Enterprise Architecture for Electric Vehicle Ecosystems: EV-EAM

Francisco de Medeiros Pavao

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Supervisors: Prof. Dr. Alberto Manuel Rodrigues da Silva
Prof. Dr. Hugo Gabriel Valente Morais

Examination Committee

Chairperson: Prof. Dr. Fernando Mira da Silva
Supervisor: Prof. Dr. Alberto Manuel Rodrigues da Silva
Members of the Committee: Prof. Dr. António Manuel Raminhos Cordeiro Grilo
Prof. Dr. Hugo Gabriel Valente Morais

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Declaration

I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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I would like to thank my parents for their friendship, encouragement and caring over all these years, for always being there for me through thick and thin and without whom this project and academic journey would not have been possible.

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To each and every one of you – Thank you.

Abstract

In response to global challenges such as the transition to sustainable energy and the preservation of the ozone layer, electric vehicles (EVs) have emerged as a solution. However, the EV domain is complex involving many stakeholders with various interconnected elements including electrical grids, vehicle manufacturers, EV users, on-site operators, and government entities. Understanding and improving this ecosystem is challenging due to its multifaceted nature. Within the framework of the EV4EU project, the objective of this research is to define and discuss business and application models specifically tailored to three key EV ecosystems: Home, Building, and Company based ecosystems. By proposing new business models, the aim is to make EV ownership more economically sustainable and create fresh business opportunities for both EV-users and participants in EV markets. The development of these models seeks to address the need for a more comprehensive understanding of the EV domain and contribute to its continuous improvement. By exploring innovative approaches to business and application models, this work strives to drive the adoption of EVs and facilitate their integration into various sectors of society. Ultimately, the goal is to harness the potential of EVs in mitigating environ- mental challenges and fostering sustainable transportation systems. The business models are represented through the application of several methods, such as the Value Proposition Canvas, the Business Model Canvas or the Service Business Model Canvas. The applicational layer of the ecosystems is represented through the ArchiMate, UML and ITLingo RSL languages.

Keywords

Electric Vehicle, Ecosystem, Business model, Application model, Vehicle-to-Everything

Resumo

Como resposta a desafios globais, como a transição para energia sustentável e a preservação da camada de ozôno, os veículos elétricos (EVs) surgiram como solução. O domínio dos EVs é complexo, envolvendo diversos intervenientes, como redes elétricas, fabricantes, utilizadores, operadores e entidades governamentais, tornando a compreensão e melhoria do ecossistemas desafiadoras devido à sua natureza multifacetada. No projeto EV4EU, a pesquisa visa definir modelos de negócios e aplicação para três ecossistemas-chave de EVs: casas, edifícios e empresas. Ao propor novos modelos, pretende-se tornar a posse de EVs economicamente sustentável, criando oportunidades para utilizadores e participantes nos mercados. O desenvolvimento destes modelos busca uma compreensão abrangente do domínio dos EVs e contribuir para a sua melhoria contínua. Explorando abordagens inovadoras para modelos de negócios, o trabalho visa impulsionar a adoção de EVs e facilitar sua integração em vários setores. O objetivo final é aproveitar o potencial dos EVs na mitigação de desafios ambientais e na promoção de sistemas de transporte sustentáveis, representando modelos de negócios por meio de métodos como Value Proposition Canvas, Business Model Canvas e Service Business Model Canvas. A camada de aplicação dos ecossistemas é representada por meio das linguagens ArchiMate, UML e ITLingo RSL.

Palavras Chave

Veículo Elétrico, Ecosistema, Modelo de negócio, Modelo aplicacional, Vehicle-to-Everything

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Listings

Acronyms

BRP Balance Responsible Party

CPO Charging Point Operator

DSO Distribution System Operator

EA Enterprise Architecture

EMAM Electric Mobility Architecture Model

EMSA E-Mobility Systems Architecture

EV4EU-EA Enterprise Architecture for Electric Vehicle Ecosystems

EVs electric vehicles

HEMS Home Energy Management System

ICE internal combustion engine

KPI Key Performance Indicator

RES Renewable Energy Sources

RSL Requirement Specification Language

SBMC Service Business Model Canvas

SGAM Smart Grid Architecture Model

SOC State of Charge

TOGAF The Open Group Architecture Framework

TSO Transmission System Operator

UML Unified Modeling Language

V2B Vehicle-to-Building

V2H Vechile-to-Home

V2X Vehicle-to-Everything

VPC Value Proposition Canvas

1

Introduction

Contents

The demand for electric vehicles (EVs) has grown since the beginning of the 21st century to replace one of the most problematic greenhouse gas pollutants, the internal combustion engine (ICE) vehicles. Even though a lot of work is being conducted by governments, regulators, and private corporations, there is still a long way to go before EVs would be the go-to kind of vehicle. The challenges that the adoption of these vehicles face are, on one hand technological, in the sense that a lot of infrastructure is, and still must be developed, and on the other hand, the bias that the general population has when it comes to the electric vehicle alternative. The focus of this present work is to study how enterprise architecture techniques are used to help define and discuss ecosystems in a way that creates value and allows to represent them holistically.

1.1 Context and Motivation

Society is facing several challenges, such as the global warming crisis, the oil crisis, and the exponential growth of cities. All these imminent issues require society to rethink mobility to make a change. A small step in achieving that change is achieving a large-scale deployment and adoption of electric vehicles. This mass-scale adoption faces many issues, either from the industry, infrastructure, technological developments or even the mindset of the public [9].

This research belongs to a project that is being developed in the context of Electric Vehicles Management for carbon neutrality in Europe, the EV4EU project. The EV4EU project proposes and implements bottom-up and user-centric Vehicle-to-Everything (V2X) management strategies creating the conditions for the mass deployment of electric vehicles. These strategies will cover a vast range of needs from the users, the cities' transformations, the integration with energy markets, and the impacts that these new technologies have on batteries [10].

The EV4EU project is divided in 11 work packages. The Enterprise Architecture for Electric Vehicle Ecosystems (EV4EU-EA) disseration collaborates on Work-Package 1, which goal is to " define road e-mobility evolution scenario in different sectors considering different technologies of EVs". This dissertation focuses mainly on sections 1.4 and 1.5 of Work-Package 1, named respectively "V2X Related Business Models" and "Use Case Specifications" [10].

The V2X management strategies proposed will be tested in four demonstration sites spread across Europe, namely in Portugal, Slovenia, Denmark, and Greece. The Portugese demonstrator in São Miguel, Azores, will test the feasibility of two V2X business models. The first is related to Renewable Energy Sources (RES) issues, mainly in houses. The second V2X business models proposed focus on the building´s and fleet´s managers to take place at the Regional Laboratory of Civil Engineering counting with EVs from EDA.

The purpose of these demonstrators is to evaluate the proposed methods and tools. Consequently, the most promising business models and solutions shall be identified [11].

An open-source approach will be used for the software development that support the V2X management strategies. This software will consider scalability, security, interoperability, and privacy requirements while guaranteeing the exchange of information between the system and stakeholders [12]. The EV4EU project has several objectives and related outcomes. The focus of our work within these objectives is to have a better understanding of the Enterprise Architecture (EA) ecosystem surrounding EV ecosystems.

1.2 Problem Addressed

Enterprise Architecture for EV based ecosystem are ever-changing and intrinsically linked to the ICE ecosystem. For any business to be profitable, its revenue must be higher than its costs. One of the issues in EV production is that manufacturers face high production costs, linked to the batteries, and the technological and environmental costs. As a result, the public finds difficult to adhere to this technology [13].

Another difficulty to sell EVs a mentality shift needs to occur to the end customer. Even though many awareness and publicity campaigns are being used, the way the EV industry has tackled this problem is by adopting business models used in the ICE industry and making small adjustments over time.

Although this enables the EV manufacturers to sell to customers a similar product to what they are used to, business model changes are slow due to the lengthy approval process required. An important thing to note is that the main business model adaptations are seen primarily on the service side [14].

Due to the reasons mentioned above, along with the existence of several competitors in the EV market, there is still no “best” EV business model [12]. Recently, some convergence is noticeable in areas such as regulation, customer preferences, tech development, and the emergence of best practices [9].

The main problem to be tackled in this research is the adaptation of new emerging technologies to the already existing business models. For example, V2X brings several advantages to the already existing business models, such as optimizing traffic flow, improving journey time reliability, or reducing emissions from vehicles. On the other hand, it also suffers from some restrictions, most of the charging stations are not adapted to V2X: degradation of batteries can be higher when using V2X, policies do not consider V2X possibilities, and users should agree with using those V2X services [15].

1.3 Objectives

This research proposes to developed and discuss new models for the business and application sides of the EV based ecosystems. The first objective is to study and develop several business models related to three different EV ecosystems: the Home, Company, and Building ecosystems. The development of business models is important because in the starting phase of any organization or technology these models help plan costs, needs, attract investment, recruit talent, and motivate management and staff. However, they are not only important in the starting phases but also at the later stages of the development process. Business models are quite useful at mapping and structuring the end product in a simple and comprehensive manner not only to top administrators but also to every employee [16].

A second objective of this project is to present different applicational models to serve as an applicational backbone for the business models developed. These applicational models are fundamental for the correct functioning of the business since they allow the description of the system's intended functionality and its environment, thus allowing to relate what is needed from a system to how the system delivers those needs [17]. The integration of the developed business and application-level models forms the foundation of the EV-EAM.

The third objective is to present a critical evaluation of the work developed.

1.4 Research Method

This research follows the Design Science Research methodology (DSR). The DSR is an iterative method that combines principles, practices, and procedures. It guides research in Information Systems (IS) as well as other disciplines. Design Science emphasizes systematic, testable, and communicable methods.

The DSR methodology can be translated into the following steps [18]: Problem identification and motivation: This phase occurred between October and December of 2022. During this stage, the research and identification of the problem were developed with the help of ITLingo EASL , which is an MS-Excel template focused on ASL concepts, where the main business and application subjects, objects, and actions were picked out.

1.5 Dissertation Outline

This dissertation has seven chapters. Chapter 1 presents the context of this project and the motivation, problems addressed, goals. Chapter 2 introduces several concepts related to the business and application topics regarding the EA of the EV domain. Chapter 3 presents and discusses the theoretical and scientific grounds of this thesis, such as previously developed methods, strategies, and frameworks.

Chapter 4 presents business models for each EV ecosystem, so that new services can be offered to an end-user. The Chapter 5 proposes a variety of applicational models to serve as a backbone and support the proposed business models. The Chapter 6 where the feedback provided by experts in the EV and EA fields is presented and discussed. Chapter 7 summarizes the results of this work, its main outcomes, shortcomings, and contributions to the EV domain. It also suggests the next steps for Future Work to follow. The appendix includes the RSL description of the applications presented in chapter 5.

2

Background

Contents

The concepts in this chapter are divided by three sections, the business, application and e-Mobility sections. First, on the business section, the concept of Business Ecosystem is explored, along with three tools used to describe a Business Ecosystem. The concept of Enterprise Architecture is also introduced as well as two languages to develop an Enterprise Architecture. Second, on the application section, the concepts of Unified Modeling Language (UML) and Requirement Specification Language (RSL) are presented. Finally, the EV mobility section presents core concepts related to electric mobility.

2.1 Business Concepts

The business concepts and techniques used in the development of this work are presented below.

2.1.1 Business Ecosystem

Davis Moore defines a business ecosystem as an economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world [19]. Iansiti and Levien add to Moore´s description that the three success factors for any business ecosystem are productivity, adaptability, and the ability to be or create a niche in a certain industry [20]. Both definitions agree that a business ecosystem has the goal of creating and sharing a collective value for a common set of clients. The need for an ecosystem exists because the ecosystem collectively is capable of creating a higher level of value than any organization or person individually.

2.1.2 Value Proposition Canvas

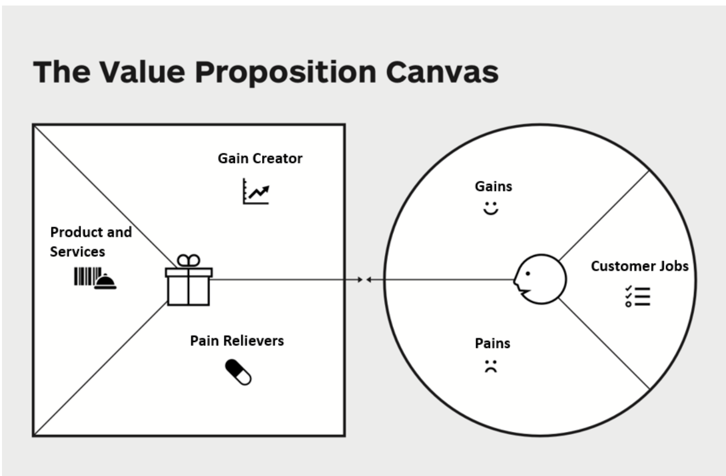

Figure 2.1: The Value Proposition Canvas template (extracted from [1])

A Value Proposition Canvas (VPC) is a modeling technique used to describe the relationship between customer profiles and value propositions [1].

The VPC can be used when there is the need to refactor an existing product or service or even when starting to develop something from the ground up.

A customer profile defines the gains and pains that customers experience when using a specific product or service. It also tries to understand how customers use a certain product.

The other part of the VPC is the value map. The value map is the section of a VPC where a new product or service is proposed, along with its benefits. It also depicts how the product or service proposed eases some of the difficulties faced by a customer while using similar products. A generic template is depicted in Fig. 2.1.

2.1.3 Business Model Canvas

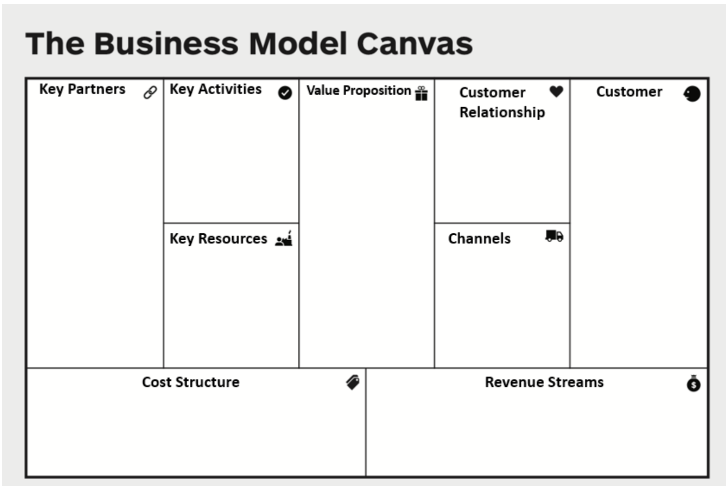

Figure 2.2: The Business Model Canvas template (extracted from [2])

The most known Business Model Canvas (BMC) method is the one developed by Osterwalder and Pigneur [2]. The "Key Partners", "Key activities", "Key resources" and " Cost Structure" sections of the template are relative to the service provider. The "Value Proposition" section is dedicated to the value that the service provider offers to the customer. Finally, the "Customer Relationship", "Channels", "Customer" and "Revenue Stream" sections are focused on the several avenues that a customer can come in contact with the service provider, as well as the revenue streams for the customer. A BMC template is depicted in Fig. 2.2.

2.1.4 Service Business Model Canvas

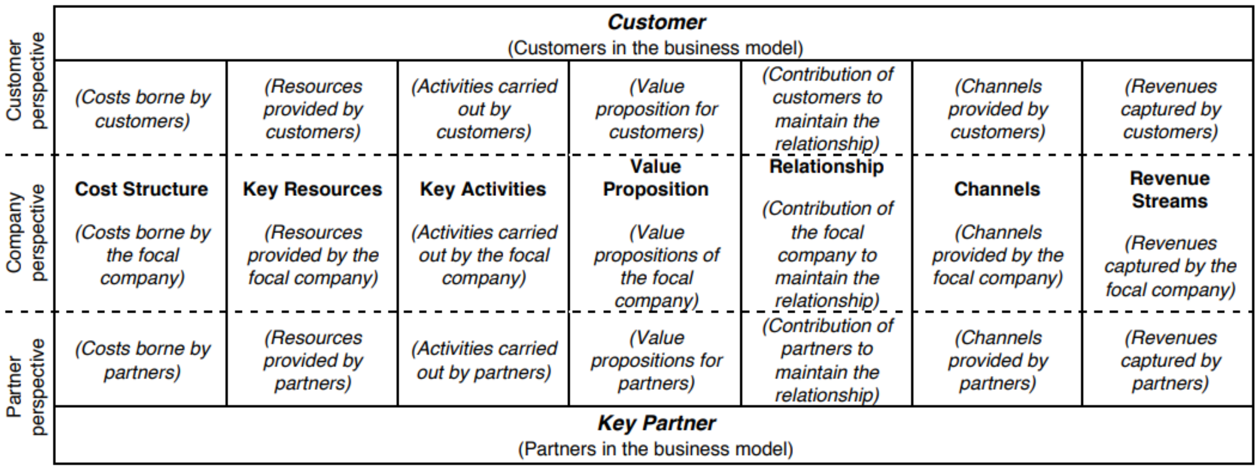

Figure 2.3: The Service Business Model Canvas template (extracted from [3])

Services are a crucial part of many organizations. While traditional BMCs focus on value creation and value capturing, these models do not consider service-specific nuances [21]. The main service-reliant sector is the technology industry, namely the aerospace, IT, automotive, and medical engineering fields. By relying on services, these companies can secure their revenue streams and stay competitive in nowadays markets [21].

While the BMC treated the service provider and customer from a left-to-right approach, the Service Business Model Canvas (SBMC) tackles the customer and service provider from a top-to-bottom approach. An SBMC has 7 columns, where the cost structure, key resources, key activities, value proposition, relationships, channels, and revenue streams are depicted [3]. The SBMC can be seen in Fig. 2.3.

2.1.5 Enterprise Architecture (EA)

An EA offers a coherent body of principles, methods, concepts, and models used in the analysis, design, realization, and implementation of the artifacts of an organization [22].

The common target system of an EA is the organization. An organization is a set of actors and all elements associated with them, who share objectives or common goals [22]. An organization can take many forms, such as a company, a division of a company, a department, a project, a team, and many others.

There are many elements involved in an organization, for example, people, strategy, business processes, and IT support. These elements are treated as artifacts in the scope of an EA.

The EA model studies an organization on four main domains: the Strategy Layer, the Business Layer, the Application layer, and the Technological Layer.

2.1.6 ArchiMate

ArchiMate is a language for defining an Enterprise Architecture that is supported by different tool vendors and consulting firms. [4]. The ArchiMate language gives enterprise architects the ability to visualize, analyze and describe architecture domains in an unambiguous form.

ArchiMate´s goal is to graphically represent the architecture of an organization. ArchiMate does not provide an approach to visualize different aspects of architecture together, but also it enables a synchronous representation for diagrams. The several elements of ArchiMate are usually categorized into layers: The business layer, application layer, technology layer, and physical layer. Fig. 2.4 presents a better depiction of these elements.

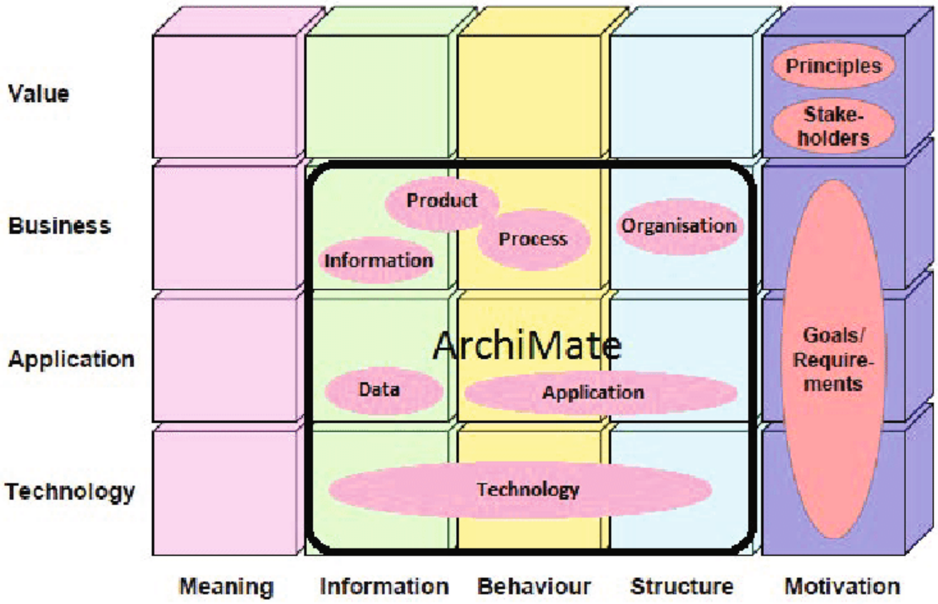

Figure 2.4: ArchiMate matrix (extrated from [4])

2.2 Application Techniques

The applicational tools and techniques required in the development of this work are presented below.

2.2.1 Unified Modeling Language (UML)

UML is a standardized modeling language based on an integrated set of diagrams [23]. UML purpose is to help system and software developers specify, visualize, construct and document the artifacts needed for the proper functioning of software systems by providing a standard notation that can be used by object oriented methods [17]. The existing types of UML diagrams are presented in Fig. 2.5.

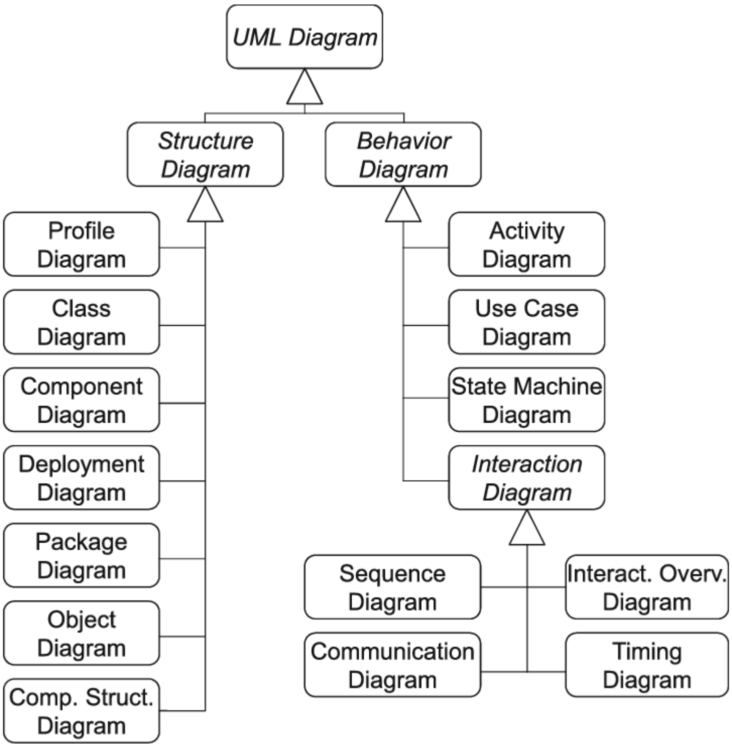

Figure 2.5: UML model types

2.2.2 Requirement Specification Language

RSL is a controlled natural language that helps the production of both requirement and test specifications in a systematic and rigorous manner. It relies on a vast set of constructs to create requirement specifications with different abstraction levels. RSL is capable of producing requirement specifications for several organizational layers, such as business, application and software layers .

ITLingo RSL is an approach used to describe a requirement specification, based on linguistic patterns, and follows a multi-language strategy based on two languages: RSL-PL (Pattern Language) for defining linguistic patterns, and RSL-IL (Intermediate Language)that acts as a formal requirements interlingua [24, 25]. The classification of RSL constructs is represented in Fig. 2.6

System (isFinal vs isReusable)	Concerns / Abstract Levels	Active Structure (Subjects)	Behavior (Actions)	Passive Structure (Objects)	Require-ments	Tests	Other	Relations & Sets
	Business Application Software Hardware Other	Stakeholder Actor	ActiveElement (Task, Event) StateMachine	DataEntity DataEntityCluster DataEnumeration	Goal QR Constraint FR UseCase UserStory	AcceptanceCriteriaTest UseCaseTest DataEntityTest StateMachine Test	GlossaryTerm Risk Vulnerability Stereotype IncludeAll IncludeElement	SystemsRelation Requirements Relation TestsRelation SystemElements Relation ActiveFlow SystemView SystemTheme

Figure 2.6: Classification of RSL constructs (extracted from [5])

2.3 E-Mobility concepts

The most important E-mobility concepts that support the development of this work are described below.

2.3.1 Electric Mobility

Electric mobility encompasses the use of various electric vehicles, including electric cars, e-bikes or pedelecs, electric motorbikes, and e-buses. These vehicles share a common characteristic: they are powered either entirely or partially by electricity, have energy storage capabilities on board, and primarily draw their energy from the power grid, as described in the citation [26]. This form of transportation is a key component of efforts to reduce carbon emissions and promote sustainable mobility solutions.

2.3.2 Smart Charging

Smart charging of an electric vehicle refers to a charging process that can be modified in response to external factors and events. This adaptability enables more flexible and intelligent charging behaviors, empowering the EV to seamlessly integrate into the broader power grid and cater to the preferences of the user. This concept of smart charging aligns with the principles of sustainable consumption and has the potential to make a substantial contribution to enhancing the energy security aspect of our energy systems, as suggested in the citation [27].

2.3.3 Aggregator

The aggregator is the entity equipped to harness the flexibility offered by smart charging, effectively overseeing the intricate smart charging procedures across a network of interconnected charging stations. As managing smart charging on a large scale entails inherent complexities and specific demands, it becomes imperative for emerging aggregators to establish a well-structured business model meticulously tailored to address the distinct requirements of their operations, as highlighted in the citation [28].

2.3.4 Distribution System Operator (DSO)

Distribution System Operator (DSO) play a crucial role in efficiently distributing and managing energy from various sources to end consumers. Embracing digitalization is pivotal to fortifying the DSO model, necessitating investments in cutting-edge technologies such as automation, smart meters, real-time systems, big data, and data analytics. Central to the DSO model are smart meters, enabling bidirectional energy flow reading and real-time communication. This capability not only detects interruptions promptly but also automates supply restoration. Furthermore, it empowers consumers by offering digital platforms for real-time monitoring of their daily energy consumption, enhancing overall efficiency and customer satisfaction [28].

2.3.5 Flexibility

Flexibility within a power system signifies its capacity to adjust its operations when faced with variations or uncertainties, either by altering electricity consumption or generation. This adaptability can be achieved through various mechanisms, including dispatchable power plants, demand response, energy storage, and interconnection. Notably, demand response and energy storage are flexibility options that can be sourced from the demand side of the power system. These two solutions have garnered significant attention in both academic and industrial circles for their pivotal roles in enabling the integration of renewable energy sources [28].

3

Related Work

Contents

The following modeling techniques have been applied and adapted to the EV ecosystems to represent and model different participants, their actions, the relationship between the business, application, and infrastructure parts of the domain.

A presentation and critical assessment of different frameworks developed and researched over the past 10 years is presented. The advantages and disadvantages of these frameworks are discussed and a comparison is depicted regarding the main characteristics of each model.

3.1 Smart Grid Architecture Model

Technological advancement and financial incentives have led in recent years to the expansion of distributed generation of electrical power and the increasing number of devices connected to lower grid levels [29]. The management of this complex system falls upon the DSO. There is no convergence to a “right” system solution by the DSOs because the investment in the development and maintenance of the grid is long-term and there is a need to constantly evaluate the available technologies for their use cases.

DSOs expressed a need for a framework that supported their decision-making process with state-of-the-art information. One of the frameworks developed to tackle this issue was the Smart Grid Architecture Model (SGAM), which is the outcome of the EU Mandate M/490´s Reference Architecture Group [29]. The goal of SGAM is to share information among projects that implement similar use cases based on different technological solutions [30].

SGAM presents five layers that are an adaption of the ArchiMate layers [6]. The business layers encompass business aspects of the Smart Grid, such as business subjects, objects, or even processes. The function layer describes services and their relationship between the technical and business sides. The information layer adheres to data models and represents the information being exchanged by the function layer. The communication layer exchanges the outputs of the information layer with the component layer. This is the lowest level layer, composed mostly of physical equipment, for example, grid devices, batteries, chargers, and the functions that allow these devices to communicate with each other and the grid. The several SGAM layers and connections are depicted in Fig. 3.1.

This model focuses on grid integration and considers e-mobility a sub-domain of electricity. The main challenge of SGAM-related frameworks, according to Uslar and Gottschalk [31], is the definition of a sector-specific structure mainly on the zones and domain subsections.

The evaluation was conducted through a use case template, based on the M/490 use case template [29], and adapted for this specific project, for example, by adapting the Key Performance Indicator (KPI) to better suit the necessities of the SGAM evaluation.

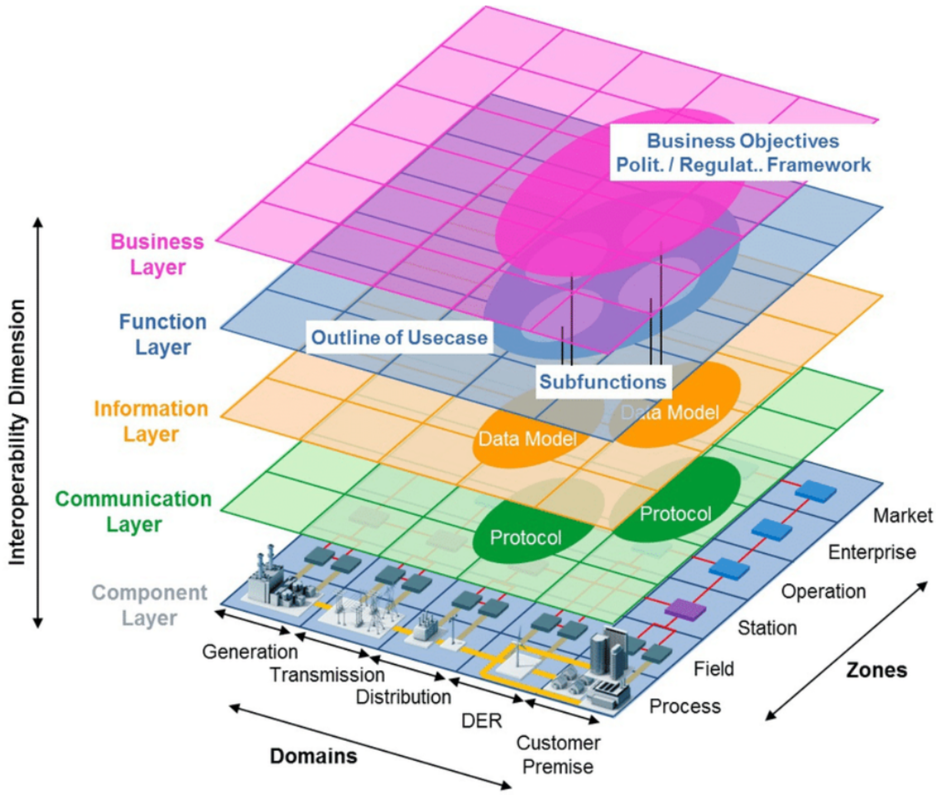

Figure 3.1: SGAM Matrix View (extracted from [6])

3.2 Electric Mobility Architecture Model

Electric Mobility Architecture Model (EMAM) is a specification of SGAM for the EV ecosystem. Even though SGAM is capable of modeling and standardizing the Smart Grid very successfully in dozens of projects [31], since electrical mobility is a small only piece of the smart grid, a better fit can be achieved when adopting the SGAM to electric mobility.

Recent work conducted by Uslar et al. [31] suggests changing the SGAM as little as possible so that EMAM models can be compatible with other existing methods, as depicted in Fig. 3.2. Electric mobility introduces mobile assets into the modeling ecosystem, but SGAM provides no time dimension, so, in this first iteration of EMAM, all aspects are treated as static.

This first iteration of EMAM has several flaws compared to its counterpart. The definition of domains is very elementary, and the zone dimension does not have the hierarchical organizational granularity that SGAM provides. This proposed model even though it addresses the interoperability of the business, communication, and information layers, it does not describe any standards to be used.

Finally, even though complexity handling tries to be like SGAM´s, it falls short in the sense that there is very little guidance, the documentation is non-existent, and no evaluation was conducted [31].

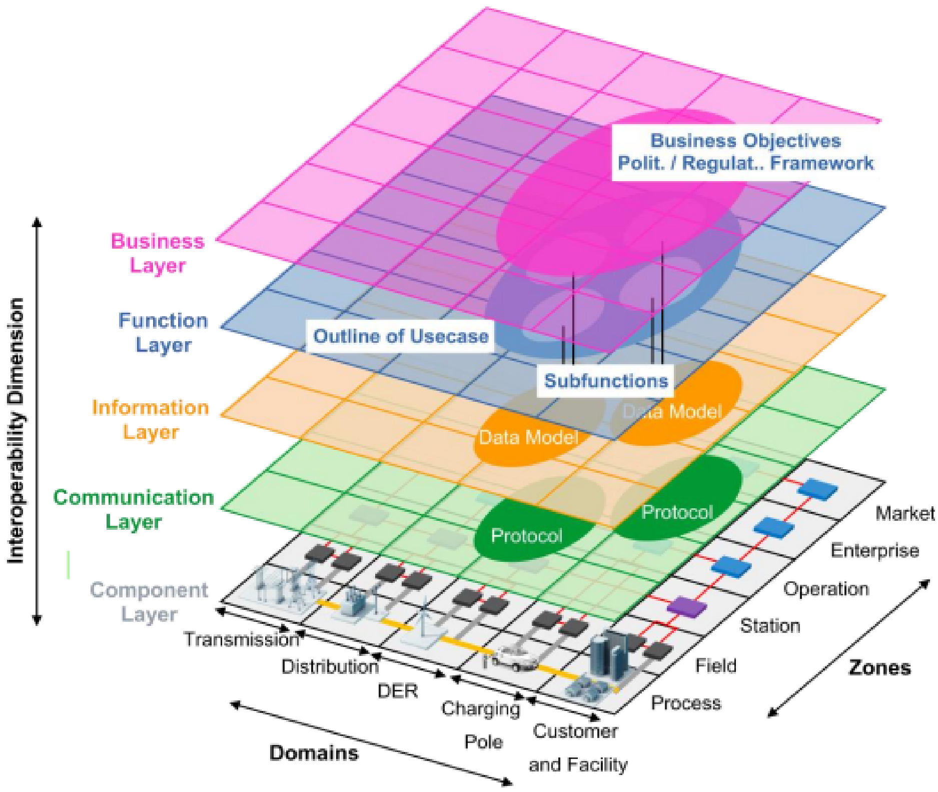

Figure 3.2: EMAM Matrix View (extracted from [7])

3.3 Interoperability Architecture for Electric Mobility

The Interoperability Architecture for Electric Mobility proposes a new reference architecture for electric mobility. To do so, the authors of this research followed several stages. Firstly, it was necessary to investigate and understand the concept of electric mobility. Secondly, the objectives of the reference architecture were defined based on the main problems found by the investigation. Finally, an elaboration of the smart charging concept was elaborated and therefore a reference architecture for electric mobility was derived [7].

The technologies used to create the architecture were mainly The Open Group Architecture Framework (TOGAF), as the architecture development method, and ArchiMate as the framework and modeling language. The final architecture is based on the views from phases B, C, and D of the TOGAF ADM cycle, which corresponds to the business, information systems, and technology architecture views. Phases E and F were also followed to describe the implementation and migration paths of the architecture.

The result is a one-dimensional structure, depicted in Figure 3.3, that consists of four layers: business, business services, application, and infrastructure. It does not provide any standards but does provide interoperability and complexity handling on a conceptual level. It also is not intended for the engineering of complex systems since it provides no tools or guidelines. The evaluation of this architecture was validated through expert interviews.

The conclusions of the evaluation, despite being quite promising, revealed certain limitations of the architecture. Some of these are: the level of abstraction being too high, the application layer needing further refinements with concrete guidelines, and the validation of the architecture was only made through a small sample size of interviews. Brand et al. [7] suggest the study of more concrete business cases have a more open discussion with the corresponding stakeholders.

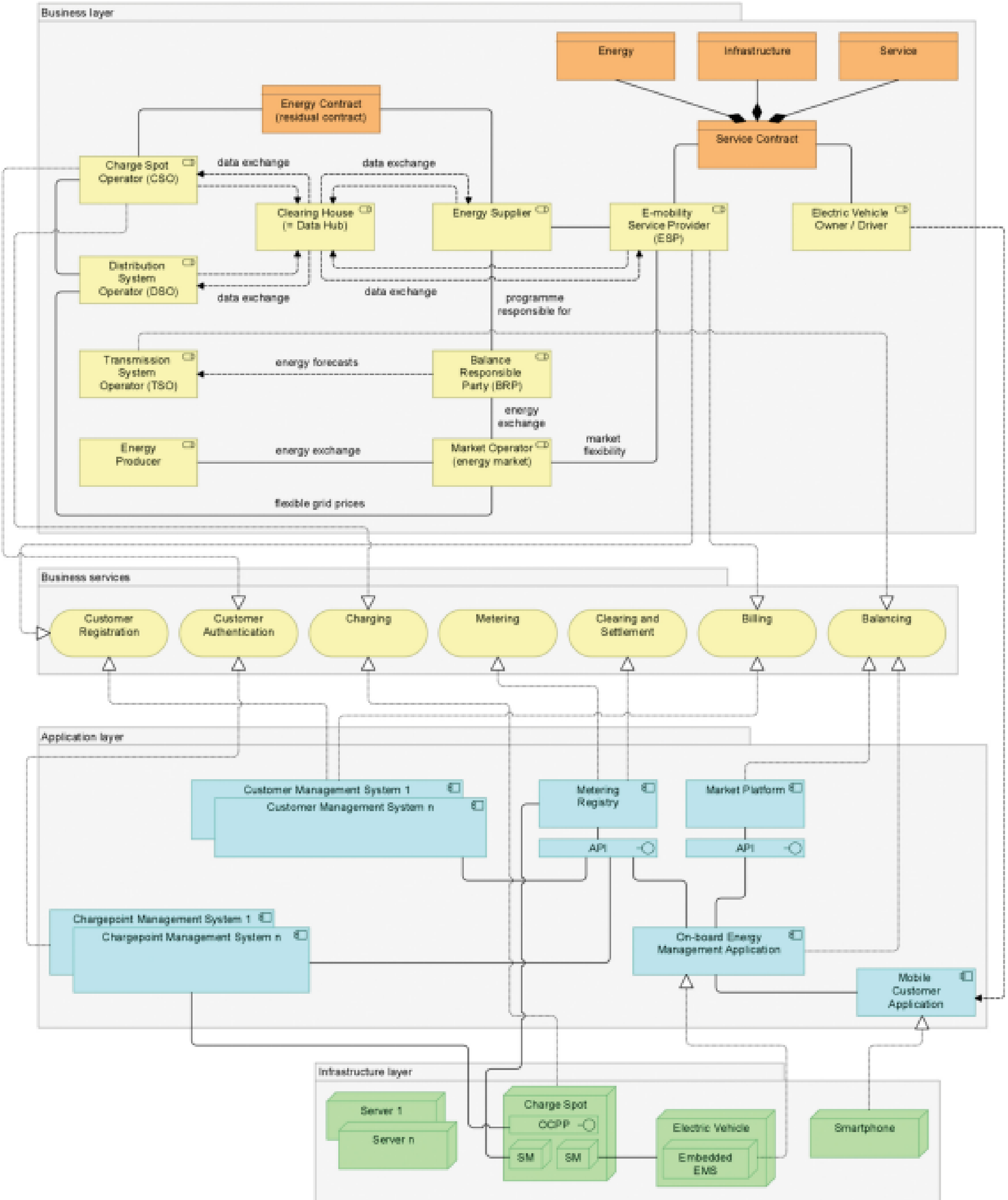

Figure 3.3: Interoperability Architecture for Electric Mobility (extracted from [7])

3.4 E-Mobility Systems Architecture

Kirpes et al. [32] proposed the E-Mobility Systems Architecture (EMSA) model. The principles extracted from SGAM and EMAM serve as a base for the design of this model. The main design principles taken away are, first, the scope and applicability: the model is intended to be comprehensive and cover the complete scope of the e-mobility sector. Second a multi-dimensional structure: the model is intended to provide an appropriate number of useful sector-specific dimensions, and lastly, the allocation, localization, and consistency: the main goal of the model is to provide an appropriate allocation of all e-mobility entities to its structure.

Since this model had the previously discussed models as a reference, it follows a similar approach to these: the number of layers and zones are the same as SGAM, and the definition of the domain and the zones is updated to be more centered around the e-mobility environment.

Taking inspiration from Schuh et al. [8], the domains being proposed are also divided into immobile and mobile. The business layer on this architecture models several economic and legal aspects, for example, regulatory constraints, business services, business cases, business models, and many more aspects. It also makes use of standardization notation languages, mainly UML. It is important to note that the EV user was separated between EV Owner and EV Fleet User. An EV Fleet User in the context of EMSA is an EV that is owned by the EV fleet operator.

In the function layer, the functional architecture and elements of the system are described. It is also where the business cases and connected with their physical implementation by abstracting their functions. At the information layer, three major aspects are being tackled: data management, integration concepts, and information exchange interfaces. Furthermore, several standards, standards from IEC, ISO, ETSI, and IEEE can be used in different dimensions of the framework.

The main goal of the EMSA communication layer is to present an abstract of the communication infrastructure and identify the gaps in the communication standards. An example of an EMSA component layer model is depicted in Fig. 3.4. The basis of the four upper layers is the component layer. The focus is the hardware and software components of the e-mobility ecosystem, for example, the EV, batteries, and charging stations. The evaluation of this framework was primarily performed qualitatively through an observational case study. In this study, first, a comparison with the SGAM model was conducted, then the fulfillment of the requirements of the EMSA framework was performed. All in all, EMSA is capable of being applied with systems in the entire e-mobility ecosystem. It was also verified that the system architecture model proposed by them also fulfills the above-mentioned requirements, and, as future work, the authors are looking to expand this model to a complete framework including an engineering process, with more guidance, documentation and a reference architecture for e-mobility information systems [32].

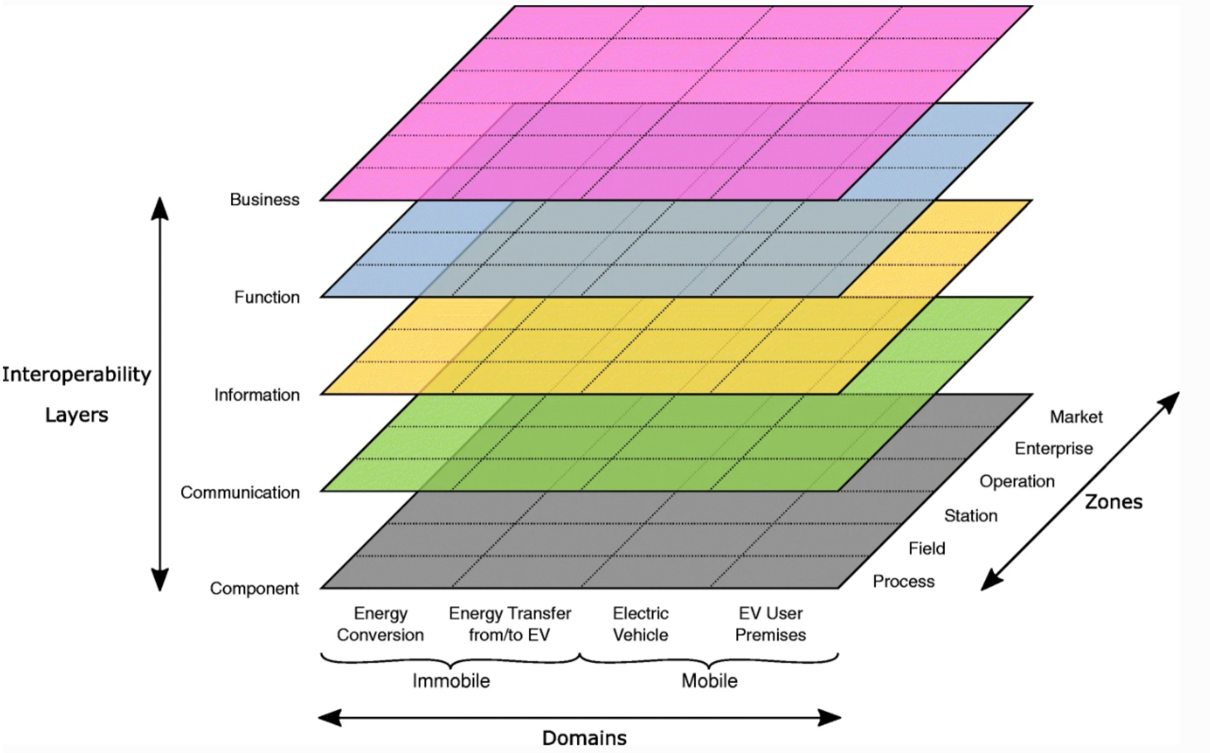

Figure 3.4: EMSA Matrix View (extracted from [8])

3.5 Discussion

Table 3.1 overviews the architectural models and frameworks discussed above.

The table has five columns: Name , represents the identifier of the research papers resulting from the Systematic Literature Review (SLR).

Basis indicates which existing frameworks or methodologies served as a foundation or support for the development of the frameworks discussed in these research papers.

Scope describes the specific focus or area of interest for each framework. Although all the frameworks are related to the EV domain, they may have different perspectives and objectives.

Dimension outlines how each framework is divided or structured, providing insights into its organizational framework.

Evaluation provides information on how each of these frameworks was evaluated or assessed in the respective research papers.

By analysing Table 3.1 it is possible to analyse that SGAM and the Interoperability Reference Architecture were based on ArchiMate and EM-ISA, EMSA and EMAM based their frameworks on SGAM. Each framework has a different scope, for example SGAM is more focused on Smart Charging while EMSA is focused on E-Mobility on a wider perspective. The majority of the framework is divided in three parts, layers, domains and zones. In the last column it is also possible to understand that EMAM and EM-ISA did not have an evaluation process, while the other three frameworks all followed different evaluation paths.

Table 3.1: E-mobility architecture models overview

Name	Basis	Scope	Dimension	Evaluation
EM-ISA	SGAM,ISA	E-Mobility IS	3 (layers,domains,zones)	-
SGAM	ArchiMate	Smart Charging of ECs	3 (layers,domains,zones)	Case Study
Interoperability Reference Architecture	ArchiMate	EV-Grid Integration	1 (layers)	Expert Interviews
EMSA	SGAM,EMAM,EM-ISA	E-Mobility EA	3 (layers,domains,zones)	Observational Case Study
EMAM	SGAM	Electric cars	3 (layers,domains,zones)	-

4

EV-EAM: Business Level

Contents

An overview of the business and ArchiMate models developed for the EV domain and its ecosystems is presented in this chapter. The focus lies on the Home, Building, and Company ecosystems since these are the focus of the EV4EU Portuguese Demonstrator, presented in chapter 1.

One objective of this thesis is to tailor new emerging V2X technologies to innovative business models. The ultimate objective is to enhance the economic optimization of EV charging, promote greater reliance on RES, and reduce charging times and battery deterioration.

By adapting these cutting-edge technologies to novel business models, we seek to generate value for end-customers and offer enhanced services, benefiting not only organizations but also partners and customers alike. The aim is to contribute to the EV charging landscape and create a positive impact on these EV ecosystems.

4.1 General Business View

The EV domain can be divided into two distinct sides: the market side and the demand side. The market side primarily deals with the production and trading of electric energy until it reaches the final consumer. On the other hand, the demand side, encompasses the EV ecosystems and is focused on delivering services and creating value for end-users.An aggregator bridges the two sides by acting as a middleman to support business models that involve trading flexibility obtained from the demand side and selling it in various electricity markets.

By facilitating the exchange of services and resources between the market side and the demand side, the aggregator aims to improve the adoption of EVs by consumers. This section delves into the services provided by the aggregator to both the market side and the demand side. It explores strategies and approaches that can enhance the overall EV adoption experience for consumers, ultimately contributing to the growth and sustainability of EV ecosystems.

4.1.1 Market Side

The flow of energy usually starts in power plants. There are several materials that can be used for this production, such as natural gas, coal, nuclear fission, biomass, petroleum or RES [33]. The main entity responsible for this production is known as the energy producer. In Portugal, companies such as Iberdrola or EDP Renováveis act as energy producers. Then, a market operator, is the entity responsible for overseeing the energy market and offers services to several other actors [7].

Following, a Balance Responsible Party (BRP) buys and sells electricity from the market operator, and can handle balance responsibility for end customers. The Iberian Energy Market Operator is an example of a market operator in Portugal. Besides their balance responsibility, this entity may also deliver ancillary services, for example, forecasting services to a Transmission System Operator (TSO).

The TSO, for example Redes Energéticas Nacionais, is the entity charged with maintaining the stability of the electrical transmission system. After the energy is transported through the transmission grid, it arrives at the distribution grid. The main responsible for managing the local grid is the DSO [11]. There are several entities that act as DSOs in Portugal, such as E-REDES in the mainlaind, EDA in the Azores or EEM in Madeira. Next, a retailer, for example EDP Comercial, acquires energy from the producers in the wholesale market and sells it to the end customer. Typically, in a very broad perspective, this is how the electrical ecosystem is shaped [34].

Finally, considering the EV service potential, one more entity is added to the general view of the EV domain, the aggregator.

Capwatt is an example of a company, in Portugal, that acts as an aggregator. The purpose of an aggregator, on the market side of the EV domain, is to offer flexibility to the market participants. Flexibility is the ability of a power system to adapt its operation in response to variability or uncertainty, by modifying electricity demand or generation [28]. Since RES introduce more imbalance on the grid than other traditional methods, flexibility can be used as a tool to fix this imbalance in a more economical manner. Fig. 4.1 represents the monetary transactions that occur in the market side of the EV domain.

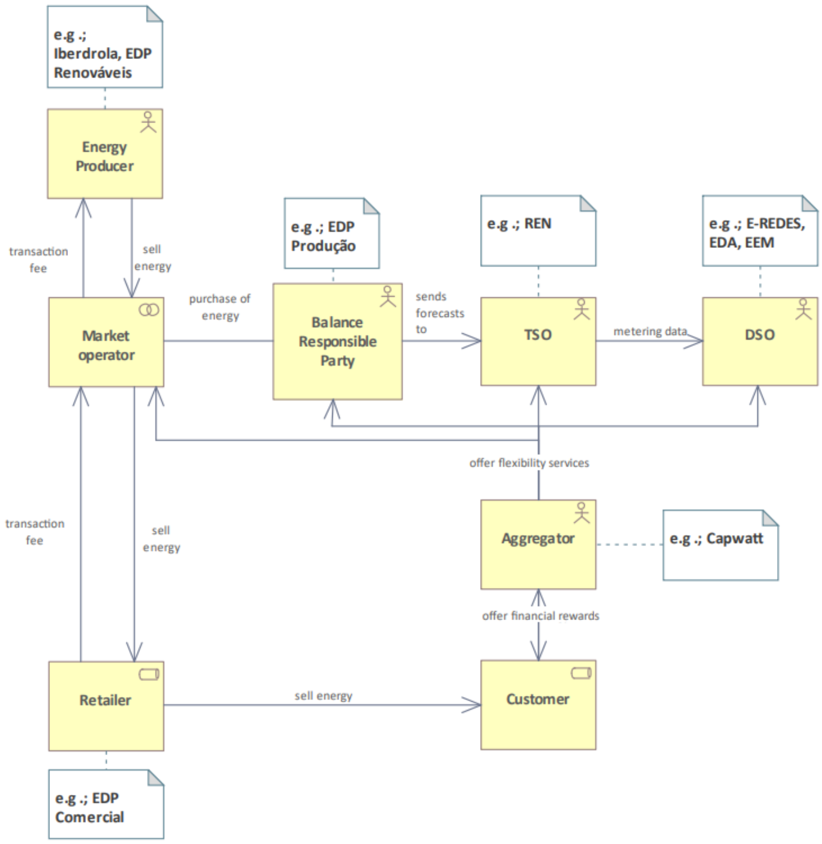

Figure 4.1: Market Side of EV Domain (ArchiMate notation)

Within the EV domain, the energy flows differently than the monetary transactions. While both flows share the same starting point, the energy producer, afterwards the energy flows directly to a TSO, then to a DSO and finally to a customer. The energy flow between different market entities is presented in Fig. 4.2.

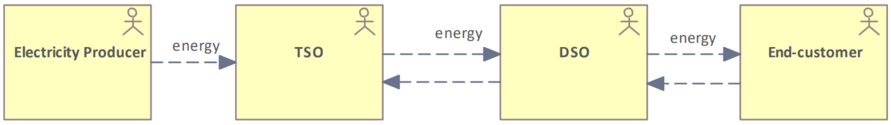

Figure 4.2: EV Domain energy flow (ArchiMate notation)

4.1.2 Demand Side

The purpose of the aggregator on the demand side is to receive energy from its customers, and, in turn, offer them financial rewards and services to lower their energy costs [28]. The aggregator does not generally interact directly with an end user, instead, interacts with a V2X manager.

The function of the V2X manager is to serve as a middleman between an end user and the aggregator. The entity who realises the job of V2X manager depends on which ecosystem is concerned. For example, in the Home ecosystem, the homeowner can be the V2X manager and, solely in this case, interact directly with an aggregator. However in the cases of the Building or Company ecosystems, the role of V2X manager could be outsourced to a third-party company, or conducted in-house by either a building manager or a company operator respectively.

An end customer in order to participate in this business, first needs to own an EV. Since one of the biggest barriers to EV adoption is the entry investment, battery manufacturers and public entities have a big stake in that matter. Battery manufacturers can offer services such as battery leasing, or acquiring a battery once it is depleted and using it as a stationary energy storage unit.

The European Commission has defined several carbon neutrality targets for 2050 and EVs play a pivotal role in achieving those goals [35]. So that these targets are achieved by the year 2050, public entities need to implement measures that incentive electric vehicle adoption and usage.

Finally, it is important to note that, even though an end-customer is an EV user, each ecosystem has its own actors that play this role. A representation of the demand side is presented in Fig. 4.3.

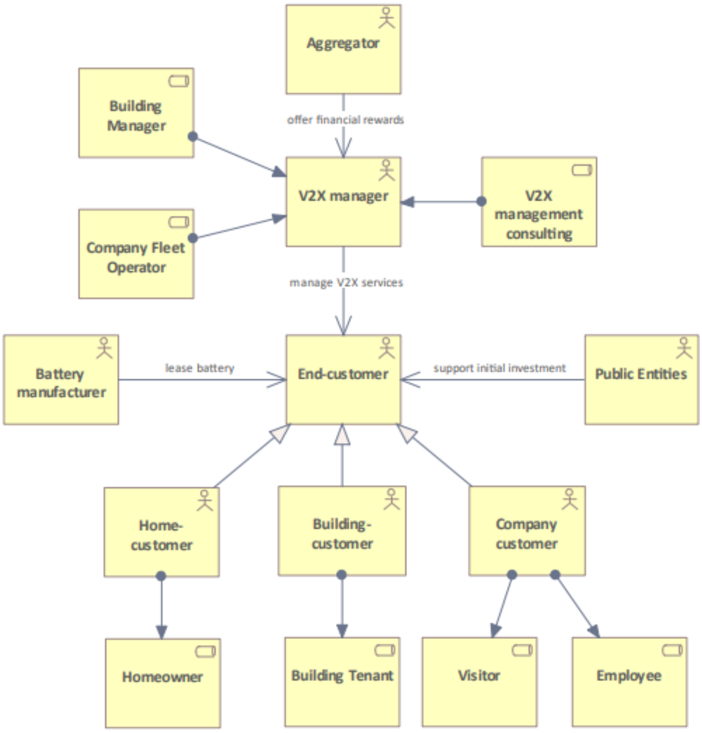

Figure 4.3: Demand Side of EV Domain (ArchiMate notation)

4.2 Specific Business View

The aggregator implements business models by trading flexibility from their consumers' assets in different electricity markets [28]. These business models rely on services to perform the trading of flexibility between the consumers and the market.

Services are favored over other business models because, for flexibility trading to be effective, it requires a mutual integration of resources and activities. Flexibility trading also relies on the interaction between different actors, that is applied for the benefit of another party, thus services are the most effective business model to adopt [33].

The economic feasibility of the proposed business models is dependent on how much money the aggregator makes, how much the consumer earns, and the degree of degradation that the consumer´s assets suffer from offering flexibility [36].

The aggregator is the service provider of the following proposed business models and offers services to both the electricity market and the demand side of the EV Domain. The following business models are divided into the electricity market category or demand side category since the services provided to each category are fundamentally different in their goals and operation.

4.2.1 Market Side Business Model

The flexibility traded by the aggregator, using his consumer´s energy, allows new services to be developed and offered to both DSOs and TSOs. The TSO is traditionally responsible for solving frequency constraints constraints and stability problems in the grid, while the DSO is responsible for solving congestion and voltage issues. The main difficulty in solving these voltage and congestion issues is how expensive each repair is, and the constant maintenance and upgrading the grid needs to keep up with the ever-evolving demand.

In this business model, as suggested in Fig. 4.4, it is proposed that the aggregator offers new tools to both the DSO and TSO, based on flexibility, to solve the congestion and voltage problems. This, in turn, allows for a reduction in the cost of expanding the grid, since further improvements can be delayed, on a more stable network, and even on a reduction of greenhouse gas emissions, since renewable energy source generation is helped by these flexibility services. Not only that but there are numerous processes that are incompatible between DSOs, TSOs, and aggregators. The flexibility services could be a way to uniform standards and allow for greater and easier cooperation between these entities.

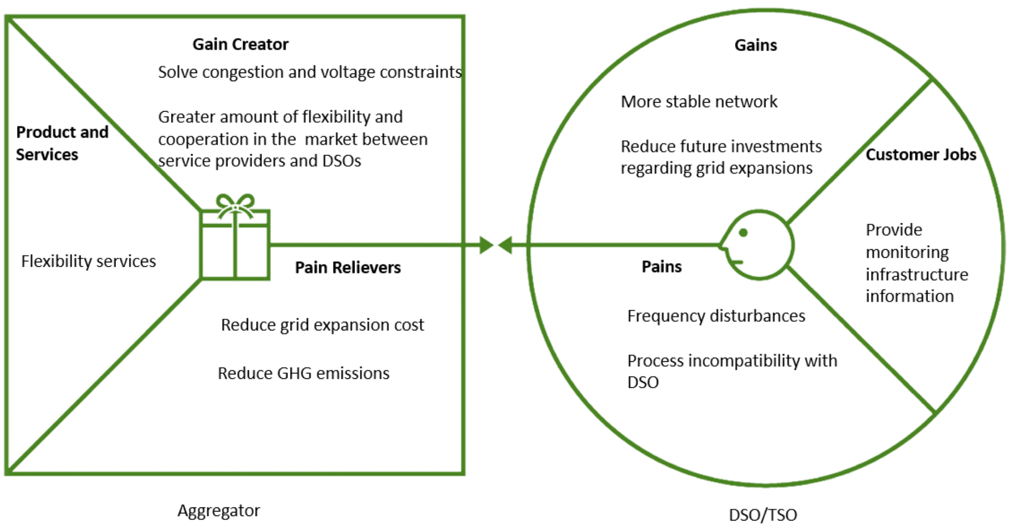

Figure 4.4: Market Side (VPC notation)

The aggregator forms a service contracts with its clients and interacts with them through its digital platform and its B2B channel. The main costs for the aggregator are the development and maintenance of the flexibility services. On the other hand, revenue stems from the payments realized by DSOs and TSOs, from the participation of V2X in the electricity markets and, by contributing to the stability of the grid it provides and opportunity for greater EV aggregation, as depicted in Fig. 4.5. Finally, it is also important to stress that the aggregator´s partners for this business model are the EV users that allow their electrical assets to be pooled, represented in Fig. 4.6.

Key Partners	Key Activities	Value Proposition	Customer Relationship	Customer
EV-user	Offer flexibility services to DSO Frequency containment reserve and frequency adjustment management	Reduce grid expansion cost Solve congestion and voltage constraints Greater amount of flexibility and cooperation in the market between VPPs and DSOs Reduce GHG emissions	Contract	DSO /TSO
	Key Resources		**Channels**	
	DSO/TSO monitoring infrastructure information Flexibility from demand side		B2B Digital Platform	

Cost Structure	Revenue Streams
Services development and maintenance	A better, stable, and secure electricity grid provides the opportunity for greater aggregation of EVs. Activation payments by the DSO/TSO Participation of V2X in the electricity and ancillary services markets

Figure 4.5: Market Side (BMC notation)

	Customers: DSO/TSO						
DSO/TSO	Grid services payment Grid monitoring services	Distribution monitoring infrastructure	State estimation service Forecast flexibility	Improve RES usage Reduce grid expansion cost	Service Contract Price Signals	Digital Platform	Carbon offset returns Lower future investment cost on grid expansion
Service-provider	Cost structure	Key resources	Key activities	Value proposition	Relationship	Channels	Revenue stream
EV-user	EV purchase EV charging	EV	Allow pooling of EV	Reduce charging costs Receive financial rewards	Service Contract	Digital Platform	Reduce charging costs Receive financial rewards
	Key partners and agents: EV-user						

Figure 4.6: Market Side (SBMC notation)

4.2.2 Home Ecosystem Business Model

Once the electric energy reaches the home, it is managed by the Home Energy Management System (HEMS). A HEMS is a combination of hard and software components designed to efficiently manage the energy usage of the home.

This device also relies on the intersection of home appliances, metering, and communication network data. One of the new emerging technologies used in this thesis for the Home ecosystem is the Vechile-to-Home (V2H) technology. This technology allows the home to have a smart micro-grid in which the EV is connected to the home through a bi-directional inverter and its charging-discharging regime. [37]

As depicted in Fig.4.7, the primary customer of the proposed Home ecosystem is the homeowner. The homeowner is responsible for providing the aggregator access to the home´s electrical assets, mainly the CP. In turn, the aggregator offers financial incentives and V2X services. The financial incentives are time-varying financial rewards based on the energy provided by the home. The V2X services are, for example, informing the HEMS of optimal energy pricing so that energy costs can be reduced [28].

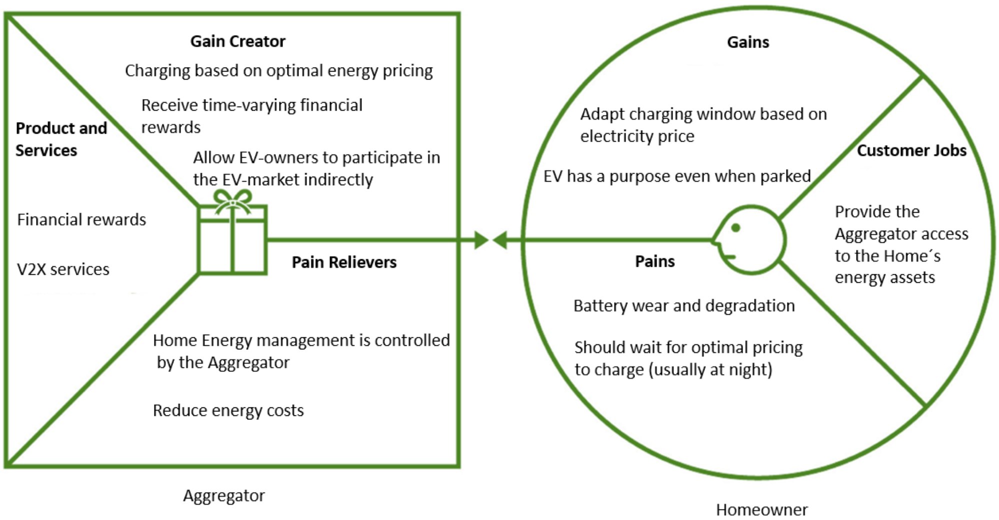

Figure 4.7: Home Ecosystem (VPC notation)

The main aggregator partners needed to provide value are the DSO and the TSO. The DSO and TSO are responsible for providing a grid monitoring infrastructure and grid congestion management services to the aggregator. The main costs stem from the fees paid to the homeowner for pooling its assets, and the development and maintenance of the flexibility services. The revenue from this business model comes from the fee paid by the DSO and TSO for the flexibility services, RES curtailment minimization returns and the aggregator reduces its own energy imbalance by reducing the consumers' imbalance [20]. The mentioned partnerships, costs and revenue streams are depicted in Fig.4.8 and Fig.4.9.

The Home ecosystem is the core of the EV ecosystems. The homeowner, on one hand, is required to have a service contract with a energy supplier, so that the home´s electric appliances can function. That contract determines the period in which the service is offered, the voltage contracted, provides a smart meter, and updated and transparent energy costs. The energy supplier provides energy to the

Key Partners	Key Activities	Value Proposition	Customer Relationship	Customer
DSO and TSO	Flexibility service development	Charging based on optimal energy pricing Receive time-varying financial rewards Allow EV-owners to participate in the EV-market indirectly	Service Contract	Homeowner
	Key Resources		**Channels**	
	Development team EV pool		Sales: B2C Support: App, digital platform	

Cost Structure	Revenue Streams
Fee paid to Homeowner for pooling his assets V2X services development and maintenance	Fee paid by DSOs and TSOs for flexibility services RES curtailment minimization returns Reduces own energy imbalance by reducing the consumers imbalance

Figure 4.8: Home Ecosystem (BMC notation)

	Customers: Homeowner						
Homeowner	Purchase an EV Pay energy	Home assets (EV, HEMS,CP)	Connect EV, even when not charging	Lower energy bill Time-varying financial rewards	Service Contract	B2C	Lower Home´s energy costs Fee paid by the Aggregator for pooling the Homeowner´s EV
Service-provider	Cost structure	Key resources	Key activities	Value proposition	Relationship	Channels	Revenue stream
DSO/TSO	Grid maintenance	Grid monitoring infrastructure	Grid congestion management	Aggregator offers power reserves to eliminate imbalance Improve RES usage	Contract	B2B	Lower congestion management costs Lower future investment cost on grid expansion
	Key partners and agents: DSO/TSO						

Figure 4.9: Home Ecosystem (SBMC notation)

homeowner in turn for monthly energy cost payments [28].

On the other hand, in order to realize the business models proposed, the homeowner also needs to create a contract with an aggregator. That contract determines the minimum period the homeowner must have its EV connected to a CP, the V2X services the aggregator will provide, and the duration of the contract. The aggregator provides financial rewards to a homeowner in turn for having access to the home´s energy assets. The Home ecosystem is depicted in Fig. 4.10.

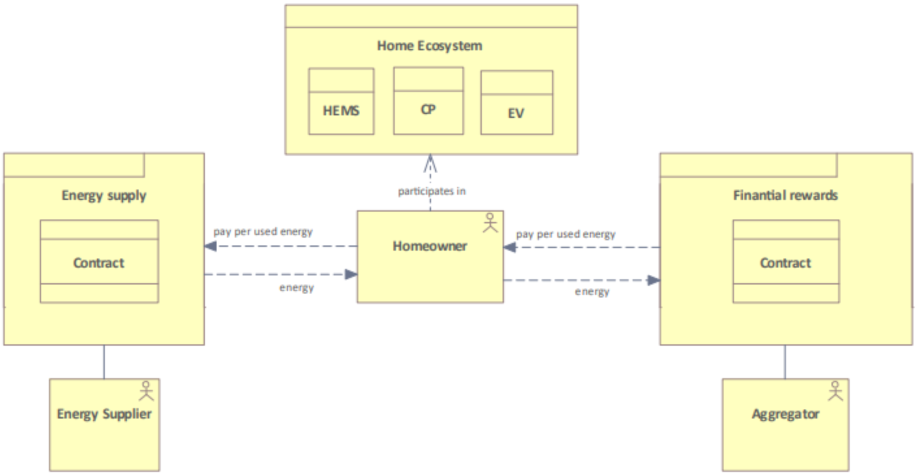

Figure 4.10: Home Ecosystem (ArchiMate notation)

4.2.3 Building Ecosystem Business Model

Once the electricity from the grid reaches a building, it is first directed to a switchboard and from there to a lighting panelboard and a power panelboard. This process enables the regular use of electricity in a building, for lighting, heating, and providing energy, but its only source of energy is the grid [38].

The Vehicle-to-Building (V2B) technology enables buildings to draw power from multiple electric vehicles, therefore enabling buildings to lower their power consumption from the grid. This is an opportunity to develop new business models that bring advantages to Buildings, EV users, and even service suppliers, such as charging an EV with 100% green energy, having easy control over an EVs State of Charge (SOC), or even reducing the initial and ongoing costs of owning an EV.

The main customer of the proposed Building Ecosystem business model is the building tenant, as presented in Fig. 4.11. A building tenant is anyone who works or lives in a building, therefore it has access to charging its EV in the building. The building manager, who can be any of the tenants or an outsourced company, is responsible for managing the V2X services provided to the tenants, by the aggregator [39].

This business model brings several advantages, both for the building as a whole, as well as for the individual EV owner. Firstly, in case of grid failure, V2B can sustain the building for a period, thus reducing the building´s dependency on the grid. The aggregator also enables easing the integration between flexibility services and the Building´s energy system. The previously discussed advantages are presented in detail in Fig. 4.12 and Fig. 4.13.

Similarly to the Home ecosystem, the Building ecosystem also requires an aggregator and an energy

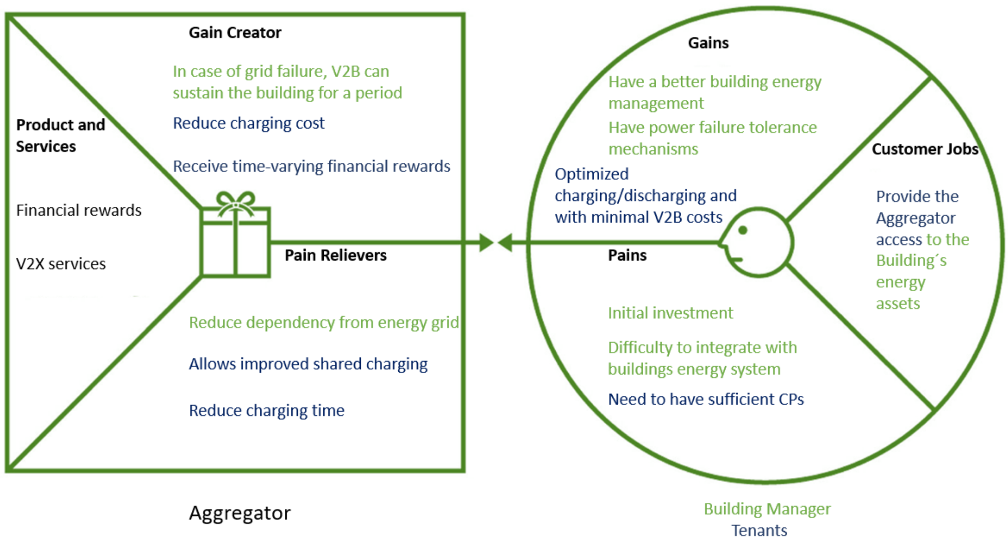

Figure 4.11: Building Ecosystem (VPC notation)

Figure 4.12: Building Ecosystem (BMC notation)

supplier. The main difference is the introduction of a V2X manager, that, in the situation of the Building ecosystem, this role falls upon a building manager or a third-party outsourced firm. In this ecosystem, the V2X manager is responsible for carrying out the contracts with the energy supplier and the aggre-

	Customers: Building Manager, Building tenants						
Building Manager	Lease charging equipment	Installation site	Provide asset to Building´s energy assets	Optimize Energy Consumption Fee paid by the VPP for pooling the buildings EVs	Service Contract	B2B	Reduce building energy costs Fee paid by the VPP for pooling the buildings EVs
Building Tenants	Purchase an EV	EV	Connect EV, even when not charging	Lower charging cost Fee paid by the Building for allowing the EV to be pooled	Service Contract	B2C	Lower charging costs Fee paid by the Building for allowing the EV to be pooled
Service-provider	Cost structure	Key resources	Key activities	Value proposition	Relationship	Channels	Revenue stream
DSO/TSO	Grid maintenance	Grid monitoring infrastructure	Grid congestion management	Aggregator "offers" power reserves to eliminate imbalance Improve RES usage	Contract	B2B	Lower congestion management costs Lower future investment cost on grid expansion
	Key partners and agents: DSO/TSO						

Figure 4.13: Building Ecosystem (SBMC notation)

gator. Those contracts generally state that the V2X manager provides access to the Building´s energy assets while in turn, the aggregator will provide financial rewards to the building manager [39]. The V2X manager also needs to establish a contract with every tenant that owns an EV. That contract states that the V2X manager is responsible for the management of the V2X services provided by the aggregator, within the building. It also obliges the distribution of the financial rewards attributed by the aggregator, to the tenants who own an EV. In turn for the services provided, the V2X manager is allowed to keep a small fraction of the financial rewards received. The Building ecosystem is depicted in Fig. 4.14.

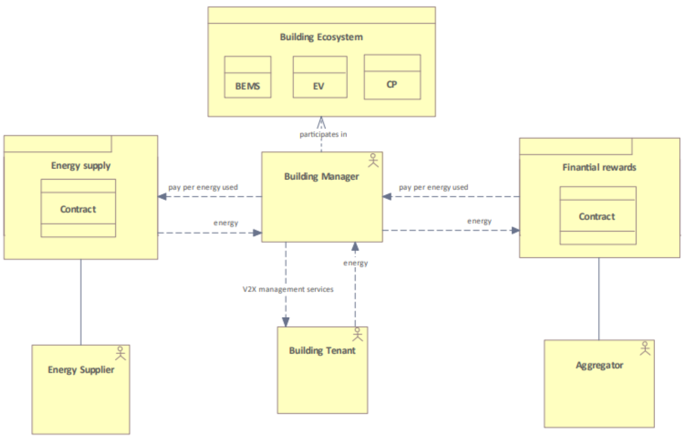

Figure 4.14: Building Ecosystem (ArchiMate notation)

4.2.4 Company Ecosystem Business Model

The Company Ecosystem is managed by a company operator that is responsible for managing the V2X services for both employees and visitors. This ecosystem is mostly similar to the Building Ecosystem, the major differences are the charging priority given to each EV owner and the actors needed to achieve this balance. In the Building ecosystem, every tenant has the same priority since they serve a similar role in the building.

For a company, it might make sense for an employee to have a higher charging priority than a visitor, or for an university, for a teacher to have a higher priority than a student. Another important point, presented in Fig. 4.16 and Fig. 4.17, is that this model requires two additional partners, besides the ones mentioned on previous models. A Charging Point Operator (CPO) is required since it is the entity responsible for the management of the EV charging points within public premises. A roaming operator is also necessary to allow any EV user to have access to the company´s charging points, independently of the EV user´s contractualized charging point provider [40].

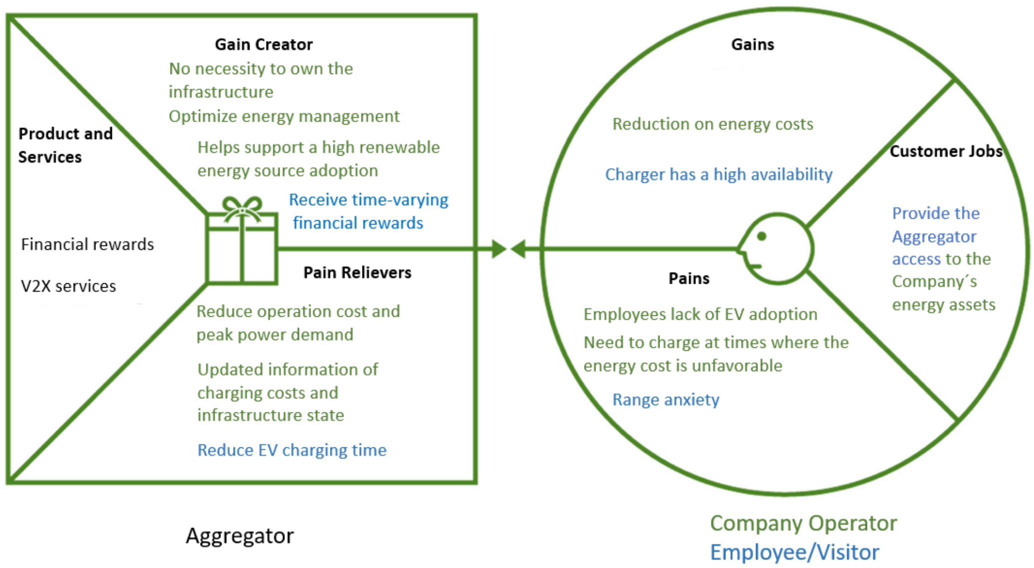

Figure 4.15: Company Ecosystem (VPC notation)

After these requirements are met, there are several upsides, both for a company and for its employees and visitors, discussed in Fig. 4.15. The partnership with a CPO allows a company to not need to own a charging infrastructure of its own. Besides, the V2X charger allows optimized energy management, operation, peak power demand reduction, and updated information of SOC. The employees and visitors are able to receive financial rewards if they allow their EV to be pooled by an aggregator, and keep their vehicle connected even when it is fully charged.

Key Partners	Key Activities	Value Proposition	Customer Relationship	Customer
DSO and TSO CPO Roaming Operator	Flexibility services development	For company: Optimize company energy management No need to own infrastructure, reducing initial costs For employee/visitor Lower charging cost Fee paid by the Company for allowing the EV to be pooled	Service contract	Company Operator Employee/Visitor
	Key Resources		**Channels**	
	Development team EV pool		Sales: B2B Support: App, digital platform	

Cost Structure	Revenue Streams
V2X service development Fee paid to Building for pooling its assets	Initial charger installation / Charger lease Fee paid by DSO and TSO for flexibility services RES curtailment minimization returns Higher EV aggregation

Figure 4.16: Company Ecosystem (BMC notation)

Customers: Company Operator fleet operator, Employee, Visitor

Company operator	Lease charging equipment	Installation site	Provide asset to Company´s energy assets	Optimize Energy Consumption Fee paid by the VPP for pooling the companies EVs	Service Contract	B2B	Reduce building energy costs Fee paid by the VPP for pooling the companies EVs
Employee/ Visitor	Purchase an EV	EV	Connect EV, even when not charging	Lower charging cost Fee paid by the Company for allowing the EV to be pooled	Service Contract	B2C	Lower charging costs Fee paid by the Company for allowing the EV to be pooled
Service-provider	Cost structure	Key resources	Key activities	Value proposition	Relationship	Channels	Revenue stream
DSO/TSO	Grid maintenance	Grid monitoring infrastructure	Grid congestion management	Aggregator “offers” power reserves to eliminate imbalance Improve RES usage	Contract	B2B	Lower congestion management costs Lower future investment cost on grid expansion
CPO	Public Charging Network maintenance	Charging Network	Manage their public charging network	Increase the range and efficiency of the public charging network coverage	Contract	B2B	Charging Point lease
Roaming Operator	Roaming service maintenance	Roaming service	Allows EV drivers to charge their cars outside their charging service provider's network	Allow EV owners to access any charging point	Contract	B2C	Roaming fee paid by the EV user

Key partners and agents: DSO/TSO, CPO, Roaming Operator

Figure 4.17: Company Ecosystem (SBMC notation)

The Company ecosystem is based on the two previously discussed ecosystems. In this case, the role of the V2X manager belongs to a company operator or a third-party outsourcing firm. The main distinction is the need for a CPO and a roaming operator. The CPO, who is responsible for installing the charging points in the company, has a partnership with a roaming operator. This allows any EV user to be able to use the company´s charging points, independently of the charging point provider the user is affiliated with, in exchange for a roaming fee [40]. The Company ecosystem is depicted in Fig. 4.18.

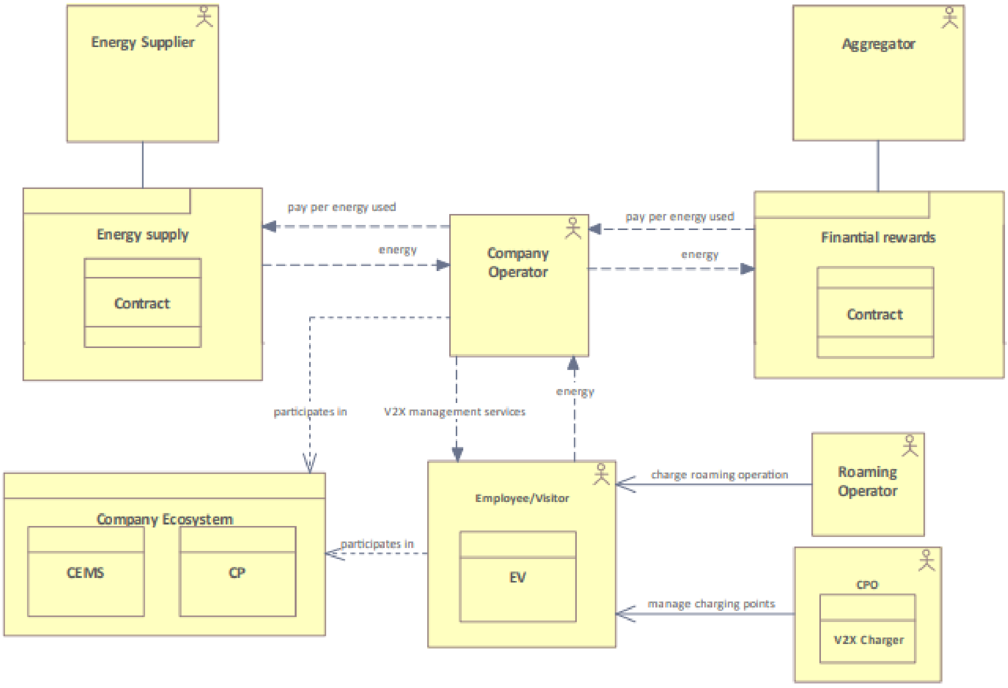

Figure 4.18: Company Ecosystem (ArchiMate notation)

5

EV-EAM: Application Level

Contents

This chapter presents application model propositions that support the business models introduced in Chapter 4. The application models are, firstly, developed with the ArchiMate language and, secondly, with UML developed to depict different use case scenarios and domain models for the applications proposed. The UML representation is necessary to describe the system´s intended functionality and its environment, thus allowing to relate what is needed from a system to how the system delivers those needs [17].

Thirdly, a requirement specification was developed, based on the proposed UML models, to help structure the concerns of such systems. A good requirement specification has several benefits by supporting the project scope's validation and verification, or contributing to the establishment of a contract between customers and suppliers [5].

5.1 General Application View

The first step for any customer to interact with the proposed business models, independently of which ecosystem he belongs to, is to create an account on the EMS system. This account creation requires information such as the customer´s address, social security number, the EV license, and banking information so that it is possible to later deposit the financial rewards. After the account creation request is sent by the customer, the EMS system will verify whether the introduced information is valid or not, and, accept or refuse the request. The application is responsible for the management of the aggregator´s system is called "Aggregator Management System" and offers applicational services such as "Customer Validation" or "Customer Registration".

The second step is the Charging Point Installation. The CPO is responsible for installing the charging point, or charging points, in the customer´s premises. After it is installed, the EMS admin is responsible for connecting the CP to the ecosystem´s EMS, through the EMS system. Next, the aggregator admin is responsible for connecting an ecosystem´s EMS to the aggregator´s network. Finally, the aggregator´s system is responsible for verifying the communication between the CP and the system. Then, integration can be concluded or retried, depending on the success of the operation. This integration test is provided by the "Aggregator MS" application, through the "pooling service", which is in control of pooling the customer´s assets to the aggregator´s network.

The third step is EV charging. First, a customer needs to authenticate itself on its ecosystem EMS. Once this process is concluded successfully, all that is left to do is to connect the EV to the CP and choose the V2X operation, through the "CP Management System" application. Two operations are offered, either charging the EV or providing energy to the Aggregator´s network. If the second option is chosen, the Aggregator´s system is in control of measuring the energy provided by a customer and adding the financial rewards to the customer´s account.

It is also important for customers to be able to cancel their subscription to the service. This is done simply by logging on to the aggregator´s application, accessing the cancelation page, and submitting the cancelation request. The aggregator´s system will validate or invalidate the request, depending on whether a customer´s fidelization period is over. This verification is the responsibility of the ”Customer Cancelation” service.

In order for the proposed business models to support the business processes discussed above, three central systems are needed: the ”Charging Point” system, the ”EMS” system, and the ”Aggregator” system. Firstly, the ”Charging Point” system is the foundation of the applicational models and it is highly connected to the physical layer of the EV ecosystems. The ”CP Management” application is the core of the ”Charging Point” system and is the result of the aggregation of several applications. Some of these applications are the ”Optimized Charging Algorithm” which calculates the times when the charging costs are optimal, the ”Energy scheduling algorithm” which schedules the charging of an EV based on optimal costs and the ”Charging Monitoring” application that allows a customer to access his EV´s charging data. This system also offers an API that allows EV users to interact with the charging point.

The ”EMS” system serves as a bridge between the Charging Point and the Aggregator´s systems. It includes the EMS of each EV ecosystem. Each ecosystem application has small differences, for example, the ”Home EMS” application only relies on the information provided by the ”Electrical appliances management system” that is responsible for gathering the energy expenses of every electrical appliance in a home. The ”Building EMS” application requires a ”V2X storage system” so that it can store energy and serve as a backup generator in case of grid failure, and a ”Photovoltaic system”, in case it has photovoltaic panels installed. When it comes to the ”Company EMS” it relies on the ”Shared Charging System”, which is an algorithm that will determine the charging schedule of EV´s based on the owners' priority, and the ”Company Electrical Appliances” application that gathers the energy expenses of every gadget in a company.

Finally, the ”Aggregator Management System” application is the core of the Aggregator´s system. It is composed of two applications, the ”Financial Reward” application, which allows a customer to track and access its financial rewards, and the ”Pooling” application, which is responsible for pooling a customer´s electrical assets and directing the energy of the energy of the electric asset to both DSO´s and TSO´s. The applications needed to support the proposed business models are represented in Fig. 5.1. This applicational backbone provides several applicational services that supply the business layer and are fundamental for the business models proposed to be provided and create value for any customer.

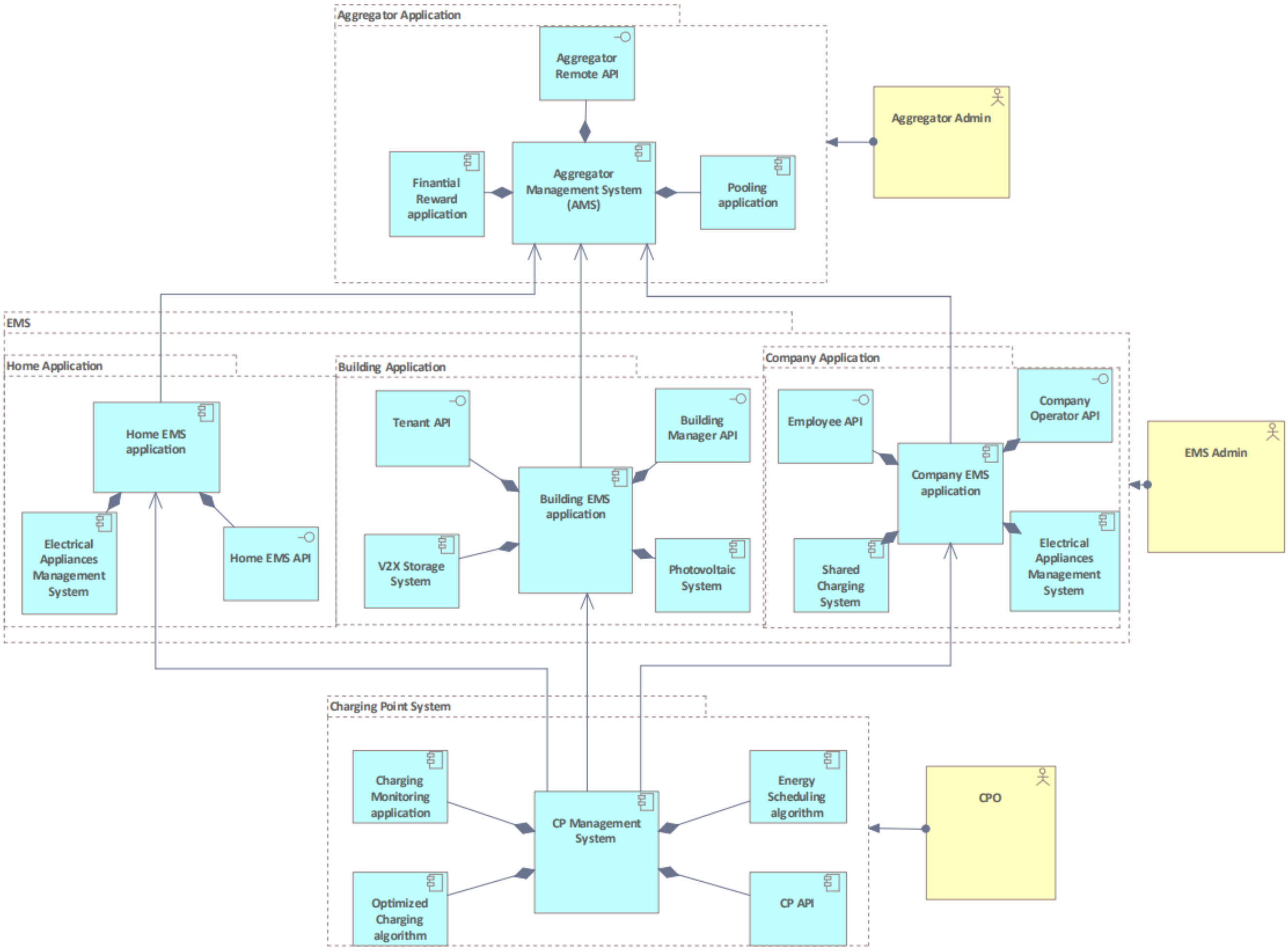

Figure 5.1: EV Domain applicational backbone (ArchiMate notation)

5.2 Specific Application View

A use case model and a domain model were developed for the ”Charging Point”, ”EMS”, and ”Aggregator” systems. The use case diagram is important to model the behavior of a system and help capture the requirements of that system, being used in all phases of the development cycle. The domain diagram is created in the initial phase of software development and is important to record and define terms identified during the Requirement Analysis, providing a single definition of these terms and their relationships [17].

5.2.1 Charging Point Application

The initial step in utilizing the ”CP” system is the CP configuration, which is managed by a ”CP Operator”. After successful configuration, the integration with an EMS is required. For this integration to be accomplished, coordination between the CP-Operator and EMS-Operator is necessary. Once this communication link is established, the "CP" system promptly notifies the "EMS" system.

Subsequently, end-customers must authenticate themselves within the system. Although the "CP" application provides an authentication interface, the actual authentication process is conducted exclusively within the "EMS" system, as it holds the responsibility of maintaining authentication details. Once the authentication step is successfully completed, end-customers gain the capability to perform two fundamental operations: charging or discharging their electric vehicles. Additionally, end-customers have the option to track the history of their operations conducted within the system (Monitor Operations) . Fig. 5.2 shows the "CP" system´s use case model.

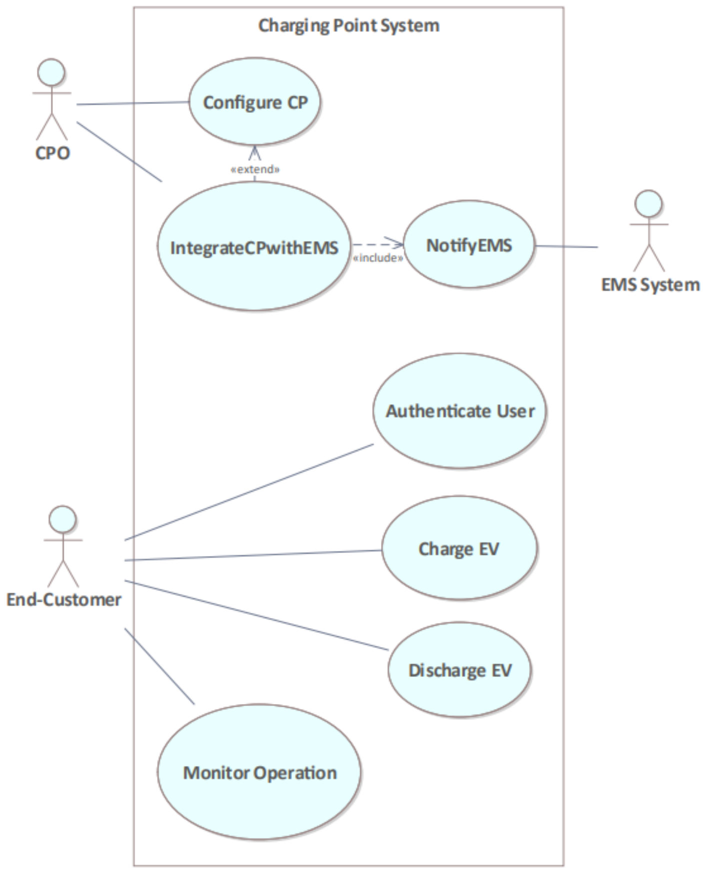

Figure 5.2: Charging Point Use Case model (UML Notation)

To support the system effectively, several key entities are required. The first entity is "CPSetup" which holds essential attributes like the charging point's IP address and security key. This allows for a secure integration with the EMS system, ensuring a secure flow of data between these systems.

After a successful integration, the "Operation" entity keeps track of crucial information such as the start time, end time, and duration of each operation conducted within the system. This data enables comprehensive monitoring and analysis of charging and discharging activities.

Each user within the system is represented by the "User" entity, which possesses a unique identifier, a name, and a description. These attributes facilitate proper identification and management of individual users and their respective activities.

For a visual representation of the "CP" system's domain model, please refer to Fig. 5.3.

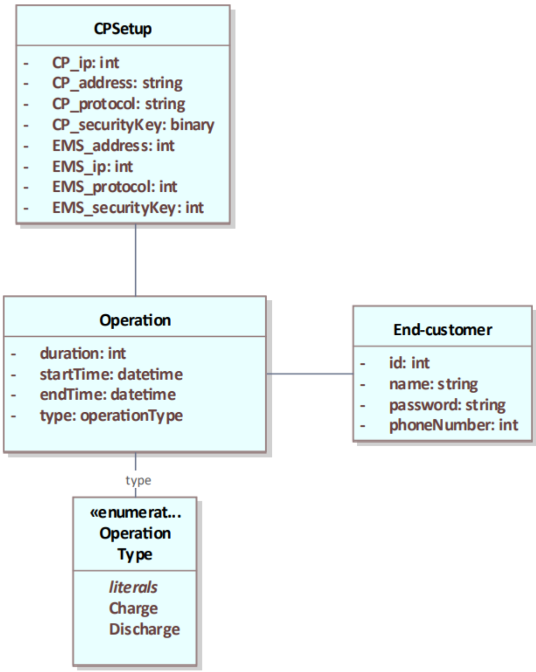

Figure 5.3: Domain Model of the CP System (UML Notation)

The development of a requirement specification holds significance in the early stages of application development. It empowers developers to proactively identify key elements such as actors, use cases, user stories, and their relationships, thereby saving time and costs during the development process. By clearly defining the system's concerns, this specification sets a solid foundation for the application's development [41].

In this thesis, the requirement specification design was based on UML models presented in section 5.2. While the focus in this section lies on the requirement specification for the "CP" system, the complete requirement specification for the "CP", "EMS", and "Aggregator" systems can be consulted in A. The development process and structure for these systems follow the same approach as the charging point system.

The initial step in the requirement specification process involved identifying the actors. Actors represent end-users and external systems that directly interact with the system under study. In certain situations, they may also include timers and other complex conditions that trigger specific use cases [5]. The analysis of UML use case diagrams facilitated a systematic specification of actors for the application systems, as exemplified in Listing 5.1.

```
Actor aU_CP-Operator "CP-Operator" : User
Actor as_EMSystem "EMS System" : External System
Actor aU_End-Customer "End-Customer" : User
```

Listing 5.1: Charging Point system actor specification

The second step in the requirement specification process involved defining actions. In the context of a requirement specification, an action refers to an activity performed by one or more actors within the system to achieve a specific result. These actions play a crucial role in shaping the behavior and functionality of the application.

For the charging point application, the specified actions are outlined in Listing 5.2. These actions outline the tasks and operations that various actors can perform to interact with the system and attain desired outcomes.

```
ActionType aConfigure "Configure"
ActionType aIntegrate "Integrate"
ActionType aNotify "Notify"
ActionType aAuthenticate "Authenticate"
ActionType aCharge "Charge"
```

Listing 5.2: Partial Charging Point system action specification

The third step in the requirement specification process involved specifying data entities. A data entity represents an abstraction from the physical implementation of database tables [42]. These entities define the essential data elements and their relationships, providing a clear understanding of the data structure and organization within the system.

For the Charging Point system, the data entities have been derived from the Charging Point domain model, and they are outlined in Listing 5.3. These entities encompass the key data elements and attributes that are integral to the functioning of the system, enabling effective data management and manipulation.

```
DataEnumeration OperationType values (Charge,Discharge)

DataEntity e_Operation "Operation" : Transaction [
```

```
attribute StartTime "startTime" : DateTime [constraints (PrimaryKey)]
attribute EndTime "EndTime" : DateTime
attribute Duration "Duration" : Integer
attribute OperationTyp "OperationType" : DataEnumeration OperationType
description "Operations"]
```

Listing 5.3: Partial Charging Point system data entity specification

The final step in the requirement specification process was the use case specification. Traditionally, a use case refers to a sequence of actions that one or more actors perform in a system to achieve a specific result. The RSL UseCase, however, refines this definition by incorporating various aspects and rules, enhancing its clarity and precision [5].

The use case specification developed for the charging point application is presented in Listing 5.4. It is important to note that this specification is not overly detailed, as it is intended for the initial stages of an agile project. As such, it may not include elaborate scenarios and step-by-step instructions. Instead, it provides a concise and high-level overview of the use cases, outlining the essential interactions and functionalities that actors can perform within the system.

```
UseCase uc_ConfigureCP "Configure Charging Point" : EntityUpdate [
    primaryActor aU_CP Operator
    dataEntity e_CPSetup
    actions aConfigure, aUpdate
]
```

Listing 5.4: Partial Charging Point system use case specification

Finally, for a more comprehensive understanding of the proposed model, the complete RSL specification for the ”Charging Point” system is presented in Listing. A.1.

5.2.2 EMS Application

The operation of the ”EMS” system commences with the crucial ”CPSetup” process, a foundational step that lays the integration groundwork. This initial phase acts as the backbone upon which the entire EMS system is built. Once this intricate integration process is successfully concluded, the system moves forward under the capable hands of the ”EMS Admin.” It is the responsibility of the ”EMS Admin” to activate the EMS services, ushering in a new realm of energy management for its users.

Upon activation, these services delve deep into the heart of every ecosystem, vigilantly monitoring the energy consumption patterns. This meticulous observation serves a dual purpose. Firstly, it empowers the adept ”EMS Admin” to optimize the consumption of each ecosystem under its purview. Through insightful analysis of the gathered data, the administrator can implement strategies that promote efficient energy use, thereby contributing to a more sustainable environment.

Secondly, the data collected during this monitoring process becomes a valuable tool for every EMS user. It offers an unprecedented opportunity for individuals to track their own energy consumption patterns, fostering a heightened awareness about their ecological footprint. Moreover, this data also provides users with insights into the collective energy consumption of the entire ecosystem, fostering a sense of community and shared responsibility among its members.

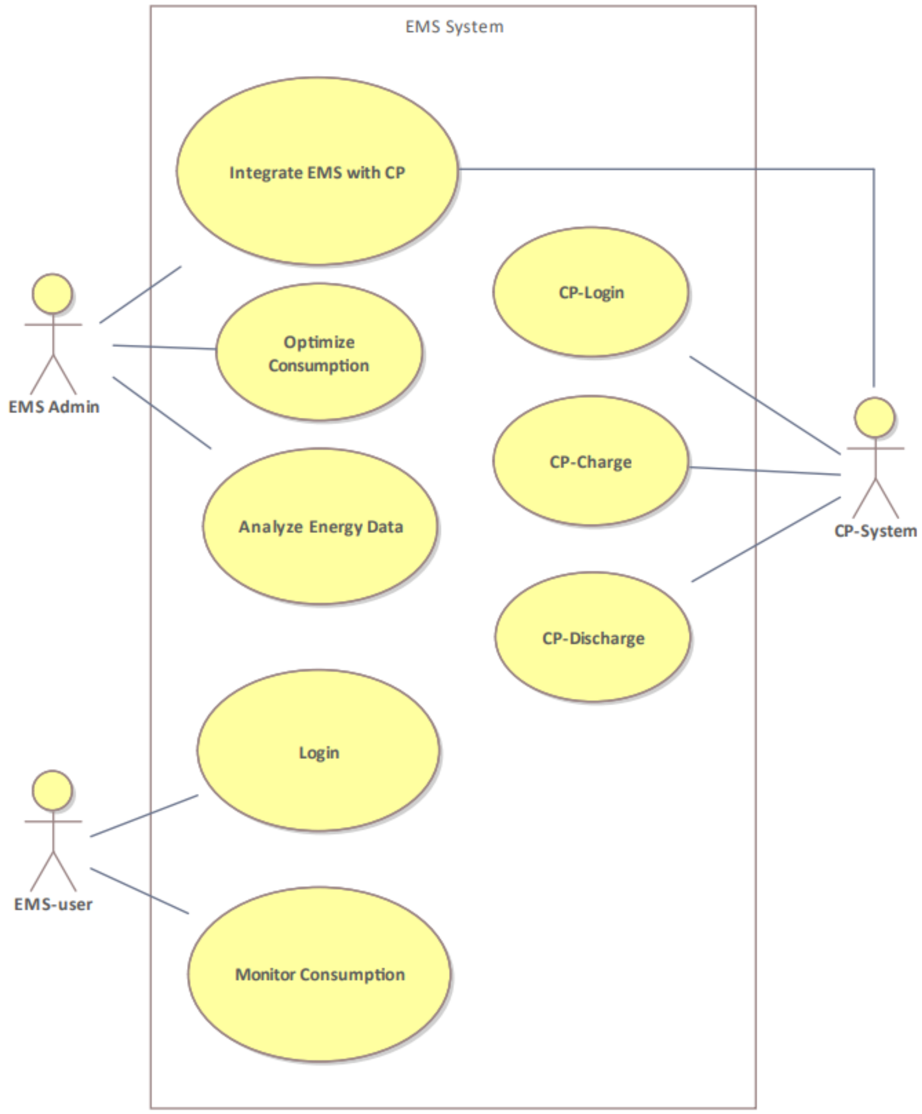

Figure 5.4: EMS Use Case model (UML Notation)

The EMS use case model, as illustrated in Figure 5.4, and the EMS domain model, as illustrated in Figure 5.5, encapsulate this intricate process. It stands as a visual representation of the seamless integration, meticulous monitoring, and user-centric approach that defines the EMS system. Through this comprehensive model, the complexities of energy management are streamlined, empowering both administrators and users alike to make informed decisions, thereby shaping a more sustainable future for all.

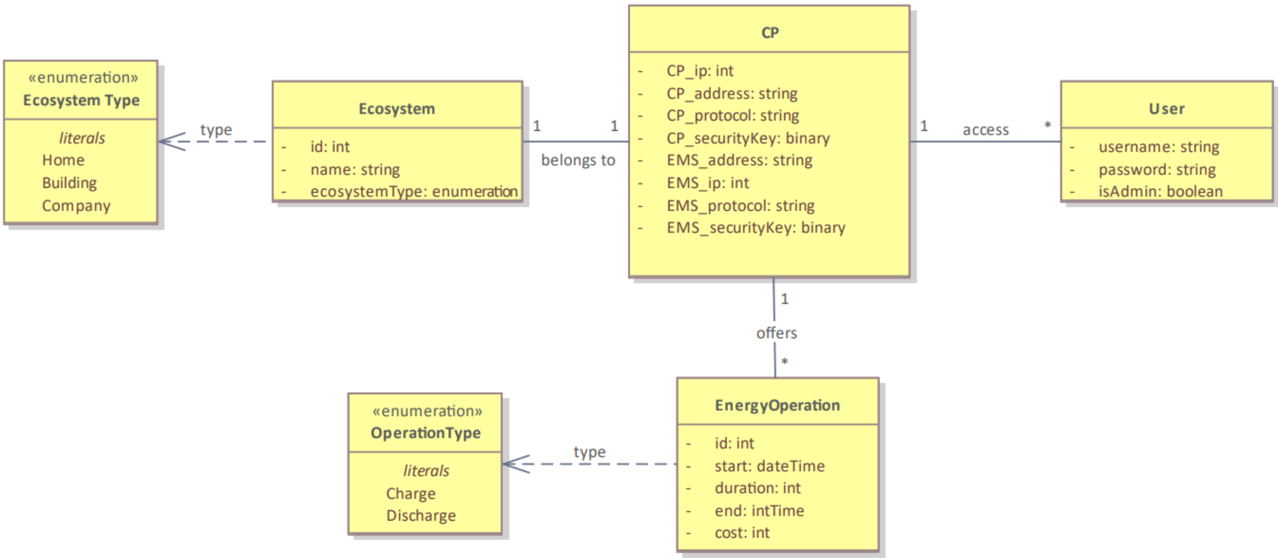

Figure 5.5: Domain Model of the EMS System (UML Notation)

5.2.3 Aggregator Application

The utilization of the "Aggregator" system begins with integration into the existing EMS, a collaborative effort facilitated by the Aggregator Admin and the EMS Operator. This integration is a crucial step in ensuring the smooth operation of the system, as it paves the way for the aggregation and management of electric assets from various sources.

Once this integration is successfully accomplished, the Aggregator Admin delegates the V2X service management within the ecosystem to a dedicated V2X Manager. This managerial role is pivotal in overseeing the day-to-day operations of the V2X services, ensuring they meet the needs of the ecosystem's participants.

With the integration of electric assets from various customers, the "Aggregator" system gains the capability to offer V2X services to both DSOs and TSOs . These services, managed at a local level by a V2X manager, enable a more dynamic and responsive approach to managing electricity supply and demand. DSOs can optimize their grid operations, while TSOs can better balance the broader energy network.

Moreover, the "Aggregator" system empowers users with financial rewards and convenient V2X services. Users can leverage their electric assets, such as electric vehicles and stationary batteries, to contribute to grid stability and earn incentives in return. This not only benefits individual users but also contributes to a more resilient and sustainable energy infrastructure. The "Aggregator" system's application is presented in Fig. 5.6.

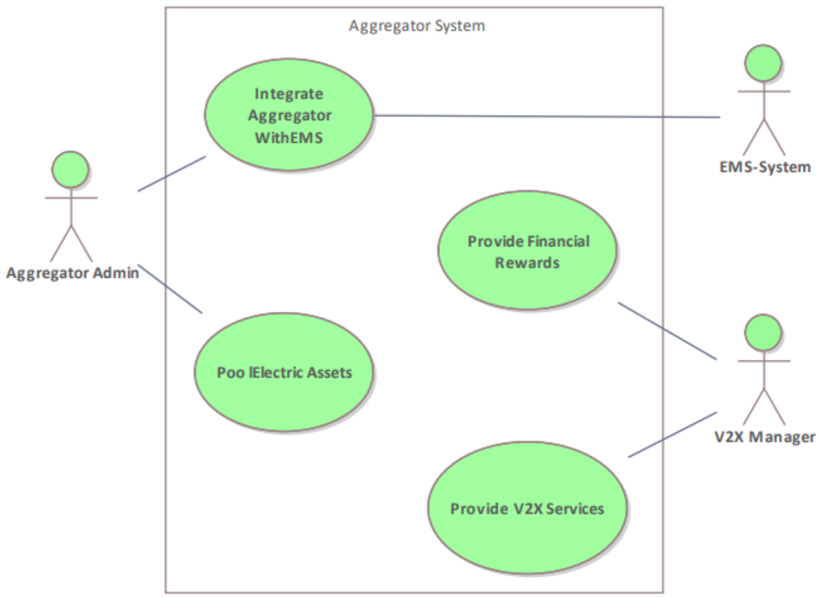

Figure 5.6: Aggregator Use Case model (UML Notation)

To ensure the smooth functioning of the "Aggregator" system, several crucial entities and processes come into play. Firstly, the Aggregator setup demands specific attributes, including the aggregator and EMS addresses. These attributes serve as the foundation for the system's integration into the existing energy infrastructure, ensuring that data and control signals are accurately routed to and from the right locations.

Secondly, it is essential to keep track of the pooled electric assets within the system. This entails maintaining a comprehensive inventory of the electric assets contributed by various users, along with the identification of the respective ecosystems they belong to. This tracking is instrumental in optimizing asset utilization, as it allows for efficient allocation and management of these resources within the aggregator's ecosystem. Lastly, the management of financial rewards within the "Aggregator" system is crucial. It must be closely aligned with the energy provided by each user. This synchronization enables fair and balanced compensation for users based on their contributions to the system's energy balance. Users who provide more energy,by adjusting their energy consumption patterns or sharing excess energy, should receive commensurate rewards, incentivizing active participation and support for grid stability. A visual representation of the ”Aggregator” system’s domain model is depicted in Fig. 5.7. Finally, for a more comprehensive understanding of the proposed model, the RSL specification for the ”Aggregator” system is presented in Listing A.3.

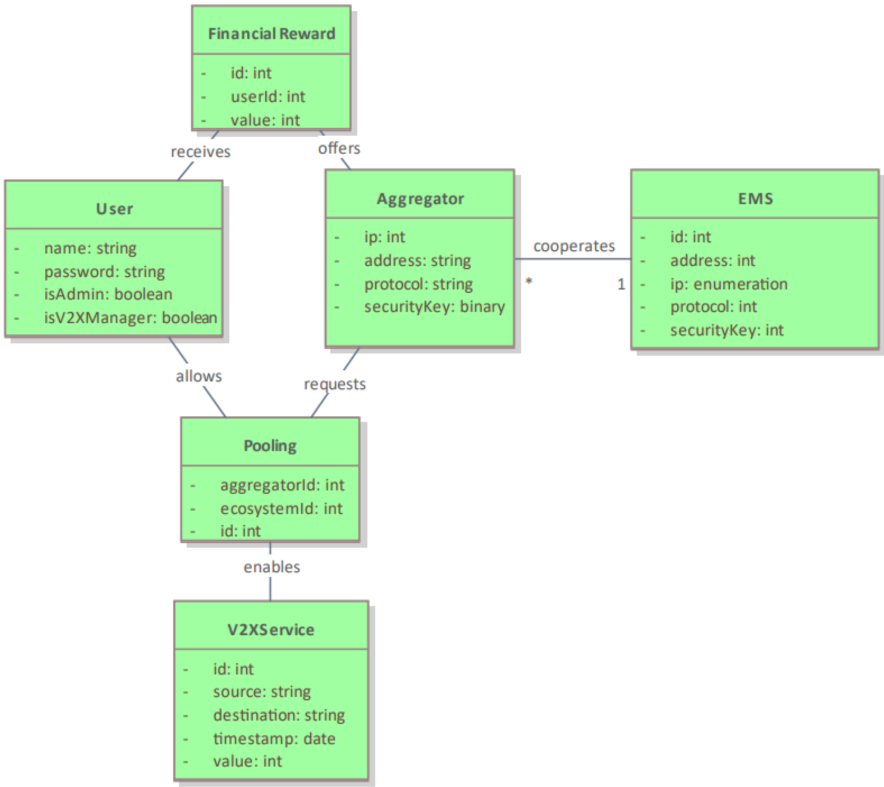

Figure 5.7: Domain Model of the Aggregator System (UML Notation)

6

Evaluation

Contents

After successfully implementing the business and application models presented in the previous chapters, the subsequent phase involves conducting a thorough evaluation to assess their effectiveness and relevance. To ensure a rigorous evaluation process, careful participant selection is crucial. This chapter outlines the process of participant selection, with a focus on identifying individuals with expertise in the fields of electric mobility and systems architecture.

6.1 Participants

The evaluation process for the complex and abstract subject matter prioritized professionals and researchers with expertise in electric mobility and systems architecture. The selection of participants aimed to ensure a diverse and representative group, considering factors such as their relevant knowledge and experience in the field.

To meet these criteria, the pool of participants was drawn from the ”EV4EU” partner pool, which provided several advantages. First, it offered a large number of participants, allowing for a comprehensive and varied evaluation. Second, the participants came from four different countries, bringing diverse perspectives on electric vehicle realities and system modeling from different regions. This geographical diversity provided a broader understanding of the subject matter and its implications across various contexts.

Furthermore, the participants in the ”EV4EU” partner pool held different positions and roles within the electric mobility domain, ranging from industry professionals to academic researchers and government representatives. This ensured a wide range of viewpoints and expertise in the evaluation process.

Table. 6.1 presents the demographic characteristics of the participants in the evaluation. The participants are representatives from four countries, with Portugal having the highest representation. It is important to note that all survey respondents were male, indicating a gender imbalance in the participant pool.

Regarding professional experience, the majority of individuals fall within the 10 to 20 years of experience range, showcasing a significant level of expertise in their respective fields. The participants come from diverse backgrounds within the electric mobility and systems architecture domain, occupying various roles and positions.

While the participants' expertise and experience are valuable for the evaluation, the lack of gender diversity is a notable limitation. Overall, the evaluation benefits from the wealth of knowledge and expertise brought by the participants, but addressing gender diversity in future evaluations will enhance the overall quality and representativeness of the feedback received.

Table 6.1: Evaluation interviewees

Country	Gender	Academic Level	Years of Professional Experience	Professional Fields
Denmark	Male	PhD	Between 10 and 20	Professor/Reseacher
Denmark	Male	PhD	Between 10 and 20	IT consultant
Greece	Male	MSc	More than 20	Production Manager
Portugal	Male	BSc	Between 10 and 20	Smart Grid Manager
Portugal	Male	MSc	Between 10 and 20	Architecture Manger
Portugal	Male	MSc	Between 10 and 20	Senior Engineer
Portugal	Male	PhD	Between 10 and 20	Professor/Researcher
Portugal	Male	PhD	Between 10 and 20	Smart Grid Manager
Slovenia	Male	PhD	More than 20	Professor/Researcher
Slovenia	Male	MSc	More than 20	Architecture Manager

6.2 Questionnaire

The survey sent to the participants was designed using Google Forms and consisted of several pages. Given the balance between brevity and clarity, the questionnaire and accompanying draft paper centered predominantly on the Home business model within the realm of business-level models. Similarly, when exploring application-level models, the primary focus was on the Charging Point application.

The first page served as an explanation page, where participants were introduced to the context of the questionnaire. It provided information about the focus of the survey, which was centered on the Home-based ecosystem, and included a summary of the thesis contents. Additionally, the first page introduced the writers and supervisors of the thesis. The explanation page also outlined the steps necessary to complete the questionnaire, ensuring that participants were aware of the process and what to expect. This clear guidance facilitated a smooth and efficient survey completion process.

The second page of the questionnaire focused on gathering information about the participants. It included questions related to the demographic characteristics of the participants, such as their country of representation, gender, and professional experience. This information helped in understanding the diversity and expertise of the participant pool, which was particularly valuable in the evaluation process.

On the third page, the evaluation of the business models took place. Multiple choice grids were used to assess the correctness and real-world impact of the proposed models. Participants were given the opportunity to select their responses and provide additional feedback in open-ended text boxes below each question. Each question had the possible five following answers: 0 (Do not know), 1 (Very low), 2 (Low), 3 (Medium), 4 (High), 5 (Very High). By incorporating a range of response options and open-ended text boxes, the evaluation sought to capture both quantitative and qualitative feedback from participants. This hybrid approach facilitated a comprehensive assessment of the business models, allowing participants to express their views and expertise while also providing numerical ratings for a more standardized evaluation.

The fourth page was dedicated to the evaluation of the application-level models, following a similar structure as the previous page. This section aimed to gather insights into the effectiveness and suitability of the application models in supporting the proposed business models.

Finally, on page five, participants were presented with three optional open-ended questions. These questions encouraged participants to share their perspectives and insights on the real-world impact of the proposed models. This open-ended format allowed participants to provide in-depth feedback, suggestions, and reflections beyond the scope of the multiple-choice questions.

6.3 Result analysis

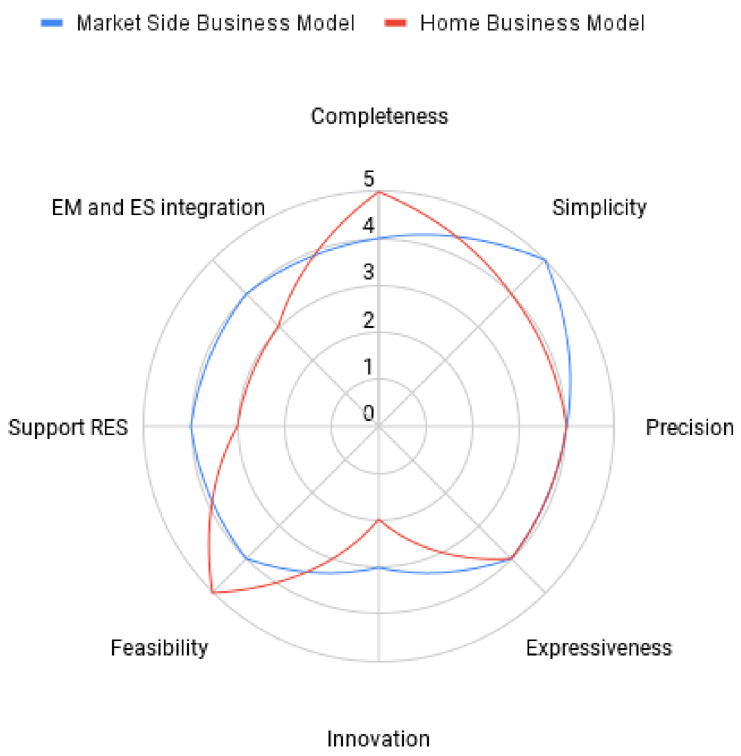

Figure 6.1: Business Model evaluation results

The outcomes of the business model evaluation process are illustrated in Figure 6.1 . The scores, ranging from 0 to 5, were calculated by averaging the responses from each expert and rounding to the nearest whole number.

As evident from the chart, the Market Side business model garnered higher perceived cohesiveness ,feasibility and integration between the electricity market and the electric system, signaling its potential for relatively straightforward implementation in the near future. This may stem from the ongoing shifts within the market, already aligning with the proposed direction.

The Home business model exhibited lower levels of innovation, yet it showcased robust expressiveness, simplicity, and precision. Notably, the results underscore the models' strong points, particularly their thoroughness and practical viability.

In summary, the evaluation outcomes emphasize the different strengths of the two business models. While the Market Side model aligns well with current trends, the Home model stands out for its clarity and feasibility. These findings provide valuable insights into the models' attributes and their potential real-world impact.

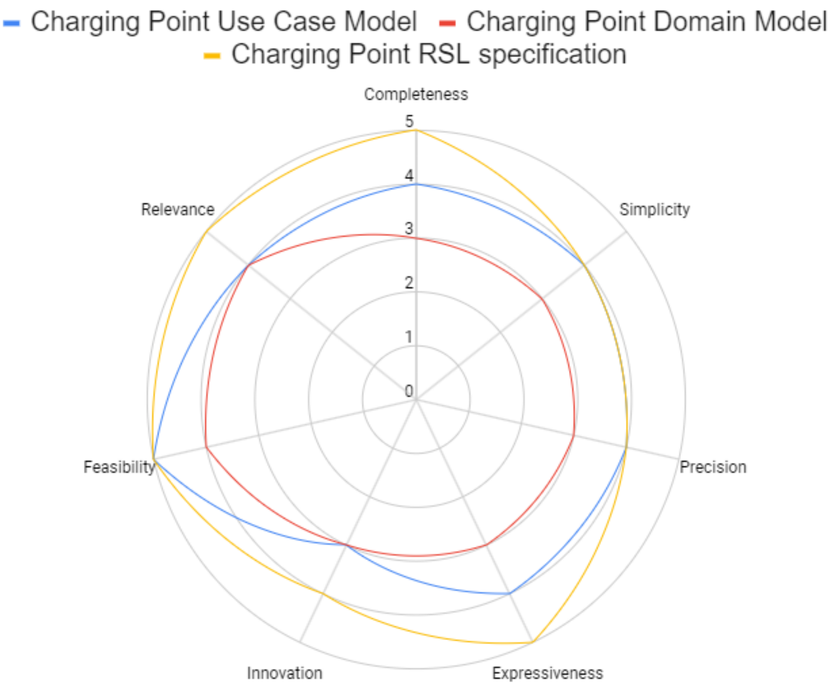

Figure 6.2: Application Model evaluation results

The evaluation of the application models, as presented in Figure 6.2, reveals important observations and areas of strength and improvement. Starting with the Charging Point use case model, it is evident that its primary strength lies in its feasibility, suggesting that its proposed functionalities are practical and attainable. However, the model's relatively lower innovation score may stem from its strong alignment with current industry practices, potentially limiting its forward-looking approach.

Turning to the Charging Point domain model, it becomes apparent that this model received lower scores compared to the other two. Feedback from experts regarding this model was varied, highlighting a divergence of opinions. While some experts found the model to be overly simplified and lacking certain essential elements, others considered it to be overly complex, potentially impeding its comprehensibility.

Lastly, the Charging Point RSL specification garnered the highest scores among the application models. This result underscores its effectiveness in conveying complex data in a straightforward and complete manner. The balance between simplicity and comprehensiveness likely contributed to the positive perception of feasibility.

7

Conclusion

Contents

This final chapter presents the conclusion of the research and implementation of the EV ecosystems models and the future work that still remains open and that would allow to further improve these models.

7.1 Contributions

The purpose of this dissertation was to propose innovative business models for different EV ecosystems as well as their corresponding applicational requirements.

To achieve this objective, the proposed business models are built upon three distinct business modeling techniques focused on providing innovative products and services utilizing cutting-edge V2X technologies and methods to an end customer. These techniques serve as a foundation for creating sustainable and profitable business ventures within the electric mobility domain. By leveraging state-of-the-art V2X technologies and methods, the business models aim to unlock new opportunities for delivering enhanced experiences, optimizing energy management, and fostering the integration of electric vehicles into the broader energy grid.

To ensure a practical implementation of the business models, it is necessary to establish a seamless applicational integration among the diverse entities involved. For the context of the Home, Building, and Company ecosystems, three main applicational systems were proposed, the ”Charging Point”, ”EMS” and ”Aggregator” systems. In addition to representing these systems in ArchiMate, the modeling development process involved the creation of a use-case and domain model. This approach had the objective of capturing the requirements of each system and recording and defining important terms. In the final phase of the modeling development, the requirement specification for each system was compiled. This specification serves as a comprehensive record of the system´s stakeholders, data entities, use cases, and constraints.

The models proposed were evaluated by experts in the fields of electric mobility and systems architecture belonging to the EV4EU project. The results were encouraging, namely regarding the correctness of the models proposed. However, it is important to acknowledge the limitations faced during the evaluation process, notably the lack of female participants.

All in all, our proposal aims at increasing the economical viability of adopting and supporting EVs, to both market participants and end-customers alike. This increased economic attractiveness is attributed to two main factors: improved cost-efficiency in electrical energy usage and the introduction of new energy trading services.

7.2 Future Work

There are several ways of continuing the work developed in this project. The first and foremost is to improve the business and application models developed based on the feedback received during the evaluation phase. The main features to improve during the refinement would be the feasibility of the business models and to increase the accommodation of RES adoption.

This dissertation focused mostly on the enterprise architecture of the EV ecosystems, thus the use cases proposed were UML based. It would also be interesting to develop business use cases. The main advantage of business use-cases over UMl use-cases is that a business use case follows a much more strict and complete framework and outline [43].

The evaluation conducted centers mostly on qualitative data gathered from experts answering a questionnaire. Moving forward it would be interesting to perform the evaluation following two different approaches. One approach would be to introduce KPI to the newly developed business use cases. By defining specific KPIs for each business use case, it becomes possible to measure and track the performance and success of the implemented models in a quantifiable manner. By incorporating a quantitative evaluation approach with the use of KPIs, it becomes possible to measure and communicate the tangible results and success of the business models, supporting informed decision-making and enhancing the overall understanding of their value and impact [44].

An alternative and valuable evaluation approach would involve primarily targeting EV users and assessing the alignment of their EV usage patterns with the proposed business models. This user-centric evaluation would provide insights into how well the business models cater to the needs and behaviors of the end customers, ensuring their satisfaction and engagement. By targeting EV users and assessing the alignment of their usage with the proposed business models, this evaluation approach offers a user-centered perspective, ensuring that the models meet the needs and expectations of the end customers, ultimately leading to increased adoption and success in the market [45].

Summing up, the introduction of business use cases and the evaluation either through KPIs or user-centered would shed new light on the models developed and would help improve these models both in terms of economic viability and user satisfaction.

A

RSL Specifications

This appendix provides a comprehensive overview of the developed RSL specifications. The initially presented is the "Charging Point" RSL specification, followed by the "EMS" and "Aggregator" speficiations.

```
Package EV4EU_EA

Import EV4EU_EA_Libs.Common.*

System CPApp "CP-App" : Application
 [ description "CP-App ≡ responsible to
 ∩act within the user whilst the EV
 charging process occurs, and ∀ows the
 choice to which V2X option the EV user wants to opt on"
]
```

```
DataEntity e_CPSetup "Charging Point Setup" : Parameter [
  attribute CP_Ip "CP Ip" : Integer [constraints (PrimaryKey)]
  attribute CP_Address "CP Address" : String(30)
  attribute CP_Protocol "CP Protocol" : String(30)
  attribute CP_SecurityKey "CP SecurityKey" : Binary
  attribute EMS_Ip "EMS Ip" : Integer
  attribute EMS_Address "EMS Address" : String(30)
  attribute EMS_Protocol "EMS Protocol": String(30)
  attribute EMS_SecurityKey "EMS SecurityKey" : Binary
  description "Charging Point Setup"
]
DataEntity e_End-Customer "End-Customer" : Master [
  attribute Id "Id" : Integer [constraints (PrimaryKey)]
  attribute Name "Name" : String(30)
  attribute Description "Description" : String(30)
  description "Customers"
]
DataEnumeration OperationType values (Charge,Discharge,Save)

UseCase _ConfigureCP "Configure Charging Point" : EntitiesManage [
    primaryActor aU_CP Operator
    dataEntity e_CPSetup
    actions aConfigure
]
UseCase IntegrateCPWithEMS "IntegrateCPWithEMS": EntitiesManage [
    primaryActor aU_CPO supportingActors as_EMSAdmin
    dataEntity e_CPSetup
    actions aIntegrateEMS
    extensionPoints xp_Notify
]
UseCase NotifyEMS "NotifyEMS": EntitiesInteropSendMessage [
    primaryActor as_EMSAdmin
    dataEntity e_CPSetup
    actions aNotify
    extends IntegrateCPWithEMS onExtensionPoint xp_Notify
]
UseCase uAuthenticateUser "AuthenticateUser": EntityOther [
    primaryActor aU_End-Customer
```

```
    dataEntity e_End-Customer
    actions aAuthenticate
]
UseCase ChargeEV "ChargeEV": EntityOther [
    primaryActor aU_End-Customer
    dataEntity e_End-Customer
    actions aCharge

]
UseCase _DischargeEV "DischargeEV": EntityOther [
    primaryActor aU_End-Customer
    dataEntity e_End-Customer
    actions aDischarge
]
UseCase uMonitorOperationList "MonitorOperationList": EntityDashboard [
    primaryActor aU_End-Customer
    dataEntity e_End-Customer
    actions aMonitor
]
```

Listing A.1: Charging Point System complete specification

```
Package EV4EU_EA

Import EV4EU_EA_Libs.Common.*

System EMSapp "EMSapp" : Application
[ description "EMSapp connects
the CPapp to the AgregatorApp.
It also ≡ responsible to keeping operation
and user authentication data. This specification
focuses on the EMS ´systems pointof view. "
]
Actor aU_EMS-user "EMS-user" :
EMS-user [description "Customer uses electric assets"
]
```

```
DataEntity e_User "User" : Master [
  attribute Name "Name" : String [constraints (PrimaryKey)]
  attribute Password "Password" : String
  attribute ≡Admin "isAdmin" : boolean
  attribute ≡V2XManager "isV2XManager": boolean
  description "User"
]
DataEntity e_Ecosystem "Ecosystem" : Master [
  attribute Id "Id" : Integer [constraints (PrimaryKey)]
  attribute Name "Name" : String
  attribute ecosystemType "ecosystemType" : boolean
  description "Ecosystem"
]
DataEntity e_EnergyOperation "EnergyOperation" : Master [
  attribute Id "Id" : Integer [constraints (PrimaryKey)]
  attribute Start "Start" : dateTime
  attribute Duration "Duration" : Integer
  attribute End "End" : dateTime
  attribute Cost "Cost" : Integer
  description "Ecosystem"
]
DataEnumeration EcosystemType values (Home,Building,Company)

DataEnumeration OperationType values (Charge,Discharge)

UseCase IntegrateEMSWithCP "IntegrateEMSWithCP" : EntitiesManage [
    primaryActor aU_EMSAdmin
    dataEntity e_EMSetup
    actions aIntegrateEMS
    extensionPoints xp_Activate
]
UseCase Login "Login" : EntitiesManage [
    primaryActor as_EMS-user
    dataEntity e_Operation
    actions aAuthenticate
]
UseCase OptimizeEnergyConsumption "OptimizeEnergyConsumption" : EntitiesManage [
    primaryActor aU_EMSAdmin
```

```
    dataEntity e_EnergyConsumption
    actions aOptimize
]
UseCase MonitorConsumption "MonitorConsumption" : EntitiesManage [
    primaryActor aU_EMS-user
    dataEntity e_EnergyConsumption
    actions aAnalyzeData
]
UseCase AnalyseEnergyData "AnalyzeEnergyData": EntityUpdate [
    primaryActor aU_CustomerAdmin
    dataEntity e_EMSetup
    actions aManage
]
```

Listing A.2: EMS System complete specification

```
Package EV4EU_EA

Import EV4EU_EA_Libs.Common.*

System AggregatorApp "Aggregator Application" : Application
[ description "AggregatorApp serves two sides:
the market and demand side to the EV domain.
The app offers flexibility services to the
market side and financial rewards to the demand side."
]

Actor aU_AggregatorAdmin "Aggregator Admin" :
User [description "AggregatorAdmin manages the funcionalities
to the Aggregator App"
]

Actor aU_V2XManager "V2X Manager" :
User [description "V2XManager acts like a middleman between
the Aggregator and the User"
]
```

```
DataEntity e_Aggregator "Aggregator" : Parameter [
  attribute Ip "Ip" : Integer [constraints (PrimaryKey)]
  attribute Address "Address" : String(30)
  attribute Protocol "Protocol" : String(30)
  attribute SecurityKey "SecurityKey" : Binary
  description "Aggregator"
]
DataEntity e_EMS "EMS" : Parameter [
  attribute Ip "Ip" : Integer [constraints (PrimaryKey)]
  attribute Address "Address" : String(30)
  attribute Protocol "Protocol" : String(30)
  attribute SecurityKey "SecurityKey" : Binary
  description "EMS"
]
DataEntity e_Pooling "Pooling" : Parameter [
  attribute Id "Id" : Integer [constraints (PrimaryKey)]
  attribute AggregatorId "Aggregator Id" :
        Integer [constraints (NotNull ForeignKey (e_AggregatorSystemSetup))]
  attribute EcosystemId "Ecosystem Id" :
        Integer [constraints (NotNull ForeignKey (e_User))]
  description "Pooling"
]
DataEntity e_User "User" : Master [
  attribute Name "Name" : String [constraints (PrimaryKey)]
  attribute Password "Password" : String
  attribute ≡Admin "isAdmin" : boolean
  attribute ≡V2XManager "isV2XManager": boolean
  description "User"
]
DataEntity e_V2XService "V2XService" : Parameter [
  attribute Id "Id" : Integer [constraints (PrimaryKey)]
  attribute Source "Source" : String
  attribute Destination "Destination" : String
  attribute Value "Value" : Integer
  attribute TimeStamp "TimeStamp" : Date
  description "V2XService"
]
DataEntity e_FinancialReward "FinancialReward" : Master [
```

```
  attribute Id "Id" : Integer [constraints (PrimaryKey)]
  attribute UserId "UserId" : Integer [constraints (NotNull ForeignKey (e_User))]
  attribute Value "Value" : Integer
  description "Financial Rewards"
]
UseCase IntegrateAggregatorWithEMS "IntegrateAggregatorWithEMS" : EntityCreate [
    primaryActor aU_AggregatorAdmin supportingActors aU_EMS-System
    dataEntity e_AggregatorSystemSetup
    actions aIntegrateAgg
]
UseCase PoolElectricAssets "PoolElectricAssets" : EntitiesManage [
    primaryActor aU_AggregatorAdmin
    dataEntity e_Pooling
    actions aPool
]
 UseCase ProvideFinancialRewards "ProvideFinancialRewards" : EntitiesManage [
    primaryActor aU_V2XManager
    dataEntity e_FinancialReward
    actions aProvideReward
]
 UseCase ProvideV2XServices "ProvideV2XServices" : EntitiesManage [
    primaryActor aU_V2XManager
    dataEntity e_V2XService
]
```

Listing A.3: Aggregator System complete specification

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