POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

Software Engineering 2 Requirements Analysis and Specification Document

Author(s): **Irfan Cela - 10694934**
Mario Cela - 10685242
Alessandro Cogollo - 10571078

Academic Year: 2022-2023

Contents

1 | Introduction

The EVs are eco-friendly vehicles that will be on our roads in the next future. 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. EVs consumption is measured in kilowatt-hours per 100 kilometers, and 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.

In this context, 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 offered to two types of users: EVDs and CPOs.

To the firsts will be given the possibility to manage in an easy way their EV thanks to the functionalities of booking, knowing location and information of charging stations, searching active special offers done by CPOs, and being suggested of a charging process smartly elaborated by the system so to minimize the costs and the time needed to charge the battery of the EV.

The seconds one are companies that decide to 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 obtain it as a SaaS (Software as a Service). The main functionalities that eMALL offers to CPOs are charging stations managing, DSO interfacing, and energy usage and/or storage strategy.

Follows a table that lists all the goals of the eMALL system:

ID	Description
G1	The EVD can see charging stations nearby a specific location on the map
G2	The EVD can get the detailed information of charging stations
G3	The EVD can search for special offer provided by charging stations
G4	The EVD can book a charge for his EV at a charging station for a specified time frame
G5	The EVD can pay for the recharging service
G6	After the EVD inserts a new activity into the calendar, he/she receives suggestions about charging the EV
G7	The CPO can get information about its charging stations
G8	The CPO can start charging a vehicle and monitor the charging process to know when to stop
G9	The CPO can obtain the internal status of one of its charging station
G10	The CPO can acquire by the DSOs information about the current price energy
G11	The CPO can decide from which DSO to acquire energy
G12	The CPO can decide how to get energy for charging (DSO or battery storage, a mix of the two)

Table 1.1: The goals.

1.2. Scope

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 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
EVD	Electric Vehicle Driver
EV	Electric Vehicle

Table 1.4: Acronyms used in the document.

1.4. Revision history

1.5. Reference Documents

The specification document `Assignment RDD AY 2022-2023.pdf`.

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

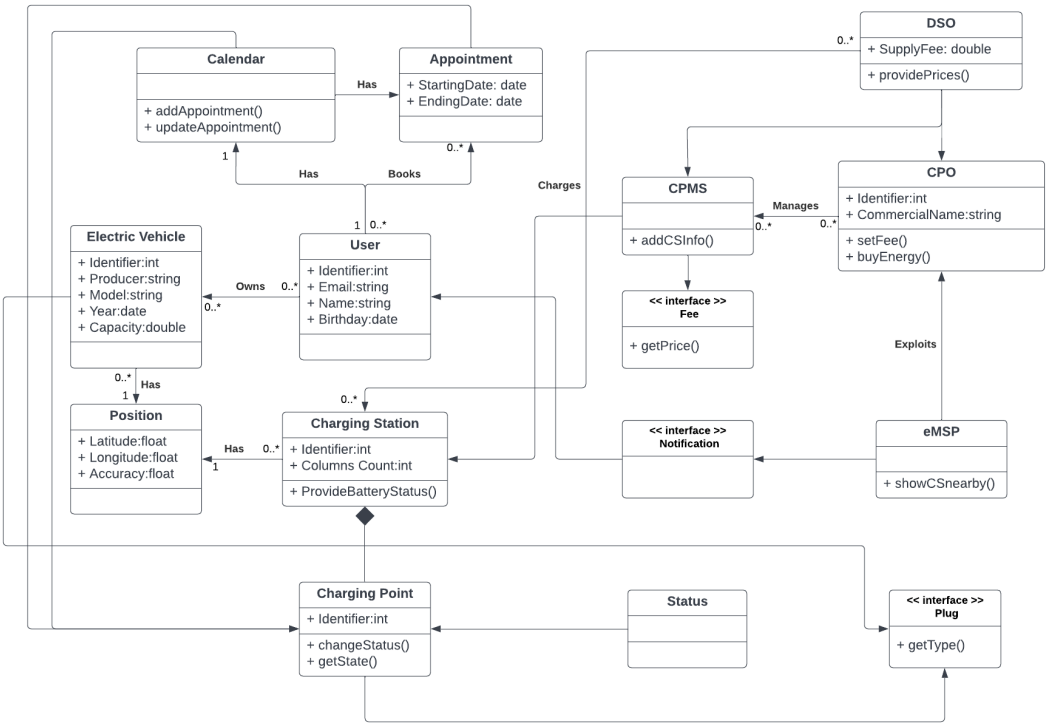

Figure 2.1: A simplified Class Diagram

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 bar. From the huge amount of charging stations, he decides to decide the one that costs less than the other ones. So, 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.

It is shown a state diagram that summaries the flow of activities done in the charging stations navigation process:

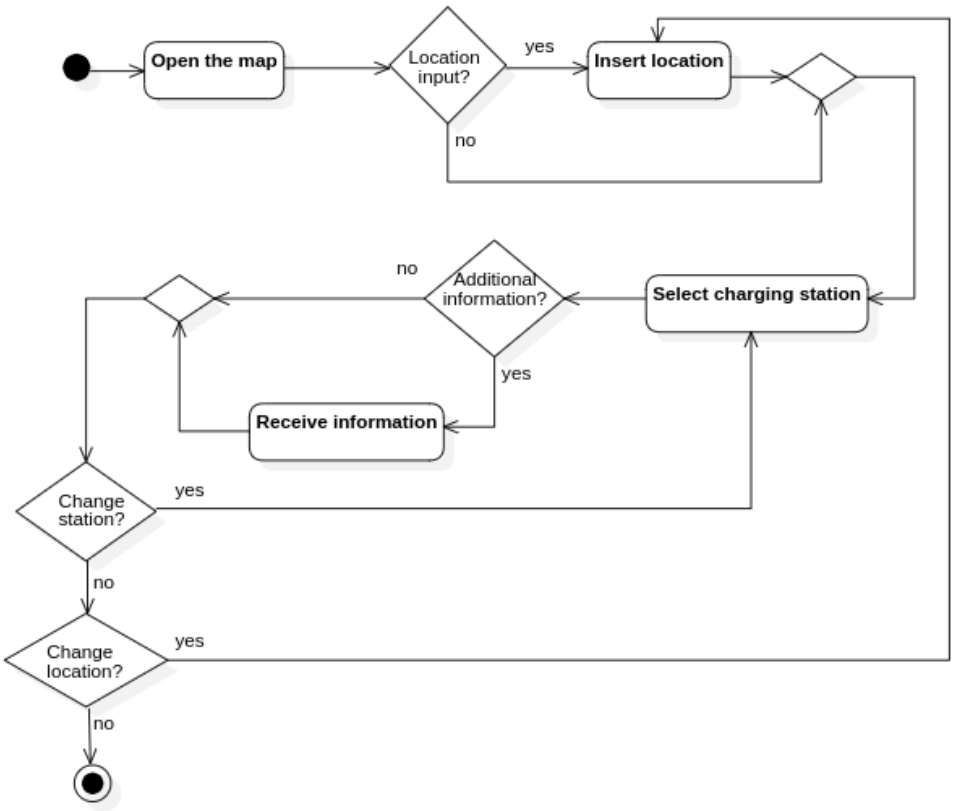

Figure 2.2: Get locations of charging stations state diagram

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 of no availability status. 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 gets the availability schedule of the charging station and selects when he thinks to go to charge. The system asks to pay a deposit to the EVD, which makes the payment. 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:

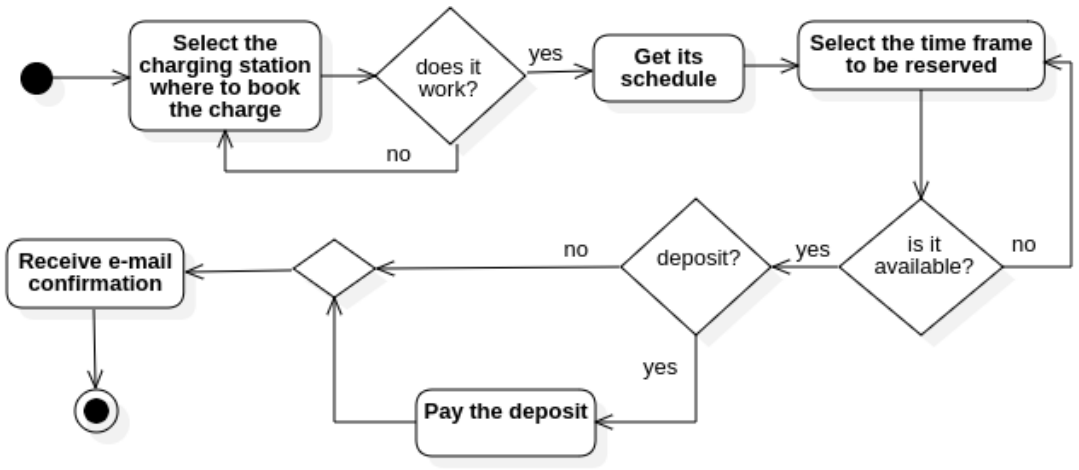

Figure 2.3: Book a charge state diagram

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. When they insert a new charging point that belongs to a new charging station, they create it, too. So, they insert all the requested information (location, costs, 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:

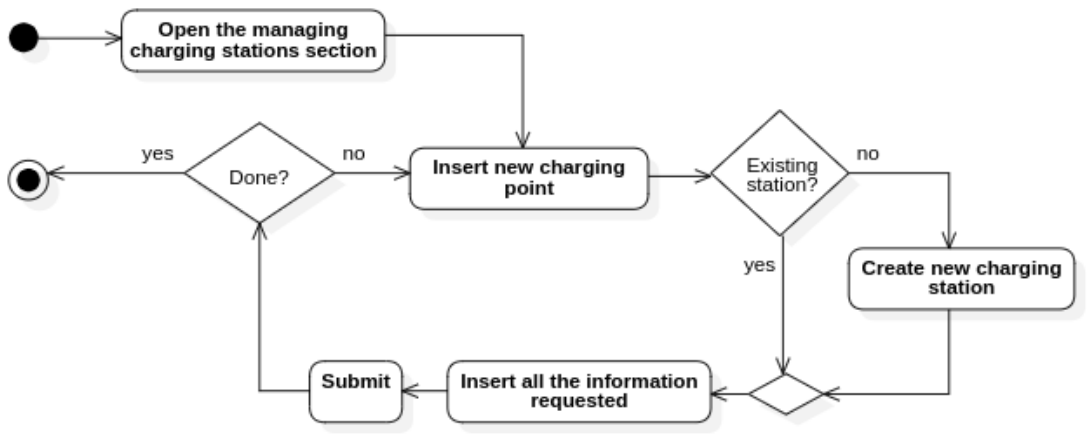

Figure 2.4: Insert charging points state diagram

2.1.3. Scenarios

Unregistered EVD creates an account. Mike Hoar 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. He inserts his name, second name, date of birth, living address, e-mail address, password, and telephone number. 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 start using the application.

The EVD charges his/her EV. After booking a charge, NomeFantasia 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 charge at that charging point, the application communicates to the user that the connectors are now unlocked and ready for charging his EV. 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. Joe 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, 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 the 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 the 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. The 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 the eMALL finishes the booking process by sending an informative email to the EVD that resumes all the booking info.

In the email, the 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
The 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, the eMALL computes the best route to reach the destination through an external navigator API. The 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 the eMALL shows him the best route with the charging stations available along the road.

The 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, the eMALL marks the route returned by the API as preferred. On the other hand, the 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 the 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 the 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 the 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 registered 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	The EVD uses a device with GPS module for navigation and localization
DA2	The EVD uses a device with internet connectivity
DA3	There is a specific compatibility between EV's plug and connectors offered by charging points
DA4	The `eMALL` system communicates with a third-party entity which provides real-time EV's information through its API
DA5	The `eMALL` system communicates with DSOs through their APIs
DA6	Charging points have their own software
DA7	Communication between CPMSs and charging points happens through the OCPP protocol

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 booking 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 or Glonass localization system.

3.1.3. Software Interfaces

3.1.4. Communication Interfaces

The eMALL system needs to communicate with other actors to offer functionalities to the users; the communication is bidirectional and permits eMALL to obtain the desired

data and serve elaborated data. Below are listed different communication interfaces used to exchange information with users:

- **CPMS and Charging Points.** The CPMSs offered to the CPO communicate with the charging point through the OCPP communication protocol. Thanks to it, the system can manage the charging session, given the possibility of starting and stopping it. Another significant functionality offered by OCPP 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.
- **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.

3.2. Functional Requirements

3.2.1. Requirements

ID	Description
R1	

Table 3.1: Requirements.

3.2.2. Mapping on goals

Goal	Domain assumptions	Requirements
G1		
G2		

G3		
G4		
G5		
G6		
G7		
G8		
G9		
G10		
G11		
G12		

Table 3.2: Mapping on goals.

3.2.3. Use case diagrams

Unregistered EVD

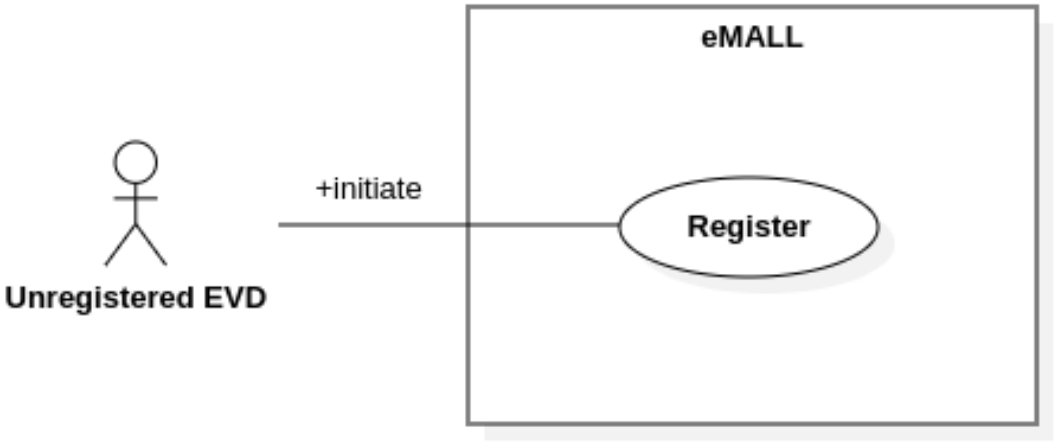

Figure 3.1: Unregistered EVD use case diagram

Registered EVD

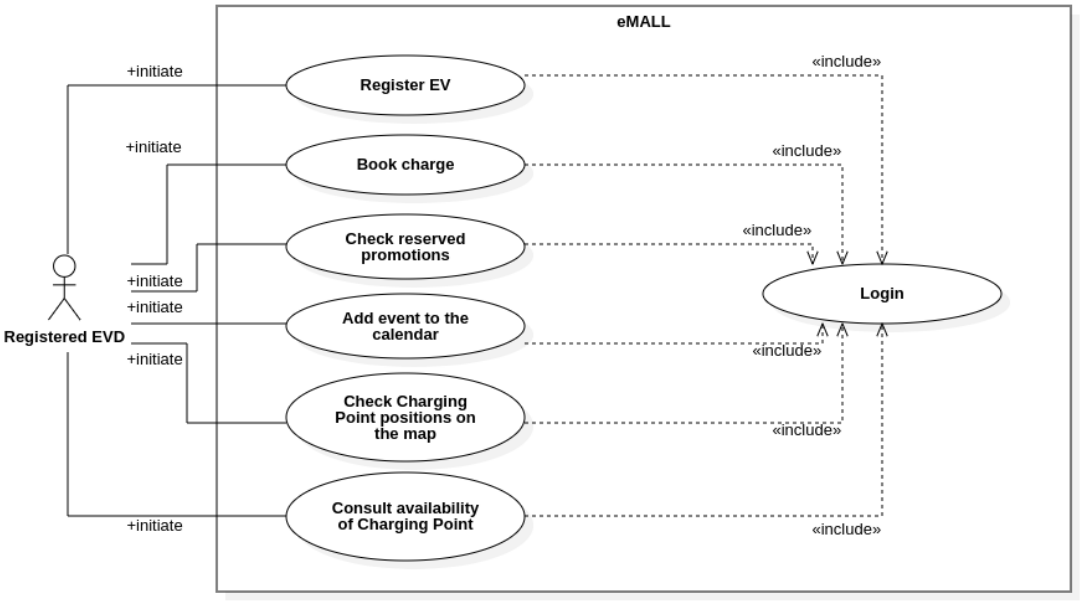

Figure 3.2: Unregistered EVD use case diagram

CPO

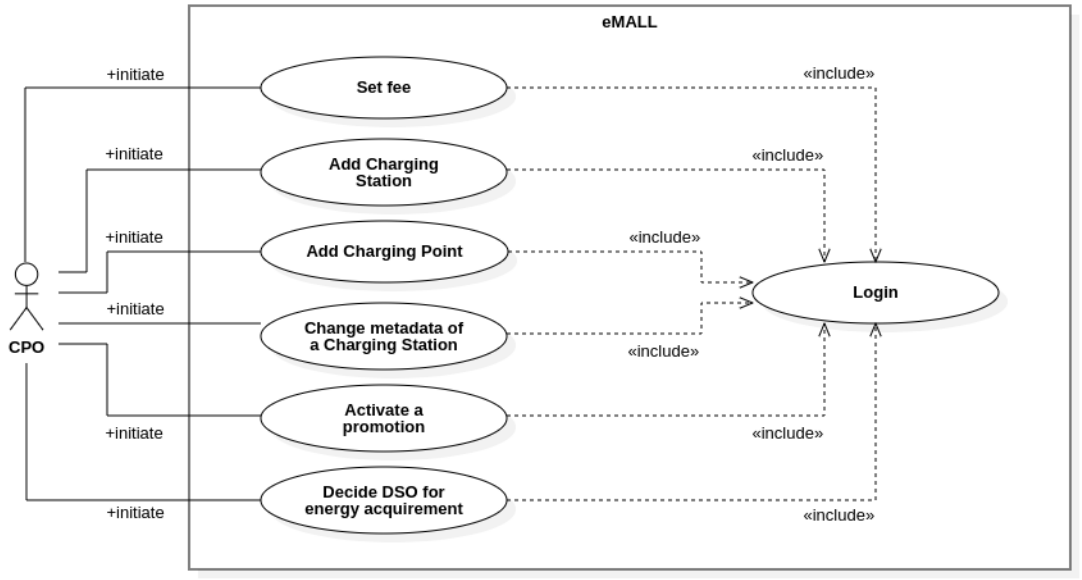

Figure 3.3: Unregistered EVD use case diagram

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.

3.2.5. Mapping on requirements

Use Case	Requirements

Table 3.3: 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 th 50% of them could be connected simultaneously.

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

3.4.2. Hardware limitations

3.4.3. Any other constraint

3.5. Software System Attributes

3.5.1. Reliability

3.5.2. Availability

3.5.3. Security

3.5.4. Maintainability

3.5.5. Portability

4 | Formal Analysis Using Alloy

5 | Effort Spent

6 | References

A | Appendix A

If you need to include an appendix to support the research in your thesis, you can place it at the end of the manuscript. An appendix contains supplementary material (figures, tables, data, codes, mathematical proofs, surveys, ...) which supplement the main results contained in the previous chapters.

List of Figures

List of Tables