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Software Engineering 2 Requirements Analysis and Specification Document

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1 | Introduction

Climate change is a topical issue for everybody these days, and it's leading a change not only in our habits but also in consumes, which implies a change in the production model our society adopted until now. Private mobility is one of the market sectors which is changing the most, depending directly from fossil fuel.

In order to keep global warming below 1.5°C, Europe have decided to reduce greenhouse gas emissions of CO2 per person per year by 2030, and, by the same year, the IEA predicts that electric vehicles will have a market share of roughly 30 percent, with a total number of 23 million e-cars on the roads: electric vehicles represent eco-friendly mobility solutions that are, and will be on our roads in the next future.

Most of the current electric cars can travel between 150 and 350 kilometers on a single charge, but premium-brand models can currently cover more than 500 kilometers. This being said, it's obvious that, when people use an electric vehicle, knowing where to charge it and carefully planning the charging process in such a way that it introduces minimal interference and constraints on our daily schedule is of great importance.

That's were `eMALL` operates: it can find charging stations owned by several Charging Point Operators - CPO - and, considering the activities in user's schedule, it can propose the best possible path of charging process in order to minimize the cost and the waisted time at the station.

1.1. Purpose

1.1.1. Goals

eMALL system is thought, designed and proposed to two types of users: EVDs (Electric Vehicle Drivers) and CPOs (Charging Point Operators).

The firsts, will be able to easily book a charge for their EV (Electric Vehicle), in addition to knowing their location and information about charging stations, any active special offers proposed by CPOs. Furthermore, EVDs will be able to receive suggestions of charge, smartly elaborated by the system in order to minimize the costs and the time needed to charge the battery of the EV.

CPOs instead, are companies that subscribe to the system after choosing a buy-strategy instead of developing the CPMS on their own. So they are looking for a system already implemented, and want to obtain it as a SaaS (Software as a Service). The main functionalities that eMALL offers to CPOs are charging stations management, interfaces with DSO, and energy usage data and/or storage strategy.

Below there's a table that lists all the goals of the eMALL system:

ID	Description
G1	The EVD can get information about charging stations.
G2	The EVD can search for special offer provided by CPO.
G3	The EVD can book a charge for his EV at a charging station for a specified time frame.
G4	The EVD can charge his EV.
G5	The EVD can manage activities thanks to a calendar.
G6	The CPO can manage its charging stations and its charging points.
G7	The CPO can manage a charging session.
G8	The CPO can manage its promotions.
G9	The CPO can manage the electricity supply.

Table 1.1: The goals.

1.2. Scope

The scope of the requirements analysis and specification document - RASD - is to provide a detailed description of the requirements for the project. It outlines what the system or product should do and how it should behave, as well as any constraints or limitations on its design and implementation. The RASD is based on a thorough analysis of the needs and requirements of the stakeholders. The scope of the RASD will cover all of the essential aspects of the system and provide a clear and detailed roadmap for its development.

1.2.1. World phenomena

ID	Description
WP1	The EVD wants to charge his EV's battery.
WP2	The EVD wants to know information of a specific charging station.
WP3	The EVD wants to know if there are any special offer he can redeem.
WP4	The EVD connects the plug of the charging point to the EV.
WP5	The EV reaches the desired level of battery charge.
WP6	Charging Points are distributed in the territory.
WP7	A charging point breaks.
WP8	It is released an update for the firmware of a charging point.
WP9	CPO defines the selling price of electricity.
WP10	CPO defines the features of a new special offers for its customers.
WP11	The DSO provides energy to charging stations.

Table 1.2: World Phenomenas.

1.2.2. Shared phenomena

ID	Description	Controller	Observer
SP1	The EVD creates an account in the eMALL system.	EVD	eMALL
SP2	The EVD logs in eMALL.	EVD	eMALL
SP3	The EVD registers an EV in his/her profile.	EVD	eMALL
SP4	eMALL gets EVD's current position.	eMALL	EVD

SP5	The EVD asks for the list of charging stations nearby to his/her position to eMALL.	EVD	eMALL
SP6	eMALL returns the list of all the charging stations nearby his/her position to the EVD.	eMALL	EVD
SP7	The EVD asks for detailed information about a specific charging station to eMALL.	EVD	eMALL
SP8	eMALL returns the charging cost per kWh of the charging station specified by the EVD.	eMALL	EVD
SP9	eMALL returns the charging cost per minute of the charging station specified by the EVD.	eMALL	EVD
SP10	eMALL returns the cost per minute of the additional fare for late unplugging of the charging station specified by the EVD.	eMALL	EVD
SP11	eMALL returns the charging power of the charging station specified by the EVD.	eMALL	EVD
SP12	eMALL returns the types of connectors accepted by the charging points of the charging station specified by the EVD.	eMALL	EVD
SP13	eMALL returns the number of charging points of the charging station specified by the EVD.	eMALL	EVD
SP14	eMALL returns the current status (available, occupied, maintenance) of the charging station specified by the EVD.	eMALL	EVD
SP15	The EVD asks for special offers that he/she can redeem to eMALL.	EVD	eMALL
SP16	eMALL returns all the active special offers to the EVD.	eMALL	EVD
SP17	The EVD asks for the schedule of a specific charging station to eMALL.	EVD	eMALL
SP18	eMALL returns the schedule of the charging station specified by the EVD.	eMALL	EVD
SP19	The EVD specifies the timeframe he/she wants to be reserved for his booking.	EVD	eMALL

SP20	The EVD books a charging point for a specific plug through eMALL.	EVD	eMALL
SP21	The EVD pays for a caution before booking a charging session through eMALL.	EVD	eMALL
SP22	The EVD inserts a new payment method and the required information into eMALL.	EVD	eMALL
SP23	eMALL returns the outcome of the validity of the payment method inserted by the EVD.	eMALL	EVD
SP24	The EVD asks to unlock the charging point he/she has booked to eMALL.	EVD	eMALL
SP25	The EVD connect the EV to the charging point and starts the charging process.	EVD	eMALL
SP26	eMALL notifies the EVD of the current state of the charging process (battery's level, current cost, estimated time, ...).	eMALL	EVD
SP27	The EVD pauses the charging session.	EVD	eMALL
SP28	The EVD ends the charging session.	EVD	eMALL
SP29	eMALL notifies the EVD that the battery of his/her EV is charged.	eMALL	EVD
SP30	eMALL suggests the EVD to end the charging session after a defined level of the EV's battery is reached.	eMALL	EVD
SP31	The EVD pays for the charging session using the module offered by eMALL.	EVD	eMALL
SP32	eMALL returns the outcome of the payment done by the EVD.	eMALL	EVD
SP33	eMALL notifies the EVD about the need of charging the EV.	eMALL	EVD
SP34	The CPO creates a Charging Point Operator account on eMALL.	CPO	eMALL
SP35	The CPO adds a new charging station in its profile specifying all the needed information.	CPO	eMALL
SP36	The CPO updates information of an existing charging station.	CPO	eMALL

SP37	The CPO activates a new special offer for its charging stations.	CPO	eMALL
SP38	The CPO manually updates the DSO which provides it energy.	CPO	eMALL
SP39	The CPO updates the selling price of its electricity.	CPO	eMALL
SP40	The CPO sets the battery capacity of a charging station.	CPO	eMALL
SP41	The CPO asks for information about the DSOs to eMALL.	CPO	eMALL
SP42	eMALL returns the information about the DSOs to the CPO.	eMALL	CPO
SP43	eMALL gets EVD's current schedule from his/her calendar.	eMALL	EVD

Table 1.3: Shared Phenomenas.

1.3. Definition, Acronyms, Abbreviations

Acronyms	**Definition**
eMSP	e-Mobility Service Provider
CPO	Charging Point Operator
CPMS	Charge Point Management System
DSO	Distribution System Operator
RASD	Requirements Analysis and Specification Document
WPX	World Phenomena X
SPX	Shared Phenomena X
GX	Goal Number X
DAX	Domain Assumptions X
UCX	Use Case X
EVD	Electric Vehicle Driver
EV	Electric Vehicle

Table 1.4: Acronyms used in the document.

1.4. Revision history

This version of RASD differs from the previous one for:

- In section 1.2, we have inserted a brief description about the scope of the document.
- In section 3.1.3, we have added the Navigator System software interface.
- In section 3.2.1, we have added the requirements R70 to the table and updated the requirement R39.
- In section 3.4, we have updated some sequence diagrams to make them coherent with the ones presented in the DD.

1.5. Reference Documents

- The specification document Assignment RDD AY 2022–2023.pdf
- Platform for Electromobility. EV Charging: How to tap in the grid smartly?
- F. Campos, L. Marques, and K. Kotsalos, Electric Vehicle CPMS and Secondary Substation Management. 2nd E-Mobility Power System Integration Symposium, Stockholm, Sweden, 15 October 2018.
- Shu Su, Hui Yan, and Ning Ding. 2018. Machine Learning-Based Charging Network Operation Service Platform Reservation Charging Service System
- September 2022 Market Analysis - MOTUS-E

1.6. Document Structure

The document is structured in six sections, as described below.

First section introduce the goals of the project, purposes, and a brief analysis on world and shared phenomena; abbreviations and definitions useful to understand the problem are listed as well.

The following section, the second one, provides an overall description of the problem: here further details on domain and scenarios are included, aside from more product and user characteristics, assumptions, dependencies and constraints.

Later on, the third section focuses on the specific requirements and provides a more detailed analysis of external interface requirements, functional requirements and perfor-

mance requirements.

Lastly, the fourth section provides a formal analysis, using alloy. This chapter is crucial to prove the correctness of the model described in the previous sections, and should focus on reporting results of the checks performed and meaningful assertions.

Section five reports the effort spent by each group member in the redaction of this document, meanwhile the last section simply lists bibliography references and other resources used to redact this document.

2 | Overall Description

2.1. Product perspective

2.1.1. Class Diagrams

The diagram below represents and describes the classes involved in the system, their basic functionalities, attributes, and the relationships between them. Some suggestions for a further expansion and deepening of the diagram could be to evaluate the use of a decorator pattern to implement the "Fee" class; also, the use of a status pattern can be evaluated, in order to set the state of a charging point (free, booked, occupied, broken) in a more versatile way. Furthermore, another suggestion could be to adopt the factory pattern to implement the "plug" interface.

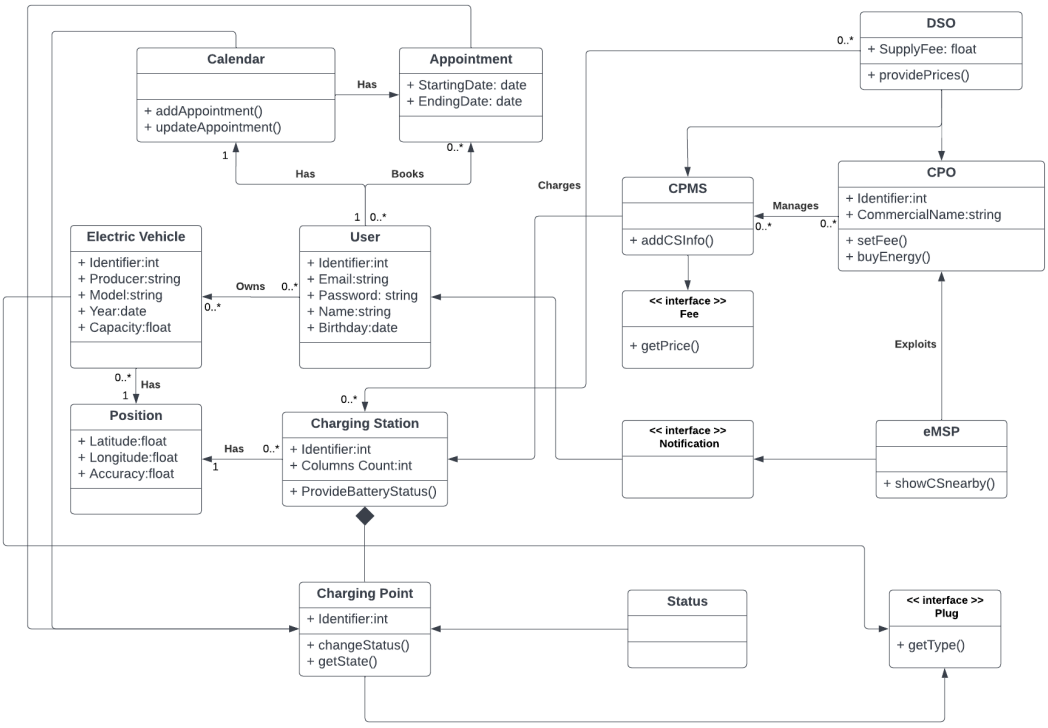


Figure 2.1: A simplified Class Diagram

2.1.2. State Diagrams

The EVD gets position and characteristics of charging stations at a certain location. EVD Andrew is going to use his car to go to the university for the Software Engineering 2 exam, but his EV is out of battery. So, he needs to decide where to charge his vehicle. To do that, he opens the `eMALL` application and enters the map section. At first, he sees if there is any charging station around him, but unfortunately at his current position, there is only one charging station, which is shown as in maintenance. So, he decides to see where to charge his EV nearby the university, inserting Milan in the location search bar. From the huge amount of charging stations, he decides to choose the cheapest one. He selects a charging station and gets its additional information. He goes on searching other stations until he finds the best one for him. At this point, the navigation process ends.

Below is presented a state diagram summarizing the flow of activities done in the charging stations navigation process:

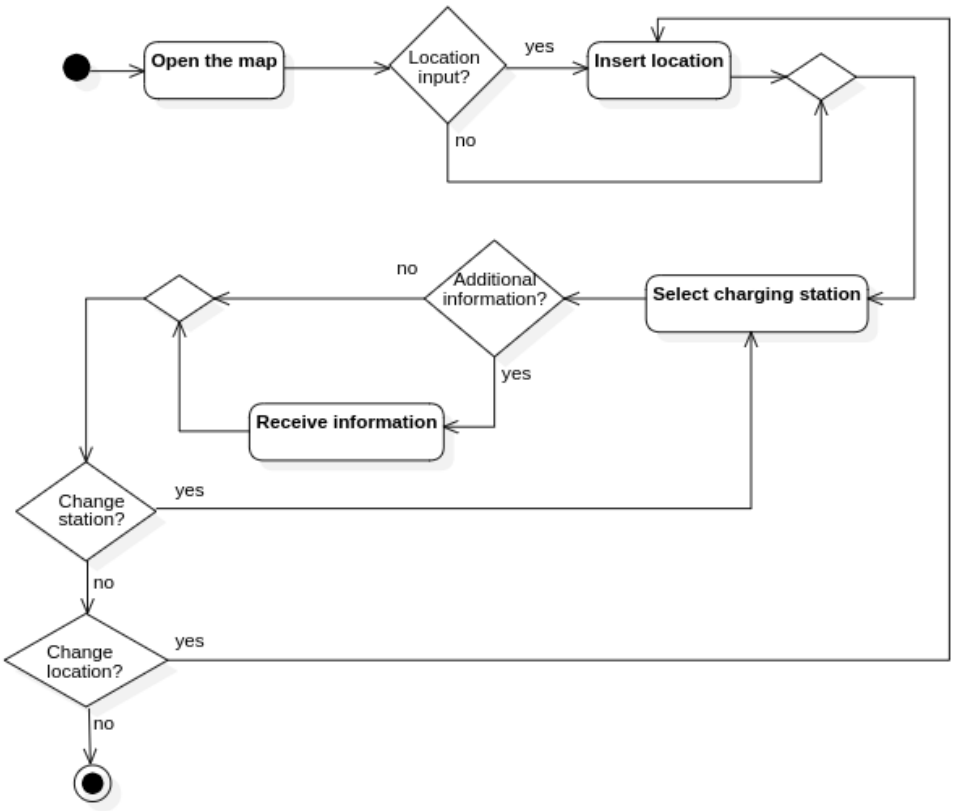


Figure 2.2: Get locations of charging stations state diagram

EVD books a charge at a specified charging station at a certain timeframe. Andrew needs to book a charge for his EV. He selects a charging station on the map and enters the booking section. Unfortunately, the charging station cannot offer a reservation to him because no spots are available. So, he searches for another one until he finds it. Andrew has to decide in which timeframe he wants the charging point to be reserved. So, he checks the availability schedule of the charging station and books a slot for its charge. The system asks to pay a deposit to the EVD, which proceed to pay. Finally, the EVD receives an e-mail with all the information that confirms the reservation.

It is shown a state diagram that summaries the activities in the booking process:

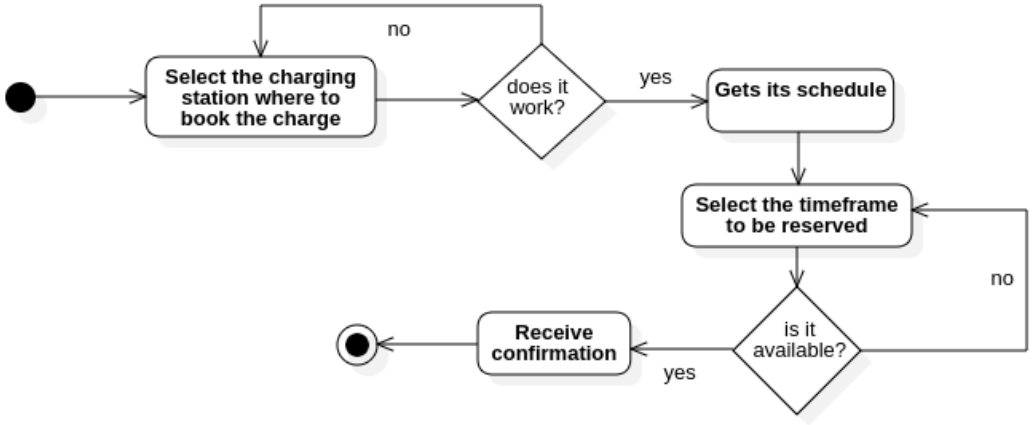


Figure 2.3: Book a charge state diagram

CPO adds charging points in its CPMS. SOLARIS is the new company of the successful businessman Hugh Peter. They decided to trust the eMALL project, entrusting them with the responsibility of managing their IT infrastructure. After logging in, they start inserting new charging points owned by them and distributed throughout the territory. The first thing they are asked to select is the charging station to which the new spot belongs. So, they insert all the requested information (serial number, location, connectors, power, etc.). After they confirm and submit what they inserted, they iterate the process until they have inserted all the charging points. It is shown a state diagram to summaries the activities in the charging points insertion process:

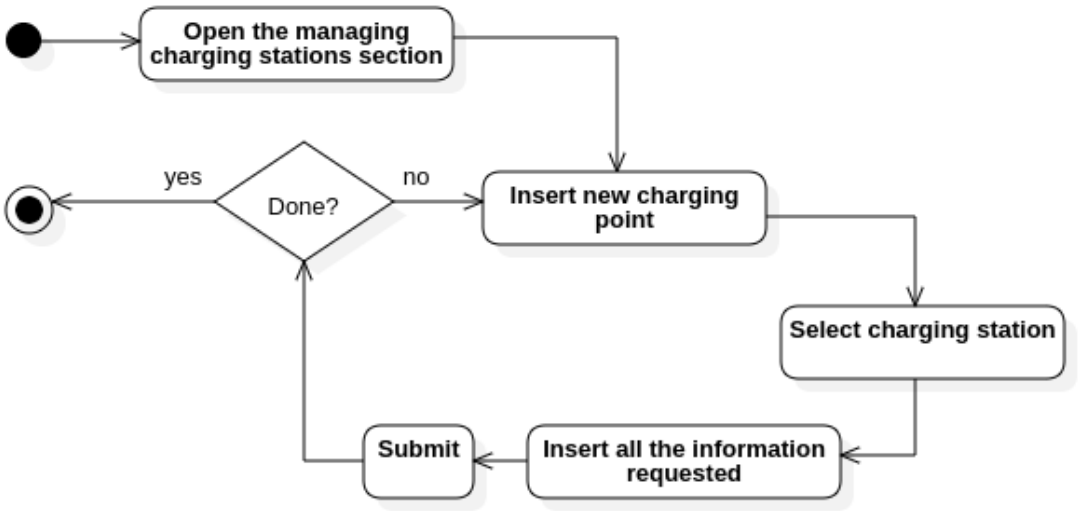


Figure 2.4: Insert charging points state diagram

2.1.3. Scenarios

Unregistered EVD creates an account. Mr. Oak has his EV and is looking for an application that offers the chance to charge his vehicle and smartly plan a charging process depending on the battery status and his daily schedule. Fortunately, he finds out `eMALL`. So, he immediately proceeds to create an account. At first, he opens the application and goes to the "sign up" section. The system asks to Mr. Oak its personal information such as first and second name, birthday, living address, e-mail address, password, and telephone number, which he inserts immediately. He receives an e-mail with a 6-digit code to be inserted in the new window shown by the `eMALL` system to confirm his e-mail address. After accepting the terms & conditions and submitting all the inserted information, the system creates his account, and he can begin using the application.

The EVD charges his/her EV. After booking a charge, Michael Scarn goes to the charging station at the chosen hour. After turning off the EV, he opens the `eMALL` application and enters the charge section. From the set of close charging points, he selects which one has the serial number he received by `eMALL` by e-mail when he booked the charge. So, he asks to charge the EV at that charging point. After verifying that the EVD can be charged at that charging point, the application notifies to the user that the connectors are now unlocked and ready to be used. While the EV is in charge, the system notifies the EVD of the current status of the charging process. When the process ends, he unplugs the connector, pays through the `eMALL` application, and gets back in his car.

The EVD inserts a new activity in its calendar and receives a suggestion for a charging process. Jimothy inserts a new activity in his calendar, specifying the hour and destination of the event. After doing that, he receives a notification that shows the EVD where and when to charge his vehicle. The system creates suggestions to minimize the cost and the time lost at the charging station. It also considers special offers activated by the CPOs registered in the eMALL system. So, Joe accepts the received proposal and confirms the book of the listed charging points, making the needed payments.

The EVD receives a notification about a new special offer activated by a CPO Joe receives a notification about a new special offer activated by the CPO `SOLARIS`. So, he opens the promotion page, reads what it is about, and gets the discount code of the offer. It consists of a 20% discount for all the EVDs that are under 25. Considering that he has to charge his EV, he decides to book a charging session at a charging station owned by the CPO `SOLARIS`. After selecting the timeframe and verifying its availability, he inserts the discount code SARTORIUS.

2.2. Product functions

The EVD books a charging session
The main functionality of `eMALL` is to book charge sessions in different charging stations for the EVD. In particular, the system shows charging stations to the EVD and waits for him to select where he wants to book a charging session.

When `eMALL` retrieves information about the charging stations available in the local area, it also retrieves all the extra info about the available plugs and power supplies.

The system has to control if the charging station is currently unavailable, and if it is not, it gets the station's schedule. The EVD has to choose a timeframe between the ones available to book a charge session. `eMALL` also queries the charging station to know if the station has or not a mandatory deposit to pay to end the booking process. If the station does not have a deposit policy, then `eMALL` finishes the booking process by sending an informative email to the EVD that resumes all the booking info.

In the email, `eMALL` also specifies the serial number associated with the charging point of the charging station where the EVD has to charge his EV.

The EVD receives charging alerts about where to charge his EV
`eMALL` offers smart functions about when the EVD might book a charge for his EV. Hence, when an EVD inserts a new activity in his calendar, `eMALL` computes the best route to

reach the destination through an external navigator API. eMALL also checks the battery status of the EV, so it notifies the best itinerary for the EVD. If the battery state doesn't allow the EVD to reach the destination, then eMALL shows him the best route with the charging stations available along the road.

eMALL tries to minimize the costs. Hence, starting from the current battery status, the system computes the maximum kilometers an EV can travel before running out of battery. If the EV can reach the destination, eMALL marks the route returned by the API as preferred. On the other hand, eMALL finds charging stations along the road and selects the one with the minimum costs because it knows the details about the EV, for instance, the plug type. The best charging station found is shown to the EVD, allowing him to decide whether to start a booking process.

If the EVD doesn't accept eMALL solution, he can book another charging station along the road and start, as well, a booking process.

The CPO manages its charging stations
A CPO should be able to manage its charging stations and relative charging points. In general, a CPO might have new charging stations to register in eMALL, and, as well, it might have charging points too. The system allows the CPO to register charging stations, by entering all the info about them, for instance, the position on the map and the number of charging points available. Furthermore, the system allows the registration of also charging points by inserting info like the available plugs and the power supply of the charging process.

Just like the CPO inserts new information about its product, it can also delete charging points or charging stations from eMALL.

The system also shows CPOs charging stations and relative charging points on the map. This functionality is necessary because they might break down, so the CPO has to change their availability status (offline, under maintenance, online).

2.3. User characteristics

The actors listed below are considered in the eMALL system

- **CPO:** owns one or more charging stations, and manages bookings and promotions about its charging points. He buys energy from DSOs, based on prices and needs. CPOs has their own IT system.
- **Unregistered EV Driver:** anybody who owns an electric vehicle, but isn't reg-

istered in the eMALL system. Before accessing its benefits, it needs to get an account.

- **Registered EV Driver:** an electric vehicle owner who already joined the eMALL system, and access its benefits. He's identified with a unique ID, and can own one or more vehicles with different specifics. They can check prices and position of charging points, in addition to receiving notifications about promotions reserved to them.

2.4. Assumptions, dependencies and constraints

ID	Description
DA1	Each user has needed competences to use the `eMALL` system.
DA2	Both the users EVDs and CPOs have an e-mail.
DA3	The EVD has a payment method.
DA4	The EVD uses a device with internet connectivity.
DA5	The EVD uses a device with GPS module for navigation and localization.
DA6	There is a specific compatibility between EV's plug and connectors offered by charging points.
DA7	Charging points have their own software.
DA8	Communication between the `eMALL` system and the charging points happens through the OCPP protocol.
DA9	The `eMALL` system communicates with EV brands API to get vehicles' specification.
DA10	The `eMALL` system communicates with DSOs through their APIs.
DA11	The `eMALL` system communicates with third-party payment services to manage the payments.

Table 2.1: Domain assumptions.

3 | Specific Requirements

3.1. External Interface Requirements

3.1.1. User Interfaces

The eMALL's user interfaces are a website and a mobile application; the first is developed to be used mainly by CPOs with a dedicated login section for businesses but can be used by EVDs too. The mobile application is available for Android and iOS and provides an enhanced experience as compared to the website since it offers users personalized suggestions based on their location. The website and the app should be easy to use since they will be used mostly by middle-aged users, who might not always be familiar with the technology. A "quick booking" section dedicated to facilitating the book process might be included, for those EVDs who are used to booking a charge at the same charging station (based on suggestions given by AI).

3.1.2. Hardware Interfaces

The system only requires a smartphone or computer with an internet connection and web browser to access websites or mobile applications. Furthermore, eMALL communicates with the EV through its company's API to get the current battery level, the charging state, so if it is plugged in and if it is charging, and the number of routable kilometers obtained on the current battery level. To access personalized suggestions, based on EV's position, the device in use has to be able to detect its location with a GPS localization system.

3.1.3. Software Interfaces

The following list describes the required software interfaces that the eMALL system uses:

- **CPMS and Charging Points.** The CPMS that is offered to the CPO communicates with the charging points through their API. Thanks to it, the system can manage the charging session, given the possibility of starting and stopping it or set

the power supply to be given to each connected EV. Another significant functionality is the diagnostic of the charging point: a CPO can reboot its charging spots, can get their log, and can update their firmware.

- **eMALL and EVs.** The eMALL system communicates with the EVs registered by the EVD. As explained in the domain assumption section, we suppose that there is a third-party system that offers its API so to get the status of the battery of the EV. An example of a system that provides these features is Smartcar, which is already used by companies like AmpUp or BeCharge to remotely retrieve the battery level and remaining range of the EVs.
- **CPMS and DSOs.** The CPMSs offered to the CPO communicate with the DSOs through their APIs. CPOs can get selling prices set by the DSOs and they can decide from which DSO to acquire electricity.
- **eMALL and third-party payment services.** The `eMALL` system offers the possibility to pay through external payment services to the EVD. The communication happens thanks to APIs offered by the companies that handle payments.
- **eMALL and Navigator Service.** The `eMALL` system communicates with an external Navigator System to be able to map the position and compute paths between the provided location and the destination place.

3.1.4. Communication Interfaces

The communication protocols that the `eMALL` system uses are:

- **Open Charge Point Protocol (OCPP).** It is used for the communication between the CPMS and the charging points.
- **HyperText Transfer Protocol over Secure Socket Layer (HTTPS).** The protocol is used every time data are exchanged with the external world. So, it is used when `eMALL` communicates with EVDs and CPOs.

3.2. Functional Requirements

3.2.1. Requirements

The `eMALL` system offers several functionalities to both EVDs and CPOs. In the following table they are listed all the detected requirements that the system should respect in order to guarantee the satisfiability of the goals:

ID	Description
R1	The eMALL system shall allow an unregistered EVD to create an account.
R2	The eMALL system shall allow a registered EVD to log in.
R3	The eMALL system shall allow a registered EVD to add an EV in his profile.
R4	The eMALL system shall communicate with EV's brand API to get needed information.
R5	The eMALL system shall allow a registered EVD to book a charge.
R6	The eMALL system shall allow a registered EVD to select a timeframe to reserve a charging point.
R7	The eMALL system shall add a booked reservation into EVD's calendar.
R8	The eMALL system shall allow a registered EVD to get all the charging station near to his current location.
R9	The eMALL system shall allow a registered EVD to insert a specific location to get charging station nearby.
R10	The eMALL system shall allow a registered EVD to move into the map of charging stations.
R11	The eMALL system shall allow a registered EVD to select a specific charging station.
R12	The eMALL system shall allow a registered EVD to get the location of a specific charging station.
R13	The eMALL system shall allow a registered EVD to get the costs of a specific charging station.
R14	The eMALL system shall allow a registered EVD to get the CPO owner of a specific charging station.
R15	The eMALL system shall allow a registered EVD to get type of connectors of a specific charging station.
R16	The eMALL system shall allow a registered EVD to get maximum power supply of the spots of a specific charging station.
R17	The eMALL system shall allow a registered EVD to get the status of a specific charging station.
R18	The eMALL system shall allow a registered EVD to get the list of active promotions.
R19	The eMALL system shall allow a registered EVD to select a specific promotion.
R20	The eMALL system shall allow a registered EVD to activate a promotion.
R21	The eMALL system shall allow a registered EVD to insert a new payment method.

R22	The eMALL system shall allow a registered EVD to select a payment method.
R23	The eMALL system shall allow a registered EVD to pay with the preferred payment method.
R24	The eMALL system shall communicate with third-party payment services to make the payments.
R25	The eMALL system shall allow a registered EVD to start a charging process.
R26	The eMALL system shall verify the identity of the EVD requesting to start a charging session.
R27	The eMALL system shall communicate to charging points to unlock their plug.
R28	The eMALL system shall communicate to charging points to start the charging session.
R29	The eMALL system shall define the source of the charging session (batteries or DSO).
R30	The eMALL system shall define the power of the charging session.
R31	The eMALL system shall get EV's battery status.
R32	The eMALL system shall send notifications about the current status of the charging session to the registered EVD.
R33	The eMALL system shall allow a registered EVD to stop the charging session.
R34	The eMALL system shall communicate to a charging point to stop the charging session.
R35	The eMALL system shall send the receipt of the charging session to the registered EVD.
R36	The eMALL system shall communicate the outcome of the payment to a registered EVD.
R37	The eMALL system shall allow a registered EVD to access in his own calendar.
R38	The eMALL system shall allow a registered EVD to add a new activity into his calendar.
R39	The eMALL system shall allow a registered EVD to specify the timeframe of a new activity.
R40	The eMALL system shall allow a registered EVD to specify the destination of a new activity.
R41	The eMALL system shall save a new activity into EVD's calendar.
R42	The eMALL system shall calculate the best schedules of where and when to charge registered EVD's EV so to minimize costs and wasted time.

R43	The eMALL system shall communicate to the registered EVD the details of the suggestions about the calculated schedules.
R44	The eMALL system shall allow a CPO to log in as a business user.
R45	The eMALL system shall allow a CPO to manage its charging stations.
R46	The eMALL system shall allow a CPO to set new selling prices for charging sessions.
R47	The eMALL system shall allow a CPO to add a new charging station in its profile.
R48	The eMALL system shall allow a CPO to specify the location of charging station (region, province, city, address).
R49	The eMALL system shall allow a CPO to specify the status of a charging station (available, maintenance, broken, unavailable).
R50	The eMALL system shall allow a CPO to add a charging point in an existing charging station.
R51	The eMALL system shall allow a CPO to specify the serial number of charging point.
R52	The eMALL system shall allow a CPO to specify the types of connectors of a charging point.
R53	The eMALL system shall allow a CPO to specify the maximum power of a charging point.
R54	The eMALL system shall allow a CPO to specify the type of connectors of a charging point.
R55	The eMALL system shall reserve a charging point in a certain timeframe.
R56	The eMALL system shall allow a CPO to manage its promotions.
R57	The eMALL system shall allow a CPO to create a new promotion.
R58	The eMALL system shall allow a CPO to specify the details of the a promotion.
R59	The eMALL system shall save the information of a promotion.
R60	The eMALL system shall initialize the information of a new promotion.
R61	The eMALL system shall allow a CPO to schedule a maintenance session for a charging station.
R62	The eMALL system shall allow a CPO to specify date and starting hour of a maintenance session for a charging station.
R63	The eMALL system shall communicate to a charging station to schedule a maintenance at a specified timeframe.
R64	The eMALL system shall allow a CPO to get the list of DSOs.
R65	The eMALL system shall allow a CPO to select a DSO from the list of DSOs.

R66	The eMALL system shall allow a CPO to update its electricity provider.
R67	The eMALL system shall communicate to a specified DSO to send energy to the charging stations of a CPO.
R68	The eMALL system shall get the electricity selling prices from the DSOs.
R69	The eMALL system shall store users information.
R70	The eMALL system shall allow the CPO to manage its company personal information.

Table 3.1: Requirements.

3.2.2. Mapping on goals

In the following section it is shown how the relation $R \wedge D \models G$ holds. In particular, at first it is shown a traceability matrix that associates domain assumptions and requirements to each goal. After that, to facilitate reading, the section reports the text of all the assumptions and all the requirements related to each goal.

Goal	**Domain assumptions**	**Requirements**
G1	DA1, DA2, DA4, DA5	R1, R2, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R69
G2	DA1, DA2, DA3, DA4, DA11	R1, R2, R18, R19, R20, R21, R22, R23, R24, R69
G3	DA1, DA2, DA3, DA4, DA5, DA6, DA7, DA8, DA9, DA11	R1, R2, R3, R4, R5, R6, R11, R21, R22, R23, R24, R69
G4	DA1, DA2, DA4, DA6, DA9	R1, R2, R4, R25, R26, R27, R28, R29, R30, R31, R32, R33, R35, R36, R69
G5	DA1, DA2, DA4, DA5	R1, R2, R7, R37, R38, R39, R40, R41, R42, R43, R69
G6	DA1, DA2, DA4	R44, R45, R46, R47, R48, R49, R50, R51, R52, R53, R54, R55, R61, R62, R63, R69, R70
G7	DA1, DA2, DA4, DA7, DA8, DA9	R4, R26, R27, R28, R29, R30, R31, R34, R44, R55, R69
G8	DA1, DA2, DA4	R44, R56, R57, R58, R59, R60, R69
G9	DA1, DA2, DA4, DA9, DA10	R4, R44, R64, R65, R66, R67, R68, R69

Table 3.2: Mapping on goals.

The EVD can get information about charging stations

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA4. The EVD uses a device with internet connectivity.
- DA5. The EVD uses a device with GPS module for navigation and localization.
- R1. The eMALL system shall allow an unregistered EVD to create an account.
- R2. The eMALL system shall allow a registered EVD to log in.
- R8. The eMALL system shall allow a registered EVD to get all the charging station near to his current location.
- R9. The eMALL system shall allow a registered EVD to insert a specific location to get charging station nearby.
- R10. The eMALL system shall allow a registered EVD to move into the map of charging stations.
- R11. The eMALL system shall allow a registered EVD to select a specific charging station.
- R12. The eMALL system shall allow a registered EVD to get the location of a specific charging station.
- R13. The eMALL system shall allow a registered EVD to get the costs of a specific charging station.
- R14. The eMALL system shall allow a registered EVD to get the CPO owner of a specific charging station.
- R15. The eMALL system shall allow a registered EVD to get type of connectors of a specific charging station.
- R16. The eMALL system shall allow a registered EVD to get maximum power supply of the spots of a specific charging station.
- R17. The eMALL system shall allow a registered EVD to get the status of a specific charging station.
- R69. The eMALL system shall store users information.

The EVD can search for special offer provided by charging stations

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA3. The EVD has a payment method.
- DA4. The EVD uses a device with internet connectivity.
- DA11. The eMALL system communicates with third-party payment services to manage the payments.
- R1. The eMALL system shall allow an unregistered EVD to create an account.
- R2. The eMALL system shall allow a registered EVD to log in.
- R18. The eMALL system shall allow a registered EVD to get the list of active promotions.
- R19. The eMALL system shall allow a registered EVD to select a specific promotion.
- R20. The eMALL system shall allow a registered EVD to activate a promotion.
- R21. The eMALL system shall allow a registered EVD to insert a new payment method.
- R22. The eMALL system shall allow a registered EVD to select a payment method.
- R23. The eMALL system shall allow a registered EVD to pay with the preferred payment method.
- R24. The eMALL system shall communicate with third-party payment services to make the payments.
- R69. The eMALL system shall store users information.

The EVD can book a charge for his EV at a charging station for a specified time frame

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA3. The EVD has a payment method.
- DA4. The EVD uses a device with internet connectivity.

- DA5. The EVD uses a device with GPS module for navigation and localization.
- DA6. There is a specific compatibility between EV's plug and connectors offered by charging points.
- DA7. Charging points have their own software.
- DA8. Communication between the eMALL system and the charging points happens through the OCPP protocol.
- DA9. The eMALL system communicates with EV brands API to get vehicles' specification.
- DA11. The eMALL system communicates with third-party payment services to manage the payments.
- R1. The eMALL system shall allow an unregistered EVD to create an account.
- R2. The eMALL system shall allow a registered EVD to log in.
- R3. The eMALL system shall allow a registered EVD to add an EV in his profile.
- R4. The eMALL system shall communicate with EV's brand API to get needed information.
- R5. The eMALL system shall allow a registered EVD to book a charge.
- R6. The eMALL system shall allow a registered EVD to select a timeframe to reserve a charging point.
- R11. The eMALL system shall allow a registered EVD to select a specific charging station.
- R21. The eMALL system shall allow a registered EVD to insert a new payment method.
- R22. The eMALL system shall allow a registered EVD to select a payment method.
- R23. The eMALL system shall allow a registered EVD to pay with the preferred payment method.
- R24. The eMALL system shall communicate with third-party payment services to make the payments.
- R69. The eMALL system shall store users information.

The EVD can charge his EV

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA4. The EVD uses a device with internet connectivity.
- DA6. There is a specific compatibility between EV's plug and connectors offered by charging points.
- DA9. The eMALL system communicates with EV brands API to get vehicles' specification.
- R1. The eMALL system shall allow an unregistered EVD to create an account.
- R2. The eMALL system shall allow a registered EVD to log in.
- R4. The eMALL system shall communicate with EV's brand API to get needed information.
- R25. The eMALL system shall allow a registered EVD to start a charging process.
- R26. The eMALL system shall verify the identity of the EVD requesting to start a charging session.
- R27. The eMALL system shall communicate to charging points to unlock their plug.
- R28. The eMALL system shall communicate to charging points to start the charging session.
- R29. The eMALL system shall define the source of the charging session (batteries or DSO).
- R30. The eMALL system shall define the power of the charging session.
- R31. The eMALL system shall get EV's battery status.
- R32. The eMALL system shall send notifications about the current status of the charging session to the registered EVD.
- R33. The eMALL system shall allow a registered EVD to stop the charging session.
- R35. The eMALL system shall send the receipt of the charging session to the registered EVD.
- R36. The eMALL system shall communicate the outcome of the payment to a registered EVD.

- R69. The eMALL system shall store users information.

The EVD can manage activities thanks to a calendar

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA4. The EVD uses a device with internet connectivity.
- DA5. The EVD uses a device with GPS module for navigation and localization.
- R1. The eMALL system shall allow an unregistered EVD to create an account.
- R2. The eMALL system shall allow a registered EVD to log in.
- R7. The eMALL system shall add a booked reservation into EVD's calendar.
- R37. The eMALL system shall allow a registered EVD to access in his own calendar.
- R38. The eMALL system shall allow a registered EVD to add a new activity into his calendar.
- R39. The eMALL system shall allow a registered EVD to specify the starting hour of a new activity.
- R40. The eMALL system shall allow a registered EVD to specify the destination of a new activity.
- R41. The eMALL system shall save a new activity into EVD's calendar.
- R42. The eMALL system shall calculate the best schedules of where and when to charge registered EVD's EV so to minimize costs and wasted time.
- R43. The eMALL system shall communicate to the registered EVD the details of the suggestions about the calculated schedules.
- R69. The eMALL system shall store users information.

The CPO can manage its charging stations and its charging points

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA4. The EVD uses a device with internet connectivity.
- R44. The eMALL system shall allow a CPO to log in as a business user.

- R45. The eMALL system shall allow a CPO to manage its charging stations.
- R46. The eMALL system shall allow a CPO to set new selling prices for charging sessions.
- R47. The eMALL system shall allow a CPO to add a new charging station in its profile.
- R48. The eMALL system shall allow a CPO to specify the location of charging station (region, province, city, address).
- R49. The eMALL system shall allow a CPO to specify the status of a charging station (available, maintenance, broken, unavailable).
- R50. The eMALL system shall allow a CPO to add a charging point in an existing charging station.
- R51. The eMALL system shall allow a CPO to specify the serial number of charging point.
- R52. The eMALL system shall allow a CPO to specify the types of connectors of a charging point.
- R53. The eMALL system shall allow a CPO to specify the maximum power of a charging point.
- R54. The eMALL system shall allow a CPO to specify the type of connectors of a charging point.
- R55. The eMALL system shall reserve a charging point in a certain timeframe.
- R61. The eMALL system shall allow a CPO to schedule a maintenance session for a charging station.
- R62. The eMALL system shall allow a CPO to specify date and starting hour of a maintenance session for a charging station.
- R63. The eMALL system shall communicate to a charging station to schedule a maintenance at a specified timeframe.
- R69. The eMALL system shall store users information.
- R70. The eMALL system shall allow the CPO to manage its company personal information.

The CPO can manage a charging session

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA4. The EVD uses a device with internet connectivity.
- DA7. Charging points have their own software.
- DA8. Communication between the eMALL system and the charging points happens through the OCPP protocol.
- DA9. The eMALL system communicates with EV brands API to get vehicles' specification.
- R4. The eMALL system shall communicate with EV's brand API to get needed information.
- R26. The eMALL system shall verify the identity of the EVD requesting to start a charging session.
- R27. The eMALL system shall communicate to charging points to unlock their plug.
- R28. The eMALL system shall communicate to charging points to start the charging session.
- R29. The eMALL system shall define the source of the charging session (batteries or DSO).
- R30. The eMALL system shall define the power of the charging session.
- R31. The eMALL system shall get EV's battery status.
- R34. The eMALL system shall communicate to a charging point to stop the charging session.
- R44. The eMALL system shall allow a CPO to log in as a business user.
- R55. The eMALL system shall reserve a charging point in a certain timeframe.
- R69. The eMALL system shall store users information.

The CPO can manage its promotions

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..

- DA4. The EVD uses a device with internet connectivity.
- R44. The eMALL system shall allow a CPO to log in as a business user.
- R56. The eMALL system shall allow a CPO to manage its promotions.
- R57. The eMALL system shall allow a CPO to create a new promotion.
- R58. The eMALL system shall allow a CPO to specify the details of the a promotion.
- R59. The eMALL system shall save the information of a promotion.
- R60. The eMALL system shall initialize the information of a new promotion.
- R69. The eMALL system shall store users information.

The CPO can manage the electricity supply

- DA1. Each user has needed competences to use the eMALL system.
- DA2. Both the users EVDs and CPOs have an e-mail..
- DA4. The EVD uses a device with internet connectivity.
- DA9. The eMALL system communicates with EV brands API to get vehicles' specification.
- DA10. The eMALL system communicates with DSOs through their APIs.
- R4. The eMALL system shall communicate with EV's brand API to get needed information.
- R44. The eMALL system shall allow a CPO to log in as a business user.
- R64. The eMALL system shall allow a CPO to get the list of DSOs.
- R65. The eMALL system shall allow a CPO to select a DSO from the list of DSOs.
- R66. The eMALL system shall allow a CPO to update its electricity provider.
- R67. The eMALL system shall communicate to a specified DSO to send energy to the charging stations of a CPO.
- R68. The eMALL system shall get the electricity selling prices from the DSOs.
- R69. The eMALL system shall store users information.

3.2.3. Use case diagrams

Unregistered EVD

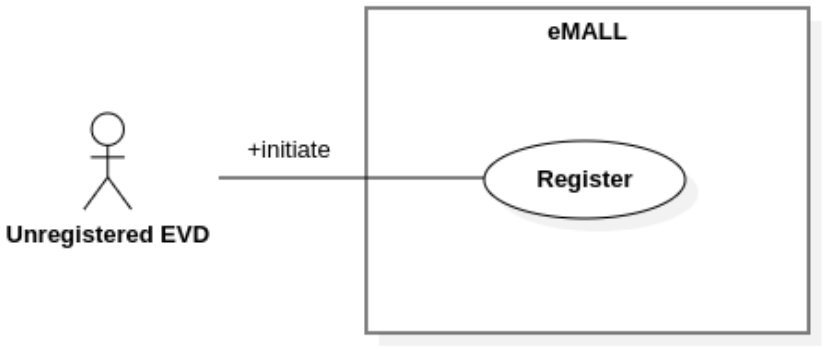


Figure 3.1: Unregistered EVD use case diagram.

Registered EVD

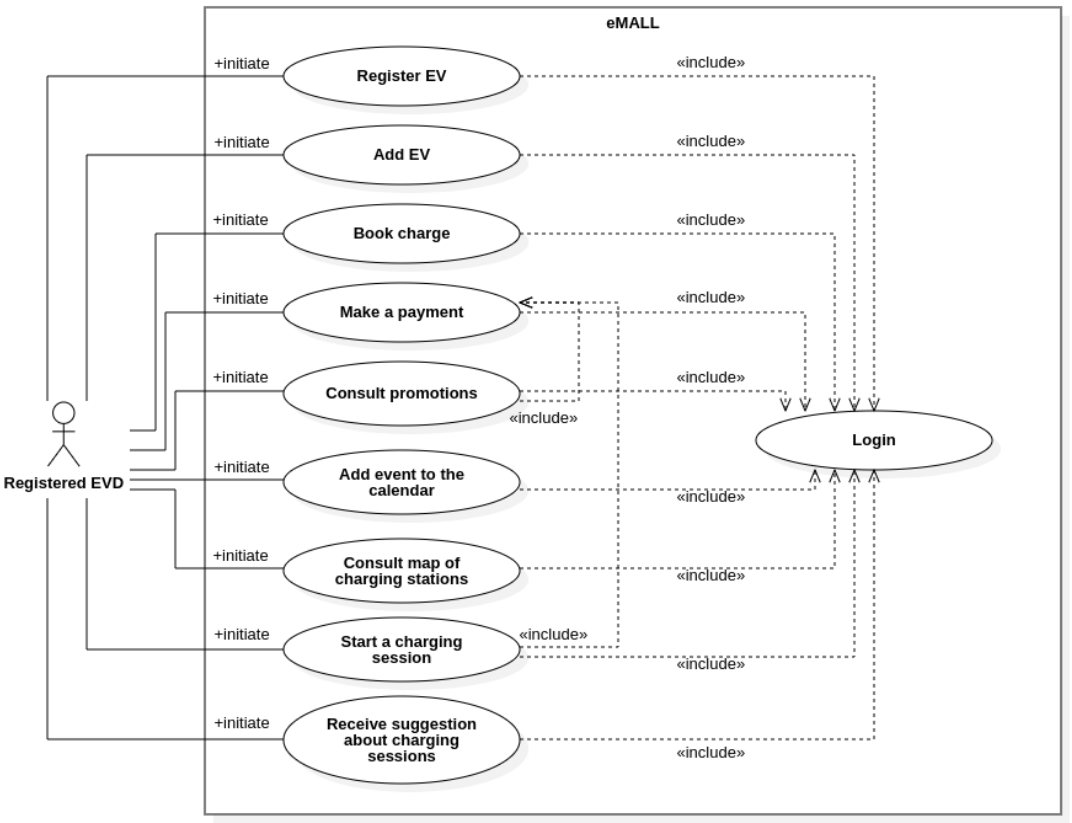


Figure 3.2: Unregistered EVD use case diagram.

CPO

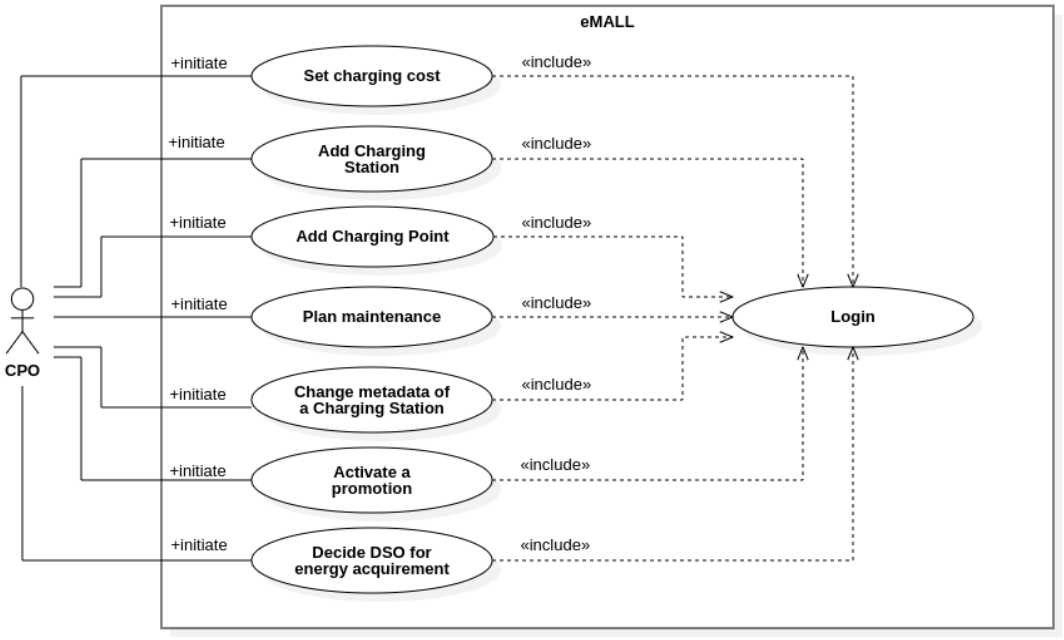


Figure 3.3: Unregistered EVD use case diagram.

3.2.4. Use cases

In this section, they are explained and represented the main identified use cases. There is a table with entry conditions, event flow, exit conditions and exception for each of them, and a sequence diagram that shows the messages exchanged between the entities and the called functions.

UC1. EVD signs up

Actor	Unregistered EVD
Entry conditions	The EVD isn't registered in the `eMALL` system, and he clicks the sign-up button
Event Flow	1. `eMALL` asks the unregistered EVD to insert personal information (i.e., name, surname, birthday, billing address, e-mail, and password).

	2. The unregistered EVD fills out the form with his personal information (name, surname, birthday, billing address, e-mail, and password) and accepts the "Terms & Conditions" and "Privacy Policy". 3. eMALL validates the inserted EVD's personal information. 4. eMALL asks the unregistered EVD to insert payment method information. 5. The EVD fills out a form with its payment method information. 6. eMALL validates the inserted EVD's payment method. 7. eMALL sends a confirmation email to the EVD. 8. eMALL sends back the EVD's registration outcome.
Exit condition	An account is created.
Exceptions	3.1. eMALL isn't able to validate the EVD's personal information. 6.1. eMALL isn't able to validate the EVD's payment method. In all these cases, the unregistered EVD is notified with an error message.

Table 3.3: EVD signs up use case.

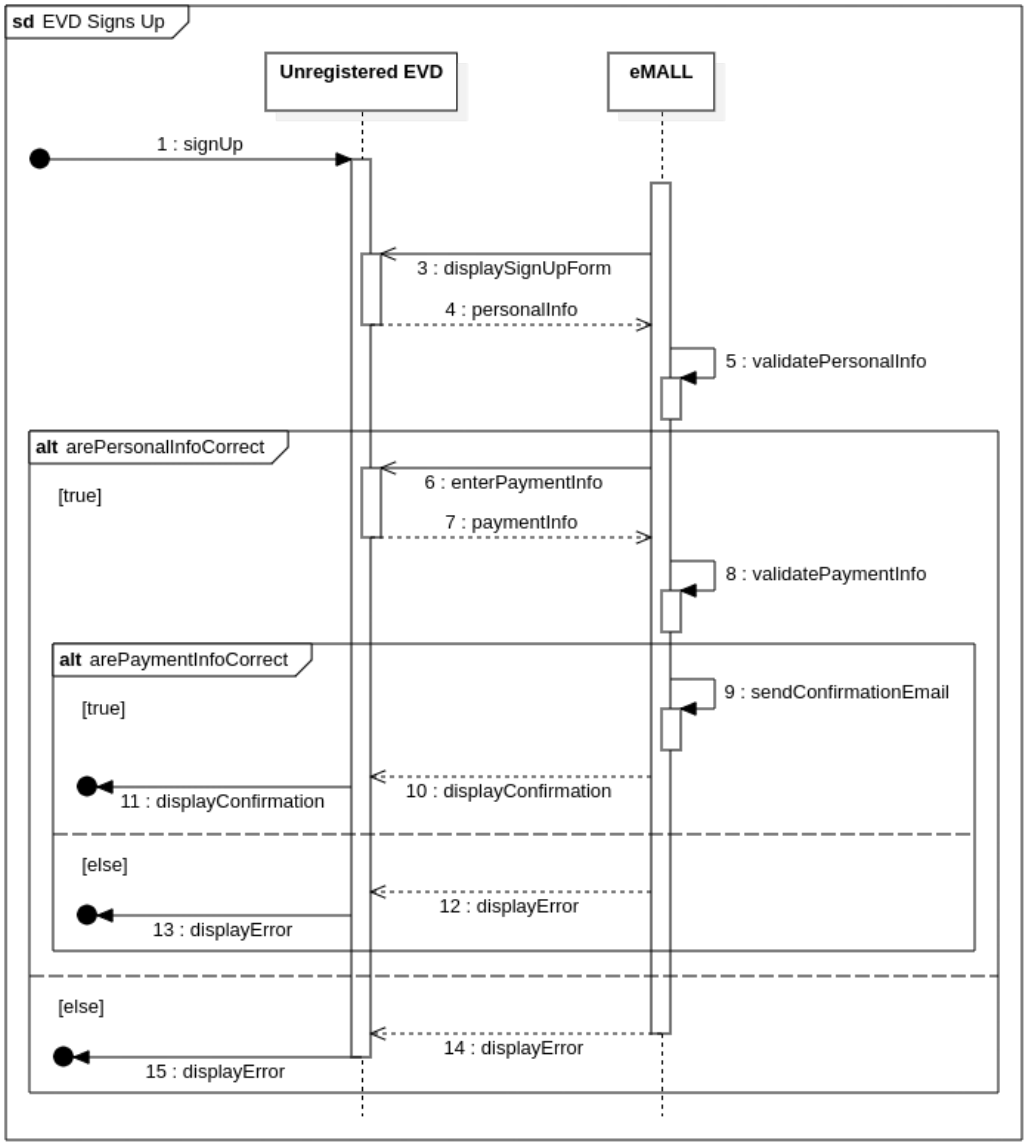


Figure 3.4: EVD signs up sequence diagram

UC2. Registered EVD logs in

Actor	Registered EVD
Entry conditions	The EVD is registered in the `eMALL` system and he clicks the log in button.
Event Flow	1. `eMALL` asks the registered EVD to insert the e-mail. 2. The registered EVD inserts the e-mail. 3. `eMALL` validates the inserted e-mail.

	4. eMALL asks the registered EVD to insert the password associated with the e-mail. 5. The registered EVD inserts the password. 6. eMALL validates the inserted password in combination with the e-mail. 7. eMALL sends back the login outcome.
Exit condition	The registered EVD access the eMALL system.
Exceptions	3.1 The e-mail is not recognized. 6.1 The password is not correct. In both cases, the registered EVD receives a notification through an error message. He has to insert his credentials again.

Table 3.4: Registered EVD logs in use case.

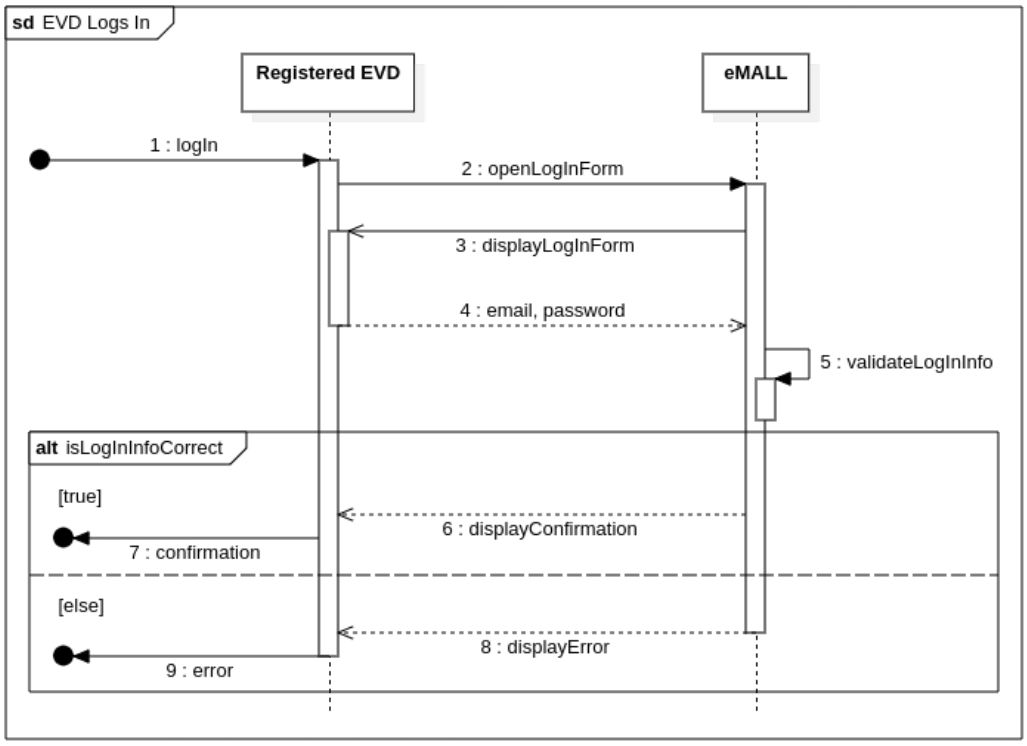


Figure 3.5: Registered EVD logs in sequence diagram

UC3. Registered EVD adds an EV

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The EVD clicks the "Add a Vehicle" button from his profile section of `eMALL`
Event Flow	1. `eMALL` asks the registered EVD to insert car information. 2. The registered EVD inserts the requested information and he sends them to the `eMALL`. 3. `eMALL` validates the information searching for possible errors. 4. `eMALL` asks the registered EVD to insert a nickname for the vehicle to save in his profile. 5. The registered EVD inserts the nickname. 6. `eMALL` validates the nickname also searching for duplicates between user EV nicknames. 7. `eMALL` sends back the registration outcome.
Exit condition	Registered EVD correctly added a new EV in the profile.
Exceptions	3.1 The e-mail is not recognized. 5.1 The inserted nickname is already taken between those owned by the user. In both cases, the registered EVD receives a notification through an error message.

Table 3.5: Registered EVD adds an EV use case.

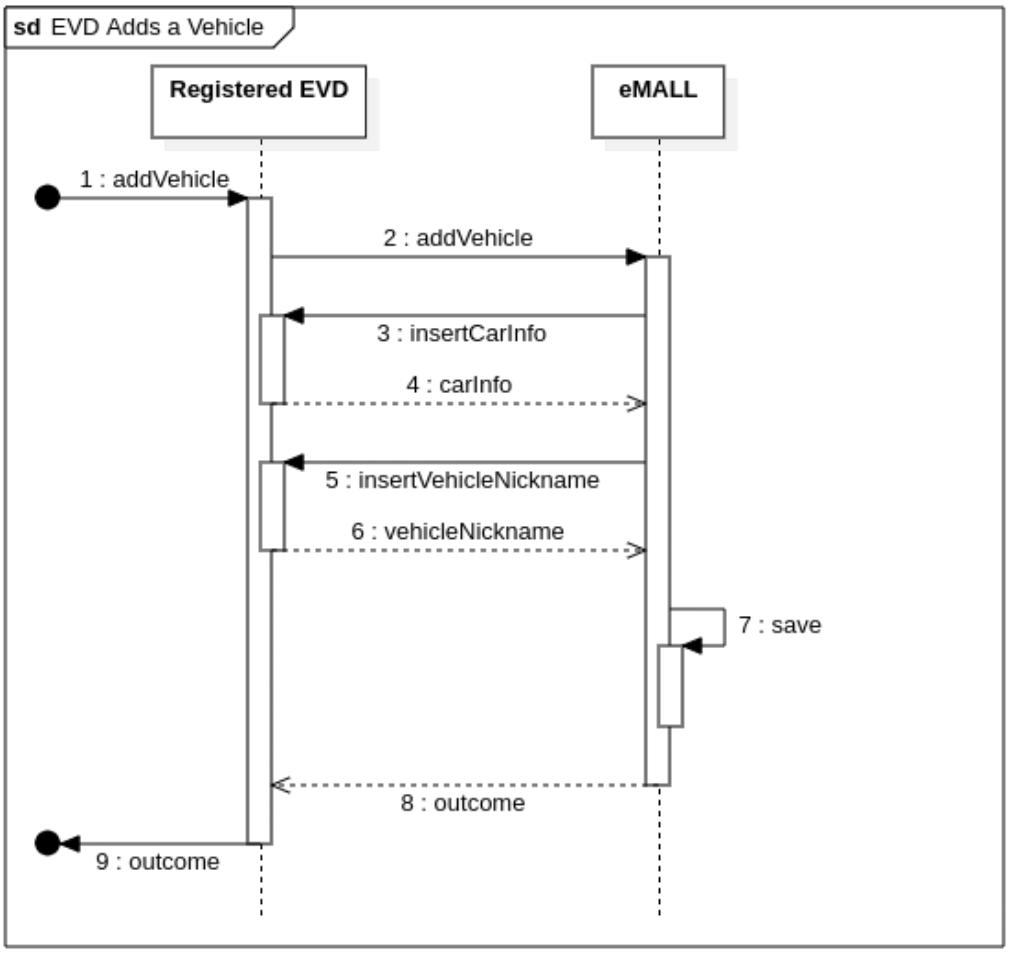


Figure 3.6: Registered EVD adds an EV sequence diagram

UC4. Registered EVD books a charge

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The registered EVD selects a specific charging station and clicks the "book" button
Event Flow	1. `eMALL` asks the registered EVD to choose a timeframe. 2. The registered EVD inserts the timeframe. 3. `eMALL` checks if the selected timeframe is currently available. 4. `eMALL` selects a charging point to reserve for the registered EVD depending on EV's specifications.

	5. eMALL asks the registered EVD to confirm the booking with the prompted information. 6. The registered EVD clicks the "Confirm" button to confirm the booking. 7. eMALL adds the booking to the registered EVD's calendar. 8. eMALL sends back the booking outcome.
Exit condition	A charging session is booked.
Exceptions	3.1. No free charging points are available at the selected timeframe. The registered EVD is notified with an error message, and asked to select a new timeframe.

Table 3.6: Registered EVD books a charge use case.

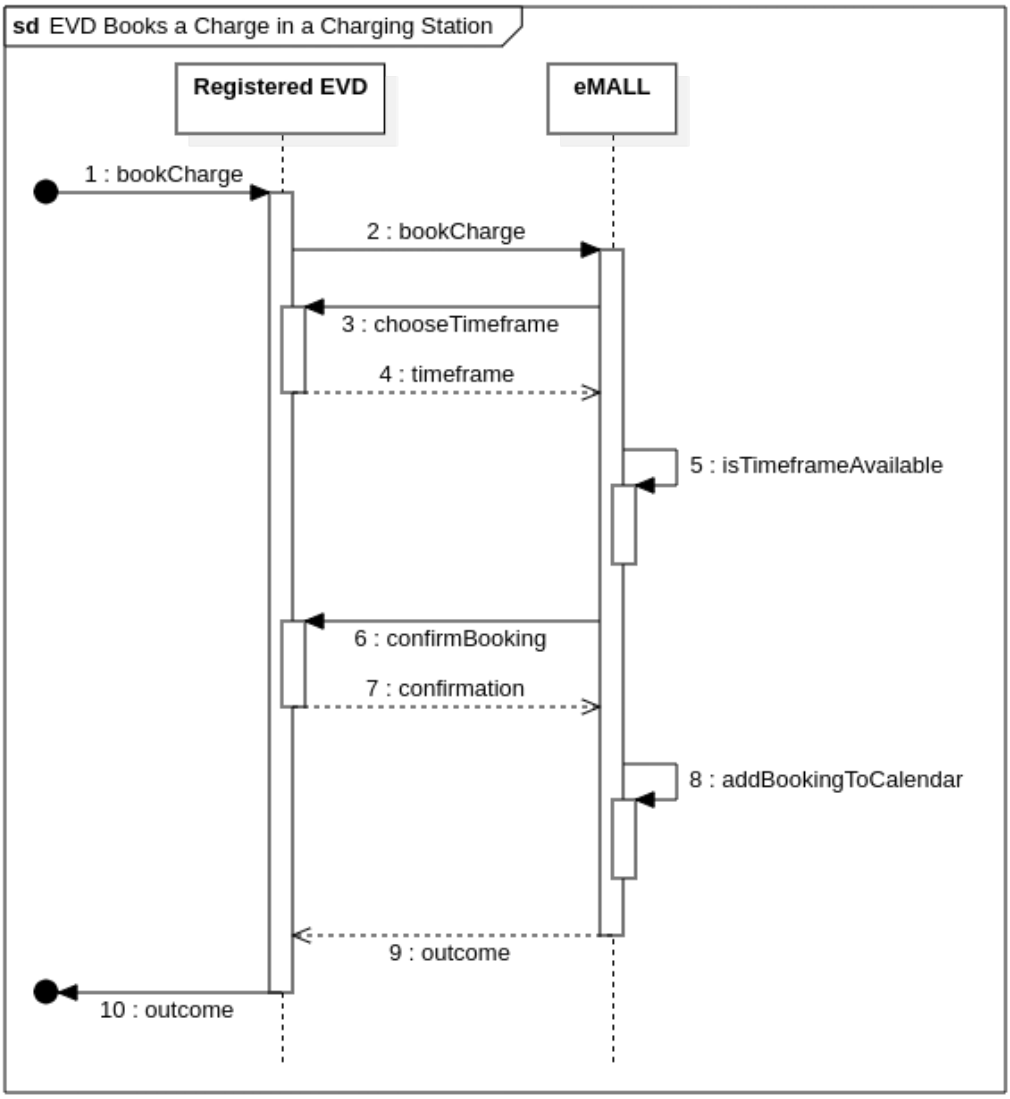


Figure 3.7: Registered EVD books a charge sequence diagram

UC5. Registered EVD consults the map of charging stations

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The registered EVD is in the map section at a given or specified location.
Event Flow	1. `eMALL` shows the map with all the charging stations available over a specific location. 2. The registered EVD moves on the map, searching for a charging station. 3. `eMALL` retrieves the charging station locations in the new place. 4. The registered EVD selects a specific charging station to get its detailed information. 5. `eMALL` retrieves the charging station's detailed information.
Exit condition	The registered EVD changes section, and moves from the dashboard.
Exceptions	1.1 The registered EVD did not accept sharing location. In this case, the registered EVD is notified by an error message and needs to move to its position manually.

Table 3.7: Registered EVD consults the map of charging stations use case.

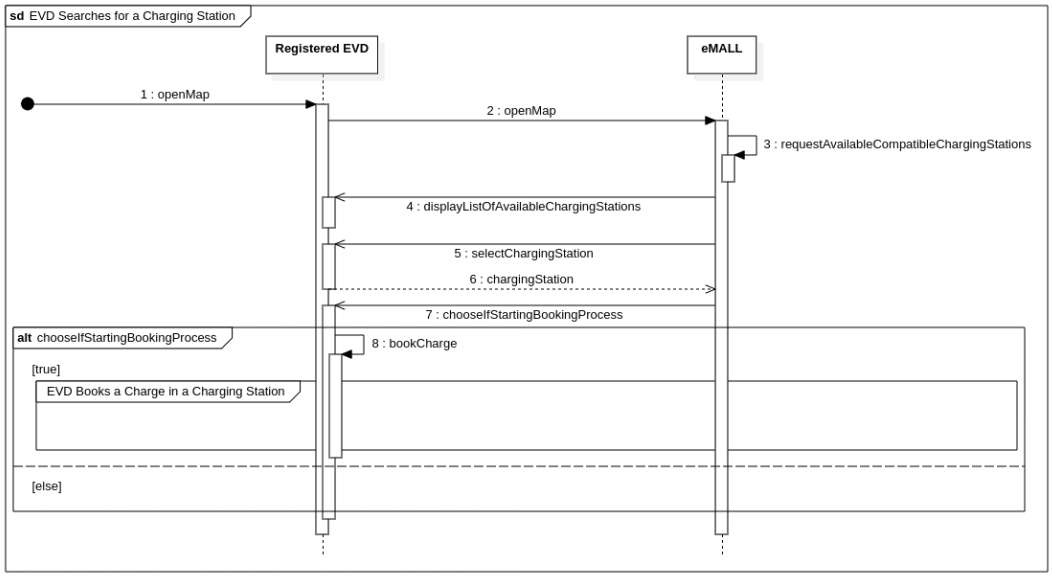


Figure 3.8: Registered EVD consults the map of charging stations sequence diagram

UC6. Registered EVD consults a specific promotion that can be redeemed

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The EVD is in the promotion section.
Event Flow	1. `eMALL` sends the promotion list to the registered EVD. 2. The registered EVD selects a promotion to activate. 3. The registered EVD triggers the offer. 4. `eMALL` asks the registered EVD to choose between his payment methods. 5. The registered EVD picks the payment method. 6. `eMALL` asks the registered EVD to confirm the payment. 7. The registered EVD authorizes the payment. 8. `eMALL` makes the payment. 9. `eMALL` sends back the payment outcome.
Exit condition	The promotion has been activated.
Exceptions	8.1. The payment fails due to no sufficient funds. 8.2. The payment fails due to the failure of the transaction. 8.3. The payment fails because of data input errors. 8.4. The payment fails due to technical issues. In these cases, the registered EVD receives a notification with an error message, and the promotion is not activated.

Table 3.8: Registered EVD consults a specific promotion that can be redeemed use case.

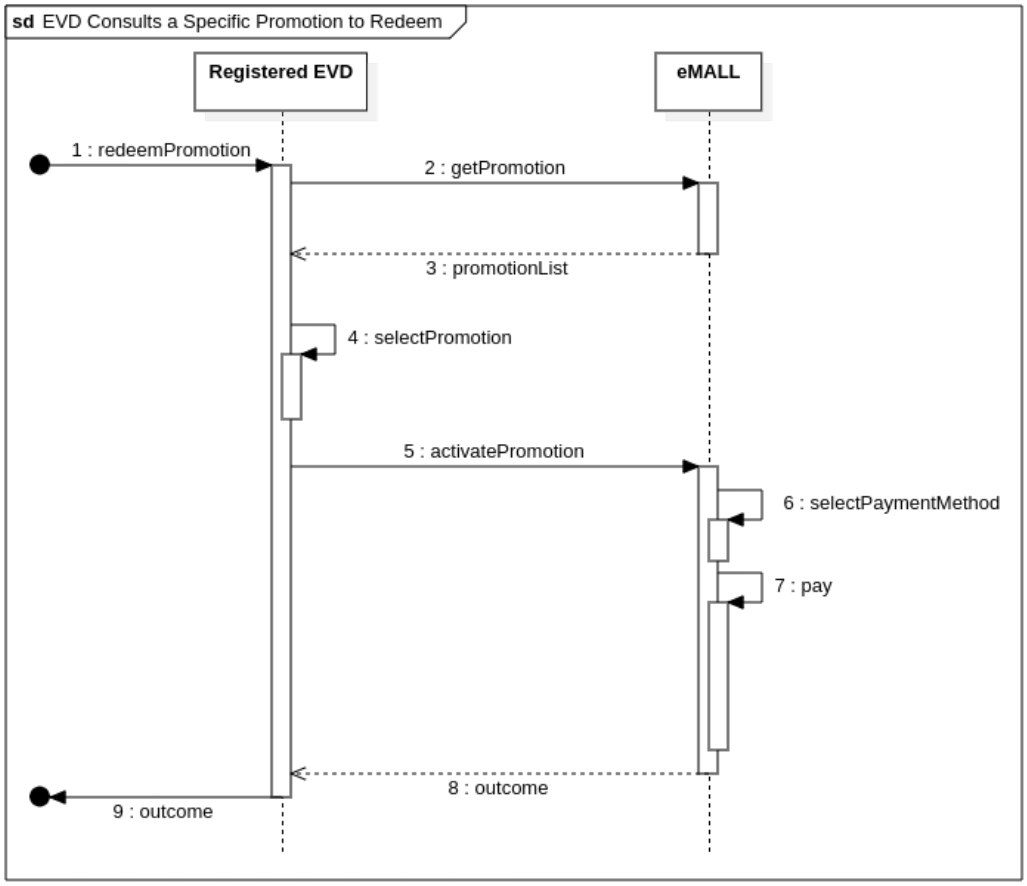


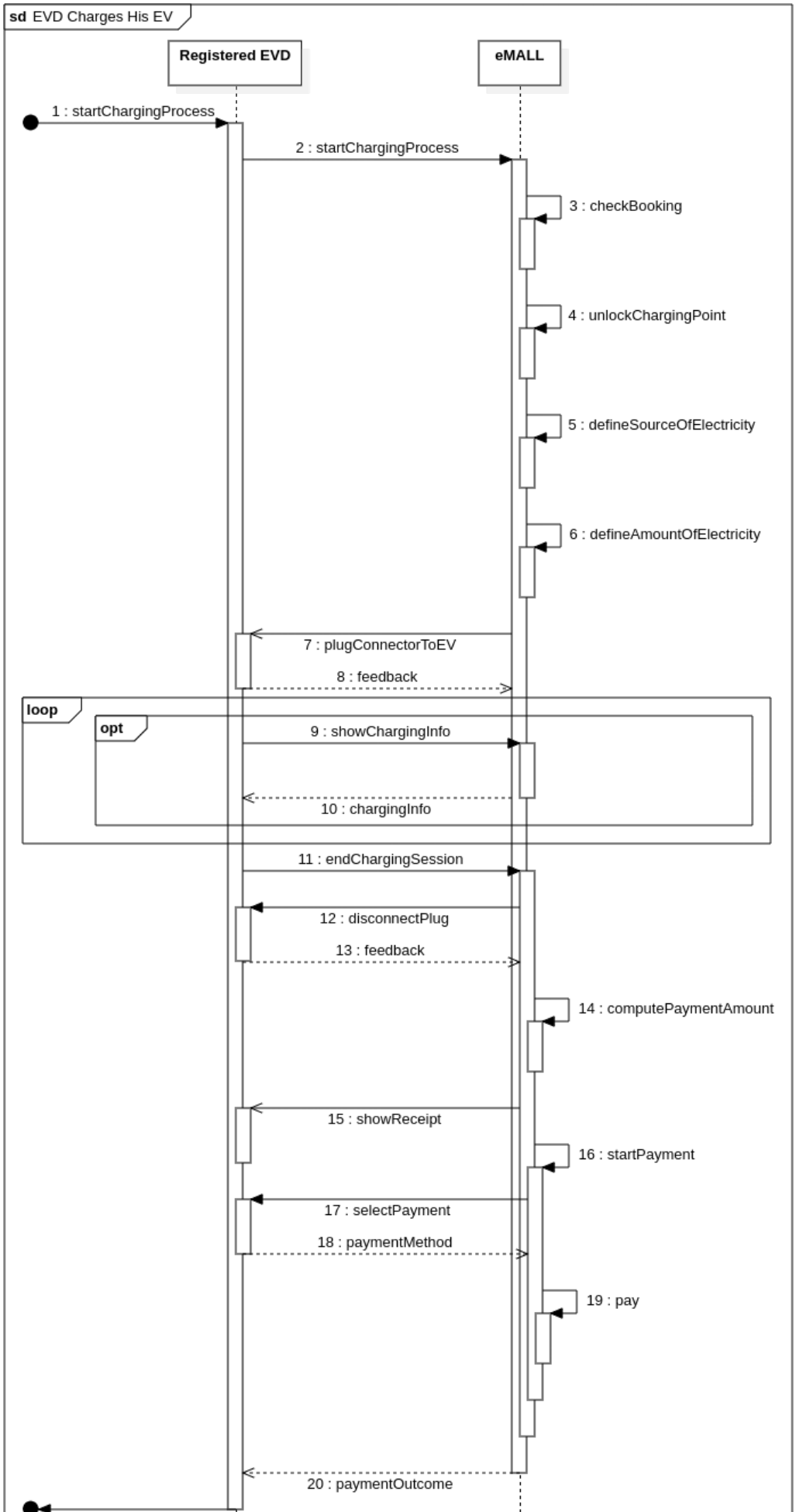
Figure 3.9: Registered EVD consults a specific promotion that can be redeemed sequence diagram

UC7. Registered EVD charges his EV

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The EVD asks the charging point to charge his EV.
Event Flow	1. `eMALL` communicates to the EVD if he has been correctly authenticated and if he can charge at the charging point. 2. The registered EVD initializes the charging process. 3. `eMALL` defines the source of the electricity (batteries or DSO). 4. `eMALL` defines how much electricity to give to the connected EV depending on actual energy demand. 5. `eMALL` sends updates of the charging session to the EVD. 6. The registered EVD stops the charging process.

	7. eMALL sends the receipt of the charging session to the EVD. 8. The registered EVD makes the payment for the charging session. 9. eMALL sends back the payment outcome
Exit condition	The registered EVD has charged the EV and paid for the service received.
Exceptions	1.1 The registered EVD is not authorized to charge the EV at that charging point. 2.1 The EV is not correctly connected and the session can't be started. In both cases, the registered EVD is notified with an error message.

Table 3.9: Registered EVD charges his EV use case.


sd EVD Charges His EV
Registered EVD
eMALL
1 : startChargingProcess
2 : startChargingProcess
3 : checkBooking
4 : unlockChargingPoint
5 : defineSourceOfElectricity
6 : defineAmountOfElectricity
7 : plugConnectorToEV
8 : feedback
loop
opt
9 : showChargingInfo
10 : chargingInfo
11 : endChargingSession
12 : disconnectPlug
13 : feedback
14 : computePaymentAmount
15 : showReceipt
16 : startPayment
17 : selectPayment
18 : paymentMethod
19 : pay
20 : paymentOutcome

UC8. Registered EVD makes a payment

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The registered EVD has decided the charging station where will charge the EV and is in the payment module.
Event Flow	1. `eMALL` shows registered EVD's payment methods and asks to select one of them. 2. The registered EVD selects a payment method. 3. `eMALL` verifies funds availability. 4. `eMALL` starts the payment process. 5. `eMALL` sends back the payment outcome.
Exit condition	The registered EVD has paid for a book or for a activation of a promotion.
Exceptions	5.1. The payment fails due to no sufficient funds. 5.2. The payment fails due to the failure of the transaction. 5.3. The payment fails because of data input errors. 5.4. The payment fails due to technical issues. In these cases, the registered EVD receives a notification with an error message, and the promotion is not activated.

Table 3.10: Registered EVD makes a payment use case.

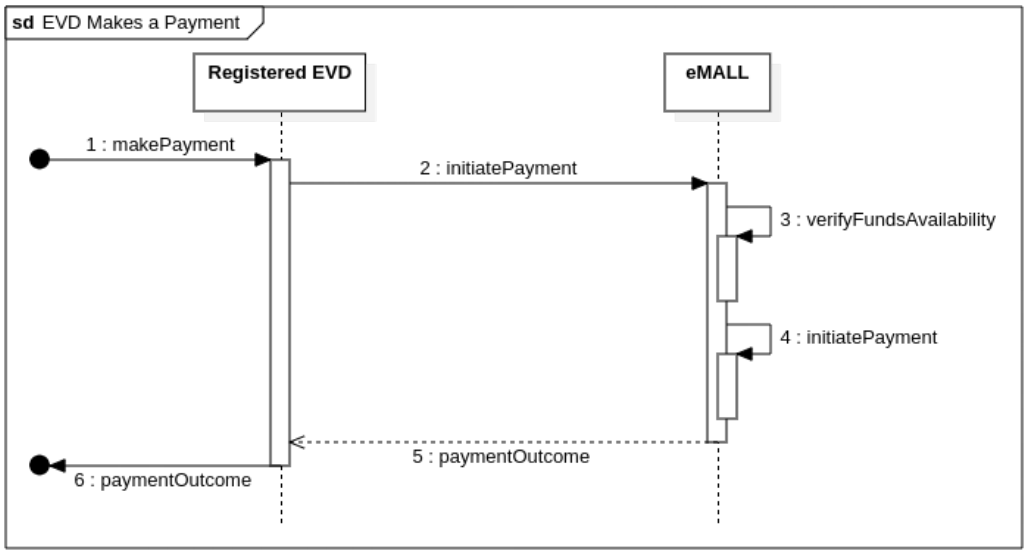


Figure 3.11: Registered EVD makes a payment sequence diagram

UC9. Registered EVD adds a new activity into the calendar and receives suggestions about charging schedule

Actor	Registered EVD
Entry conditions	The EVD is registered and correctly logged in. The registered EVD opens the calendar section.
Event Flow	1. eMALL shows the calendar to the registered EVD. 2. The registered EVD clicks the "insert new activity" button. 3. eMALL sends the form to be compiled for the addition of a new activity. 4. The registered EVD inserts and submits the requested information. 5. eMALL processes the received form. 6. eMALL saves the new activity into registered EVD calendar. 7. eMALL calculates the best schedule of where and when to charge the EV and sends it to the registered EVD. 8. The registered EVD selects a charging station from the list of stations suggested by eMALL. 9. eMALL books the selected charging station at the specified timeframe. 10. eMALL sends back the booking outcome to the registered EVD.
Exit condition	The registered EVD inserted a new activity received a suggestion about charging session.
Exceptions	5.1 The registered EVD has inserted a new activity that starts at the same hour of another one previously inserted. In this case, the registered EVD is notified with an error message and brought back to the calendar section.

Table 3.11: Registered EVD adds a new activity into the calendar and receives suggestions about charging schedule use case.

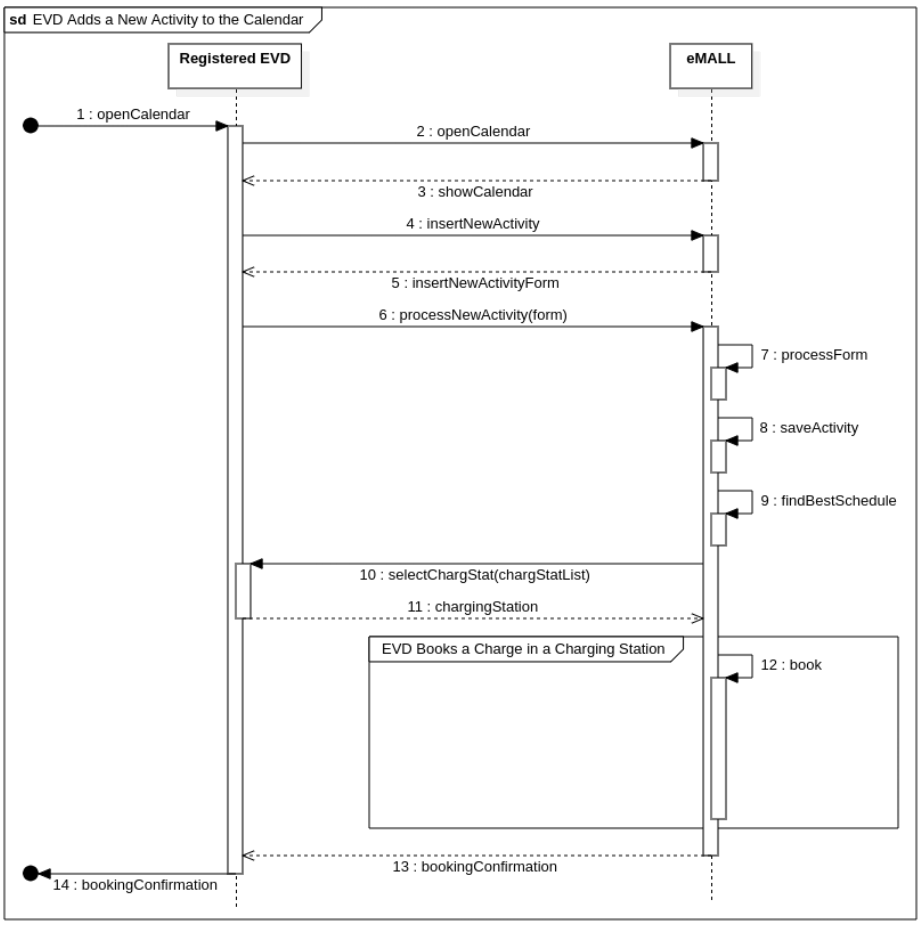


Figure 3.12: Registered EVD adds a new activity into the calendar and receives suggestions about charging schedule sequence diagram

UC10. CPO logs in

Actor	CPO
Entry conditions	CPO's operator is in the business login section.
Event Flow	1. `eMALL` asks the CPO operator to insert his credentials to log in. 2. The CPO operator inserts the CPO ID associated with its company, password, and email. 3. `eMALL` validates the inserted credentials combination. 4. `eMALL` sends back the login outcome.
Exit condition	The CPO access the business section of the `eMALL` system
Exceptions	3.1.1. CPO credentials are not correct and not validated by `eMALL`. 3.2.1. CPO's affiliate agreement has expired, and its ID is no longer allowed to access the system.

	In both cases, the user receives a notification with an error message. Also, in the second case, the operator is invited to call the sales team.

Table 3.12: CPO logs in use case.

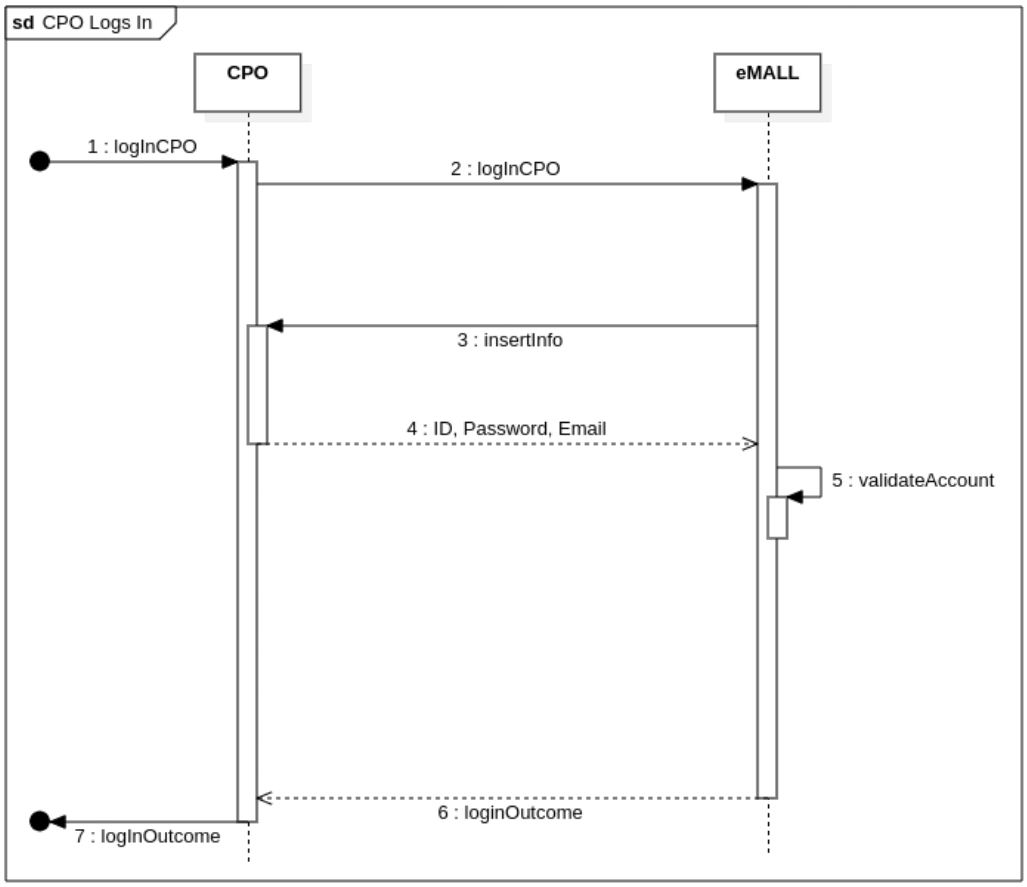


Figure 3.13: CPO logs in sequence diagram

UC11. CPO sets a fee

Actor	CPO
Entry conditions	The CPO is subscribed to the `eMALL` system and correctly logged in. The CPO enters the profile section.
Event Flow	1. `eMALL` shows the CPO his profile. 2. The CPO enters the charging station managing section.

	3. eMALL shows the CPO his managing charging station section. 4. The CPO taps the "manage price" button. 5. The CPO inserts the value of the fee. 6. The CPO taps the submission button. 7. eMALL sends back the outcome of the setting of the fee.
Exit condition	The fee is set to the new value.
Exceptions	7.1 The CPO inserted a negative value. In this case, the system asks the CPO to insert a new value.

Table 3.13: CPO sets a fee use case.

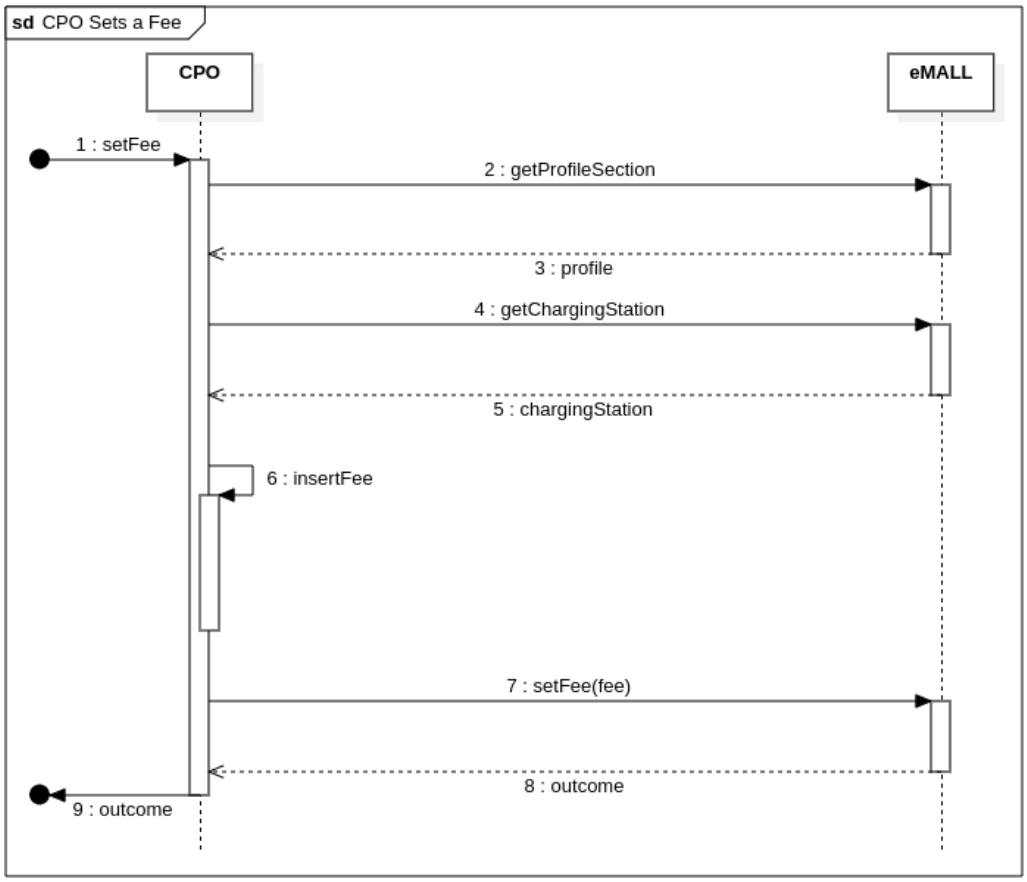


Figure 3.14: CPO sets a fee sequence diagram

UC12. CPO adds a charging station

Actor	CPO
Entry conditions	The CPO is subscribed to the eMALL system and correctly logged in. The CPO is in the charging station section from the profile section. The CPO clicks the button to add a new charging station to its profile.
Event Flow	1. eMALL asks the CPO to insert the location of the new charging station. 2. The CPO inserts the region, province, city, and address of the new charging station. 3. eMALL asks the CPO to insert the initial status of the new charging station. 4. The CPO inserts the status of the new charging station (available, maintenance, broken, unavailable). 5. eMALL asks the CPO to insert the charging costs. 6. The CPO inserts the charging costs. 7. eMALL asks the CPO to add charging points to the new charging station. 8. The CPO inserts the information of the charging points. 9. eMALL validates all the inserted information. 10. eMALL sends back the outcome of the insertion of the new charging station.
Exit condition	The charging station is created and added to the CPO's profile.
Exceptions	9.1 There is already a charging station at the same location specified by the CPO. The CPO receives a notification with an error message, and the charging station is not created.

Table 3.14: CPO adds a charging station use case.

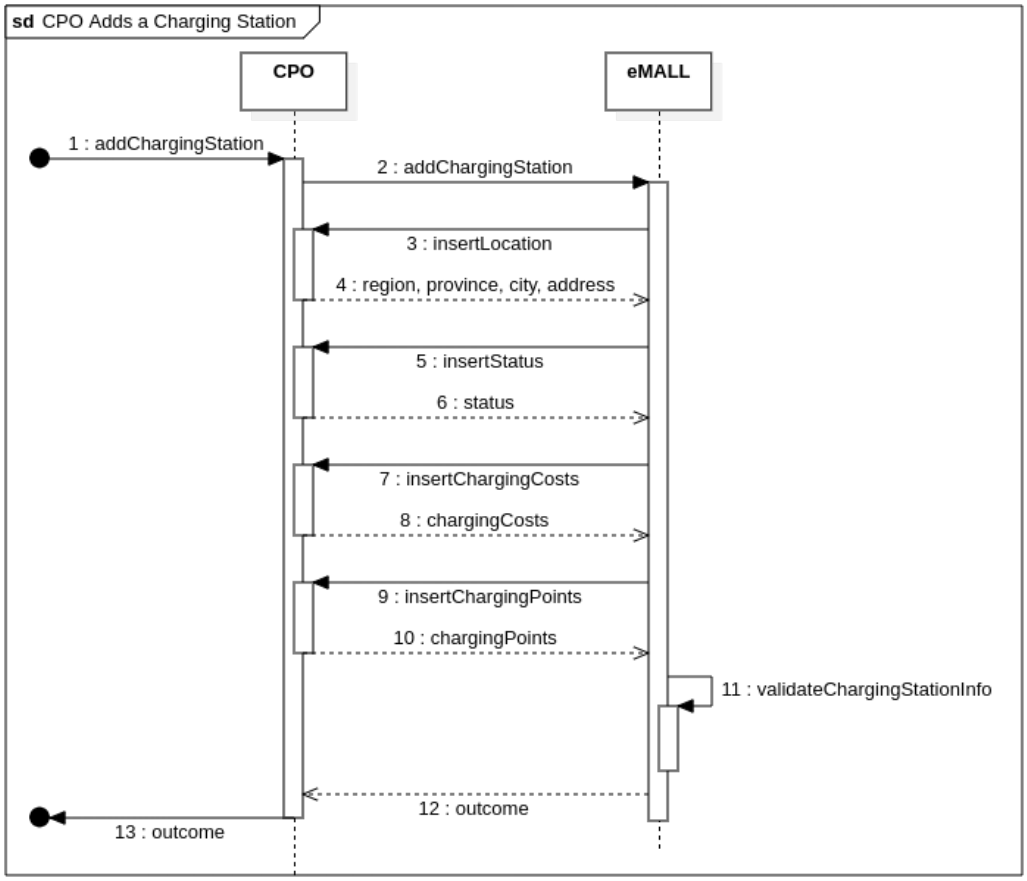


Figure 3.15: CPO adds a charging station sequence diagram

UC13. CPO adds a charging point

Actor	CPO
Entry conditions	The CPO is subscribed to the `eMALL` system and correctly logged in. The CPO is in the charging station section from the profile section. The CPO clicks the "add charging point" button.
Event Flow	1. `eMALL` shows the CPO the list of its charging stations and asks it to select one. 2. The CPO selects a charging station. 3. `eMALL` asks the CPO to insert the information about the charging station.

	4. The CPO inserts the serial number, the types of connectors installed on the charging point, the power supply, the initial status of the charging point, and the other required information. 5. `eMALL` validates the inserted information about the charging point. 6. `eMALL` sends back to the CPO the outcome of the creation of the new charging point.
Exit condition	The charging point is added to the charging station.
Exceptions	4.1 There is already a charging point with the same serial number in the profile of the CPO. The CPO receives a notification with an error message, and the charging station is not created.

Table 3.15: CPO adds a charging point use case.

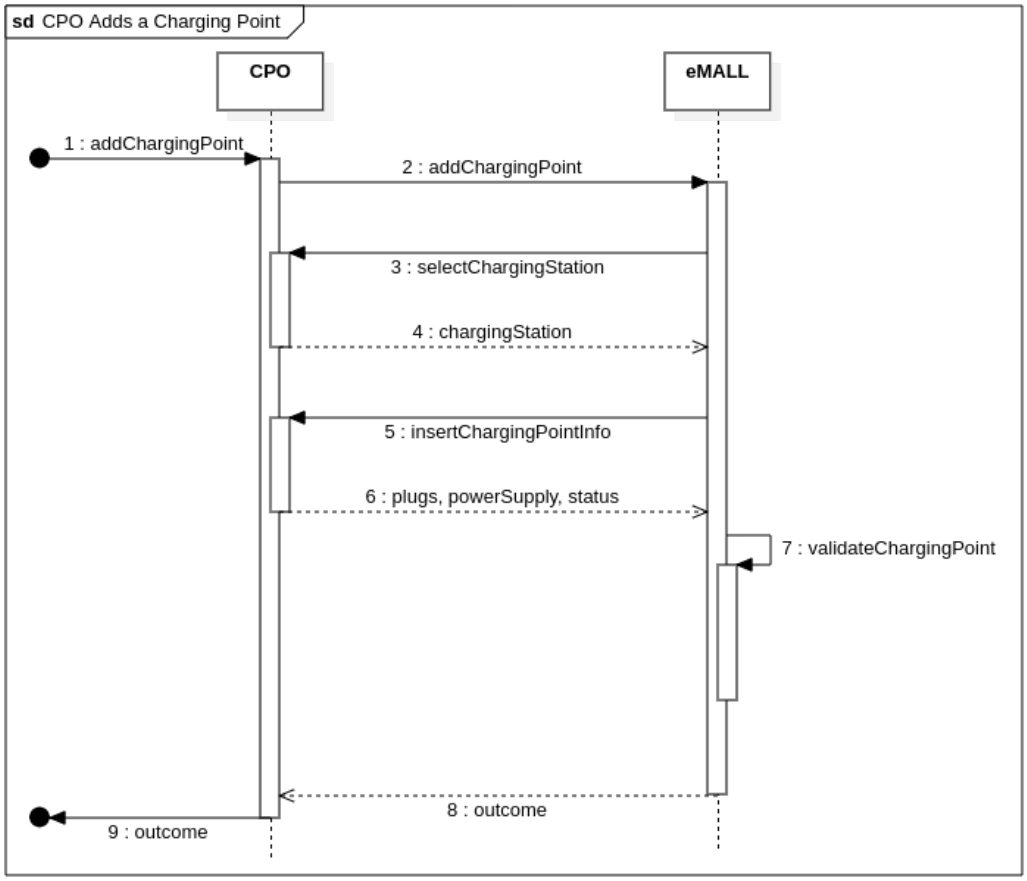


Figure 3.16: CPO adds a charging point sequence diagram

UC14. CPO changes the metadata of a charging point

Actor	CPO
Entry conditions	The CPO is subscribed to the `eMALL` system and correctly logged in. The CPO is in the charging station section from the profile section. The CPO clicks the "edit charging station" button.
Event Flow	1. `eMALL` shows the CPO the list of its charging stations and asks it to select one. 2. The CPO selects a charging station. 3. `eMALL` asks the CPO to insert the new values for the charging point. 4. The CPO edits the metadata of the charging station. 5. `eMALL` updates the charging point with the new inserted values. 6. `eMALL` sends back to the CPO the outcome of the update.
Exit condition	The metadata of the charging station is updated.
Exceptions	4.1 The CPO inserts a new serial number of a charging point that is already registered into the system. In this case, the system asks the CPO to insert again the value.

Table 3.16: CPO changes the metadata of a charging point use case.

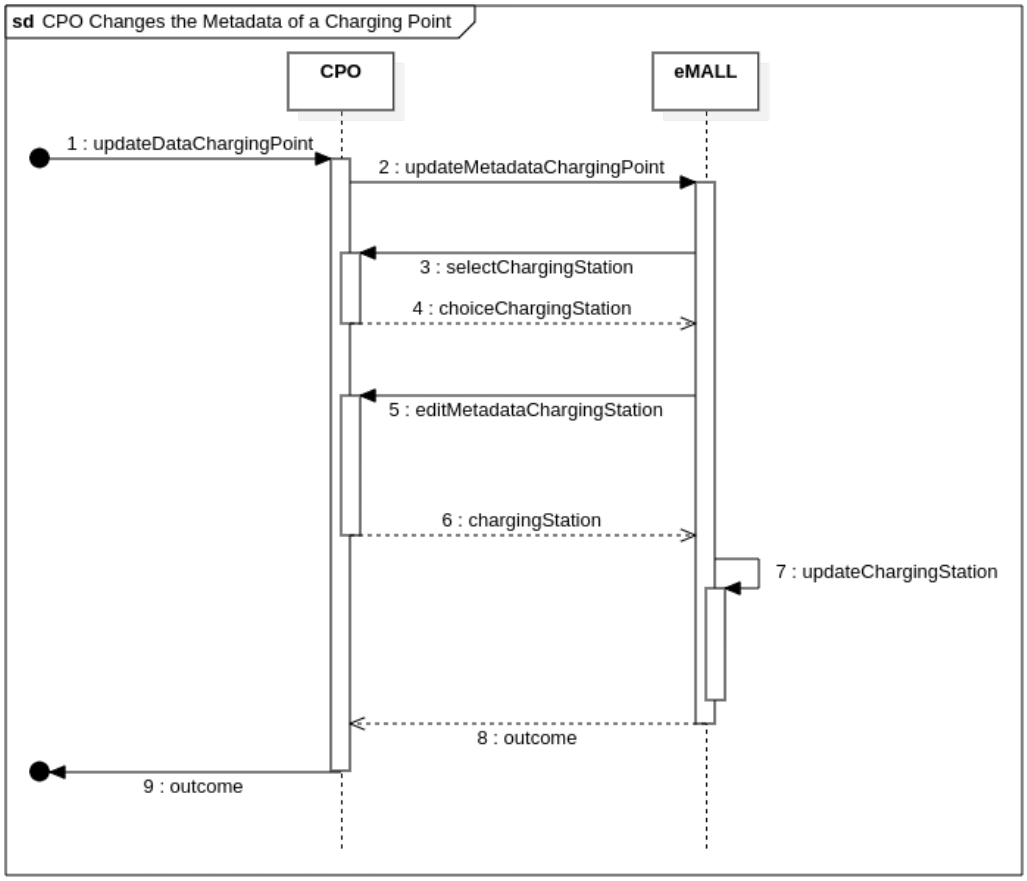


Figure 3.17: CPO changes the metadata of a charging point sequence diagram

UC15. CPO activates a promotion

Actor	CPO
Entry conditions	The CPO is subscribed to the eMALL system and correctly logged in. The CPO is in the profile section. The CPO clicks the "activate new promotion" button.
Event Flow	1. eMALL asks the CPO to define the features of the new promotion. 2. The CPO defines the features of the new promotion. 3. eMALL saves the new promotion. 4. eMALL initializes the promotion. 5. eMALL sends back to the CPO the outcome of the activation of the new promotion.
Exit condition	The promotion is created and activated.

Exceptions	2.1 The CPO inserted a date that is in the past. 2.2 The CPO inserted requirements of a promotion that conflict with its other promotions.

Table 3.17: CPO activates a promotion use case.

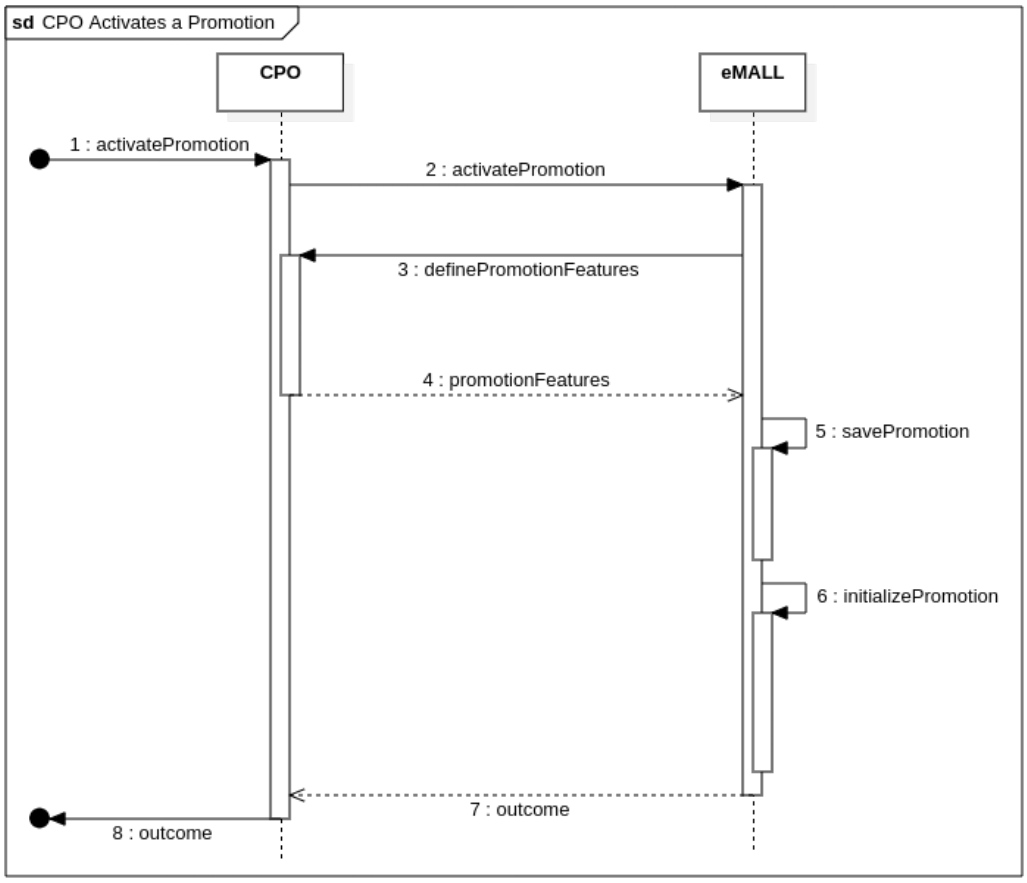


Figure 3.18: CPO activates a promotion sequence diagram

UC16. CPO plans a maintenance session for a charging station

Actor	CPO
Entry conditions	The CPO is subscribed to the `eMALL` system and correctly logged in. The CPO is in the charging station section from the profile section and has selected a station.

	The CPO clicks the "schedule maintenance" button.
Event Flow	1. eMALL asks the CPO to specify the date and the hour of the maintenance. 2. eMALL plans the maintenance session of the charging station. 3. eMALL sends back the outcome of the planning of the maintenance to the CPO.
Exit condition	It is planned a maintenance session for the specified charging station.
Exceptions	2.1 The CPO tries to schedule a maintenance in a day that is in the past. 2.2 The CPO tries to schedule a maintenance that conflicts with another maintenance session already scheduled.

Table 3.18: CPO plans a maintenance session for a charging station use case.

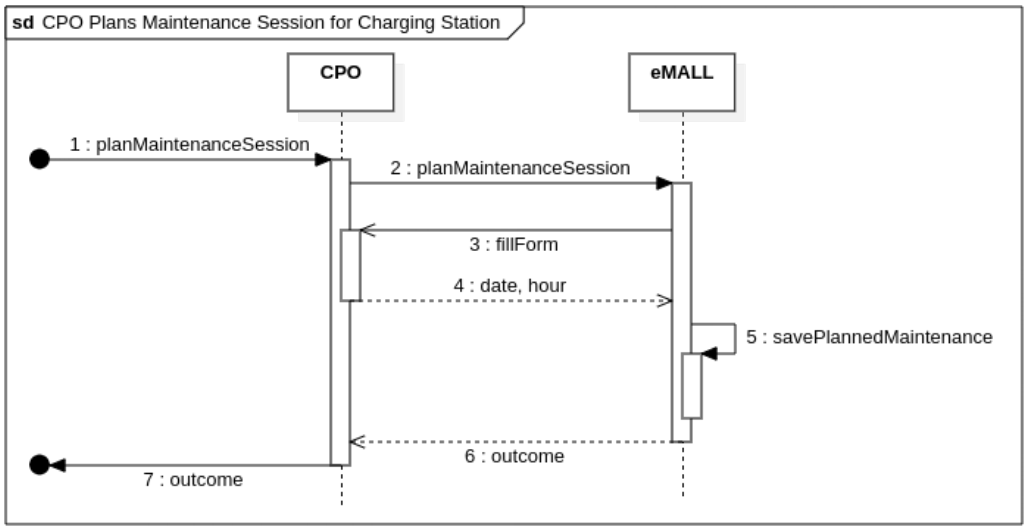


Figure 3.19: CPO plans a maintenance session for a charging station sequence diagram

UC17. CPO decides the DSO from which acquire energy

Actor	CPO
Entry conditions	The CPO is subscribed to the eMALL system and correctly logged in. The CPO is in the DSO section from the profile section.

	The CPO clicks the "set DSO" button.
Event Flow	1. eMALL shows the CPO the list of DSOs. 2. eMALL asks the CPO to select a DSO from the list. 3. The CPO selects a DSO from the list. 4. eMALL updates CPO's profile information. 5. eMALL activates the selected DSO as the one from which to acquire energy. 6. eMALL sends back to the CPO the outcome of the setting of the DSO
Exit condition	The DSO from which to acquire energy is updated.
Exceptions	3.1 It is impossible to communicate with the chosen DSO, so it can't be set as new electricity provider. In this case, the CPO is asked to select another DSO or to end the process.

Table 3.19: CPO decides the DSO from which acquire energy use case.

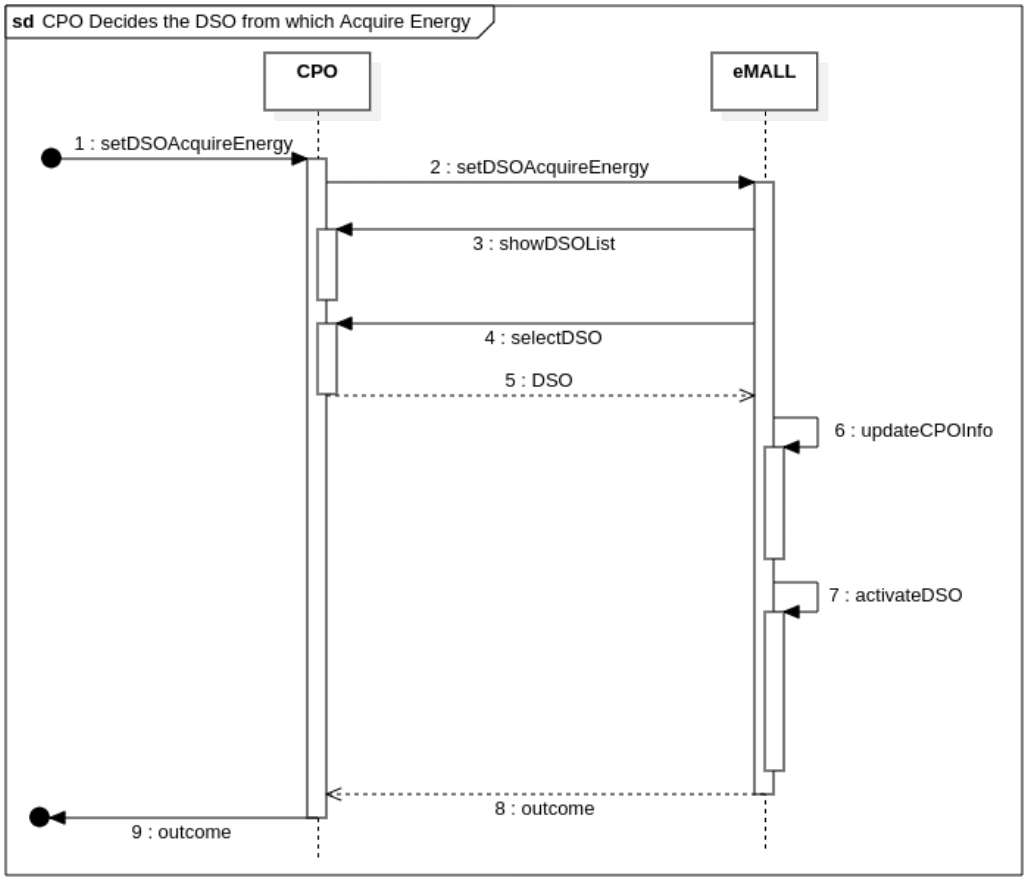


Figure 3.20: CPO decides the DSO from which acquire energy sequence diagram

3.2.5. Mapping on requirements

Use Case	Requirements
UC1	R1. The eMALL system shall allow an unregistered EVD to create an account. R21. The eMALL system shall allow a registered EVD to insert a new payment method. R24. The eMALL system shall communicate with third-party payment services to make the payments. R69. The eMALL system shall store users information.
UC2	R2. The eMALL system shall allow a registered EVD to log in.
UC3	R2. The eMALL system shall allow a registered EVD to log in. R3. The eMALL system shall allow a registered EVD to add an EV in his profile. R4. The eMALL system shall communicate with EV's brand API to get needed information.

	R11. The eMALL system shall allow a registered EVD to select a specific charging station.
UC4	R2. The eMALL system shall allow a registered EVD to log in. R5. The eMALL system shall allow a registered EVD to book a charge. R6. The eMALL system shall allow a registered EVD to select a timeframe to reserve a charging point. R7. The eMALL system shall add a booked reservation into EVD's calendar. R55. The eMALL system shall reserve a charging point in a certain timeframe. R69. The eMALL system shall store users information.
UC5	R2. The eMALL system shall allow a registered EVD to log in. R8. The eMALL system shall allow a registered EVD to get all the charging station near to his current location. R9. The eMALL system shall allow a registered EVD to insert a specific location to get charging station nearby. R10. The eMALL system shall allow a registered EVD to move into the map of charging stations. R11. The eMALL system shall allow a registered EVD to select a specific charging station. R12. The eMALL system shall allow a registered EVD to get the location of a specific charging station. R13. The eMALL system shall allow a registered EVD to get the costs of a specific charging station. R14. The eMALL system shall allow a registered EVD to get the CPO owner of a specific charging station. R15. The eMALL system shall allow a registered EVD to get type of connectors of a specific charging station. R16. The eMALL system shall allow a registered EVD to get maximum power supply of the spots of a specific charging station. R17. The eMALL system shall allow a registered EVD to get the status of a specific charging station. R69. The eMALL system shall store users information.
UC6	R2. The eMALL system shall allow a registered EVD to log in. R18. The eMALL system shall allow a registered EVD to get the list of active promotions. R19. The eMALL system shall allow a registered EVD to select a specific promotion. R20. The eMALL system shall allow a registered EVD to activate a promotion.

	R21. The eMALL system shall allow a registered EVD to insert a new payment method. R22. The eMALL system shall allow a registered EVD to select a payment method. R23. The eMALL system shall allow a registered EVD to pay with the preferred payment method. R24. The eMALL system shall communicate with third-party payment services to make the payments. R69. The eMALL system shall store users information.
UC7	R2. The eMALL system shall allow a registered EVD to log in. R22. The eMALL system shall allow a registered EVD to select a payment method. R23. The eMALL system shall allow a registered EVD to pay with the preferred payment method. R24. The eMALL system shall communicate with third-party payment services to make the payments. R25. The eMALL system shall allow a registered EVD to start a charging process. R26. The eMALL system shall verify the identity of the EVD requesting to start a charging session. R27. The eMALL system shall communicate to charging points to unlock their plug. R28. The eMALL system shall communicate to charging points to start the charging session. R29. The eMALL system shall define the source of the charging session (batteries or DSO). R30. The eMALL system shall define the power of the charging session. R31. The eMALL system shall get EV's battery status. R32. The eMALL system shall send notifications about the current status of the charging session to the registered EVD. R33. The eMALL system shall allow a registered EVD to stop the charging session. R34. The eMALL system shall communicate to a charging point to stop the charging session. R35. The eMALL system shall send the receipt of the charging session to the registered EVD. R36. The eMALL system shall communicate the outcome of the payment to a registered EVD.

	R69. The eMALL system shall store users information.
UC8	R2. The eMALL system shall allow a registered EVD to log in. R22. The eMALL system shall allow a registered EVD to select a payment method. R23. The eMALL system shall allow a registered EVD to pay with the preferred payment method. R24. The eMALL system shall communicate with third-party payment services to make the payments. R69. The eMALL system shall store users information.
UC9	R2. The eMALL system shall allow a registered EVD to log in. R5. The eMALL system shall allow a registered EVD to book a charge. R11. The eMALL system shall allow a registered EVD to select a specific charging station. R37. The eMALL system shall allow a registered EVD to access in his own calendar. R38. The eMALL system shall allow a registered EVD to add a new activity into his calendar. R39. The eMALL system shall allow a registered EVD to specify the starting hour of a new activity. R40. The eMALL system shall allow a registered EVD to specify the destination of a new activity. R41. The eMALL system shall save a new activity into EVD's calendar. R42. The eMALL system shall calculate the best schedules of where and when to charge registered EVD's EV so to minimize costs and wasted time. R43. The eMALL system shall communicate to the registered EVD the details of the suggestions about the calculated schedules. R69. The eMALL system shall store users information.
UC10	R44. The eMALL system shall allow a CPO to log in as a business user.
UC11	R44. The eMALL system shall allow a CPO to log in as a business user. R45. The eMALL system shall allow a CPO to manage its charging stations. R46. The eMALL system shall allow a CPO to set new selling prices for charging sessions. R69. The eMALL system shall store users information.
UC12	R44. The eMALL system shall allow a CPO to log in as a business user. R45. The eMALL system shall allow a CPO to manage its charging stations. R47. The eMALL system shall allow a CPO to add a new charging station in its profile.

	R48. The eMALL system shall allow a CPO to specify the location of charging station (region, province, city, address). R49. The eMALL system shall allow a CPO to specify the status of a charging station (available, maintenance, broken, unavailable). R50. The eMALL system shall allow a CPO to add a charging point in an existing charging station. R51. The eMALL system shall allow a CPO to specify the serial number of charging point. R52. The eMALL system shall allow a CPO to specify the types of connectors of a charging point. R53. The eMALL system shall allow a CPO to specify the maximum power of a charging point. R54. The eMALL system shall allow a CPO to specify the type of connectors of a charging point. R69. The eMALL system shall store users information.
UC13	R44. The eMALL system shall allow a CPO to log in as a business user. R45. The eMALL system shall allow a CPO to manage its charging stations. R50. The eMALL system shall allow a CPO to add a charging point in an existing charging station. R51. The eMALL system shall allow a CPO to specify the serial number of charging point. R52. The eMALL system shall allow a CPO to specify the types of connectors of a charging point. R53. The eMALL system shall allow a CPO to specify the maximum power of a charging point. R54. The eMALL system shall allow a CPO to specify the type of connectors of a charging point. R69. The eMALL system shall store users information.
UC14	R44. The eMALL system shall allow a CPO to log in as a business user. R45. The eMALL system shall allow a CPO to manage its charging stations. R50. The eMALL system shall allow a CPO to add a charging point in an existing charging station. R51. The eMALL system shall allow a CPO to specify the serial number of charging point. R52. The eMALL system shall allow a CPO to specify the types of connectors of a charging point.

	R53. The eMALL system shall allow a CPO to specify the maximum power of a charging point. R54. The eMALL system shall allow a CPO to specify the type of connectors of a charging point. R69. The eMALL system shall store users information.
UC15	R44. The eMALL system shall allow a CPO to log in as a business user. R56. The eMALL system shall allow a CPO to manage its promotions. R57. The eMALL system shall allow a CPO to create a new promotion. R58. The eMALL system shall allow a CPO to specify the details of the a promotion. R59. The eMALL system shall save the information of a promotion. R60. The eMALL system shall initialize the information of a new promotion. R69. The eMALL system shall store users information.
UC16	R44. The eMALL system shall allow a CPO to log in as a business user. R45. The eMALL system shall allow a CPO to manage its charging stations. R61. The eMALL system shall allow a CPO to schedule a maintenance session for a charging station. R62. The eMALL system shall allow a CPO to specify date and starting hour of a maintenance session for a charging station. R63. The eMALL system shall communicate to a charging station to schedule a maintenance at a specified timeframe. R69. The eMALL system shall store users information.
UC17	R44. The eMALL system shall allow a CPO to log in as a business user. R64. The eMALL system shall allow a CPO to get the list of DSOs. R65. The eMALL system shall allow a CPO to select a DSO from the list of DSOs. R66. The eMALL system shall allow a CPO to update its electricity provider. R67. The eMALL system shall communicate to a specified DSO to send energy to the charging stations of a CPO. R68. The eMALL system shall get the electricity selling prices from the DSOs. R69. The eMALL system shall store users information. R70. The eMALL system shall allow the CPO to manage its company personal information.

Table 3.20: Mapping on requirements.

3.3. Performance Requirements

Number of users

According to a market analysis conducted by MOTUS-E in September 2022, the number of fully electric vehicles and plug-in hybrid vehicles registered in Italy is 320.776. If we suppose that the eMALL system will be used by one in every three EVDs, the system should guarantee that it can handle an overall of 100.000 clients.
So, we can consider that the system should be able to handle simultaneously the 50% of them.

Data storage

From the data storage point of view, the eMALL system should consider several sources of data:

- **EVD's personal data.** We consider that 5 KB is enough for the storage of personal information of an EVD. Considering 10^5 EVDs, the system needs:

$$10^5 \cdot 5 \ KB = 488,3 \ MB$$

- **EVD's calendar.** One of the functionalities offered by the eMALL system is to insert new activities into EVD's calendar. The events have not much information: they specify starting time and destination of the activity. We can assume that each event requires $1KB$ of storage. Considering all the potential users and assuming that they insert three activities a day, for the first year the system needs:

$$10^5 \cdot 3 \cdot 365 \cdot 1 \ KB = 104,43 \ GB$$

- **History of charging sessions.** The eMALL system should save the information of all the charging sessions. We assume that the information of each charging session requires 3 KB of storage. To decide how many times we want to assume a generic EVD charges his EV, we have to consider different factors, such as the EVDs' habits, the storage of their EV's battery, and the distances they can drive during the day. For example, an EVD who drives long distances every day and whose EV has a small battery may need to charge it more frequently than an EVD with a larger battery who only drives short distances. Similarly, an EVD that can access fast charging infrastructure may be able to charge his EV less frequently than a driver

who only has access to slower charging stations. So, it is reasonable to assume that a generic EVD charges his EV twice a week.
For the first year, the system needs:

$$10^5 \cdot \frac{365}{7} \cdot 2 \cdot 3 \; KB = 29,84 \; GB$$

- **CPO's personal data.** If we consider that in Italy there could be more or less 50 CPOs, as we did for the EVDs, we can assume that one in every three CPOs subscribes to the eMALL system. We consider enough 5 KB of storage for each profile. So, the system needs:

$$20 \cdot 5 \; KB = 100 \; KB$$

- **Charging points registration.** Each CPO registers information about their charging points distributed in the territory. Referring again to the market analysis conducted by MOTUS-E, in September 2022, there were a total of 32.776 charging points in Italy. So, we can assume that all the CPOs register 11.000 charging points all together. We consider enough 5 KB of storage for the registration of each charging spot. So, the system needs:

$$11000 \cdot 5 \; KB = 53,71 \; MB$$

The rest of storage needed is about the several functionalities offered to the EVDs and to the CPOs. So, after summing all the values obtained in the previous list, we overestimate the memory suggested for the first year of life of the system. Summing all the values, it is:

$$488,3 \; MB + 104,43 \; GB + 29,84 \; GB + 100 \; KB + 53,71 \; MB = 134,8 \; GB$$

So, a memory storage of 200 GB will be enough for the first year of the eMALL system.

Time response

The eMALL system should handle all the requests within 3 seconds, given that there are not strict time response requirements.

3.4. Design Constraints

3.4.1. Standards compliance

First of all, the system should respect all the laws regarding privacy and data treatment and exchange with third parties (i.e. CPOs); to work in Europe, the system should respect the EU GDPR. In particular, a general description of the main principles that data should have in order to guarantee their privacy is given in Art. 5 of the GDPR document.

3.4.2. Hardware limitations

The eMALL system can be used from both web browsers and mobile applications. As explained in the system attributes section, the system is strictly related to the operating systems in which the mobile application will be implemented, so Android and IOS..

3.4.3. Any other constraint

There are not other constraints.

3.5. Software System Attributes

3.5.1. Reliability

The eMALL system should guarantee critical operations as payment. But, its functionalities are mainly about data management of the user and CPOs' infrastructure. It would not be critical if one of these operations fails, given that the process can be started and repeated. So, considering the different behaviors the system should have, it is reasonable to have a failure rate between 0.1% and 1%, so to be between high-quality reliable systems and more common systems.

3.5.2. Availability

The eMALL system should guarantee the CPO a good experience in their IT infrastructure management. So, considering the business functionalities that the system offers to the companies, it would not be acceptable a day of downtime. That's the reason why the system should guarantee 99.9% of uptime. In this section we just consider the business functionalities because the interactions between the EVDs and eMALL don't introduce constraints for the availability of the system.

3.5.3. Security

The eMALL system communicates with EVDs and CPOs, and stores their personal information. For this reason, it should assure data privacy and data encryption when information is exchanged through the internet. This is guaranteed thanks to the HTTPS. Furthermore, eMALL should encrypt all the information before proceeding with the storage.

3.5.4. Maintainability

The eMALL system should be divided in different modules depending on the offered functionalities. It is necessary to facilitate maintenance and substitution of the modules, and to eventually extend the system. Furthermore, every implemented functionality has to be well documented. What should guide the design definition process is to allow a maintenance that does not affect untouched modules and their interfaces.

3.5.5. Portability

The eMALL system is not strictly related to software and hardware. To be more portable, the system can be developed on both Android and IOS. In order to do that, it has to be decided which programming language and development tools to use: if the budget is not high and would be better to save time and effort, it is recommended to use cross-platform development tools; otherwise, the system can be implemented separately, increasing in that way the effort needed for the developing and the maintenance of the applications.

4 | Formal Analysis Using Alloy

This section describes the model built to represent the world in which the eMALL system works.

4.1. Alloy Code

```
open util/ordering[DateTime]

sig Appointment {
   startDate : DateTime,
   endDate : DateTime,
   chargingPoint : ChargingPoint
} {this in Calendar.appointments}

sig Battery {} {this in ChargingStation.batteries}

sig Calendar {appointments : disj set Appointment} {this in EVD.calendar}

sig ChargingPoint {
   eV : disj lone EV,
   plugs : some Plug
} {
   EV.plug in plugs and
   this in ChargingStation.chargingPoints
}

sig ChargingStation {
   chargingPoints : disj some ChargingPoint,
   batteries : disj set Battery,
   wayOfCharging : disj Battery + DSO
} {this in CPO.chargingStations}
```

```
sig CPO {
   chargingStations : disj some ChargingStation,
   dso : DSO
}

sig DateTime {} {this in Appointment.startDate + Appointment.endDate}

sig DSO {} {this in CPO.dso}

sig Email {} {this in EVD.email}

sig EV {plug : Plug} {this in UnregisteredEVD.eVs + EVD.eVs}

sig EVD {
   calendar : disj Calendar,
   email : disj Email,
   eVs : disj some EV,
   password : disj Password
}

sig Password {} {this in EVD.password}

abstract sig Plug {}
one sig CCS extends Plug {}
one sig ChaDeMo extends Plug {}
one sig Type1 extends Plug {}
one sig Type2 extends Plug {}

sig UnregisteredEVD {eVs : disj some EV}

/*****************************************************************************/
/*****************************************************************************/

///* An EVD cannot charge his EVs simultaneously, we assume each account is  associated
    to only one driver
fact evdsCanChargeOnlyOneEvPerTime {
   all evd : EVD, disj ev1, ev2 : EV |
      ev1 + ev2 in evd.eVs and
      ev1 in ChargingPoint.eV implies
```

```
        ev2 not in ChargingPoint.eV
}
///* An appointment must start before ending
fact appointmentsAreCorrect {
   all a : Appointment |
      lt [a.startDate, a.endDate]
}
///* A booking process must not be overlapped to another booking process in the same
    calendar and in the same charging point
fact noOverlappedAppointmentsInChargingPointSchedules {
   no disj a1, a2 : Appointment |
      a1.chargingPoint in a2.chargingPoint and
      gte [a1.startDate, a2.startDate] and
      lte [a1.startDate, a2.endDate]
   no c : Calendar, disj a1, a2 : c.appointments |
      gte [a1.startDate, a2.startDate] and
      lte [a1.startDate, a2.endDate]
}
///* EVs of EVDs are not shared with unregistered EVDs
fact evsOfEvdsAreNotSharedWithUnregisteredEvds {
   all evd : EVD, uevd : UnregisteredEVD |
      #(evd.eVs & uevd.eVs) = 0
}
///* EVs of unregistered EVDs must not be connected to charging points
fact evsOfUnregisteredEvdsMustNotBeConnectedToChargingPoints {
   all cp : ChargingPoint, uevd : UnregisteredEVD |
      #(cp.eV & uevd.eVs) = 0
}
///* Charging stations charge vehicles through their batteries and DSOs
fact chargingStationsUseTheirBatteries {
   all cs : ChargingStation, cpo : CPO |
      cs in cpo.chargingStations and
      cs.wayOfCharging in cs.batteries + cpo.dso
}

/*****************************************************************************/
/*****************************************************************************/

///* EVs are connected to compatible charging points
```

```
assert evsAreConnectedToCompatibleChargingPoints {
   no cp : ChargingPoint |
      cp.eV.plug not in cp.plugs
}
///* No overlapped appointments in charging point schedules
assert noOverlappedAppointmentsInChargingPointSchedules {
   no disj a1, a2 : Appointment |
      a1.chargingPoint in a2.chargingPoint and
         lte [a1.startDate, a2.startDate] and
         lte [a1.endDate, a2.startDate]
}

/*****************************************************************************/
/*****************************************************************************/

///* Add new appointment to the calendar for an EVD
pred addNewAppointmentToCalendarForEvd [evd : EVD, a' : Appointment] {
   evd.calendar.appointments = evd.calendar.appointments + a'
}
///* Add new charging point to a charging station
pred addNewChargingPointToChargingStation [cs : ChargingStation, cp' :
    ChargingPoint] {
   cs.chargingPoints = cs.chargingPoints + cp'
}
///* Add new charging station to a CPO
pred addNewChargingStationToCpo [cpo : CPO, cs' : ChargingStation] {
   cpo.chargingStations = cpo.chargingStations + cs'
}
///* Add new EV to an EVD
pred addNewEvToEvd [evd : EVD, ev' : EV] {
   evd.eVs = evd.eVs + ev'
}
///* Add new plug in a charging point
pred addNewPlugToChargingPoint [cp : ChargingPoint, p' : Plug] {
   cp.plugs = cp.plugs + p'
}
///* Remove appointment from the calendar of an EVD
pred removeAppointmentFromCalendarOfEvd [evd : EVD, a : Appointment] {
   evd.calendar.appointments = evd.calendar.appointments - a
```

```
}
///* Remove a charging point from a charging station
pred removeChargingPointFromChargingStation [cs : ChargingStation, cp :
    ChargingPoint] {
   cs.chargingPoints = cs.chargingPoints - cp
}
///* Remove a charging station from a CPO
pred removeChargingStationFromCpo [cpo : CPO, cs : ChargingStation] {
   cpo.chargingStations = cpo.chargingStations - cs
}
///* Remove EV from an EVD
pred removeEvFromEvd [evd : EVD, ev : EV] {
   evd.eVs = evd.eVs - ev
}
///* Remove plug from a charging point
pred removePlugFromChargingPoint [cp : ChargingPoint, p : Plug] {
   cp.plugs = cp.plugs - p
}
///* Update email in an EVD
pred updateEmailInEvd [evd : EVD, e' : Email] {
   evd.email = e'
}
///* Create a simple world
pred simpleWorld {
   #ChargingStation = 1
   #ChargingPoint = 3
   #EVD = 2
   #Appointment = 2
}
///* Create a world where there are many appointments
pred worldWithManyAppointments {
   #ChargingStation = 1
   #ChargingPoint = 4
   #EVD = 2
   #Appointment = 6
}

/*****************************************************************************/
/*****************************************************************************/
```

```
run addNewAppointmentToCalendarForEvd

run addNewChargingPointToChargingStation

run addNewChargingStationToCpo

run addNewEvToEvd

run addNewPlugToChargingPoint

run removeAppointmentFromCalendarOfEvd

run removeChargingPointFromChargingStation

run removeChargingStationFromCpo

run removeEvFromEvd

run removePlugFromChargingPoint

run updateEmailInEvd

run simpleWorld

run worldWithManyAppointments for 10

check evsAreConnectedToCompatibleChargingPoints

check noOverlappedAppointmentsInChargingPointSchedules
```

4.2. Simulations

In this section we show to simulations of the built model. The first one is a simple world, with few instances, useful to understand the basis of the relations between entities. The second world is more complex due to the representation of a higher number of instances of stations, EVDs and appointments.

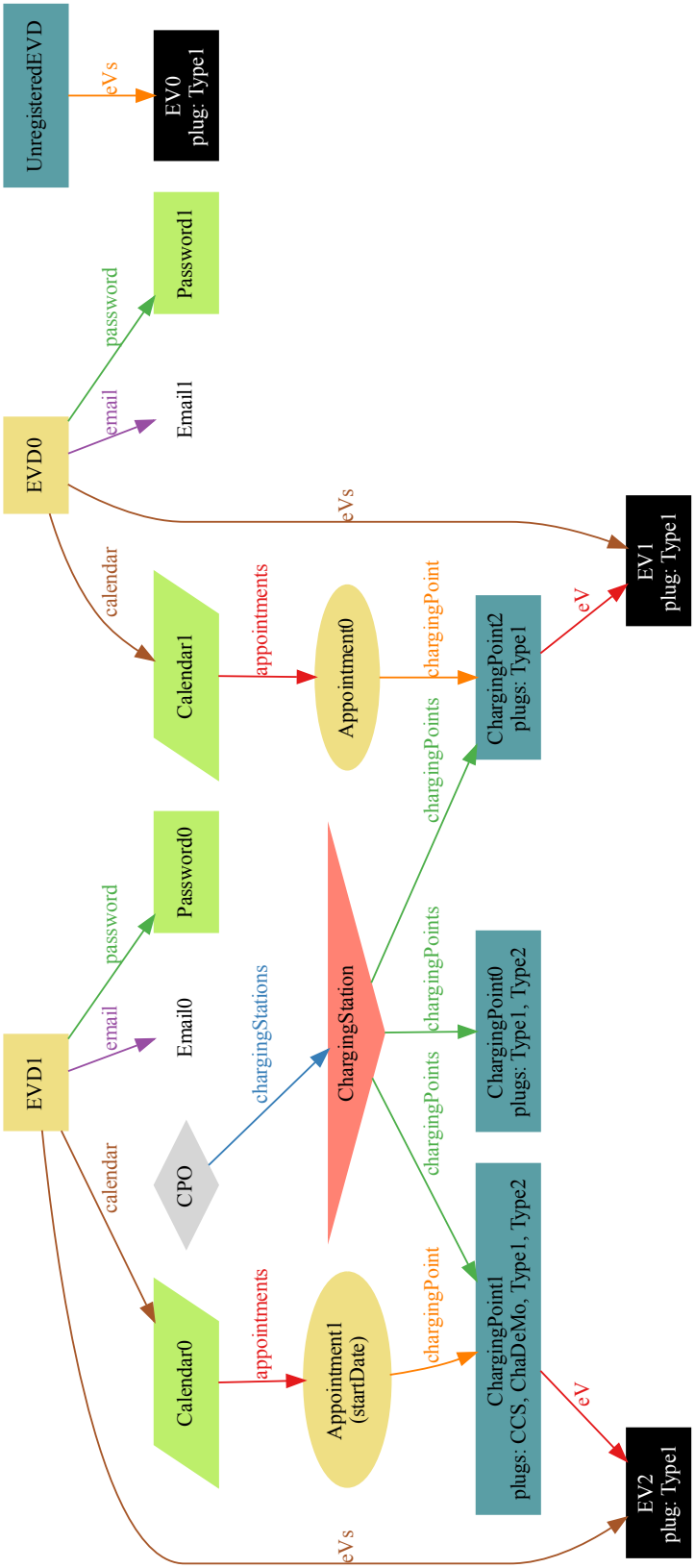


Figure 4.1: Simple world Alloy.

Figure 4.2: More complex world.

5 | Effort Spent

Member of group	Effort spent	
Cela Irfan	Introduction	9h
	Overall description	10h
	Specific requirements	11h
	Formal analysis	15h
	Reasoning	13h
Cela Mario	Introduction	9h
	Overall description	11h
	Specific requirements	24h
	Formal analysis	2h
	Reasoning	11h
Cogollo Alessandro	Introduction	11h
	Overall description	13h
	Specific requirements	18h
	Formal analysis	11h
	Reasoning	12h

Table 5.1: Effort spent by each member of the group.

6 | References

6.1. Paper references

- The specification document Assignment RDD AY 2022-2023.pdf
- Platform for Electromobility. EV Charging: How to tap in the grid smartly?
- F. Campos, L. Marques, and K. Kotsalos, Electric Vehicle CPMS and Secondary Substation Management. 2nd E-Mobility Power System Integration Symposium, Stockholm, Sweden, 15 October 2018.
- Shu Su, Hui Yan, and Ning Ding. 2018. Machine Learning-Based Charging Network Operation Service Platform Reservation Charging Service System
- September 2022 Market Analysis - MOTUS-E

6.2. Used tools

- GitHub for project versioning
- StarUML for UML diagrams
- Notion for reasoning and notes
- IntelliJ as LaTeX editor
- Alloy for formal analysis
- Visual Studio Code as Alloy editor

List of Figures

List of Tables