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Software Engineering 2 Requirements Analysis and Specification Document

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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	Given the destination inserted in an activity in his calendar application, the EVD receives suggestions to charge his 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 1.2: The goals.

1.2. Scope

1.2.1. World phenomena

ID	Description
WP1	The DSO provides energy to charging stations
WP2	The EVD wants to charge his EV's battery
WP3	The EVD wants to know the prices of a specific charging station
WP4	The EVD wants to know if there are any special offer he can redeem
WP5	The EVD wants to know the position of a specific charging station
WP6	The CPO have deals with eMSP and offer them their charging station
WP7	The EVD inserts a new activity in his calendar
WP8	Charging Points are distributed in the territory
WP9	CPO buys energy from a DSO at the price defined by the latter
WP10	CPO defines the selling price of electricity
WP11	CPO defines special offers for its customers
WP12	The EVD connects the plug of the charging point to the EV
WP13	The EV reaches the desired level of battery charge

Table 1.4: 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

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 1.6: 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.

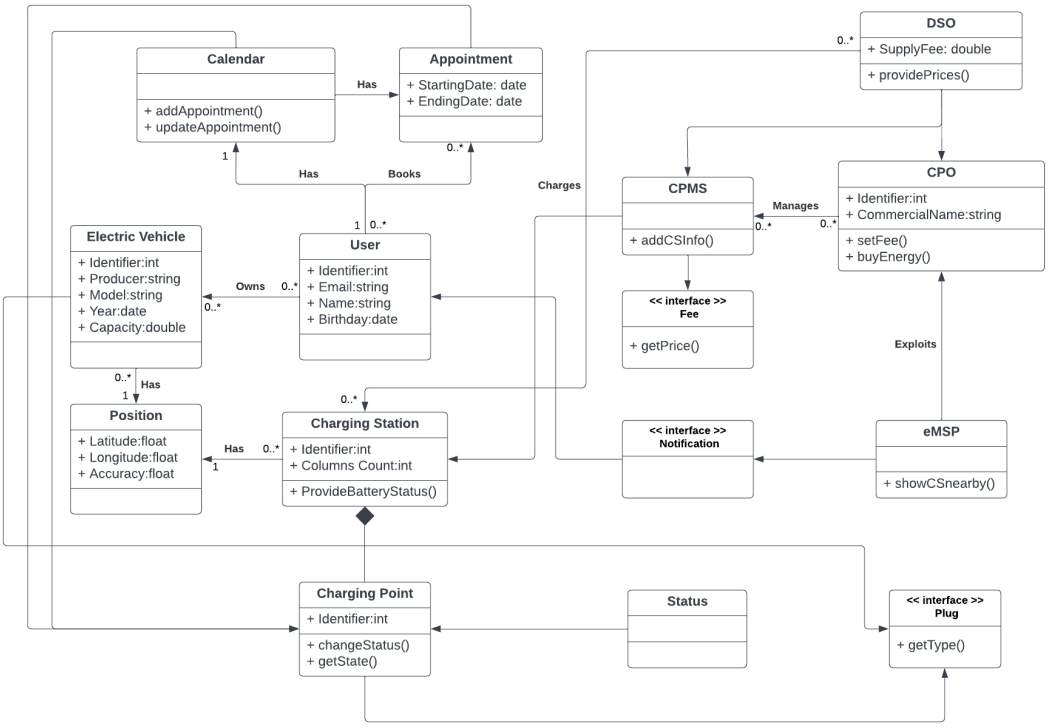

Figure 2.1: A simplified Class Diagram

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:

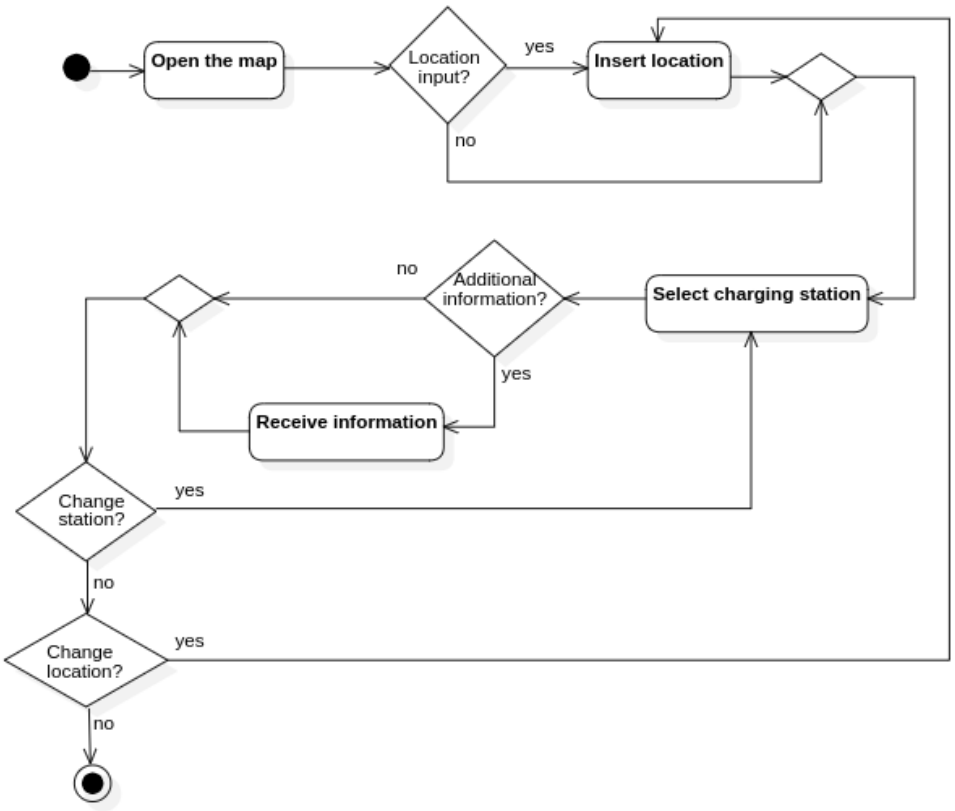

Figure 2.2: Get locations of charging stations state diagram

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:

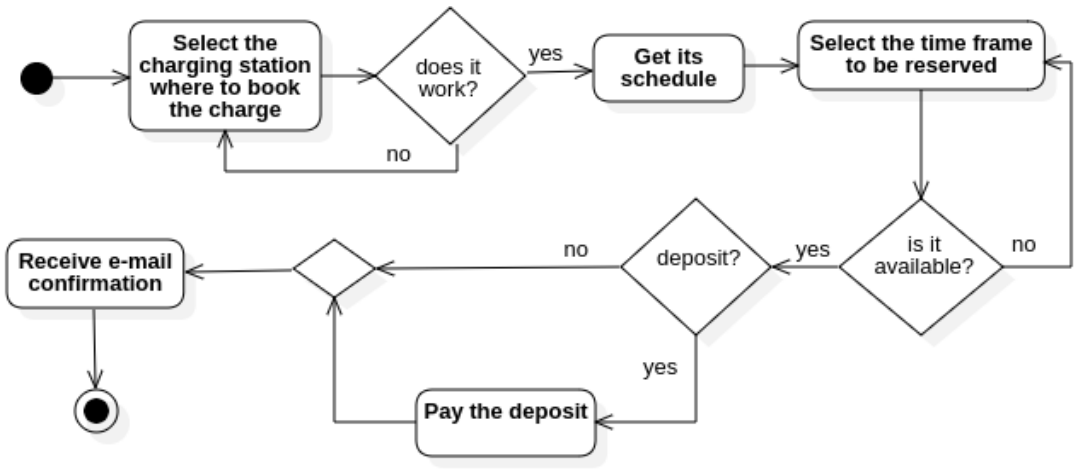

Figure 2.3: Book a charge state diagram

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:

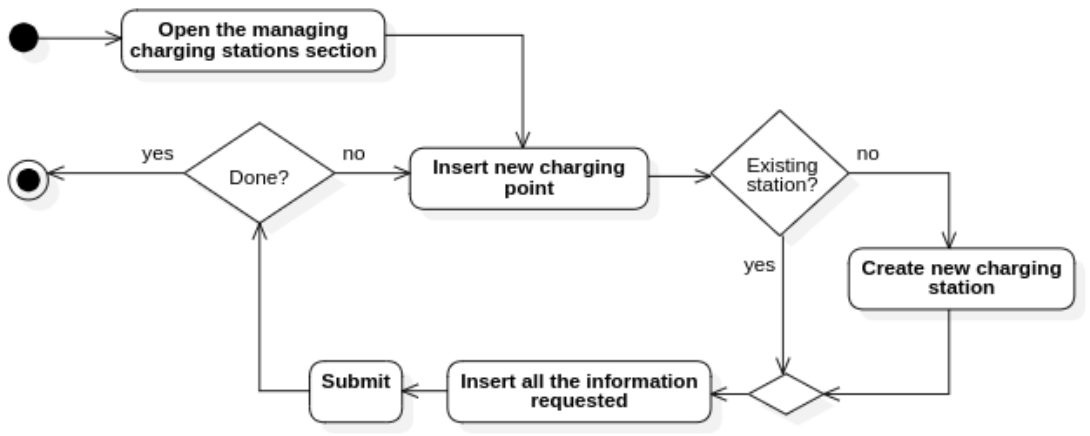

Figure 2.4: Insert charging points state diagram

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 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 caution to pay to end the booking process. If the station does not have a caution 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 place, 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 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 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 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

3 | Specific Requirements

3.1. External Interface Requirements

3.1.1. User Interfaces

3.1.2. Hardware Interfaces

3.1.3. Software Interfaces

3.1.4. Communication Interfaces

3.2. Functional Requirements

3.3. Performance Requirements

3.4. Design Constraints

3.4.1. Standards compliance

3.4.2. Hardware limitations

3.4.3. Any other constraint

3.5. Software System Attributes

3.5.1. Reliability

3.5.2. Availability

3.5.3. Security

3.5.4. Maintainability

3.5.5. Portability

4 | Formal Analysis Using Alloy

5 | Effort Spent

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