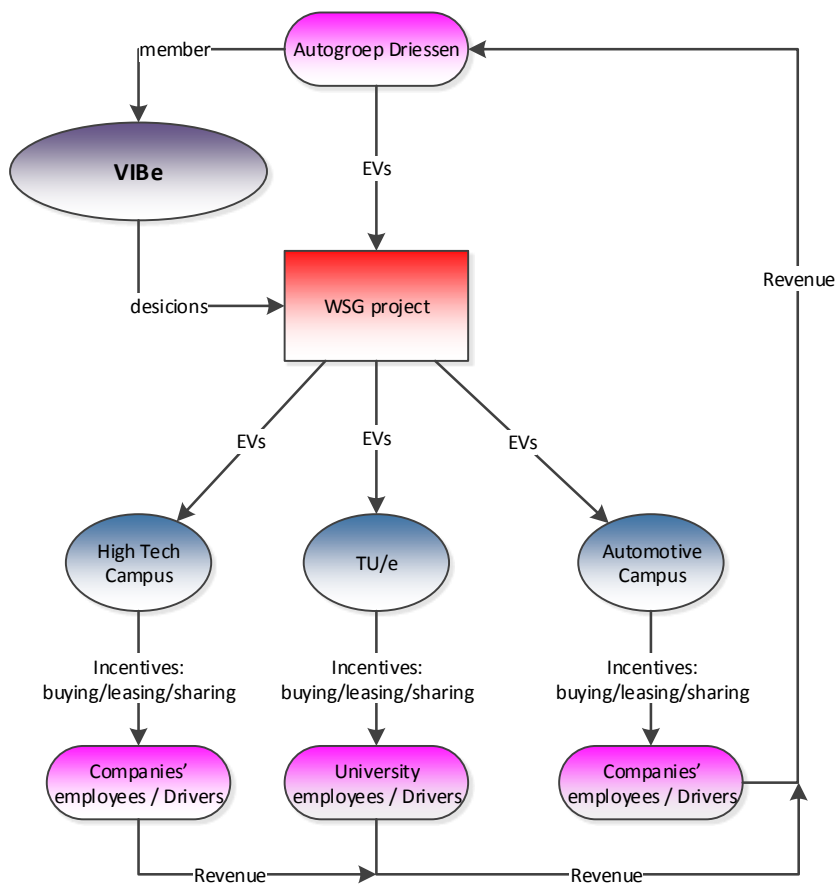
Figure 19 Autogroep Driessen value chain
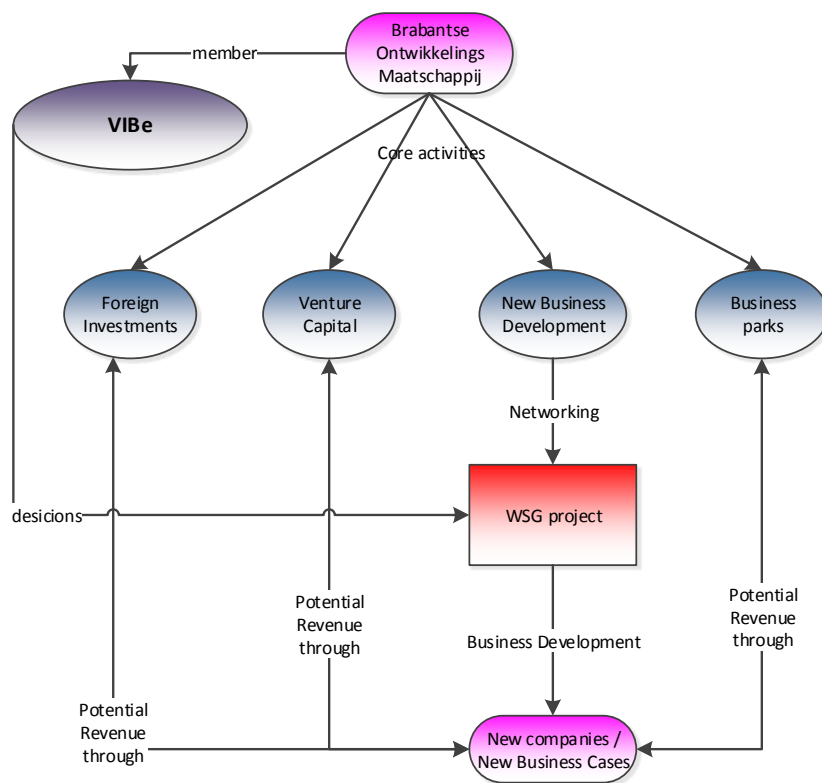
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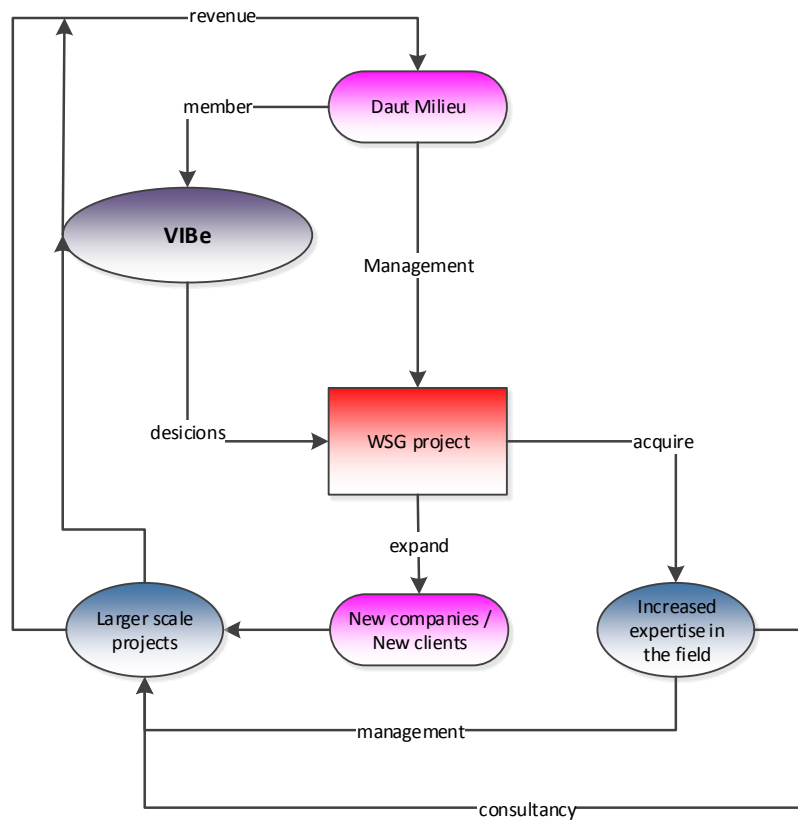
Figure 21 Daut Milieu value chain
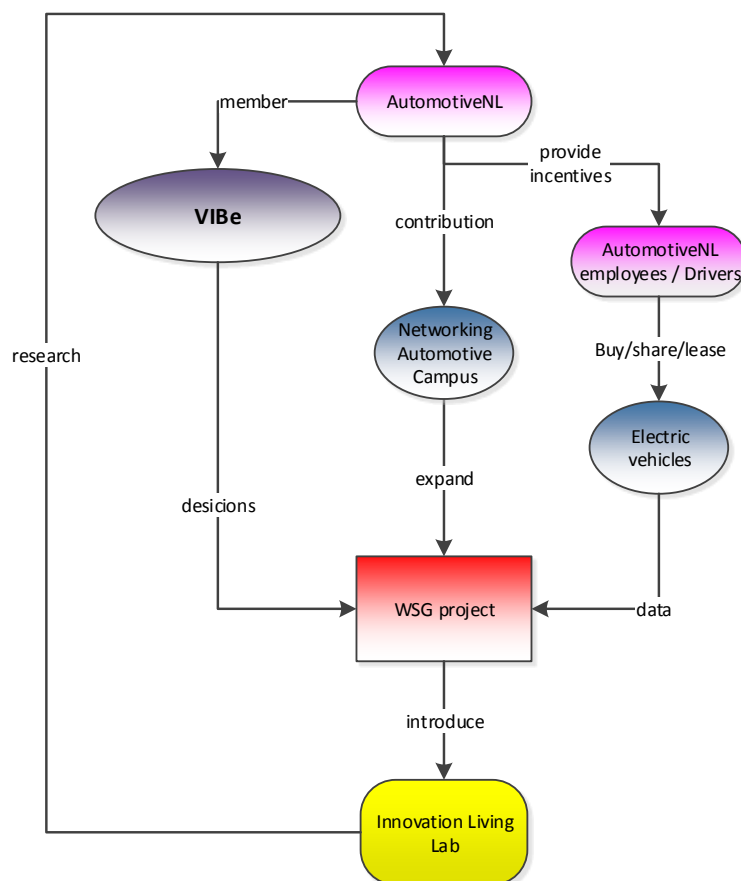
Figure 22 Automotive NL value chain
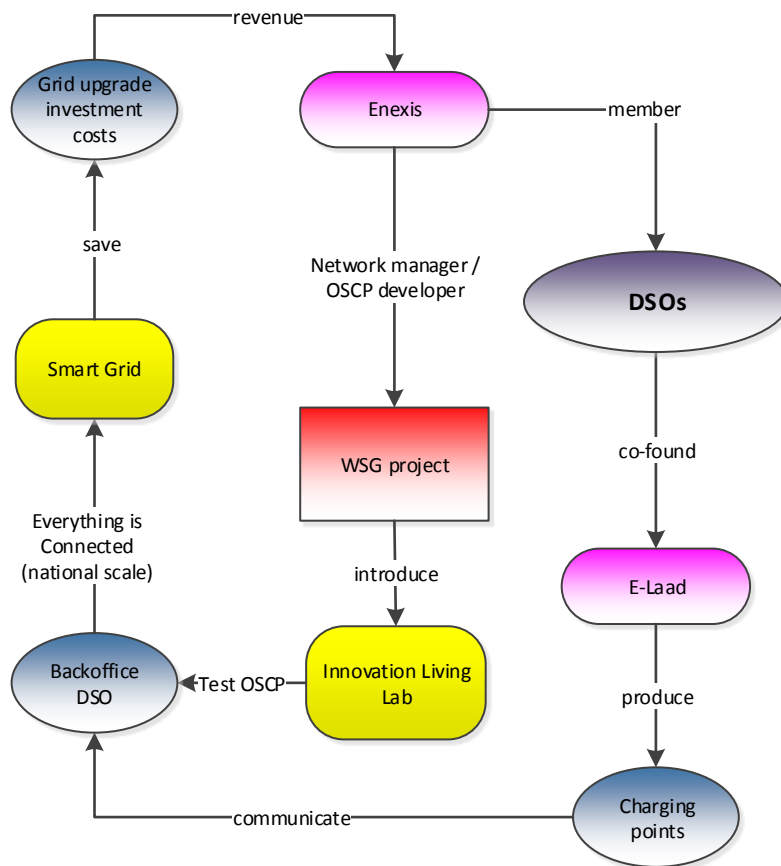
Figure 23 Enexis value chain
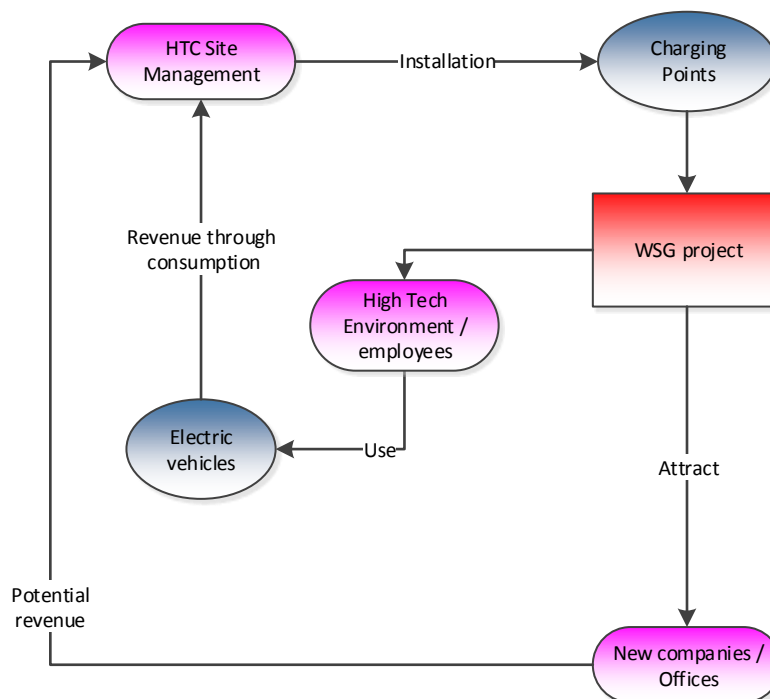
Figure 24 HTC value chain

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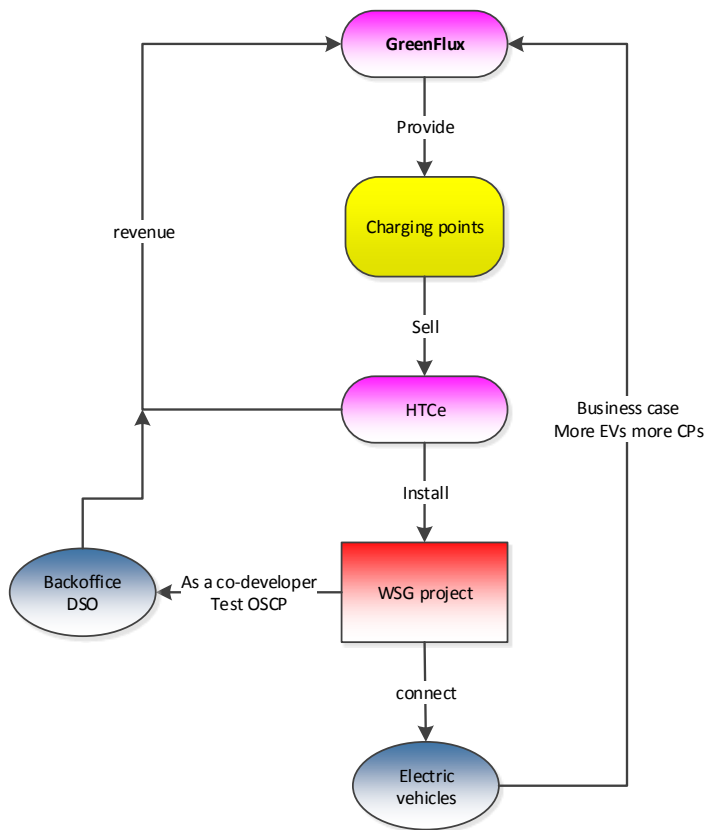
Figure 25 Greenflux value chain
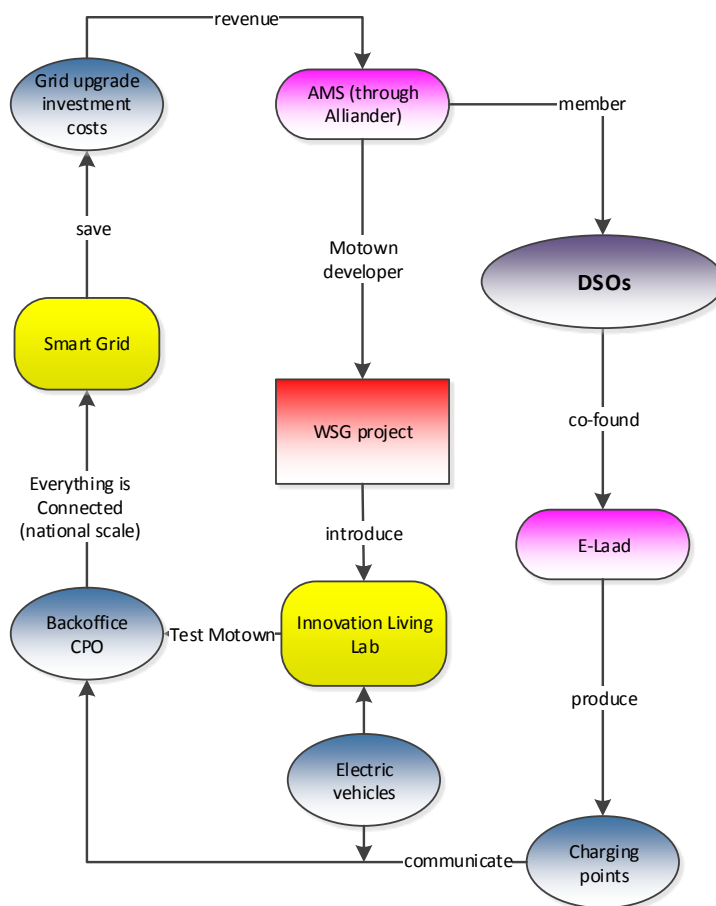
Figure 26 AMS value chain
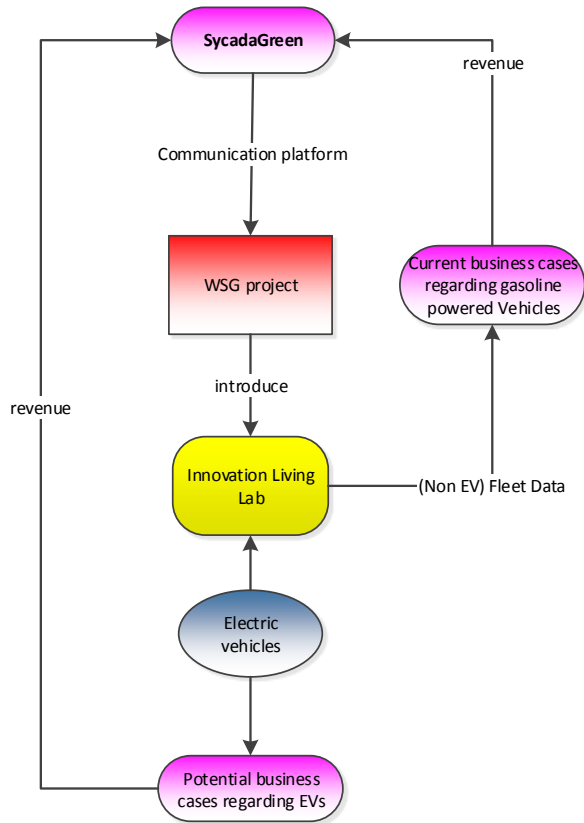
Figure 27 SycadaGreen value chain
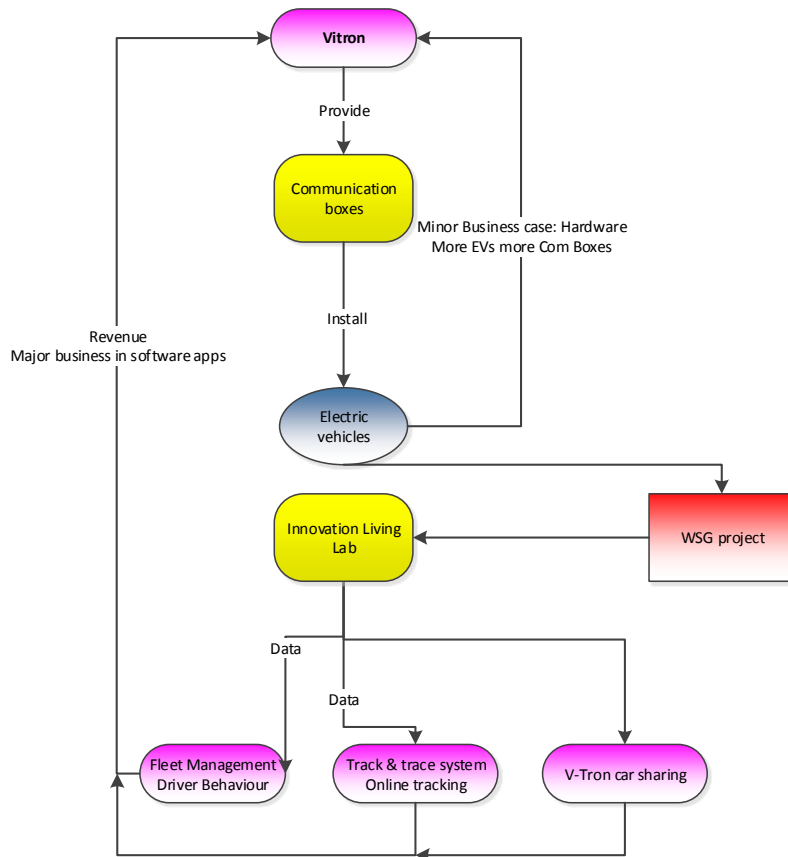
Figure 28 Vtron value chain

Appendix B

Criteria for application selection.

User perspective (weight = 1)	Usability	Trainee's project (weight = 0.85)	Electric vehicles
	Privacy		Smart charging
	Simplicity		-
	Free of charge		-
Third Party developer (weight = 0.95)	Profitability	Stakeholdes interest (weight = 0.90)	Connected cars
	Open source & Interoperability		Middleware layer demonstration
	Mass distribution		Data exploitation
	Implementation (Short - Long term)		Load management
	Plug & Play integration		-

CP Reservation & Smart Charging Solution

Business case

Executive Summary

Fundamentals of the proposed business.

> Currently there are approximately 38000 EVs and PHEVs (July 2014) in the Dutch roads that Smart Charging Solution is targeting at. Amongst them there are 5100 Fully EVs (July 2014) which they comprise the core of the business. The average commuting of drivers in a daily basis is 35 km. The average range of the FEVs is 100 km. A first rough estimation results that an EV driver needs to charge the vehicle at least every two days. Various studies show that EVs (i.e. FEVs and PHEVs) is a persistent growing market that can reach 150000 – 300000 vehicles by 2020 in the Netherlands. Consequently this company is involved in a market that is expected to increase by at least 500% in the next 6 years.

Products and services.

> Typical application that will be developed first in android and in iOS. Integration with the EV through a communication platform will take place. The subsystems that comprise the service provided are the EV, the CP, the cloud server and the interface device.
> The smart charging application having as its main layout the map of Netherlands with every CP that is installed located in the map. The CP status will be shown to the user with respect to its availability. Reservation option is offered with certain limitations that will be described later on.
> The subscription model is chosen with a monthly fee of 0.40€ / month for the basic version and 0.80€ / month for the premium version. The basic version will be include the reservation option and the premium version will include the real time pricing feature.
> It is assumed that the extreme majority of EV drivers possess the means to install an application either using a smartphone or tablet. It is also mandatory that the applications will be develop in both iOS and android operating system as a native mobile application.

Market Domain.

The domain is the applications related to the charging process in the Netherlands. The market share of the travel applications category, which the current is included, grasps the 4% of the total downloads. Based on the competition three scenarios of potential customers have been built. The first financial scenario relies on 1000 users, the second on 4000 users and the third on 7000 users for the first year. Including the payroll factor the break-even point occurs in mid-2015 while the first absolute profit is materialized after 8 years in 2022 only for the best case scenario.

It is signified that the development team should not limit themselves to the development of the Smart Charging Solution and its after-sales services. On the contrary they should develop further native mobile applications in various categories of the automotive field that will contribute to the growth of the company.

Service Application idea

For developer.

Description of application development.

Designed application to facilitate the charging process, reduce the range anxiety and establish a bi-directional communication between the consumer and the Distribution System Operator (DSO) through the back office of the Charging Point Operator (CPO).
User interface for EV drivers with

- reliable information of Charging Points (CPs)

- ability to reserve in advance charging hours from a specific unit.

- building user profile that provides an overview of the EV user charging pattern and suggestions of improvement or time-shifting.

DSOs require an application to communicate with users and influence the load demand.
The app is treated as a plug-in extension of VIBe's communication platform. The platform is designed with respect to scalability concerning the developer and/or entrepreneur. Furthermore most of the required information is stored in the database of the platform reducing the technical requirements of the tablet/smartphone.

Factors of competitive advantages or disadvantages

- + VIBe platform (cloud service) handles the communication between the CPO back office (or later on the data broker) and the consumer.
- + Real time update of information.
- + Plug and play integration to ensure adaptability is offered by the platform
- + Unique database with common output format of data from every CPO (CP)
- - Privacy issues considering location, users communication, profile sharing
- - Load flexibility option requires access from the grid operator to the charging process
- - Generally the entities that handles user information are increased
- - A user is able to skip an update, thus it is certain that users will manage their EV charging process using different versions of the app.

Unique and proprietary features

The CP reservation option is at the moment not available by the existing competition. Of course it cannot be a proprietary feature for a specific application.
The real-time pricing requires other entities' contribution but it will be developed in a pilot phase therefore it is not part of the profitable features on its own. However it is the highlighted feature that can induce more EV drivers/users to download and install this app instead of another one.
Smart charging is a B2C app and addresses directly to the EV drivers. It connects another four parties though.

1) VIBe's communication platform operator/manager
2) The grid operator who is in charge of operating a pricing algorithm that manipulates the power load during the 24h.
3) The CPO that handles the back-office and is responsible for collecting the information in a database of the common communication platform. It is designed in that way that the data from every CPO will have a common output format.

4) The data trafficking operator (data broker) that is responsible for streaming the data to the end user. Usually this entity acquires data of private nature for redistributing to service providers.

For end user.

Description of the proposed service

EV drivers need a user interface that will provide them with reliable information of Charging Points (CPs) and the ability to reserve in advance charging hours from a specific unit. On the other hand grid operators requires an application that will use to communicate with the users to influence the load demand.

An application designed to facilitate the charging process for an EV driver and to establish a bi-directional communication between the consumer and the Distribution System Operator (DSO) through the back office of the Charging Point Operator (CPO).

It creates a user profile that provides an overview of the EV user charging pattern and suggestions of improvement or time-shifting.

Most important features

- Typical CP locator displaying a map with charging stations available in your region.

- Reservation option with limitations*.

- Set radius of interest in combination with host locator.

- Reliable update of CP status: availability, in use, under service.

- Filter CP map based on vehicle type

- Set SoC target or the time of arrival and the duration.

- Individual CP history available with relating user reviews

- Peer to peer communication through a share button connecting to a EV social medium

- Futuristic: Selection of the source of the energy mix

*Limitations of the reservation option.

- Only one CP per time can be reserved
- The charging hours that are reserved cannot exceed the time that the SoC needs to reach 100%. This is ensured by the system that is able to retrieve the SoC of the EV the time that the driver asks to reserve a CP (and not allow the driver to set the SoC on his own)

User benefits

The reservation option is developed to reduce once and for all the range anxiety of the EV driver. The user books a specific charging time duration in the day choosing from a variety of solutions in a inserted radius with center the location of the user's destination.

The real time pricing feature will be developed at a first phase in a pilot mode to demonstrate the proof of concept and at a second phase (next 20 years) as a meaningful and irreplaceable development.
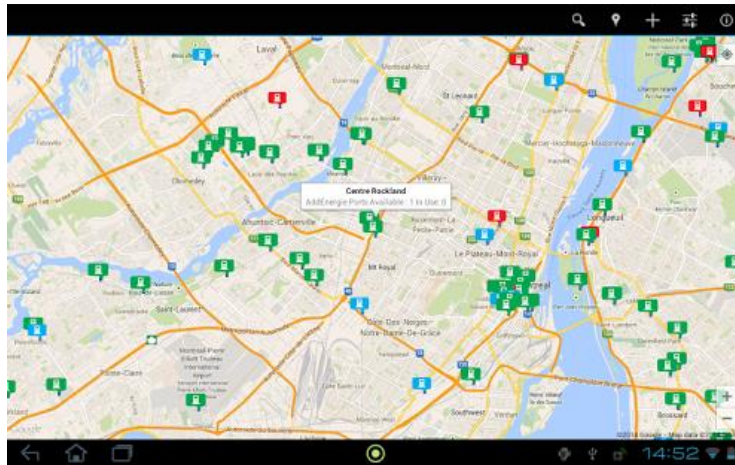
Figure 29 Map with available CPs in a selected radius

Market analysis

Trends in target market

A good start to define and size the targeted market is to examine the current numbers of FEVs and PHEVs, in the Netherlands (Table 7). There were 4.654 EVs by April 2014 registered which comprise the base market. For this market the charging process is a necessity. The rest of the EVs, the 29.413 PHEVs will be included to the potential market. The following table was used to estimate the commercial value of the application even though the numbers have been increasing steadily until the end of this project (approx. 38000 EVs including 5100 FEVs).

Aantal per Type voertuig	31-12-2012	31-12-2013	28-02-2014	31-03-2014	30-04-2014
Personenauto (FEV)	1.910	4.161	4.172	4.563	4.654
Personenauto (E-REV, PHEV) #	4.348	24.512	25.880	27.355	29.413
Bedrijfsauto < 3500	494	669	688	694	711
Bedrijfsauto > 3500	23	39	44	44	44
Bus *	67	73	85	85	85
Quadricycles (vh driewielig)	469	632	642	649	660
Motorfiets	99	125	121	137	148
Totaal op de weg	**7.410**	**30.211**	**31.632**	**33.527**	**35.715**
Bromfietsen	2.853	3.130	3.133	3.160	3.193
Snorfietsen	17.748	19.772	19.997	20.176	20.583
Brommobielen	107	141	145	153	159
Totaal inclusief brom/snorfiets/brommobiel	**28.118**	**53.254**	**54.907**	**57.016**	**59.650**

* Inclusief trolleybussen en een aantal hybride bussen; # Exclusief volledig hybride voertuigen

Table 7 Current deployment of Electric Vehicles (EVs)

The second important factor for this application is the status of the Electric Vehicle Supply Equipment. The current charging infrastructure in the Netherlands by April is presented in Figure 30. Semi-public CP means that the units are in private properties open to public for commercial reasons and thus these CPs could be reserved remotely. That means that the local charging station is possible to be owned and managed by the local business.

- The fast chargers that are of higher demand are limited to 70
- There are 8800 CPs that needed to be mapped and registered into a complete real-time communication platform

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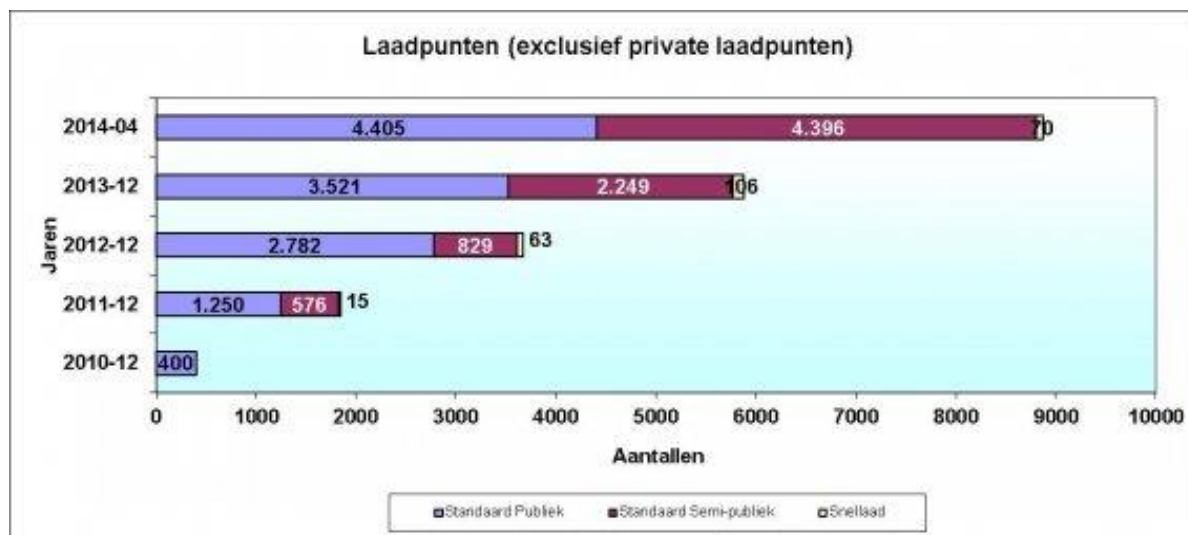
Figure 30 Number of public and semi-public CPs in the Netherlands by April 2014

The data presented in Figure 30 are from e-Laad foundation, EV-BOX BV, Nuon and Essent including figures from The New Motion and Oplaadpalen.nl.

> The third important factor is the interface with the user. <u>One basic assumption</u> of this business plan is that every EV driver possesses a smartphone or a tablet to interact with the CP infrastructure and the service providers. This is taken by default. Also every EV driver / potential client is assumed to have mobile internet connection for real-time information update of CP status.

Future market prediction

> Studies from two different sources shows that the next 6 years the number of EVs will increase to 140000 – 200000. That is translated to 400% - 600% growth of the market size. There are not that many markets in the world with projections of comparable scale (Figure 31). There are even more positive studies that mention higher deployment of EVs.

Figure 31 a) ING report on EV projections in 2020 b) Dutch government report on EV projection in 2020

The market of EVs is expected to grow rapidly in the next few decades. Of course the factors that eventually will contribute are too many and out of the scope of this plan to be analyzed.

> The second assumption that is taken into account is the 200000 EVs until 2020. This number is considered as a realistic target and it will be taken into account for the financial plan. The current percentage of the base market (i.e. FEVs) to the total market (nr. of EVs) is 13%. The base market is assumed to be increased up to 20% of the total market raising the nr of FEVs to 40.000 in 2020. The second assumption in total describes the average case scenario of the potentiality of the market.

Market competition conclusions.

> After the investigation of the three applications (Oplaadpunten, Oplaadpalen and love to load by The New Motion), the installations for each of them in total are approximately 20000. Compared to the approx. 35000 EVs (FEVs and PHEVs) it is assumed that there is part of the market that they don't use an application either because they don't have the means (i.e. no smartphone, unlikely) or they don't need to have one because they possess a PHEV (more likely.)
>
> One conclusion that easily can be derived regarding the existing competition, expressed mainly by these three apps, is that the average downloads and installation *are 3000 per operating system of the device and* 7000 per application,
>
> Of course the number of visits of the web versions was impossible to be included in this comparison. Also it is highly likely that EV drivers have downloaded and installed all three or a combination of the applications. *The significance of these assumptions leads to a weak average scenario of downloads for Smart Charging Solution app concerning the current demand in the market*.

Barriers entering this market.

- o The reservation option requires many entities involved. The Charging Point Operators (CPOs) (i.e. e-laad, NewMotion, AMS, Greenflux) are essential. Some of them are already competitors.
- o Furthermore the new features (reservation of CP, establishment of communication between consumer and grid operator) are going to be integrated into the competitors' solutions inevitably.
- o It cannot be released yet because the complementary systems or technologies have not yet been developed (establishment of communcaition platform).

Qualitative and quantitative analysis

In this section data from e-Laad foundation are presented to prove that there is a certain trend in charging transactions that the application market has not covered it yet.

There is an increase of charging transactions reaching more than 40000 transactions per month by April 2014 only in CPs operated by e-Laad (Figure 32). This expresses a definite growing need of charging and in an extent expresses a higher demand to find a CP.
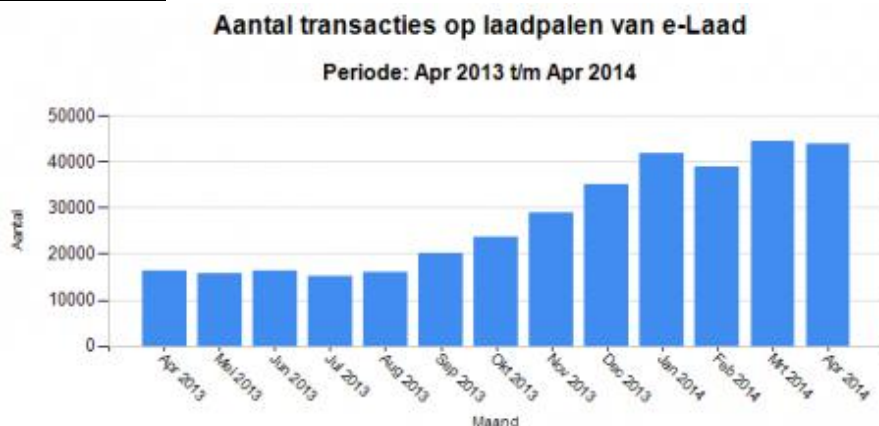
Figure 32 Number of transaction of CPs operated by e-Laad in 2013-2014

The majority of the charging transactions do not outreach the 0-1 hr range (Figure 33). This indicates range anxiety of EV drivers that every time they park their vehicle, even for short stops, they plug it to a CP. Reservation of CP is possible for semi-public infrastructure especially for limited time of booking. Therefore the low duration of the charging process necessitates the need of the customer to ensure the availability of the CP at the right time in the right place.
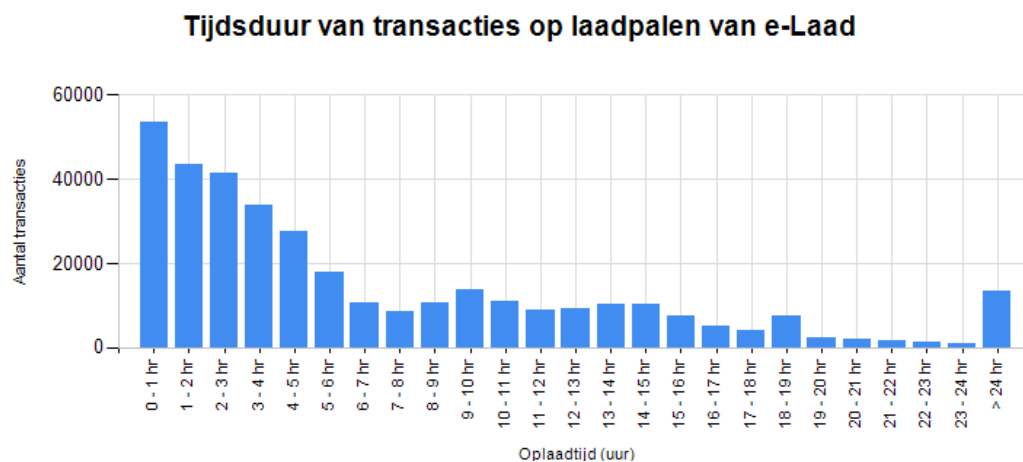
Figure 33 Duration of transactions of CPs operated by e-Laad

So far e-Laad has operated more than 500000 transactions. Also there are 55000 transactions that are below one hour. This is translated to 11% of the total transactions.

Pricing

Entering a market where the current competitor offer the basic functionality (i.e. locating a CP) for free is quite challenging in terms of setting a price first. As it was mentioned before, the USPs of this app is the CP reservation option and the pilot real-time pricing feature (bidirectional communication). The first feature according to many EV drivers opinion adds great value to the application. On the contrary the second feature does not utilize the user at present time.

It is also considered that the development team has a series of conceptual applications in plans, being this one the first out of many. Therefore the profit goal of Smart Charging Solution app is to secure the continuation of the future project developments and not to become a one-time success.

Two models of pricing were investigated, the subscription model (€/month) and the download model (€/download) (Figure 34). Another two existing models (i.e. In-app purchases and In-app advertising) were rejected There are not suitable because of the functionality that it offers and the technology field.
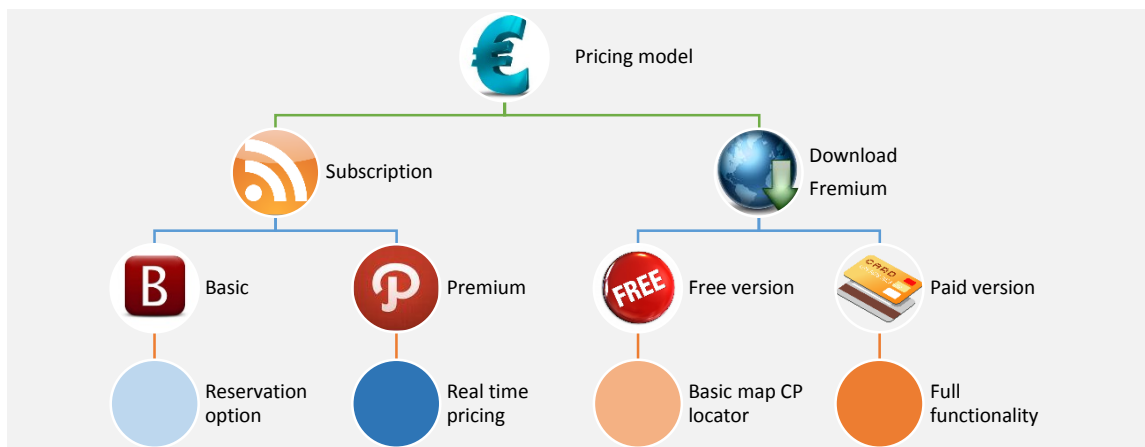
Figure 34 Pricing models: Subscription and Fremium

Three basic scenarios are introduced. The worst case scenario contains 1000 downloads in both iOS and android operating systems. It is considered as a pessimistic scenario regarding two factors:

- There will be a percentage of the fleet of EVs (150 EVs initially) from the WSG project that can support the application in the first phase (regional scale).
- The network that is established from the stakeholders involved in the WSG project can facilitate its spread.

The average scenario contains 4000 users at a national scale. That is the approximate number of FEVs that there are registered in the Netherlands. For their drivers the key functionality of reserving a CP is essential and they are a realistic target group

The best case scenario is 7000 users and it is estimated based on the current assumed number of downloads of the competition in both operating systems.

It should be mentioned that the user estimations of these scenarios refer to after one year from its release date. Also by the end of 2015 a 10% - 15% increase of the EVs is expected. A similar increase of the number of CPs is assumed.

Both of these augmentations are not taken into consideration.
A first basic estimation of the expected revenue based on the selected models are presented in Table 8.

Scenarios	Subscription		Fremium	
Pricing	Basic account (0.4€ / mo)	Premium account (0.8€ / mo)	Free version	Paid version (5€ / download)
Worst scenario – 1000 users total	4000€ / year	9600€ / year	-	5000 €
Average scenario – 4000 users	16000€ / year	38400€ / year	-	20000 €
Best scenario – 7000 users	28000€ / year	67200€ / year	-	35000 €

Table 8 Scenarios of pricing models

This table defines the range that Smart Charging Solution app could profit based on these assumptions (i.e. pricing models, pricing set).

As a second step it should be estimated the shift of the percentage of users in each version of each pricing model. Also it should be taken into consideration that the Fremium model holds an advantage against the Subscription model.

- The free version of an app attracts more users to try it without cost and that can increase the amount of users of each scenario compared to the Subscription model.
- The Fremium model also facilitates the shifting of users from the free version to the paid one.

Scenarios (after one year)	Subscription model		
Pricing	Basic account 80% of the users	Premium accoun 20% of the users	TOTAL
Worst scenario – 1000 users total	3840€ / year	1920€ / year	5760€/ year
Average scenario – 4000 users	15360€ / year	7680€ / year	23040€/ year
Best scenario – 7000 users	26880€ / year	13440€ / year	40320€/ year

Table 9 Subscription model based on the distribution of the users after one year release

Scenarios (after one year)	Fremium model		
Pricing	Basic account 30% of the users	Premium accoun 70% of the users	TOTAL
Worst scenario – 1500 users total	-€ / year	5250€ / year	5250€/ year
Average scenario – 5000 users	-€ / year	17500€ / year	17500€/ year
Best scenario – 9000 users	-€ / year	31500€ / year	31500€/ year

Table 10 Freemium model based on the distribution of the users after one year release

The last factor that will be taken into consideration is the psychology factor. The difference in the revenue is not that high in order to decide just with this criterion. Therefore it should be investigated how the users prefer to pay:

- A considerably high onetime price (compared to the average price of paid apps that is 0.99€) or a
- A visually very low price per month

<u>Two other factor are considered before selection</u>.

- The majority of paid applications in the App store and in Google play use the Fremium model
- The nature of the Smart Charging Solution is dynamic which means that maintenance and service should be arranged in regular basis as well as integration of user feedback in order to evolve the app continuously.

> The latest reason contributes to the fact that a monthly payment is a fairer system for constant support of the app. Also the subscription model guarantees a repetition of transactions in form of virtual contracts between the company and the customer. These contracts are valued as assets contributes to the attractiveness and the evolution of the business. Finally the subscription model as structured with two accounts is possible to be enriched with more features in each account and varied prices. Therefore it is decided to use the subscription model for this application.

Nevertheless in case of not meeting the predicted revenue, a partnership with a strategic stakeholder should be considered in order to exploit their network. In that case it is possible to ensure a onetime fee for the service, without including a pricing model, because a big company can have indirect economic benefits through a free version of an application (e.g. sales increase etc). These kind of companies can be subsidiaries of grid operators (such as Liander, EVnetNL)

Business system and organization

Discrete business activities

The discrete activities of a mobile application development company is described in a typical business system (Figure 35). Each of these activities are defined by specific processes and sub-stages that requires a multidisciplinary approach. The individual activities are analyzed in this section. The management/development team is able to perform the Design – Development – Services (Operation) activities. The distribution part initially is quite straightforward therefore support is not crucial. There is limited experienced in the Marketing and Distribution that might require outsourcing some of the subtasks.

Figure 35 Typical business system adjusted to Application development
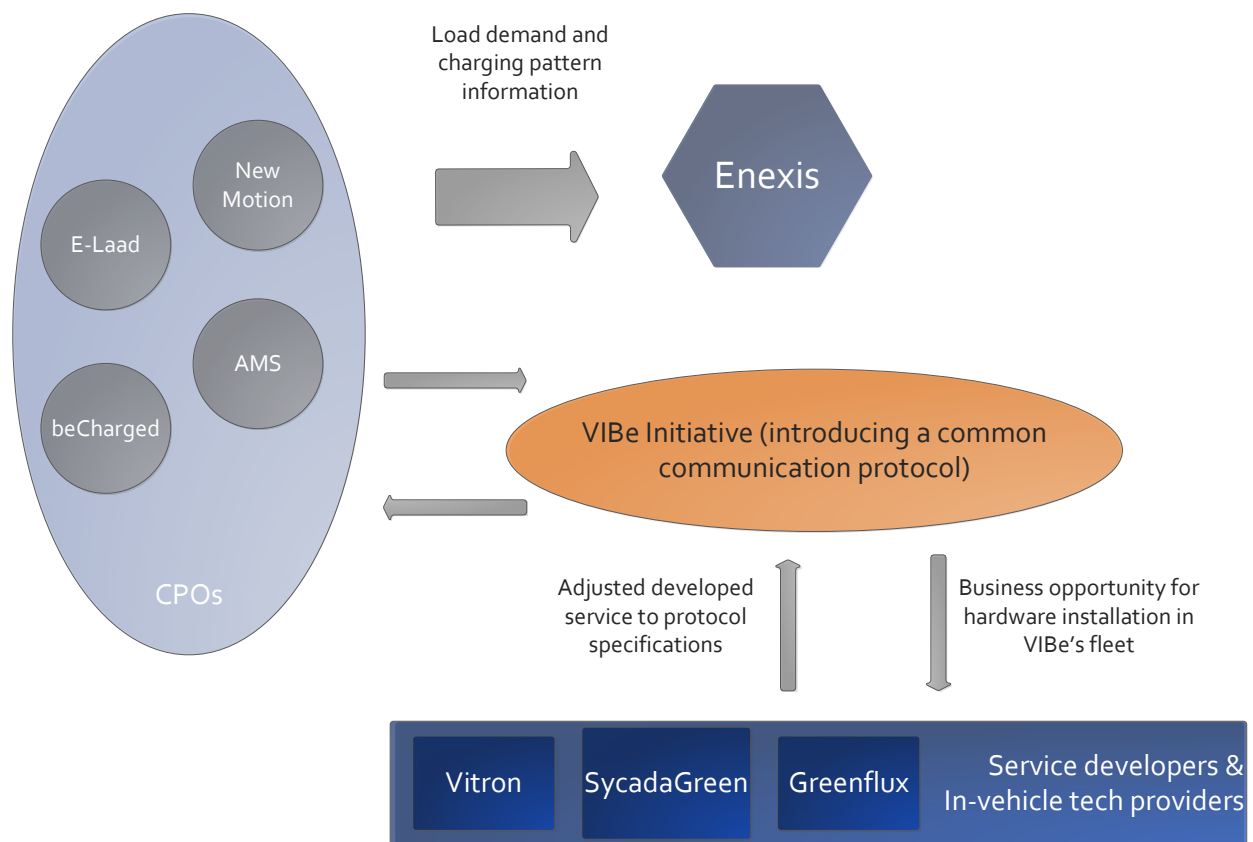
Figure 36 Business ecosystem of charging infrastructure and smart charging

It is worth mentioning that some work has already been done in the first activity generating the main concept and describing the high level specifications of the application.

Furthermore the innovation lab that is one of the primary goals of the WSG project is the ideal platform for every phase that is described in the V model and especially in the integration and testing phase. For validation and verification phases as well as a future demonstration there is an existing fleet of 10 EVs of mainly NXP employees with communication boxes installed. There is an existing network of companies involved in the project that under circumstances can be of help especially at the integration phase.

Marketing and sales

The marketing activity as well as the sales will be initiated by the existing team. In addition there is a defined network of entities in the field of electric vehicles and charging infrastructure that are willing to assist in promoting entrepreneurial efforts. Specific example are given in the next section of partners and suppliers.

The World's Smartest Grid project ensures an initial small scale network of EV drivers that the Smart Charging Solution will address to. This will be the first step of presenting the product to customers. The benefits from this direct communication with a group of users (e.g. HTC, TU/e, automotive campus employees) are:

- 'Mouth to mouth' promotion of the application
- The spatial distribution of the users taking part in the project enhances the needed marketing dispersion
- Assessment of beta version for faster system validation by a dedicated sample of users
- Expansion of VIBe network of connected EVs increases the dynamics of the development team
- Strong relationships with the current WSG project stakeholders
    - multiply the possibilities of financial support (e.g. BOM)
    - increase the potential of a future sale of the development company to competitors (e.g. Alliander Mobility Services, Sycada.Green) and cover the investment of every party

Basically the initial sample of users is a high percentage of the target of VIBe concerning the deployment of Electric Vehicles (approximately 150 EV drivers by the end of 2014). This will be the direct sales group.

The previous list includes partially solutions how to increase demand of the product based on the existing market. Other ways to promote is with dedicated advertisements. This is a marketing strategy that takes into account the assumption that EV drivers usually visit websites with related information.

Mass marketing strategy is not part of the immediate plans considering the current deployment of EVs. However targeted ads in specific EV groups of mass social media will be included.

Distribution

The distribution channels are common in the mobile application business. At the first phase where the native app is going to be developed the Google Play and the App Store are the main starting locations. The positive about the mobile applications business is that the distribution can be direct to the customer without any obvious intermediaries.

Partners and suppliers

Vehicle Innovation Brabant electric

Nr.	Partners	Role	Contact Person
1	Daut Milieu / VIBe	Project manager	Jaap Willems
2	Enexis	Developer of Open Smart Charging Protocol Network Manager	Lennart Verheijen
3	HTC Site Management	Charge Point Provider	Harrie Arends
4	TU/e	Research institute development OSCP and open innovation	Ewit Roos Maarten Steinbuch
5	Driessen Au-togroep	Provider of fleet	Ron Beukers
6	BOM	Chairman Steering committee (stuurgroep) VIBE / networking role and business development	Marc de Haas
Nr	**Participants**	**Role**	**Contact person**
1	NXP/VIBe	Trekker architecture team de-velopment open innovation VIBe	Hans Brouwhuis Maurice Gereards
2	Automo-tiveNL	Networking role and business development	Anton Wolthuis

Table 11 List of stakeholders that are involved currently in the WSG project

Alliander Mobility Services (AMS), New Motion, e-Laad and iHomer as co-developers of Motown assist the integration of plug-in application to their communication platform.

Sycada.Green and Vitron are service providers and developers of individual communication platforms that they can also be part of the collaboration environment at the integration phase.

Risk management

Risk strategies are mandatory in order to predict negative incidents and prepare a strategy either to avoid the consequences of the event or to mitigate them in case it occurs. The nature of application development is such that there are no high financial risks. The capital is of that level that divided by two people is not a complete disaster considering the worst case scenario.

	Helpful wrt the objective	Harmful wrt the objective
Internal Origin Organization	**Strengths** • Features that are first introduced in the Dutch market of EV charging. • Fast integration of user feedback from VIBe's EV sample. • Ideal development conditions - availability of innovation lab	**Weaknesses** • Limited marketing team capabilities • Existing and more experienced competition • Limited profit due to EV deployment
External Origin Environment	**Opportunities** • Scalable communication platform. • Increased market due to VIBe's expansion to other campus • Involvement in an existing collaboration environment facilitates partnerships with service providers • Higher chances of investment return	**Threats** • The delays in the communication platform development provide the current competitors with time to evolve their own apps

Figure 37 SWOT analysis on the Smart Charging Solution

Financial Plan

This section estimates the financial future of the application. Based on calculations from market research, the amount of money that is needed to launch and run the business will be presented. The amount of cash needed to meet current liabilities at any given moment will be estimated. Finally there will be a proposition of the sources that the funding can be obtained from.

As it was estimated in the Budget and Pricing session for the first year 25000€ are needed. According to **Error! eference source not found.** only the 15000 are expenses per year. Based on the three scenarios from the market research it will be identified whether there can be profit.

12-Month Profit and Loss Projection

Four months of development	01/09/14 - 31/12/14	01/01/15 - 31/08/15		01/09/15 - 31/12/15
	Development phase	Release date	First year milestone	End of 2015
Startup expenses	25000			5000
Salaries*	50000			12500
Worst case	1000 users	5760		
Average case	4000 users	23040		
Best case	7000 users	40320		

Table 12 Development phase and first year of release: Cost and profit

*The indicated salaries is for both developers. Here is indicated that the salaries have to be quite low for the company to survive. Therefore it is considered a typical gross annual salary of a PDEng trainee.

Profit – loss statement			
Revenue	31/12/15		
Income from Service	5760	23040	40320
Accumulated Costs	92500		
Interest expenses (in case of loan)	?		
Taxes	0		
Net income	− 86740	− 69460	− 52180

Table 13 Simple profit-loss statement for year 2015

5-year profit-loss projection

The projection of the three scenarios are based on the projections of EVs in 2020. The following assumption is taken into account.

- 140000 EVs is translated to 5000 users
- 200000 EVs is translated to 8000 users
- 300000 EVs is translated to 11000 users

Four months of development	2016	2017	2018	2019	2020
Yearly expenses	15000	15000	15000	15000	15000
Salaries	51000	52000	53000	54000	55000
Worst case 1000 – 5000	5760	11520	17280	23040	28800
Average case 4000 - 8000	23040	28800	34560	40320	46080
Best case 7000 - 11000	40320	46080	51840	57600	63360

Table 14 Five years: Cost and profit
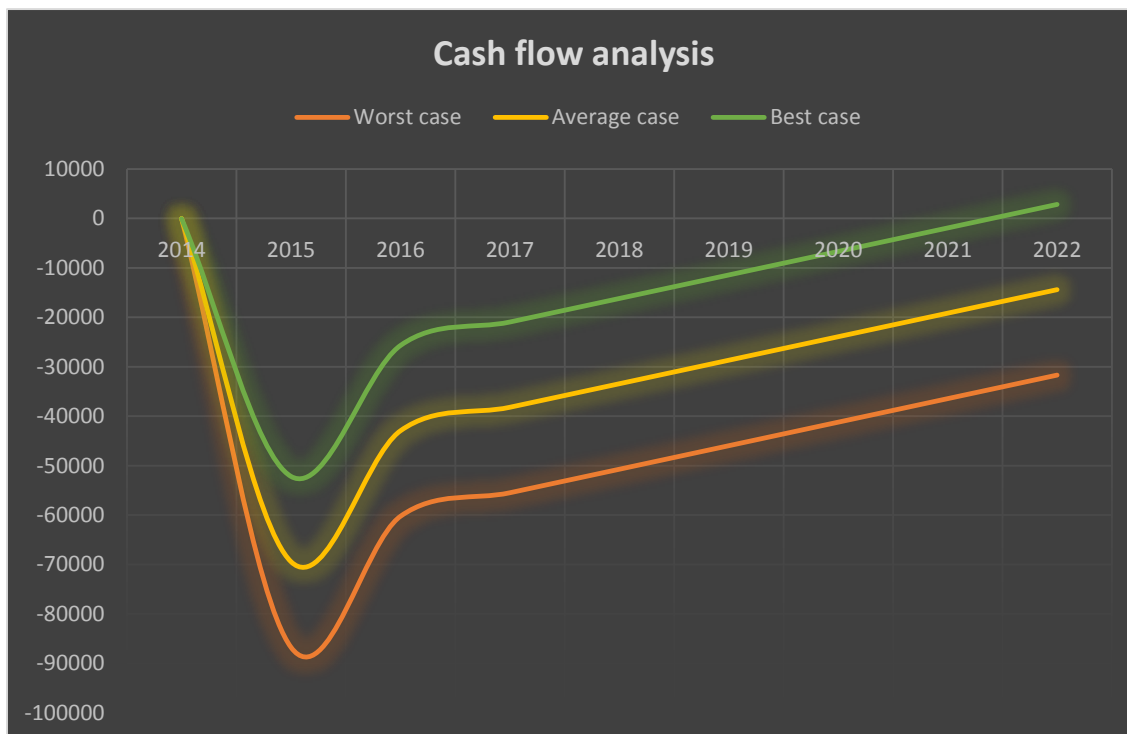
Figure 38 Cash flow projected up to 2022
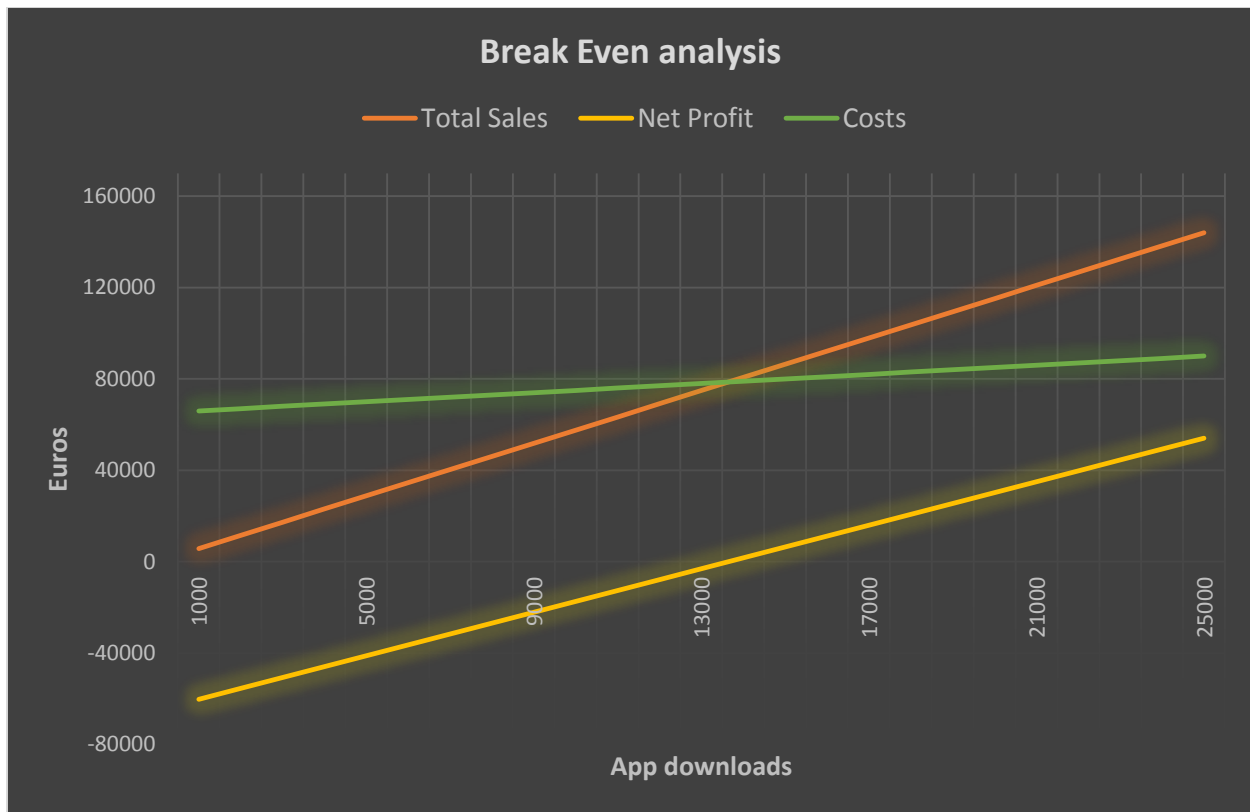
Figure 39 Break even analysis based on the number of app downloads

In general in order to reach the point where the application bring profit to the company the number of download must reach the 13000 with the current pricing model.

Appendix C

In this section the dedicated functional and non-functional requirements of the following applications are presented:
- Smart charging & CP reservation application
- Seat Market Manager
- HTC EV Parking Solution
- EV Path Planner

The section is divided into three parts.
1. Use cases consisted of the main success scenario and their extensions are built.
2. Full functionality map is attempted to be described through flow charts
3. Decomposed requirements are stated.

Functional Requirements

Functional requirements describe the features and functionalities of the application. The process includes high-level functional requirement that, where was needed, have been broken down into more lower-level requirements. Use case diagrams facilitated the elicitation of high-level functional requirements.

Must have requirement; means that the definition is an absolute requirement of the design.

Nice to have, means that the requirement is optional. The developer may choose to include the requirement because it enhances the product's value or he/she can leave the specific feature for later addition.

Non-Functional Requirements

Non-functional requirements represent quality-related design criteria that can assess the operational behavior of the system:

Interfacing Requirements

Interfacing requirements represent characteristics (e.g. visual, sound, display) of the interface of the system with the user.

Reservation & Smart Charging application

Use Case: RSC 002

Name:	Achieve smart charging with DSO
Brief Description:	Smart charge to facilitate the effort of DSO to do peak shaving
Scope:	Smart charging system demonstrating VIBe platform and OSCP
Level:	Summary
Actor(s):	EV driver (EVD), Distribution System Operator (DSO)
Stakeholders & Interests:	VIBe, Enexis, CPOs

Pre-Conditions	
Title	**Description**
Middleware layer	VIBe platform with bidirectional communication is established,
DSO – CPO communication protocol	Open Smart Charging Protocol is developed and standardized

Guarantees	
Minimal	Driver charges his EV
Success guarantees	EV driver charges his EV and during the process he is included in the peak shaving plan of the DSO
Trigger	EV's SoC is low and forces the driver to ensure an available CP

Main Success Scenario
<1> EVD: Presses the RSC launch icon on his smartphone   <2> EVD: Inserts the username and password to log in   <3> EVD: Chooses from a map the available CP on his way inside the radius of available EV range   <4> CPO: Updates the CP map legend based on usage, out of service   <5> EVD: Reserves the CP and sets the ETA and the duration (or sets desired target SoC)   <6> EVD: Approves (checks) the smart charging feature   <7> EVD: Confirms the service and completes the billing transaction   <8> EVD: Reaches the CP station through navigation, finds it available and plugs in the EV   <9> DSO: Is notified by the system for potential peak load   <10> DSO: Informs the EV driver for including his EV to the process and asks once more for his approval displaying him the two different prices for each mode   <11> EVD: He approves smart charging by selecting the cheaper price

Extensions	
Title	**Description**
EVD does not take any action	<9a> DSO: Proceed with smart charging taking into consideration the prior approval <9b> DSO: Informs the EVD of the current power output based on the by default selection, the current price and the charging process (e.g. estimated SoC in time)

Post-Conditions	
Title	**Description**
Success	The CP map must be accurate
Real-time	Real time pricing should differentiate greatly to have an impact to the EV driver's decision
Related information	
The communication between the DSO and the end user occurs through the CPO back office. VIBe platform is not the only constraint to establish this communication. Motown is also very important to be published to achieve smart charging. In any case (if it is not Motown) a CP management platform is built based on the OCCP to introduce smart charging. Similar platform based on OSCP is built to establish the communication between DSO and CPO.	

Top Level Use Case Diagram: RSC 002
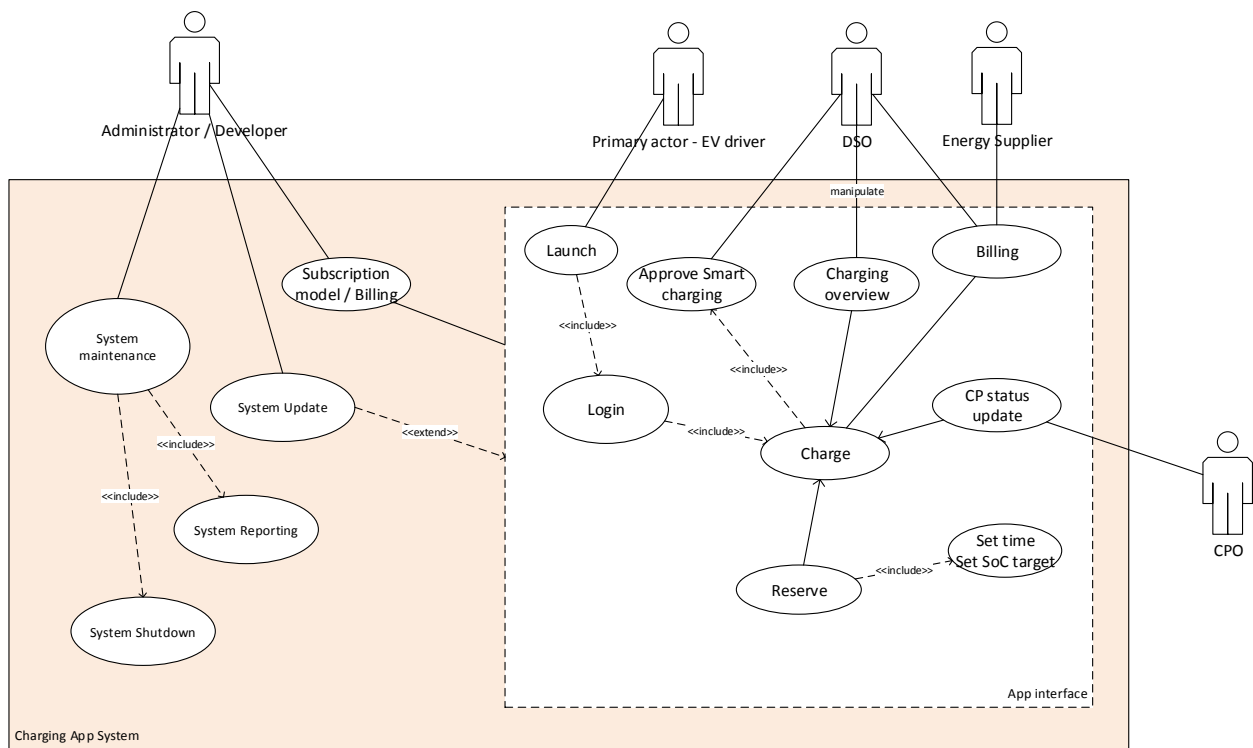
Full functionality map of the application
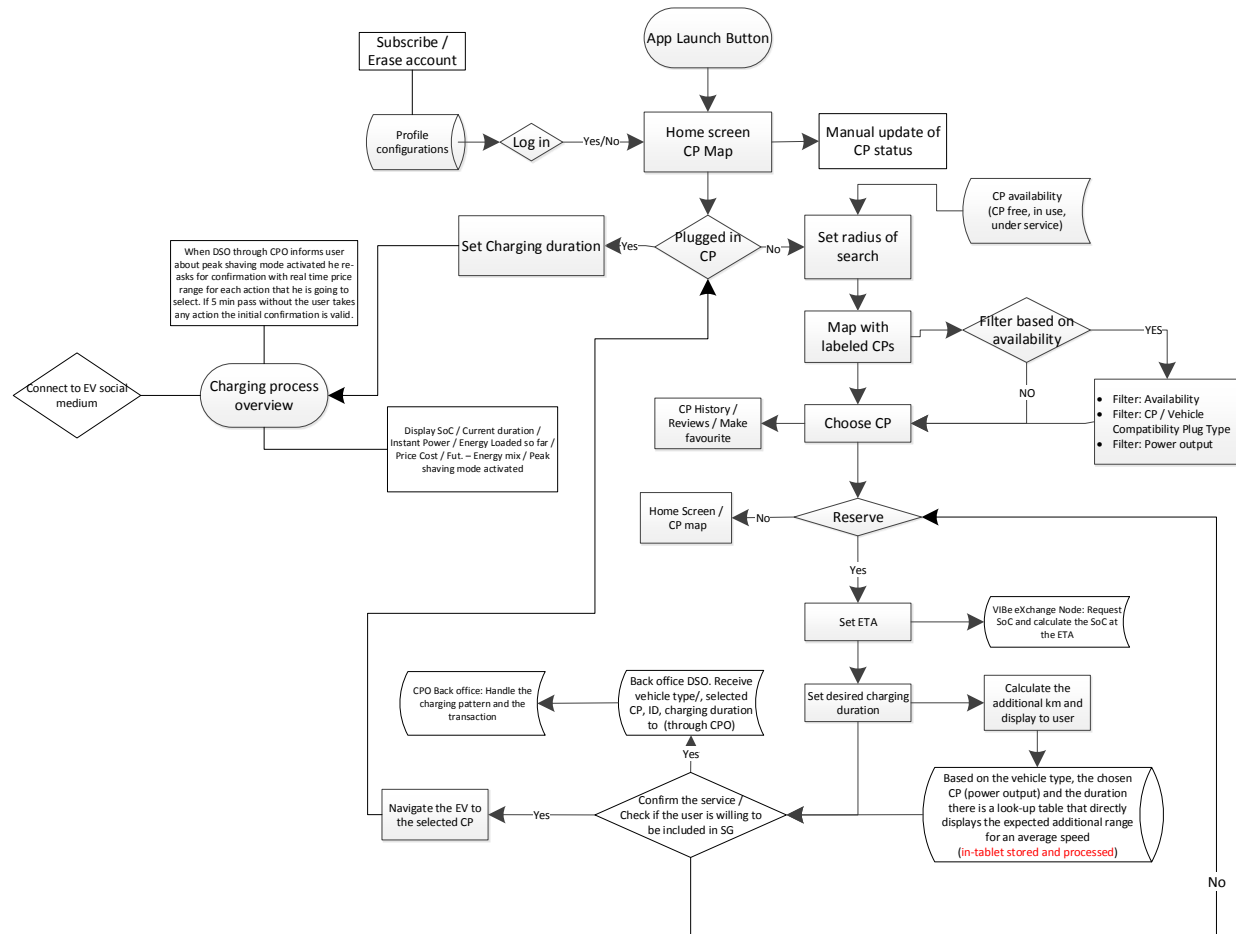
Figure 40 Functional flow diagram of the base operations of CP reserve & Smart charging

List of app functionalities / commands

Subscribe / Cancel Subscription

Login / Logout

Create / edit profile

Update CP map

Request CP review, photos and status

Reserve CP

Set radius of search

Set Charging time

Set SoC target

Erase profile

Save (e.g. daily route, favorite CP)

Erase favorite CP

RSC_001: To check CP availability

> RSC_001A: Low latency Data exchange enabled from CP unit to CPO Back Office
>
> RSC_001B: Low latency Data exchange enabled from CPO Back Office to VIBe fleet drivers
>
> RSC_001C: CP availability displayed based on the selected filters

RSC_002: To reserve CP

RSC_003: To request CP review

RSC_004: To receive information about the charging process

RSC_005: To upload CP review

RSC_006: To smart charge

Functional requirements

Functional requirements of the complete communication platform (including VIBe's middleware) wrt Smart Charging & CP Reservation app

The first part describes the functional requirements of the application with respect to communication platform characteristics and capabilities. The functional requirement is **describing the behavior of the system** as it relates to the system's functionality.
The first general requirement RSC_001 is the near real-time exchange of information in order to update the status of the Charging Points. The RSC_001 is decomposed into three lower level requirements based on the latency of communication between the CP and the CPO back office and the CPO backoffice and the end user.

Business rules:

1. CP infrastructure with data transmitter (location, availability, unique ID, timestamp)
2. The user details must be validated by the system when he/she signs/logs in with his account password
3. The CP manufacturers have to share in a common protected database specific information important for the functionality of the system and for serving interoperability
4. Specific permissions are given to the user/EV driver to read but also to write and edit (i.e. his profile/account, his CP review). Furthermore the CPO (through the developer) is able to read, write, and edit data. Also is able to erase accounts due to specific circumstances.
5. The system has to validate that there are not users with duplicate information registered.
6. Specific rules will be applied when a user makes an account inserting a username and a password (specific range of characters, symbols and numbers).

Functional requirement ID <RSC_001>	
Description: Check near real time CP availability based on the status	
Assumptions	The VIBe platform and Motown are developed and established, CP infrastructure is online
Persona	EV driver CPO manager
Impact	MUST HAVE
Primary Actor	App end user (usually EV driver)
Input	Low SoC in EV battery, manual request for CP update
Action	CPO should be able to take status update of the CP infrastructure in a selected frequency and push the information to the platform and in an extent to the end
Output	CP availability based on a legend of occupied, available, out of service
Exceptions	Power outage, blackout
Dependencies	Motown, Open Charging Point Protocol (OCPP)

Functional requirement ID <RSC_001A>

Description: Low latency Data exchange enabled from CP unit to CPO Back Office through (Motown?) (Open Charging Point Protocol)

Assumptions	The VIBe platform and Motown are developed and established, CP infrastructure is online
Persona	EV driver and CPO manager
Impact	MUST HAVE
Primary Actor	CPO manager
Input	Predefined frequency of CP data flow (Fixed time intervals depending on network bandwidth limitations)
Action	Push information from Charging Point (CP) to the back office of Charging Point Operator (CPO)
Output	Information regarding the status of the CP is stored at the CPO server and pushed to the application layer
Exceptions	Power outage
Dependencies	Motown, Open Charging Point Protocol (OCPP), the system is online

Functional requirement ID <RSC_001B>

Description: Low latency Data exchange enabled from CPO Back Office to VIBe fleet drivers through VIBe platform

Assumptions	The VIBe platform operates and communicates with
Persona	EV driver and CPO manager
Impact	MUST HAVE
Primary Actor	CPO manager
Input	Predefined frequency of CP data flow (Fixed time intervals depending on network bandwidth limitations)
Action	Push information from Charging Point (CP) to the back office of Charging Point Operator (CPO)

Output	Information regarding the status of the CP is stored at the CPO server and pushed to the end users electronic devices (e.g. tablets, smartphones)
Exceptions	Power outage, blackout
Dependencies	Motown, OSCP

Functional requirement ID <RSC_001C>	
Description: CP availability displayed based on the selected filters	
Assumptions	The VIBe platform and Motown are developed and established
Persona	EV driver and CPO manager
Impact	MUST HAVE
Primary Actor	EV driver
Input	Low SoC in EV battery, manual request for CP update
Action	CPO should be able to take status update of the CP infrastructure in a selected frequency and push the information to the platform and in an extent to the end
Output	CP availability based on a legend of occupied, available, out of service
Exceptions	Power outage, blackout
Dependencies	Motown, OSCP

Functional requirement ID <RSC_002>	
Description: Reserve the selected CP	
Assumptions	The VIBe platform and Motown are developed and established, Most importantly the system should be interoperable
Persona	EV driver and CPO manager
Impact	MUST HAVE
Primary Actor	EV driver
Input	Select a CP, choose from list with favorite CPs, press reserve and confirm the transaction

Action	The system should push the reservation event (along with the timestamp), the selected duration (time of start and end of reservation not necessarily charging) and update the CP map according to the latest events
Output	The system is excluding the specific CP from the list of the available CPs for the specific time that it is reserved
Exceptions	Power outage, days of extreme demand , unavailability
Dependencies	Motown, OCPP, CP manufacturer interoperability

Functional requirement ID <RSC_003>	
Description: Request CP review	
Assumptions	The VIBe platform and Motown are developed and established (Platform based on OCPP is established for all manufacturers)
Persona	EV driver (other users as well), CPO manager
Impact	Nice to Have
Primary Actor	EV driver
Input	Select a CP and press it once (a small window pops up with the address), press it twice (more-information button) to request a full description of the CP unit
Action	The system displays information regarding the specific CP in a separate page (from the main page/map) after the user pressed twice the specific CP
Output	Reviews (along with photos etc) that have been uploaded by EV drivers, CPOs include statistics for each CP based on the usage (i.e. overall charging time/energy, today's charging time/energy etc.)
Exceptions	No exceptions are predicted, information can be available even offline although next to each information the date and hour should be attached
Dependencies	Motown OCPP establishment

Functional requirement ID <RSC_004>	
Description: Receive information about the charging process	
Assumptions	The VIBe platform and Motown are developed and established. The charging transaction is confirmed and the EV is plugged in the CP

Persona	EV driver (other users as well), CPO, Energy suppliers
Impact	Must have
Primary Actor	EV driver
Input	EV driver has confirmed the transaction and he/ she has plugged his/her EV at the CP unit
Action	The system pushes almost real time information related to the charging process
Output	Current charging power, charging duration, SoC, current charging price
Exceptions	Power outage, free of charge energy consumption at specific CPs
Dependencies	Motown, OCPP establishment

Functional requirement ID <RSC_005>
Description: To upload CP review

Assumptions	The VIBe platform and Motown are developed and established. The charging transaction is confirmed and the EV is plugged in the CP
Persona	EV driver, CPO
Impact	Nice to Have
Primary Actor	EV driver
Input	After one charging process with specific CP, an option is enabled in the application for the specific user account to write a review and upload it along with a photo
Action	The system uploads the review and makes it public after the CPO manager verifies the user, the actual CP usage and after he approves the contents (i.e. language etc)
Output	A full-text review with information about the status of the CP, its condition, a verification of the exact location compared to the app map, the charging power, the duration, the SoC percentage increased, the vehicle type.
Exceptions	When the user hasn't used a CP at all, when the review has been assessed as non-disclosed because of language or fake information
Dependencies	Motown, OCPP

Functional requirement ID <RSC_006>	
Description: Do Smart charging	
Assumptions	The VIBe platform and Motown are developed and established. The charging transaction is confirmed and the EV is plugged in the CP
Persona	EV driver, CPO, DSO, Energy supplier?
Impact	Must have
Primary Actor	EV driver
Input	Approve the participation in smart charging by the user when he/she confirms a charging transaction
Action	The system sends the verification order to the DSO that the specific EV charging can be included in case peak shaving is needed. Then the charging process can be manipulated by the DSO
Output	The charging price per kWh is reduced, the power output is reduced when necessary until the peak load is balanced
Exceptions	The user does not approve the smart charging and he is charged with higher prices, Power outage,
Dependencies	Motown, OSCP

Non-functional requirements of Smart Charging & CP Reservation app

The non-functional requirement **elaborates a performance characteristic** of the system.

Non-functional requirements	
Performance	Certain tasks (i.e. CP availability, CP reservation, Smart charging cost) especially when almost real-time information is requested are time-sensitive and the software system has to be able to operate functions in a scale of milli-secs. Other functions such as create, edit and/or upload CP review are less time-sensitive. How quickly transactions must be processed.
Security	Integrity requirements define the security attributes of the system, restricting access to features or data to certain users and protecting the privacy of data entered into the software.
Audit requir. & Visual requir.	Personas has to be built based on EV drivers profiles in order to make feedback iteration on the visual and sound signal of the application and to improve the appearance and the user-friendliness
Usability	The app is EV driver dedicated, the available functions have to be well balanced to avoid confusion and support ease-of-use (i.e. user friendly) functionality that will be learnt after a couple of iteration by the end-users
Responsiveness	Similar to performance the system must have a very fast response to the user commands, nevertheless the hardware quality plays a significant role in this requirement.
Localization	Multiple languages option has to be supported starting from English and Dutch. Then it can be extended to German, French and other languages depending on the national EV deployment and the CP infrastructure.
Scalability	Regarding the current FEV fleet deployment (5084 until June 2014) it is expected that the app will have around 3500 users online / per day

High Tech Campus: Electric Vehicle Parking solution

Use Case: HTCEVP 001

Name:	EV driver selects a Charging Point (CP) in the HTC
Brief Description:	Provide the EV driver (employee or visitor) with the required steps in order to charge at a CP of the High Tech Campus (HTC).
Scope:	EV Charging in the High Tech Campus in Eindhoven
Level:	Summary
Actor(s):	EV driver (EVD), HTC Electric Vehicle Parking (HTCEVP)
Stakeholders & Interests:	VIBe, EV drivers, CPOs, Automotive services developers, site management of HTC, Enexis (grid operator)

Pre-Conditions	
Title	**Description**
Native application	The app is downloaded and successfully installed in a smartphone/tablet
Common database	An EV profile is created and registered in the HTC's server (visitor or regular employee) including the type of EV (i.e. FEV, PHEV)

Guarantees	
Minimal	The EV driver selects a CP either as a visitor or an employee
Success guarantees	The EV driver reserves a CP on a regular basis
Trigger	EV charging at the working environment where the EV possibly stands still for 8 hours

Main Success Scenario

<1> EVD: presses the HTCEVP launch icon on the smartphone

<2> EVD: chooses the employee checkbox

<3> EVD: enters the required Username and Password to log in as an employee

<4> EVD: selects parking lot of preference (default preference is displayed) and leaves unchecked the check-box of 'provide navigation directions' and the reservation option

<5> HTCEVP: displays a list of CPs with the availability status

<6> EVD: chooses an available CP

<7> EVD: sets estimated time of arrival and departure

<8> EVD: confirms the procedure

<9> HTCEVP: informs the EV driver that he will be included in the smart charging process

Extension	
Title	**Description**
Visitor choice	<2a> EVD: selects the visitor choice
	<2b> HTCEVP: asks EVD if he requires navigation directions to a CP
	<2c> EVD: accepts the navigation directions
	<2d> HTCEVP: asks EVD what building (number) is going to visit
	<2e> EVD: responds with the specific building number
	<2f> HTCEVP: suggests a parking lot with a specific available CP

	<2g> EVD: accepts the CP selection
	<2h> EVD: sets estimated time of arrival and departure
	<2i> EVD: confirms the procedure
Reservation option	<4a> EVD: checks the reservation option
	<4b> HTCEVP: displays a more limited list of CPs with the availability
	<4c> EVD: sets date or specific dates (maximum 3 per week)
	<4d> EVD: chooses an available CP
	<4e> EVD: sets estimated time of arrival and departure
	<4f> EVD: confirms the reservation

Post-Conditions

Title	Description
CP reservation	User is able to reserve for a specific number of days and hours
Additional CP reservation	The User is unable to reserve another CP when he has already reserved one.

Related information

Every EV is registered in the same database. EV driver possesses an EV charge RFID card. Employees are included in the smart charging processed by the grid operator (i.e. Enexis). Some of the CPs installed are available for reservation only for Fully Electric Vehicles. The limitations in the maximum days per week are related to the fact that the CP infrastructure inside the HTC is quite limited at the time being. If the visitor requests more than 5 hours of charging it is possible to be included in the smart charging. Parking lot preference for employee profile can be stored.

Top Level Use Case Diagram: HTCEVP 001

Case: HTCEVP 002

Name:	EV driver have a charging process overview
Brief Description:	EV driver after he finds the CP and plugs it in, he has an overview of the charging process along with choices over the pricing (smart charging)
Scope:	EV Charging in the High Tech Campus in Eindhoven
Level:	Summary
Actor(s):	EV driver (EVD), HTC Electric Vehicle Parking (HTCEVP)
Stakeholders & Interests:	VIBe, EV drivers, CPOs, Automotive services developers, Enexis (grid operator), site management of HTC

Pre-Conditions	
Title	**Description**
Middleware layer	VIBe platform with bidirectional communication is established
OSCP	The Open Smart Charging Protocol is developed, tested and operational to establish communication between the CPO (or HTC site management) and the grid operator (Enexis)
Native application	The app is downloaded and successfully installed in a smartphone/tablet
Common database	An EV profile is created and registered in the HTC's server (default profile of a visitor or a regular employee) including the type of EV (i.e. FEV, PHEV)

Guarantees	
Minimal	Display an overview of the charging process
Success guarantees	Facilitate smart charging process providing real-time pricing incentive
Trigger	EV charging at the working environment where the EV possibly can stand still for 8 hours

Main Success Scenario
This use case starts when the EV driver has the EV plugged in the CP.

<1> EVD: presses the HTCEVP launch icon on the smartphone

<2> EVD: chooses the employee checkbox
<3> EVD: enters the required Username and Password to log in as an employee

<4> HTCEVP: Displays the charging process, showing the SoC, the current power, the kwh transferred, the price

<5> HTCEVP: Informs the EV driver that the charging process reached goal (time of arrival or SoC) |

Extension	
Title	**Description**
Facilitate smart charging	<4a> HTCEVP: informs the EVD that the load reached a high peak and peak shaving is activated

<4b> HTCEVP: displays the new reduced price and the charging plan

<4c> EVD: accepts the new price and allows to include his EV in the peak shaving mode |

Postpone time of departure	<5a> HTCEVP: informs the EV driver that the initial time of departure have come (without reaching 100%).
	<5b> HTCEVP: asks if the driver would like to continue charging with a new price
	<5c> EVD: chooses to continue charging setting a new time of departure and accepting the new price

Post-Conditions	
Title	**Description**
Smart charging	The final charging goals of an EV must not be influenced by the peak shaving
Real-time	The site man/ment of HTC should update CP status frequently (e.g. every 30 min)

Related information
Every EV is registered in the same database. EV driver possesses an EV charge RFID card. Employees are included in the smart charging processed by the grid operator (i.e. Enexis).

Top Level Use Case Diagram: HTCEVP 002

Full functionality map of the application

Figure 41 Functional flow diagram of the base operations of HTC EV parking

List of app functionalities / commands

Login / Logout
Create / Erase profile
Select parking lot
Display of CPs with availability status
Choose CP
Set arrival and departure time
Reserve CP
Navigate EV driver to the CP
Provide real-time pricing
Postpone the time of departure

HTCEVP_001: To organize the CP availability

HTCEVP_002: To find a CP for an EV driver

HTCEVP_003: To navigate the EV driver to parking lot

HTCEVP_004: To realize CP reservation

HTCEVP_005: To facilitate smart charging (peak shaving activation)

HTCEVP_006: To extend the charging process

Functional requirements

Functional requirements of the HTC EV Parking Solution

Functional requirement ID <HTCEVP_001>	
Description: To organize the CP availability	
Assumptions	The VIBe platform is developed (Vehicle data management), user(s) successfully logged in (full functionality of application is approved),
Persona	EV driver, male/female, 35-55, accustomed to mobile applications
Impact	MUST HAVE
Primary Actor	HTC EV Parking application, the System
Input	Time of arrival and departure are set in 5 minute steps. Classification messages from EV drivers (i.e. plugin, reserve), CPO (i.e. under service), CP itself (i.e. status unknown) in case of potential malfunction
Action	Organize the timeslots of each CP according to the type of requests, classify the status of the CP at the back office of the app administrator - HTC Site management (or CPO)
Output	(Outlook) Timeslot layout providing the status of the CP based on occupancy, reservation, availability, under service and unknown
Business rules	By definition the timeslots cannot be overlapped. The Site management is responsible to organize the status of the CP especially when it is under service.
Exceptions	Communication between administrator (HTSE or CPO) and CP is not established, Power outage
Dependencies	Online user connection, CP management platform,

Functional requirement ID < HTCEVP _002>	
Description: To find a CP for an EV driver	
Assumptions	User(s) successfully logged in (full functionality of application is approved),
Persona	EV driver, male/female, 35-55, accustomed to mobile applications
Impact	MUST HAVE
Primary Actor	HTC EV Parking application, the System
Input	A request is pushed by an EV driver for a parking spot provided with CP at the HTC. The employee has a default selection of a preferred parking lot. The visitor has the capability to enter the building number that he visits.

Action	The System filters the available CPs in the desired parking lot based on the type of the input.
Output	A list with available CPs is provided to the user in the interface of the system.
	Limited list of CP options based on the preferred parking lot for the employee.
	One CP option based on the nearest parking lot to the visiting building for the visitor.
Business rules	If many EV drivers with employee profile prefer one specific parking lot then the System is able to warn them about possible frequent CP unavailability.
Exceptions	When every CP is occupied and/or reserved and/or under service.
Dependencies	Online user connection, CP management platform,

Functional requirement ID <HTCEVP _003>	
Description: To navigate the EV driver to parking lot	
Assumptions	The VIBe platform is developed (Vehicle data management), user(s) successfully logged in (full functionality of application is approved).
Persona	EV driver, male/female, 35-55, accustomed to mobile applications
Impact	MUST HAVE
Primary Actor	HTC EV Parking application, the System
Input	GPS location signal is sent to the System to inform (landmark on a sketch map) the driver of the entrance that he is using.
Action	The System combines the received GPS location with the parking lot. Then the System matches that combination with one set of directions.
Output	Auditory and visual navigation directions are given by the System until the entrance of the parking lot, which was selected.
Business rules	There are three vehicle entrances and six parking lots at the HTC. There are 18 prefixed navigation directions that are loaded and displayed to the driver.
	The tablet or the in-vehicle communication box do not transmit GPS messages (e.g. because the driver switched it off or hasn't given any permission).
Exceptions	GPS malfunction, Communication between administrator (HTCSM or CPO) and CP is not established
Dependencies	Online user connection

Functional requirement ID <HTCEVP_004>	
Description: To realize CP reservation	
Assumptions	User(s) successfully logged in (full functionality of application is approved), employee profile is required, CP infrastructure is online
Persona	EV driver, male/female, 35-55, accustomed to mobile applications
Impact	MUST HAVE
Primary Actor	HTC EV Parking application, the System
Input	Request by the user to provide a parking spot with CP that has the option to be reserved (this request is pushed to the System through the HTCSM or the CPO)
Action	The System updates the CP status with the label 'reserved'
Output	Displays a confirmation message to the user's interface
Business rules	An interface is placed next to the CP to inform the driver if the CP is reserved.
Exceptions	Every CP that has the option of reservation is reserved
Dependencies	Online user connection, CP management platform

Functional requirement ID <HTCEVP _005>	
Description: To facilitate smart charging (peak shaving activation)	
Assumptions	CP infrastructure is online, VIBe platform is developed and established
Persona	EV driver, male/female, 35-55, user, accustomed to mobile applications
Impact	MUST HAVE
Primary Actor	HTC EV Parking application, the System
Input	Peak-shaving activation request from DSO to CPO (or the HTCSM) to the EV driver
Action	The system triggers an approval question to the EV driver. Whether the response is positive or negative the system sends the message back to the DSO (through the intermediate channels) and stores the event into a logger with a timestamp.
Output	The system displays the question to the user's interface 1) Positive response: updates the price along with power output and charging pattern through time.

	2) Negative response: Values related to charging at the same state as before.
Business rules	The return message to the DSO cannot be null. In case of non-response by the user the return message will be negative. If there is an apriori agreement between the parties then the initial consensus stands.
Exceptions	
Dependencies	CP management platform (e.g. Motown), OSCP developed for communication between DSO and CPO

Functional requirement ID <HTCEVP_006>	
Description: To extend the charging process	
Assumptions	CP infrastructure is online, VIBe platform is developed and established
Persona	EV driver, male/female, 35-55, accustomed to mobile applications
Impact	MUST HAVE
Primary Actor	HTC EV Parking application, the System
Input	Request by the user to extend the charging process after the initially scheduled time of departure (completion of charging).
Action	The request is examined (for approval) by the HTCSM (or CPO) and a new (increased) price is set.
Output	The System displays new price set by the HTCSM and asks new time of departure from the user.
Business rules	-
Exceptions	In case of CP reservation the request is rejected.
Dependencies	Online user connection, CP management platform

Non-functional requirements of HTC EV Parking app

Non-functional requirements	
Performance	The processing time (e.g. loading, calculating, updating CP status) should be minimized to the least possible. The system should be able to minimize its resource consumption (i.e. battery).
Privacy	App user's identities or other information (e.g. location) should not be provided to third parties without their consent.
Usability	The application should consist of the least possible interface screens. The amount of iterations that a user needs to understand and learn the full functionality of the system should be minimized. The Graphical User Interface (GUI) should be simple and user-friendly.
Expandability	The system should be able to be expanded geographically, i.e. to the other campuses of TU/e and Automotive campus
Scalability	The system should be designed to operate for 100 users/EV drivers at the same quality level up to 1000..

Interfacing requirements	
Description: Display the list of CP including the availability status	
Impact	MUST HAVE
Source system	Back office of CPO or monitor / administration HTC management
Target system	White the available , red the reserved ones, R next to the CP that can be reserved, Orange the occupied ones, grey the under service or unknown status
Output Data	Small but readable textboxes containing the mentioned information

Seat Market Manager

Use Case: SMM 001

Name:	Arrange daily commuting at work
Brief Description:	Make reservation to ensure daily commuting back and forth to work with arranging a combination of transportation means at the desired time
Scope:	Seat management including almost real time transportation needs demonstrating VIBe platform
Level:	Summary
Actor(s):	Commuting User (CU)
Stakeholders & Interests:	VIBe, Autogroep Driessen, NS, Bus agencies, App developer(s)
Pre-Conditions	
Title	**Description**
Middleware layer	VIBe platform with bidirectional communication is established
Profile configurations	Default profile preferences set to convenience (i.e. only use of cars)
Guarantees	
Minimal	Arrange a commuting ride back and forth to work
Success guarantees	Arrange commuting in a regular basis optimizing the duration of the trip
Trigger	Reduce commuting expenses, eliminate car ownership expenses, and facilitate the daily commuting
Main Success Scenario	

<1> CU: Presses the SMM launch icon on his smartphone

<2> CU: Inserts the username and password to log in

<3> CU: Insert a location of departure and destination

<4> CU: Set the time of departure with a margin of ±20 mins

<5> CU: Filter the commuting frequency to daily basis

<6> CU: Sort the listed solutions based on minimum duration

<7> CU: Search for available combination of transportation solutions

<8> CU: Select and confirm the desired trip

<9> CU: Complete the transaction after the validation of the other driver

Extension	
Title	**Description**
Use EVs only	<6a> CU: presses the preferences (options) button <6b> CU: select pure green transportation only <6c> CU: Search for available combination of transportation solutions <6d> CU: Select and confirm the desired trip

	<6e> CU: Complete the transaction after the acceptance and the confirmation of the other driver
Post-Conditions	
Title	**Description**
Environment sensitive	The case that the commuter wants to travel only with Fully Electric Vehicles requires mass EV deployment
Real-time	The billing transaction should be confirmed
Related information	
The estimated duration of each trip is set by the driver that offers the available seats based on his online history (connected car).	

Top Level Use Case Diagram: SMM 001

Use Case: SMM 002

Name:	Travel a long distance trip across two countries
Brief Description:	Find and use the right combination of transportation means to achieve minimum price and travel duration
Scope:	Chain mobility services demonstrating what VIBe platform can become by integrating data of thousands of vehicles and other means of transportation
Level:	Summary
Actor(s):	Traveler User (TU), Other Driver (OD)
Stakeholders & Interests:	VIBe, Autogroep Driessen, potential for NS, Bus agencies, App developer(s)

Pre-Conditions	
Title	**Description**
Middleware layer	VIBe platform with bidirectional communication is established
Profile configurations	Default profile preferences set to minimum price

Guarantees	
Minimal	Arrange a travel to trip from Eindhoven to Paris
Success guarantees	Find available seats to reach Paris based on the minimum duration of the trip and the best price
Trigger	Reduce travel expenses, increase travel comfort

Main Success Scenario
<1> TU: Presses the SMM launch icon on his smartphone <2> TU: Inserts the username and password to log in <3> TU: Insert a location of departure and destination <4> TU: Select the return trip option (back and forth) and set the time of departure with a margin of ±30 mins <5> TU: Sort the listed solutions based on minimum duration <6> TU: Search for available combination of transportation solutions <7> TU: Select and confirm the desired trip <8> TU: Complete the transaction after the validation of the involved parties (e.g. other drivers, buses and trains)

Extension	
Title	**Description**
Secure the transition	<8a> TU: communicates through a pm to the OD to arrange an earlier departure time and ensure that the transition won't be lost <8b> OD: accepts the time rearrangement

Post-Conditions	
Title	**Description**
If a transition is lost	It is possible to search for alternative solutions almost simultaneously with the time that they are uploaded due to the platforms capabilities

Drivers' reviews	The listed available solutions are assessed based on reviews of the drivers' style, the type of the vehicle, the train type
Related information	
The estimated duration of the trips made by the cars that offers the available seats are based on their online history (connected car). Also the transaction is aggregated into one bill. The Seat Manager is responsible for handling the division of the cost to the individual parties.	

Top Level Use Case Diagram: SMM 002

Use Case: SMM 003

Name:	Driver finds co-passengers in Seat Manager
Brief Description:	Search and find passenger at the last moment for a small trip to reduce travel expenses and improve driving conditions
Scope:	Chain mobility services demonstrating what VIBe platform can become by integrating data of thousands of vehicles and other means of transportation
Level:	Summary
Actor(s):	Main Driver (MD), Traveler User (TU)
Stakeholders & Interests:	VIBe, App developer(s)

Pre-Conditions	
Title	**Description**
Mass scale of transportation means	A variety of vehicles and a quantity of users is a hard prerequisite
Time flexibility	The trip is not possible to be postponed more than 60 minutes
Save travel history	In MD's profile is already registered the vehicle and the history of his trips is stored

Guarantees	
Minimal	Find a passenger to accompany MD at his trip
Success guarantees	Find two passengers to accompany MD at his trip 30 minutes prior to departure
Trigger	Reduce travel expenses, increase travel comfort, reduce cars in roads

Main Success Scenario
<1> MD: Presses the SMM launch icon on his smartphone <2> MD: Inserts the username and password to log in <3> MD: Insert a location of departure and destination <4> MD: Set the time of departure with a flexibility margin of ±60 mins <5> MD: Pre-Sort the passengers based on desired departure time (short notice) <6> MD: Select the top two based on their history reviews as well <7> MD, TU: Confirm the agreement and the trip <8> MD, TU: Complete the billing transaction after the approval of the involved parties

Extension	
Title	**Description**
Cancellation scenario	<7a> TU: communicates through a pm to the MD and cancel his participation <7b> MD: accepts the cancellation and searches again for passengers that want to leave for the specific destination in 30 min

Post-Conditions	
Title	**Description**

-	-

Related information

The estimated duration of the trips made by the cars that offers the available seats are based on their online history (connected car). The MD in his profile can select the option to search for passengers instead of searching for a ride (seat). MD also is able to check the reviews of the passengers based on other drivers' opinions. Price is reduced per capita when two passengers join. The passengers have (in this use case) 30 minutes to cancel their participation

Top Level Use Case Diagram: SMM 003
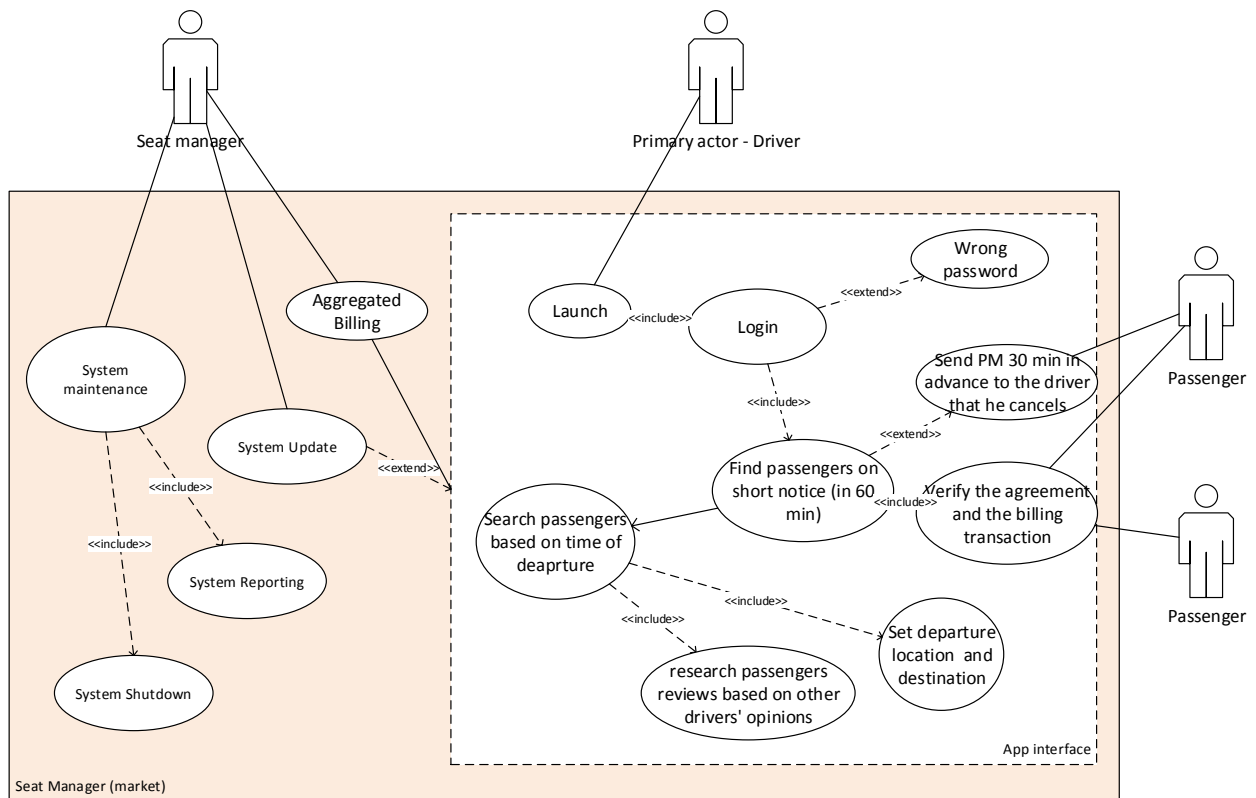
Full functionality map of the application
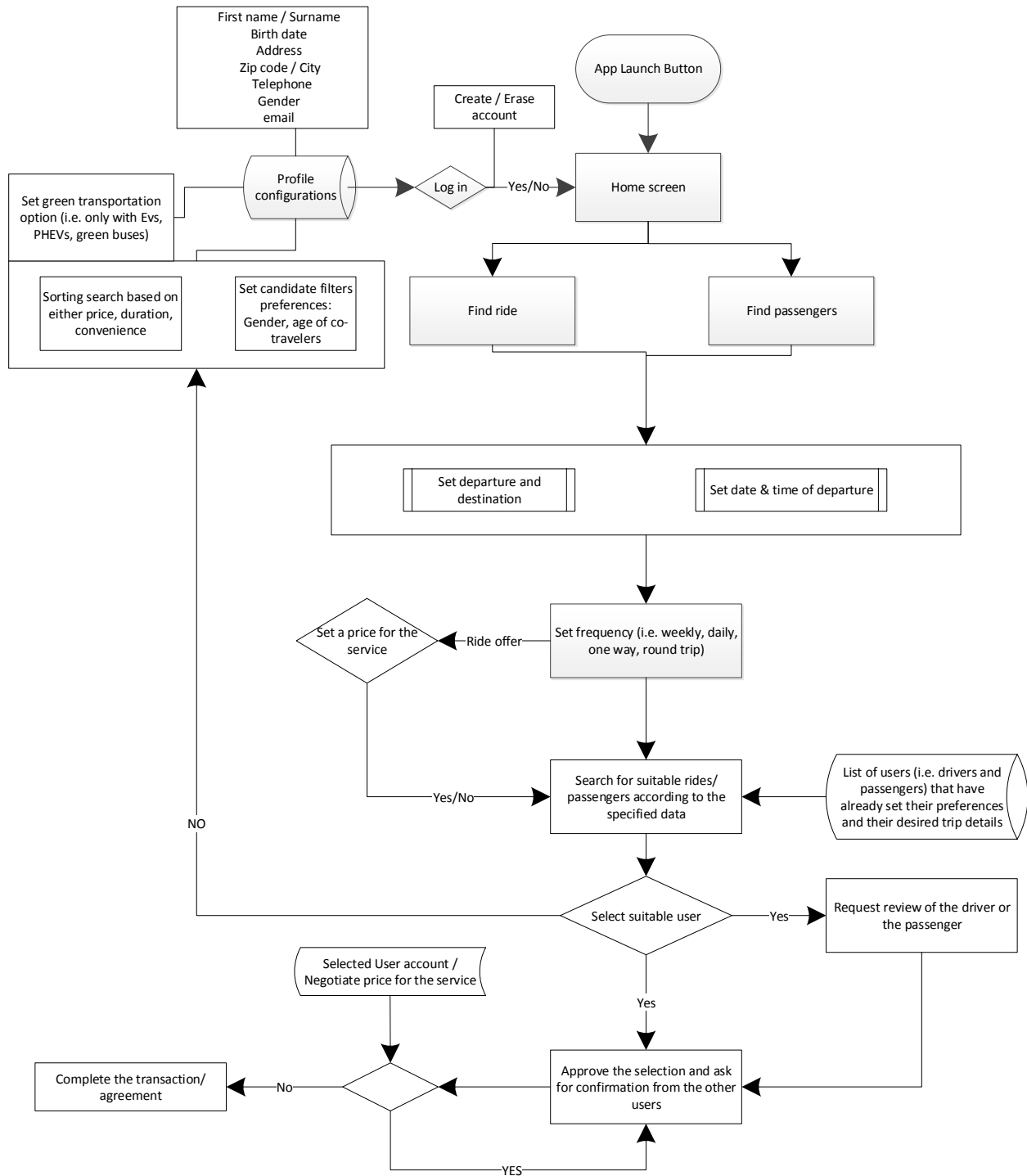
Figure 42 Functional flow diagram of the base operations of Seat market manager

List of app functionalities / commands

Subscribe / Cancel Subscription

Login – insert username and password

Logout

Create / edit profile

Filter the information that is visible to others (a minimum is necessary and not editable)

Erase profile

Search for passengers

Search for rides

Set departure location and destination

Set time of departure

Set frequency of trip

Request review of driver or passenger

Set price for ride offer (driver)

Negotiate price (passenger)

Functional requirements

SMM_001: To search for suitable passengers

    SMM_001A: To define the individual user suitability

    SMM_001B: To match the selected criteria with users already in the database

SMM_002: To search for suitable rides

SMM_003: To receive a review or the travel history of a driver or a passenger

SMM_004: To upload a ride/driver/passenger review

SMM_005: To establish a private communication between the involved parties

    SMM_005A: To facilitate a multi-way communication between more than two parties

SMM_006: To complete the billing transaction between the involved parties (if any)

Functional requirements of Seat Market Manager app wrt to the VIBe's middleware layer

The first part describes the functional requirements of the application with respect to the communication platform's characteristics and capabilities. The functional requirement is **describing the behavior of the system** as it relates to the system's functionality.

Business rules:

1. The user details must be validated by the system when he/she signs/logs in with his account password
2. User's privacy must be protected at all costs. Otherwise the application's and the platform's integrity is questioned.
3. Specific permissions are given to the user to read but also to write and edit (i.e. his profile/account, his ride review). Furthermore the application manager is able to read, write, and edit data. Also is able to erase accounts due to specific circumstances.
4. The system has to validate that there are not users with duplicate information registered.
5. Specific rules will be applied when a user makes an account inserting a username and a password (specific range of characters, symbols and numbers).

Functional requirement ID <SMM_001>	
Description: Search for and select suitable passengers	
Assumptions	A respectable amount of users have already installed and use the app, user profile configurations have been set, in the Home screen the 'find passengers' button is pressed VIBe platform is developed and established
Persona	Driver, commuter, traveler, passenger, app user
Impact	MUST HAVE
Primary Actor	Driver
Input	Departure time and location, frequency selection and price set
Action	Publish a ride service for a certain price (or not) to the users of the app Transmit the request to the interface of the middleware
Output	Send a private message to the selected passengers Offer one more option to the list of available choices for the users (if it is not able to be satisfied directly) The offer is added and stored in the database of the app server
Exceptions	Offline usage, Passenger(s) don't confirm the transaction
Dependencies	User availability, communication server

Functional requirement ID <SMM_001A>	
Description: Define the suitability of the individual user for including him/her in the final selection list	
Assumptions	VIBe platform is developed and established
Persona	Driver, commuter, traveler, passenger, app user
Impact	MUST HAVE
Primary Actor	Driver
Input	Login information (username and password), edit profile configuration (preferences)
Action	Set age and gender preferences, set time and location margin, save profile changes
Output	Desired profile of passengers have been set in the database of the app server
Exceptions	-
Dependencies	-

Functional requirement ID <SMM_001B>	
Description: Match the selected criteria with users already in the database	
Assumptions	The interface of VIBe middleware is operational
Persona	Driver, commuter, traveler, passenger, app user
Impact	MUST HAVE
Primary Actor	Driver
Input	The filtering configurations of potential passenger have been set, departure time and location as well as destination has been fixed
Action	Read the database of the application server for passengers with similar input in a margin of 15 minutes and 200 m (both values are indicative and configurable)
Output	Display a list of passengers that match the input sorted by the closest in time or place
Exceptions	The profile configurations has not been saved
Dependencies	Application server is up and running and user online

Functional requirement ID <SMM_002>	
Description: To search and select for suitable rides	
Assumptions	A respectable amount of users have already installed and use the app, user profile configurations have been set, in the Home screen the 'find ride' button is pressed The VIBe platform is developed and established
Persona	Driver, commuter, traveler, passenger, app user
Impact	MUST HAVE
Primary Actor	Passenger
Input	Departure time and location, frequency selection, price range
Action	Press search, for matching user requirements with suitable rides Send a private message to the selected passengers
Output	Display a list of rides sorted by range (configurable) Offer one more option to the list of available choices for the users (if it is not able to be satisfied directly) The offer is added and stored in the database of the app server
Exceptions	Offline usage, Passenger(s) don't confirm the transaction
Dependencies	User availability, communication server

Functional requirement ID <SMM_003>	
Description: To request and view a review or the travel history of a driver or a passenger	
Assumptions	Users have made reviews for their experience, VIBe platform is developed and established
Persona	Driver, commuter, traveler, passenger, app user
Impact	Nice to Have
Primary Actor	App User (either driver or passenger)
Input	When the list of potential passengers or drivers is displayed, the option to view other people reviews about them is enabled
Action	One click on their name and displays name and the most recent review, two clicks and a separate page with all reviews included. Especially for reviewing drivers there is an extensive description of the vehicle they are diving

Output	Reviews (along with photos etc) that have been uploaded by the users, driver, passenger and vehicle statistics for their trips overall are presented,
Exceptions	The user has requested from the app manager to discard a specific review that is ambiguous
Dependencies	Communication platform

Functional requirement ID <SMM_004>	
Description: To upload a ride/driver/passenger review	
Assumptions	The VIBe platform is developed and established.
Persona	Driver, commuter, traveler, passenger, app user
Impact	Nice to Have
Primary Actor	App user, Driver, passenger,
Input	The trip itself. After the completion of the trip there is an option for reviewing the experience including the passenger, the driver, the vehicle
Action	Upload the review. The format is stored in the database of the application server
Output	The review is available and visible for any interested party that views a list of candidates for soon to-be arranged trip
Exceptions	-
Dependencies	The transaction is confirmed and the trip which the user wants to review is past

Functional requirement ID <SMM_005>	
Description: To establish a private communication between the involved parties when the arrangement is at the stage of the transaction	
Assumptions	A match between the ride requirements and the passengers have been made. The VIBe platform is developed and established.
Persona	Driver, commuter, traveler, passenger, app user
Impact	Must Have
Primary Actor	Driver, passenger
Input	Final selection approval, send request of confirmation from other users

Action	The driver sends a private message through the application server to the passenger
Output	A private message is displayed to the drivers inbox of the application
Exceptions	The transaction is confirmed without pm exchange due to the participants history Either side is offline
Dependencies	The PM exchange should be filtered by the app manager At the transaction phase there is the option of negotiation for each side not only in the price but also at the location and the time.

Functional requirement ID <SMM_005A>

Description: To facilitate a multi-way communication between more than two parties (i.e. driver and two passengers)

Assumptions	Interface of the application server The VIBe platform is developed and established.
Persona	Driver, commuter, traveler, passenger, app user
Impact	Nice to Have
Primary Actor	Driver, passengers
Input	The requirements of the trip arrangement are set. Two passenger have been selected to join the trip.
Action	The driver requests a multi-communication with two passengers from the application interface manager
Output	Open a private messenger is provided to fasten the communication between the involved parties
Exceptions	If there is a transaction history between the participants it is not mandatory to proceed to private communication.
Dependencies	Online status of the parties involved, communication protocols established to secure privacy

Functional requirement ID <SMM_006>	
Description: To complete the billing transaction between the involved parties (if any)	
Assumptions	The VIBe platform is developed and established.
Persona	Driver, commuter, traveler, passenger, app user
Impact	Must Have
Primary Actor	Driver, passenger
Input	The driver have set a price for the ride, the passenger(s) have accepted the proposal
Action	Application server manager handles the transaction of both sides by checking the cards details
Output	A receipt of the transaction between the participants have been sent to their emails.
Exceptions	The details of one of the participants does not check out (for the second time). In that case the other passenger's participation is valid and the driver has the option to reselect a passenger.
Dependencies	Protocol to ensure safe transactions handled by the manager

Non-functional requirements of Seat Market Manager app

The non-functional requirements are specified to define the qualities that assess the operation and each one **elaborate a performance characteristic** of the system.

Non-functional requirements	
Performance	Real-time communication is requested in the private messenger. Also short notice ride offers are time-sensitive and the software system has to be able to operate functions in a scale of seconds. Low latency in PM exchange is mandatory to facilitate fast transactions and trip arrangements. Other functions such as upload review are less time-sensitive.
Security	The transactions must be processed based on authentication and authorization procedures between the app manager and the clients' banks.
Usability	The app will be peer to peer based. The available functions have to be well balanced to avoid confusion and support ease-of-use (i.e. user friendly) functionality that will be learnt after a couple of iterations.
Responsiveness	Similar to performance the system must have a very fast response to the user commands, nevertheless the hardware quality plays a significant role in this requirement.
Localization	Multiple languages option has to be supported starting from English and Dutch. Then it can be extended to German, French.
Scalability	The app requires as many users as possible to provide an oversupply of options to drivers or passengers. A preliminary estimation requires that the system should be able to handle approx. 20000

Interfacing requirements	
Description: The convenience configuration refers to the variety of transportation means that a passenger is willing to change. When the option is set to random buses and trains are included in the seat market.	
Assumptions	The bus and train companies have to approve their participation in the application. The transaction is processed in one bill for better quality service of the traveler.
Impact	SHOULD HAVE
Source system	Government, Public transportation, 9292.nl, NS, bus routes database,
Target system	The application has to interface with the VIBe's middleware layer and push a request of external information from the source systems
Input data	Time and location of departure, Time and location of arrival, choice of optimization (i.e. duration, price),
Output Data	A combination of transportation means sorted based on minimum duration or price

EV Path Planner

Use Case: EPP 001

Name:	Create an EV profile
Brief Description:	Allow the EV driver to become a register user Input a detailed profile to facilitate the optimization of CP routing
Scope:	EV navigation - Trip planning exclusive for Electric Vehicles
Level:	Summary
Actor(s):	EV driver (EVD), EV Path Planner (EPP)
Stakeholders & Interests:	VIBe, EV drivers, CPOs, Automotive services developers

Pre-Conditions	
Title	**Description**
Native application	The app is downloaded and successfully installed in smartphone/tablet
Common database	The EV profile registration is stored to a common server

Guarantees	
Minimal	-
Success guarantees	Create a profile that will allow the user to operate the EV path planner
Trigger	Using an EV for longer trips and reduce range anxiety

Main Success Scenario
<1> EVD: presses the EPP launch icon on the smartphone <2> EVD: enters the required *User Account* information values and requests <3> EVD: saves the entered values (i.e. Name, email, username, password, gender). <4> EPP: validates the entered *User Account* information. <5> EPP: stores the values for the *User Account* information in the User's account. The system notifies the User that the account has been created. <6> EPP: sends a confirmation mail of the registration to the user <7> EVD: Logs into his account with username and password

Extension	
Title	**Description**
Erase profile	<7a> EVD: Enters account options <7b> EVD: Presses 'Remove Profile' <7c> EPP: Requests the user's password <7d> EVD: Enters the password and confirms the account cancellation
User Enters Invalid User Account Information	If during Create Account, the system determines that the User entered invalid *User Account* information, the following occurs:

	<1> EPP: describes which entered data was invalid and presents the User with suggestions for entering valid data.
	<2> EPP: prompts the User to re-enter the invalid information.
	<3> EVD: re-enters the information and the system re-validates it.
	<4> EPP: If valid information is entered, the User Account Information is stored.

Post-Conditions	
Title	**Description**
Success	The User entered data is stored in the user account. Confirmation is sent to the appropriate email address. Username and password are made.
The user account was not created	The User entered invalid data or chose to cancel the account creation request. In either case, no account will be created.
Related information	
Every EV is registered in the same database. EV driver possesses an EV charge RFID card.	

Top Level Use Case Diagram: EPP 001

Case: EPP 002

Name:	Plan an EV trip
Brief Description:	Set, plan and request navigation for an EV trip through specific CP route from location A to destination B
Scope:	EV navigation - Trip planning exclusive for Electric Vehicles
Level:	Summary
Actor(s):	EV driver (EVD), EV Path Planner (EPP)
Stakeholders & Interests:	VIBe, EV drivers, CPOs, Automotive services developers

Pre-Conditions	
Title	**Description**
Middleware layer	VIBe platform with bidirectional communication is established
Internet of Cars	Every EV is registered in the same database
Motown	A communication platform that manages and includes every single CP
Create account	An EV profile is already made (EPP 001) and desired duration of stops have been set.

Guarantees	
Minimal	Plan the EV trip through a series of scheduled charging stops
Success guarantees	Recalculate optimum CP route in case of unplanned CP unavailability
Trigger	Using an EV for longer trips and reduce range anxiety

Main Success Scenario

This use case starts when the User accesses the system feature that enables him/her to create an account by entering information that is maintained in the User's account.

<1> EVD: Presses the EPP launch icon on the smartphone
<2> EVD: Inserts the username and password to log in
<3> EVD: Chooses from a map the place of departure and sets the time if it is not now.

<4> EVD: Sets the destination on the map

<5> EVD: Sets the current State of Charge or available range
<6> EPP: Calculates optimum CP route based on trip duration
<7> EVD: Views the total duration, total price, duration and number of charging stops on his smartphone

Extension	
Title	**Description**
User encounters CP unavailability during the trip	<6a> EPP: Receives a message that an EV approaches at the same CP before EVD
	<6b> EVD: Chooses to let EPP reroute the CP path
	<6c> EPP: Recalculate the path with alternative CP stops

Post-Conditions	
Title	**Description**
Success	The CP map must be accurate

Real-time	CP management is crucial to update CP status almost real time
CP infra	The CP infrastructure in highways should consist of fast chargers (Power supply: Three phase – 43 kW, Direct Current – 50 kW)
Related information	
Filtering CP / Vehicle Compatibility Plug Type and CP selection based on power output.	
Set desired available range when the EV reaches its destination in case the driver decides to arrive at the exact location (e.g. only regular single phase 3.3kW) and not at the nearest CP.	

Top Level Use Case Diagram: EPP 002

Full functionality map of the application

Create / Erase profile

App Launch Button

Case scenario: a CP station in the planned route is unavailable by the time of arrival

Return back to central navigation screen with the initial route

- Vehicle type
- CP plug preferences
- Route optimization
  - minimum duration
  - minimum price
  - shortest path

Profile configurations

Log in → No → CP Map without any further funtionality

Warning signal of potential issue

Yes

Home screen CP Map

Confirm: Keep current route and wait in line ← Yes ← Planned to continue at the same route → No → Request: Recalculate and give alternative routes

Select place of departure and destination → Choose either the precise location or the nearest (semi-)public CP (Checkbox)

Alternate route A is selected. Home screen map is displayed

Default profile preference: Minimum duration

Set time of departure and initial SoC

Communication with Reservation Smart Charging: Input – current and future CP availability (CP free, in use, under service) — input — Calculate optimum route based on minimum duration

Yes

Reach the destination and the planned route is self-erased leaving the CP map ← Navigation from A to B through CPs with specified charging durations

Figure 43 Functional flow diagram of the base operations of EV Path Planner

List of app functionalities / commands

Login

Logout

Create / Erase profile

Set departure and arrival location

Choose nearest CP at destination

Set departure time

Set initial SoC or current range

Calculate optimum route

Calculate alternate route (under conditions)

Save (e.g. daily route, favorite CP)

EPP_001: To be identified by the system

EPP_002: To calculate optimum route

EPP_003: To access traffic information

EPP_004: To navigate the driver to the requested destination

EPP_005: To calculate alternate routes

Functional requirements

Functional requirements of the EV Path Planner

This section is divided into two parts of the functional and non-functional requirements. The purpose of this section is to document mainly the functional requirements of the application with respect to communication platform. The functional requirement is **describing the behavior of the system** as it relates to the system's functionality.

Functional requirement ID <EPP_001>	
Description: To be identified by the system	
Assumptions	The VIBe platform is developed
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	Application administrator, the System
Input	The driver has created a profile and has been registered in the system
Action	The system is able to identify the driver by matching his credentials (i.e. username and password)
Output	The system approves the driver/user's request for log in and provides the full functionality of the application
Business rules	The username and the password must comply with the system's set of rules
Exceptions	If the system cannot confirm the driver's credentials three pre-defined questions will be displayed regarding his/her personal status. If the answers are confirmed then the system approve the login request
Dependencies	Online connection

Functional requirement ID <EPP_002>	
Description: To calculate the optimum route	
Assumptions	The VIBe platform is developed, CP infrastructure is online, Communication with CP Reservation Application established
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	System EPP
Input	Must have: Place of departure, destination, State of Charge, time of departure.

	Optional: Desired SoC at the end of the journey
	Optional: In between location can be included
Action	The system calculates the optimum route based on the minimum duration
Output	A route displayed on a map from location A to location B through operating CPs
Business rules	The default configuration is set on minimum trip duration for optimizing the route
Exceptions	In case the system is not able to find CPs to satisfy the driver's request, a warning signal is displayed to the interface that the selected route cannot be fulfilled
Dependencies	CP management platform (e.g. Motown), Proper driving behavior (i.e. the calculation will occur according to the speed limits)

Functional requirement ID <EPP_002A>	
Description: To set location of departure and destination	
Assumptions	The maps of the journey are preloaded to reduce the processing time will be prerequisite
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	EV driver
Input	The name of the city(-ies) (i.e. departure and destination) that is recognized by the system
Action	Write on the displayed textboxes the desired locations
Output	Two landmarks are displayed on the map showing the selections of departure and destination
Business rules	After the first two letters are entered the system gives suggestions of cities based on the stored location in its database
Exceptions	The system doesn't recognized the input locations and request from the user to retype his/her preference
Dependencies	Database with names of locations, various maps loaded (international trips)

Functional requirement ID <EPP_002B>	
Description: To include State of Charge in the calculation	
Assumptions	The VIBe platform is developed and established, An EV profile is created including the vehicle model, Fully Electric Vehicle
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	EV driver
Input	Login information is required to enter to the home screen that allows app's full functionality including the SoC textbox
Action	The current state of charge is entered in form of percentage, alternatively the current available range is entered in km
Output	The value of the SoC is included in the optimization algorithm that will influence the charging process of the EV during the trip
Business rules	In case of percentage a number above 100 will be rejected and a new value will be requested. In case of km a number above the default range of the vehicle model stored in the profile configurations will again be rejected and a new value below the maximum possible will be requested.
Exceptions	When the battery is depleted
Dependencies	-

Functional requirement ID <EPP_002C>	
Description: To include projected CP availability	
Assumptions	CP infrastructure is online, VIBe platform is developed and established, An EV profile is created including the vehicle model, Fully Electric Vehicle
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	System EPP, CP reservation application (RSC)
Input	EPP (system) requests the CP availability from RSC (local) to check its status.
Action	If at the projected time that the driver will reach that location the CP is not reserved, it is included in the route. Otherwise EPP proceeds to the next best CP.

Output	A selection of CP available at the estimated time of arrival is carried out.
	Important note: the selection doesn't mean reservation.
Business rules	The estimated time that the driver reaches a CP is calculated based on the speed limits and the predicted traffic conditions
Exceptions	When CP status is unknown then the system requests from the driver whether or not the CP is going to be included in the route.
Dependencies	CP management platform (e.g. Motown), Proper driving behavior (i.e. the calculation will occur according to the speed limits)

Functional requirement ID <EPP_003>	
Description: To access traffic information	
Assumptions	Real-time GPS data is available for use, VIBe platform is developed and established
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	Nice to Have
Primary Actor	EPP (system)
Input	The driver requests navigation from A to B and the system calculates the optimum route
Action	EPP (system) requests live traffic information from the regional traffic manager
Output	The traffic information is included in the optimization algorithm to find the path with the minimum duration. The navigation path on the map includes green, orange or red zones according to the traffic status.
Business rules	Direct access to the GPS data is forbidden. A traffic data manager must authorize the request after checking the relevant clearance.
Exceptions	Traffic data server is offline
Dependencies	Relevant clearance has been authorized to access GPS data

Functional requirement ID <EPP_004>	
Description: To navigate the driver to the requested destination through CPs	
Assumptions	CP infrastructure is online, VIBe platform is developed and established, An EV profile is created including the vehicle model, Fully Electric Vehicle

Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	System EPP
Input	After the EPP calculates the optimum route the EV driver selects between the exact destination or the nearest available CP
Action	The EV driver selects between the exact destination or the nearest available CP
Output	The EPP displays the charging stops, their duration, the final destination and the path that connects them. Information regarding the facilities of the charging locations are shown by moving the cursor on top of the landmarks of the map.
Business rules	The EV driver could know if the exact destination has a private (semi-)fast charger that is not registered in the system. The nearest available CP is either public or semi-private. Pricing is included. In case of detour because of the EV driver decision or mistake the system is able to recalculate the route and navigate the driver back on track.
Exceptions	The trip from A to B doesn't have the required CP infrastructure.
Dependencies	Sufficient CP infrastructure along the way, fast charging

Functional requirement ID <EPP_005>	
Description: To calculate alternate routes	
Assumptions	CP infrastructure is online and managed by a CPO, VIBe platform is developed and established, An EV profile is created including the vehicle model, Fully Electric Vehicle
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	MUST HAVE
Primary Actor	System EPP
Input	A connected EV (to the VIBe platform) approaches the charging station to occupy the CP before the primary EV driver can based on the speed and the traffic
Action	The system recalculates an alternative route and displays the event to the driver.
Output	EPP provides the EV driver with a choice either to select the alternative route or to wait at the initially planned CP until the time is unoccupied.
Business rules	The system communicates almost real time with the CPO (Charging Point Operator)

Exceptions	There is not sufficient CP infrastructure to find alternative routes, the charging station has CPs that will be available until the time the EV arrives
Dependencies	Motown (CP management solution), device that runs the EPP is online

Functional requirement ID <EPP_005A>	
Description: To obtain information regarding other EVs approaching the same CPs	
Assumptions	CP infrastructure online, a centralized operator of EV Path Planner is established that communicates with VIBe platform which is developed and established
Persona	EV driver, male/female, 35-55, accustomed to mobile applications and navigators
Impact	Nice to Have
Primary Actor	EPP (system)
Input	EPP centralized operator through VIBe platform pushes information of other EVs planning to charge at the same CP (periodical updated).
Action	EPP centralized operator calculates who is going to arrive first based on the average speed so far, the speed limits of the highway and the current traffic.
Output	Then the operator informs the interested EV driver accordingly with warning signal and alternative route.
Business rules	The system communicates almost real time with the CPO (Charging Point Operator)
Exceptions	The device that runs the EPP is offline
Dependencies	Electric Vehicle data streaming through VIBe platform continuously, EVs in the region of the CP that are able to reserve it are connected to the platform as well or to similar platform that is eligible to intercommunicate.

Non-functional requirements of EV Path Planner app

Non-functional requirements	
Performance	The processing time (e.g. loading, calculating) should be minimized to the least possible. The system should be able to minimize its resource consumption (i.e. battery).
Security	The communication between the system and mobile device must be secure. For the in-vehicle version the security layer (authorization and authentication) will be built-in (by the OEM).
Privacy	App user's identities or other information (e.g. location) should not be provided to third parties without their consent. EV Path Planner should be able to operate for international trips which requires compliance with different countries privacy laws.
Usability	The application should consist of the least possible interface screens. The amount of iterations that a user needs to understand and learn the full functionality of the system should be minimized. The Graphical User Interface (GUI) should be simple and user-friendly.
Safety	The system has to ensure that it will not generate any safety issues during the navigation. (e.g. The system should be able to explicitly mention to the driver through warning signals the dangers of using the app during driving)
Expandability	The system should be able to be expanded geographically, i.e. integrate data from new areas and increase coverage
Scalability	The system should be designed to operate for 1000 users/EV driver at the same quality level up to 20000.
Maintainability	The system should be able to be upgraded without any interruptions to the provided services.

Interfacing requirements	
Description: Interactive map regarding landmarks of departure, destination, charging stops	
Assumptions	The (inter)national road infrastructure along with the CP infrastructure are pre-loaded. The user is accustomed to navigation applications or he has learnt the system over some iterations.
Impact	MUST HAVE
Source system	Centralized EV Path Planner (EPP) operator and/or VIBe platform operator pushes update information regarding CPs and EVs on the road.
Target system	Android and iOS electronic devices. The system can have preloaded information regarding the additional facilities at a charging station. The system should be able to display the nearest CP to the destination and provide information to the driver regarding the whereabouts. The system should display information (Power, plug type, availability) regarding the CPs through the EPP operator from a CP manager to the target system. The system should display information (e.g other EVs that approach the same CP) regarding the EVs through the EPP operator from a VIBe's platform to the target system.
Input data	Touch the landmarks of interest displayed after the route has been selected
Output Data	Small but readable textboxes containing the mentioned information

About the Author

Marinos Aspragkathos received his diploma (Master of engineering) in mechanical and aeronautical engineering at the university of Patras. During his studies he followed the field of energy and environment. Afterwards he worked in an engineer office as a mechanical engineer focused on renewable energy applications. In 2012 he was accepted in the ASD PDEng program.

He is mainly interested in sustainable technologies, renewable energy, electric vehicles, and smart grid technologies.