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SCUOLA DI INGEGNERIA INDUSTRIALE
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eMall – e-Mobility for all

Requirement Analysis and Specification Document - RASD

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1 | Introduction

1.1. Purpose

Widespread electrification of transport is the most efficient way to reach Europe's climate objectives for the sector and electric charging is the main asset to overcome the obstacles of the take-up of electric vehicles (EVs). EVs can reduce CO2 by an estimated annual 600,000 tons by 2030, going towards a carbon neutral Europe and the importance of this aim raises the problem of having efficient systems that manage the charging services. The e-Mall is thought as an all-encompassing application that oversees the entire process from the user interaction to the effective recharge of the EV's battery.

The main goal we want to achieve with the e-Mall software is to help The EVDs (electric vehicle drivers) to have a better access to recharge and to be able to book a charging point in order to avoid interference with his daily plans. Another important purpose of the system is to safeguard not only the users but also the providers of the service and this is made thought privacy agreements and the actual interaction that guarantees to supervise the both interested parts, in order to get the best possible service and pay for it accordingly, having also a technical and economic exploitation of the charging infrastructures.

In this context there is an increase in the requested electric energy, but large amounts of power in short periods would require investments in the reinforcement of the distribution networks, which have not been designed to accommodate such load. It becomes necessary to introduce new systems and solutions to optimize the operation of distribution networks and we can identify the DSOs as important actors that have to monitor the networks in order to have a safe and controlled supply of the energy and manage faults in the assets. The DSOs communicate with the e-Mall, and in particular with the CPMS modules that decide from where to acquire energy in order to satisfy as well as possible the CPOs economical interests.

Goal	Description
G1	The EVD is able to identify the charging stations nearby
G2	The EVD is able to visualize the tariffs of the charging stations
G3	The EVD is able to visualize any special offer available at the charging station
G4	The EVD is able to book a charge in a specific charging station for a certain time-frame
G5	The EVD is able to start the charging process at a certain station
G6	The EVD is able to pay for the obtained service
G7	The CPO can decide from which DSO to acquire energy
G8	The CPO can decide the cost of charging
G9	The CPO can set special offers
G10	The CPO can decide whether to store or not energy in batteries
G11	The CPO can decide whether to use the energy available in the batteries

Table 1.1: Goals

1.2. Scope

World phenomena	Description
WP1	The EVD wants to charge the EV's battery
WP2	The EVD wants to plan where and when to charge the EV's battery
WP3	The prices for energy often vary in real world economy
WP4	The providers of energy, as marketing strategy, have special offers during certain time periods.
WP5	The providers of the charging service make special offers during certain time periods.
WP6	EVs may have an integrated rectifier that converts AC electricity to DC
WP7	Some type of chargers have an integrated rectifier that converts AC electricity to DC. They supply the EV directly with DC current
WP8	A charging of type X, provides electricity in mode C and is given through Z connectors
WP9	A charging station is owned and managed by one CPO

WP10	A CPO owns and manages one or more charging stations
WP11	A charging station may be equipped with batteries
WP12	*Charging stations equipped with batteries grant more flexibility to CPOs on how to choose between the energy stored in the batteries and the one offered by DSOs*
WP13	Low voltage (3.7 - 11 kW) chargers need more time to charge the battery
WP14	Medium voltage (22-90 kW) chargers need less time to recharge a battery of capacity C than a low voltage charger
WP15	High voltage ($>$ 90 kW) chargers need less time to recharge a battery of capacity C than a medium voltage charger
WP16	Batteries can only be charged with direct current (DC) electric power
WP17	Given a continuous supply of power W, and a battery with finite capacity C, than the charging time T is finite.
WP18	A battery can store a finite amount of energy, given by its capacity C.
WP19	The charger of a specific charging station may be unusable because of maintenance or faults
WP20	The DSOs distribute and manage energy from the generation sources
WP21	The DSOs provide energy to a charging station
WP22	Most electricity is delivered from the power grid as alternating current (AC)
WP23	During the day the electric power supplied to the station can vary
WP24	During the day a short-duration reduction in the voltage supplied to the electrical power systems may occur due to high current demand or faults in the system.
WP25	During the day a momentary increase in voltage may occur. This may happen when a heavy load turns off in a power system.
WP26	The DSOs operate and manage the electricity distribution networks
WP27	The DSOs solve grid problems, such as faults and network breaks

Table 1.2: World Phenomena

Shared phenomena	Description	Controller	Observer
SP1	The eMall notifies the EVD when the charging process is finished	eMall	EVD
SP2	The EVD creates an account	EVD	eMall
SP3	The EVD in order to register inserts in the mobile app of the eMall the personal data (name, surname, payment details)	EVD	eMall
SP4	The EVD logs in	EVD	eMall
SP5	The EVD accepts the terms of service in order to use the eMall	EVD	eMall
SP6	The EVD shares its location with the eMall	EVD	eMall
SP7	The EVD confirms the payment from the mobile application of the eMall	EVD	eMall
SP8	The EVD deletes previously inserted EVs from its account	EVD	eMall
SP9	The EVD updates the specifications of the EVs on its account	EVD	eMall
SP10	The EVD adds a new EV to its account	EVD	eMall
SP11	The EVD inserts the maximum and minimum current supported by the EV	EVD	eMall
SP12	The EVD inserts the maximum power supported by the EV	EVD	eMall
SP13	The EVD inserts the inlet type of the EV	EVD	eMall
SP14	The EVD inserts whether the EV is equipped with a built-in rectifier	EVD	eMall
SP15	The EVD inserts the capacity of the battery in kWh	EVD	eMall

SP16	The eMall shows to the EVD the map of the charging stations nearby his location	eMall	EVD
SP17	The EVD chooses a charging station from the map	EVD	eMall
SP18	The eMall shows the user the rating of the charging station	eMall	EVD
SP19	The EVD inserts the expected time when he plans to start the charging process	EVD	eMall
SP20	The EVD inserts the expected time when he plans to end the charging process	EVD	eMall
SP21	The eMall shows to the EVD the list of available chargers of the charging station	eMall	EVD
SP22	The eMall shows the charger type and its connectors	eMci / eMma	EVD
SP23	The EVD chooses the charger he wants to use from the list of available ones	EVD	eMall
SP24	The eMall shows to the EVD the charger costs (per kWh, per minute, additional costs)	eMma/eMci	EVD
SP25	The eMall shows to the EVD the status of the charger	eMci	EVD
SP26	The eMall shows to the EVD the battery level of the connected EV	eMci	EVD
SP27	During the charging session the eMall shows to the EVD the power output of the charger	eMci	EVD
SP28	During the charging session the eMall shows to the EVD the remaining time to complete the charging process	eMci	EVD

SP29	The EVD starts the charging session from the charger	EVD	eMSP
SP30	*The CPMS asks the DSO about the current available energy sources, their prices, and special offers*	CPMS	DSO
SP31	The DSO dynamically changes the price of electricity	DSO	CPMS
SP32	The DSO changes dynamically the *energy sources* from which acquires energy	DSO	CPMS
SP33	The DSO makes special offers	DSO	CPMS
SP34	The CPO logs in	CPO	CPMS
SP35	The CPO selects the charging station for which to set the parameters (price, energy) of the charging service	CPO	CPMS
SP36	The CPO selects the DSO from which to acquire energy	CPO	CPMS
SP37	The CPMS shows to the CPO the *energy sources* and the relative current prices and special offers of the DSO	CPMS	DSO
SP38	The CPO sets the cost of charging	CPO	CPMS
SP39	The CPO can set a special offer	CPO	CPMS
SP40	The CPO selects the energy sources from which to acquire energy	CPO	CPMS
SP41	The CPMS shows if there are available batteries in the charging station	CPMS	CPO
SP42	The CPO selects the battery in which to store energy	CPO	CPMS
SP43	The CPO sets the amount of energy to store in the battery	CPO	CPMS
SP44	The CPMS dynamically shows to the CPO the number of EVs charging	CPMS	CPO

SP45	The CPMS dynamically shows to the CPO the charging stations consumption of energy	CPMS	CPO

Table 1.3: Shared Phenomena

1.3. Definitions, Acronyms, Abbreviations

1.3.1. Abbreviations

- **eMall**: e-Mobility for all
- **eMma**: e-Mall mobile application
- **eMci**: e-Mall charger interface
- **CPMS**: Charging Point Management System
- **CPO**: Charge Point Entity
- **eMSP**: Electric Mobility Service Providers
- **DMS**: Distribution Management System
- **DSO**: Distribution System Operator
- **EV**: Electric Vehicle
- **EVD**: Electric Vehicle Driver
- **EVSE**: Electric Vehicle Supply Equipment
- **HV**: High Voltage
- **LV**: Low Voltage
- **MV**: Medium Voltage
- **SCADA**: Supervisory Control and Data Acquisition
- **SCM**: Smart Charging Management
- **OMS**: Outage Management System

- **AC**: Alternating current
- **DC**: Direct current

1.3.2. Definitions

- **DSO**: typically the entity responsible for the operation and management of distribution networks – High, Medium and Low Voltage networks. For this purpose, the DSO typically owns systems such as Supervisory and Control Data Acquisition (SCADA)/ Distribution Management System (DMS) for the monitoring and general overview of the state of the network. It also owns other systems such as the Outage Management System (OMS) and Work Force Management System (WFMS) for addressing the network operation problems related with the continuity and quality of service.
- **CPO**: entity that technically manages all the EV infrastructure assets, depending of existing country regulation – this role can be assured by the DSO or other entity.
- **eMSP**: is the entity that can explore the economic side of the EV charging infrastructure, namely by selling energy for charging purposes.
- **CPMS**: is a software system that manages the charge point infrastructure – can manage the technical and economic aspects of the charging infrastructures.
- **EV Driver**: person or entity who owns an EV car and can use the public or private facilities for charging purposes.
- **EVSE**: Electric Vehicle Supply Equipment. It is an equipment that is able to charge EV batteries with AC or DC loads and with different rated powers depending on the type of equipment.
- **Private parking**: can be a condominium, industry or other entity who has private owned EV
- **Voltage sag**: a short-duration reduction in voltage of an electric power distribution system. It can be caused by high current demand or fault current elsewhere in the system.
- **Voltage swell**: the opposite of voltage sag. Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system.
- **Socket outlet**: the port on the electric vehicle supply equipment (EVSE) that supplies charging power to the vehicle

- **Plug**: the end of the flexible cable that interfaces with the socket outlet on the EVSE.
- **Cable**: a flexible bundle of conductors that connects the EVSE with the electric vehicle
- **Connector**: the end of the flexible cable that interfaces with the vehicle inlet
- **Vehicle inlet**: the port on the electric vehicle that receives charging power
- *Inverter*: It is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC).
- **Rectifier**: an electrical device that converts alternating current (AC) to direct current (DC).
- **eMma**: the eMSP subsystem responsible for the EVD interaction from the mobile app
- **eMci**: the eMSP subsystem responsible for the EVD interaction at the charger
- ***additional costs***: *overtime penalty, deposit for unregistered users*
- **Status of the charger**: can be free, occupied, booked and in maintenance
- **Smart meter**: is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor; allow the reading of energy flow and real-time usage, and consequently permit the identification of interruptions in energy flow

1.4. Reference Documents

- `IEEE 29148-2018 International Standard - Requirements engineering`: defines the construct of a good requirement and provides attributes and characteristics of requirements; provides also additional guidelines for applying the requirements and requirements-related processes
- `RDD` assignment document
- `Electric Vehicle CPMS and Secondary Substation Management by F. Campos, Efacec, Portugal; L. Marques, Efacec, Portugal and K. Kotsalos, Efacec, Portugal (15 October 2018)`: used to define the interactions between the different parts of the system and the actors; models the EV public infrastructures, the

eMSP, the DSO and the CPMS together with the APIs and protocols that allow their communication

- `EV CHARGING: HOW TO TAP IN THE GRID SMARTLY? by Platform for Electromobility (May 2022)`: used to understand the environment of the problem and contextualize the analysis

1.5. Document Structure

This document mainly follows the guidelines of the `IEEE 29148-2018 - International Standard - Requirements engineering`, with some changes in the order of the contents. Also in the final part of the document is present an `Alloy` formal analysis of the described model, an additional section with respect to the standard. The document is composed by the following parts:

- An introduction to the domain in which the system will operate (world phenomena) and an initial description of the software to be, the eMall, specifying the goals to achieve
- The overall description of the functions that the eMall has to implement specifying the requirements and a domain model, its interaction with the different users describing with diagrams the most important shared phenomena, and the domain assumptions necessary to the system to be
- A thorough list of requirements both functional and non functional: giving a detailed description of the functional requirements using use cases, use cases diagrams and UML sequence diagrams to better specify the interactions; and characterizing the non functional requirements through software system attributes
- A formal analysis using alloy in order to show the soundness and correctness of the model described in the document, considering only a part the most important requirements of the system
- A section that contains the effort spent by the members of the group working towards the completion of this document

2 | Overall description

2.1. Product perspective

2.1.1. State charts

Among the main interactions with the eMall we have decided to represent with state diagrams the initiation of a charging station and the booking operation, that we consider the most interesting and complex uses of the system, from the EVD point of view.

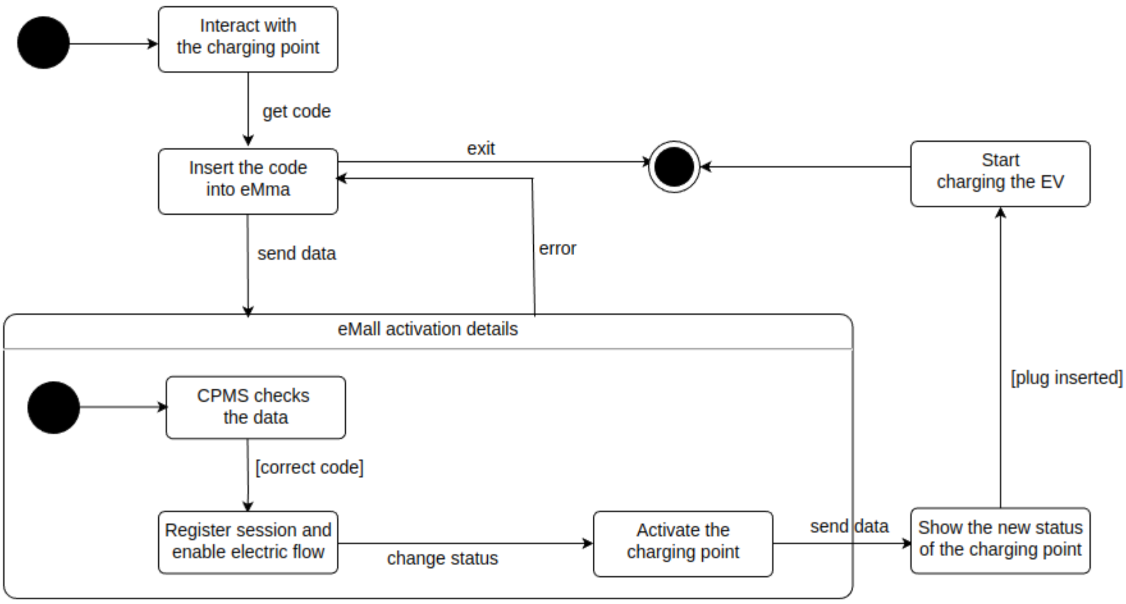

Figure 2.1: State diagram of the EVD that starts a charging session

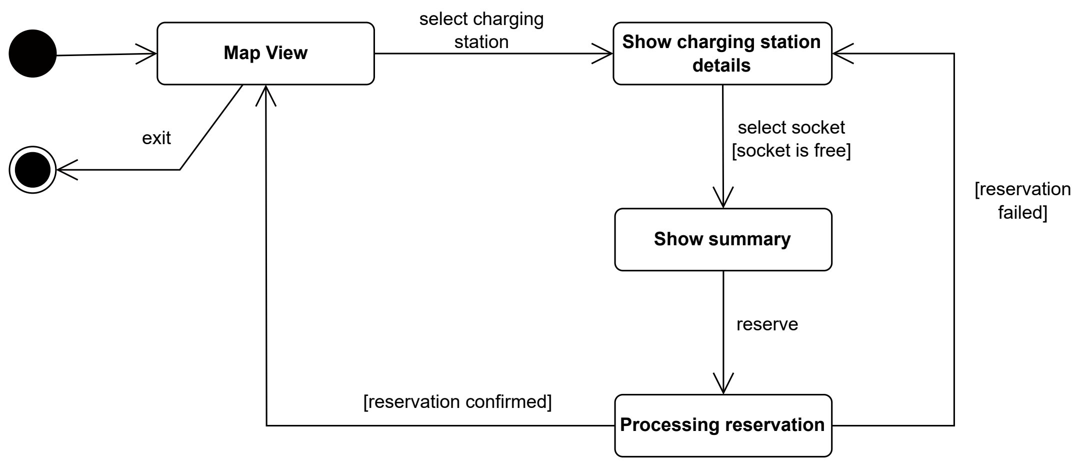

Figure 2.2: State diagram of the booking of a charging point

We also report another state diagram to represent the main interaction of the CPO with the managerial part of our software. We consider the case in which the CPO wants to modify some parameters regarding a certain charging station.

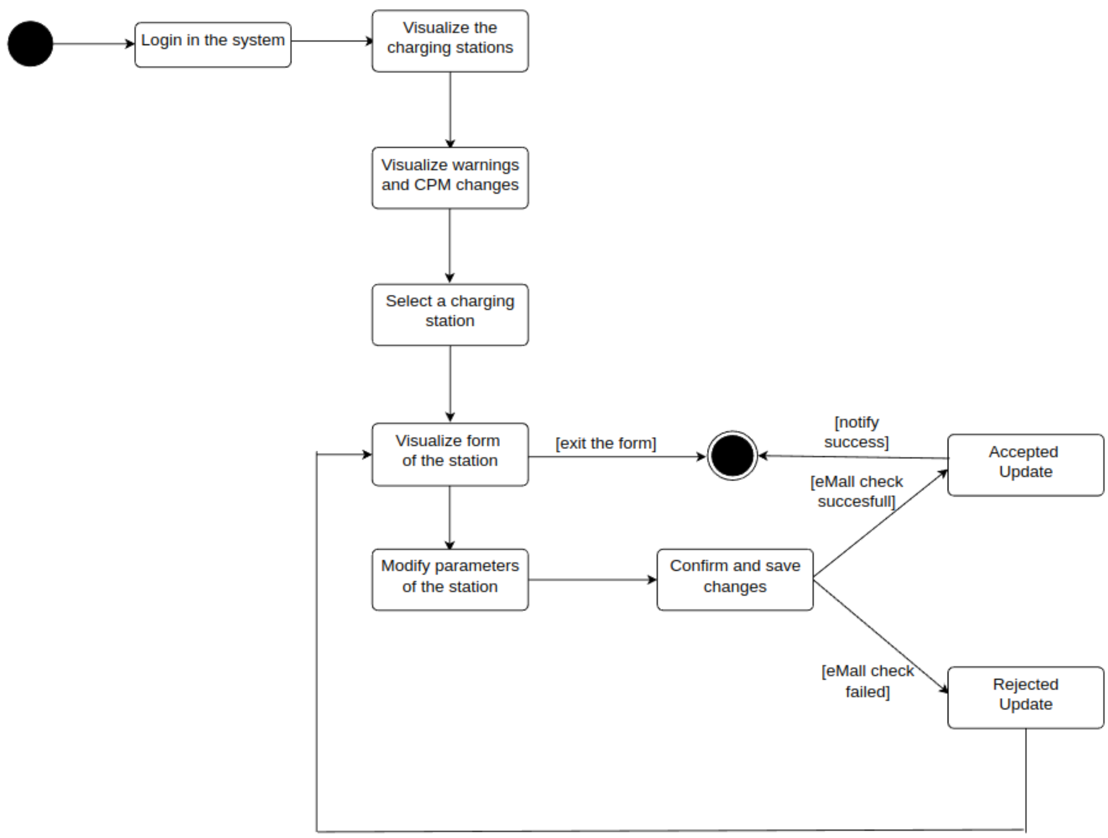

Figure 2.3: State diagram of the CPO that manages charging stations

2.1.2. Scenarios

Booking a charging socket Edward, after getting in his electric vehicle, notices that the battery is at low percentage, so he plans to book a charge at a station nearby. He grabs the smartphone and opens the mobile app eMma to look for a charging station. When Edward opens the app he is greeted with the view of a map showing him the nearest charging stations to his location. The charging stations are represented with icons of different colors. The colors are used to distinguish totally occupied charging stations from those with free sockets where to charge. After moving around the map, Edward finds a charging station with free sockets suitable to his needs. He clicks on the icon symbolizing the charging station and a new view is drawn on the screen. This view list all the available sockets, pointing out the following information for each one of them:

- The type of charging (AC/DC)
- The type of the socket (type 1, type 2, CCS, CHAdeMO, etc.)
- the charging speed denoted in kW and km/h (km gained per one hour of charge)
- The price for kWh
- The price for unlocking the socket

Scrolling down on the app, additional information regarding the station and the charging process are shown, like:

- accessibility to the station
- any additional fees set by the CPO like the cost per minute for parking there during the charging process or cost per minute for parking after finishing the charging (penalty for occupying the spot and not using it)
- Taxation information (VAT etc)

Being satisfied by the features offered by this station, Edward selects the appropriate socket for his EV and equipment (any additional charging adapter) and clicks the button to reserve the spot for the next X minutes.

Update profile details Jay is an electric vehicle enthusiast, who bought himself a new EV, in order to reduce the negative impact on the environment. Given this new purchase Jay needs to update its profile on the eMma in order to take advantage of the eMall service at its most. He logs in to its account on the mobile app and from the main page navigates to his profile. On the profile page are visible the personal information and the details about the EVs. Furthermore, there is the button that allows to update the profile and this is exactly what Jay is looking for. After pressing the button 'Update' there are different possibilities and Jay chooses the one that states 'Add new vehicle'. Now he has to fill up a form with the EV's details, such as type, capacity of the battery, supported power and current and so on. After double checking the form Jay presses the 'Ok' button and the page reloads showing again the profile page that now states among the other vehicles also the new one. Considering the eventuality of making mistakes in completing the form it is always possible to come back to the EV details and change any present field.

Visualize charging history It has been nearly 6 months since Hannah bought her first EV and now she has fully grasped how the whole ecosystem around it works. In the past few months Hannah has tried quite a few different charging stations to explore how each one is managed and organized. Having tried all these charging stations Hannah is curious to see how many charging stations she has visited, how frequently and how much she has paid for the charging. With this objective in mind Hannah opens the eMma application in her mobile phone and heads to the history section of it. This section is divided in two parts: in the top half the app shows the imminent charging booking that Hannah has reserved, if present. In the bottom half of the screen, the app shows a chronologically ordered list of all the charges processed through eMma. Each entry in the list shows the date in which the charging was done, where it was done, for how long, how many kWh were charged, the type of the socket used and how much did it cost distinguishing between cost for kWh and total cost.

Start a charging session Adeline usually goes to the supermarket nearer to her house because it has a charging station in the parking area. Most of the times she finds an available charging point so she charges her EV while she does the grocery. Once stopped the car in the available spot Adeline wants to start a charging session. She interacts with the charging point interface, visualizes the information about the available charge with the respective power and cost and inserts the code shown on the screen in the mobile app of the eMall, the eMma. Once initiated the session from the mobile phone, the data are sent to the system, and in particular to the CPMS part of the software that checks the correctness of the inserted code and registers the session related to the user. Then, the CPMS enables the flow of electricity in order to actualize the charging from the charging point. If during the check of the data and during the activation operations there are no errors the status of the charging point changes and the session is activated. Now, Adeline can insert the specific plug, compatible with her car, in the EV in order to actually start the charging, which if not stopped earlier will terminate when the battery is full.

A new user registers into eMma Michael, proud owner of an EV for 5 years, has decided to try this new charging app, eMma, that is promoting itself as a better alternative to manage in a smart way the charging process of an EV. Michael decides to give eMma a chance, downloads the app and immediately initiates the procedure to create a new account. The first phase of the registering process is straightforward; the usual information about name, family name, email and password are requested. After completing this first phase eMma prompts the user with a message asking him the consent to use his geographical location and to accept the terms of service. Micheal gladly accepts because he wants the app to show him the charging station nearest to him based on his location. After granting the consent a new page is presented to Michael. This time it is a form to be completed with the information about Michael's EVs specifications and his EV gear, like charging adapters and cables. Michael understands that this information is needed so the app can work in a smart way, showing him only the charging stations that have sockets compatible with Michael EVs connector or adapters. Finally the process to complete the registering begins; a form where Michael has to add his electronic payment details. After completing this last stage, the app opens and shows Michael a map of the area around him where the charging stations are highlighted with icons of bright colors.

Visualize the charging stations map Daisy is an unusual user of the eMall, that didn't registered an account. Anyway the system allows the possibility to use the application as a guest, but the functionalities are limited. Daisy is only interested in visualizing the charging stations nearby, so she opens the main page of the app in order to look at the map. The system retrieves, based on the location shared by the phone, the charging stations in the area and shows them on the map. Daisy can now explore the charging stations around clicking on them on the map, and she can see their rating with the relative reviews and can choose the service that better fits her needs. She can visualize the price and the available chargers with their type of connectors, but she is not able to book a charging session without an account. Once identified her preferred charging station Daisy closes the application, gets in her car and heads directly to charge her EV.

Manage the charging stations Nick is a CPO that on a typical day has to monitor the charging stations assigned to its department. After arriving to work and logging in the system with the company credentials Nick checks the list of charging stations and any new notification given by the CPMS part of the eMall about the DSOs decisions. He sees a warning regarding the recently deployed charging station in Rome and clicking on it the web application of the eMall shows a form with the various characteristics of the station. The parts that may have undergone a modification are highlighted in red and in this case the selection of the DSO has new options available and Nick clicks on it to explore the more convenient ones. He notices a change in one of the DSOs that now grants energy also through renewable resources, and given the green policy of the company he chooses this new kind of supply. Considering the price of 0.036/kWh provided by the DSO, in order to have a gain, according to the business modus operandi Nick sets the cost charging at 0.040/kWh. Once confirmed the DSO from which to acquire energy by looking carefully at the form he becomes aware of the fact that at the moment there are no EVD charging at the station and also sees that there are available batteries in which to store energy. One of the batteries is empty, so he selects it in order to store energy in it right away, until the full capacity C, given the off-peak moment. After all this operations Nick saves the changes and the eMall notifies him about the success of the procedure, that has an immediate effect on the system and his interaction with the world. Nick moves on to the next charging station of his list, checking up in similar way each one of the stations for which he is responsible.

2.2. Product functions

2.3. User characteristics

2.4. Assumptions, dependencies and constraints

Assumptions	Description
A1	The end user has internet connection
A2	The end user has a mobile phone with an integrated GPS module
A3	The end user has the mobile application of the eMSP installed on his mobile phone
A4	The CPMS shares the location of the charging station to the eMSP through APIs
A5	The end user payment from the mobile app is handled by external APIs.
A6	The EVD that creates an account inserts the personal data and the EVs specifications during registration
A7	The non registered EVD inserts the EVs specifications and payment details during the booking phase
A8	The DSOs use smart meters to detect interruptions and restore the supply of energy
A9	The CPO uses company credentials to access the CPMS

Table 2.1: Assumptions

3 Specific requirements

3.1. External Interface Requirements

3.1.1. User Interfaces

3.1.2. Hardware Interfaces

3.1.3. Software Interfaces

3.1.4. Communication Interfaces

3.2. Functional Requirements

3.3. Performance Requirements

3.4. Design Constraints

3.4.1. Standards compliance

3.4.2. Hardware limitations

3.4.3. Any other constraint

3.5. Software System Attributes

3.5.1. Reliability

3.5.2. Availability

3.5.3. Security

3.5.4. Maintainability

3.5.5. Portability

4 | Formal analysis using Alloy

5 | Effort spent

Activity	Time spent
Organization	5h
Understanding the problem	10h
Introduction to the problem	10h
Scenarios and overall description	3h
Functional and non-functional requirements	h
Formal analysis using Alloy	h
Total time spent	h

Table 5.1: The time Bianca Savoiu has spent working on this project

Activity	Time spent
Organization	5h
Understanding the problem	h
Introduction to the problem	h
Scenarios and overall description	h
Functional and non-functional requirements	h
Formal analysis using Alloy	h
Total time spent	h

Table 5.2: The time Fabio Lusha has spent working on this project

6 | References

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