eMall – e-Mobility for All

Requirements analysis and specification document (RASD)

Software Engineering 2
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1 – Introduction

The unique challenges posed by climate change have recently led to a growing push in the adoption of new technologies to reduce carbon emissions. In particular, road transportation accounted for more than 70% of the total transport emissions in the EU, which in turn was responsible for about a quarter of the EU's total CO_2 emissions in 2019 (source: shorturl.at/anryE).

Electric vehicles represent a viable solution to tackle this problem, but they require specific infrastructure and knowledge about availability of chargers, cost of energy and distribution.

eMall, a new startup based in Italy, is aiming at improving the experience of charging an electric vehicle. They offer a various range of services that will be able to take care of every aspect of charging, from displaying the location and properties of charging stations nearby and making smart suggestions that take into consideration both economic and logistical factors, to actually owning and managing charging points themselves.

1.1 – Purpose

The system should provide the user with information about every charging point location nearby. Each location should present the characteristics of its charging stalls: cost, availability, charging speed, compatibility with the charging port, special offers.

The user through the system should also be able to book a charge at a specific location for a certain timeframe, selecting through the GUI a charging station and inserting a starting time and ending time (to be able to create a real schedule, as to give the other users the possibility to book a consecutive timeframe if they're willing to).

The system should also allow the user to manage the whole charging process: they should be able to start the charging, to monitor its status and to be notified when it is done or when the booked timeframe has finished and make the user pay for the service.

Additionally, the system should provide some smart suggestions to the users, based on their location, their schedule (by having access their calendar), the current offers, the battery status of the vehicle and the availability of charging stations.

1.1.1 – Goals

Goal	Description
G1	Provide the user the information about the nearby Charging Points (this includes their cost and the special offers they provide)
G2	Make the user able to book a specific Charging Point in a specific timeframe
G3	Make the user able to start and monitor the charging process, from the start to the end
G4	Notify the user when the charging process is finishes or when the booked timeframe expires
G5	Make the user able to pay for the charging service

G6	Provide the user with smart suggestions about the charging port to go charge to, based on their location, schedule, prices and special offers (if available)

1.2 – Scope

The system should interact with the end user, so the UI should be easy to use in order to be accessible to a widest range of people possible, as electric cars are spreading rapidly and such a system could further amplify this phenomenon.

e-Mall covers the role of a CPO (Charging Point Operator), an entity which owns and manages charging stations, beside the eMSP role, so it should communicate obviously with its CPMS (Charging Point Management System) and moreover it with other CPOs, through their CPMSs as well, to offer broaden the service of prices and places comparison for the end user.

Each CPO, as stated previously, has its own CPMS which manages their physical infrastructure. For instance, it monitors the status of every socket and regulates the flow of energy to each of them while a vehicle is charging. Furthermore, the CPMS is responsible for choosing the best DSO (Distribution System Operator) to retrieve energy from, based on the current price and the mix of energy sources used to produce power. With this information, the CPO can decide and set the prices per unit of energy and also create special offers for end users.

Additionally, CPMSs are tasked with managing energy storage (if present) of a certain charging station: if supplied with physical batteries, they can opt not to buy energy from DSOs and instead use the one stored in the batteries, otherwise energy can be purchased from the DSOs and partially used to recharge them. These decisions can be both made automatically or with input from a human operator.

Each of the entities previously mentioned (the system, CPOs and DSOs) can communicate through specific APIs. The system can communicate with one or more CPMSs, each owned by a different CPO, retrieving the external status of a charging station (location, number of charging sockets available, speed of every socket, cost, estimated time left until a socket is freed).

1.2.1 – World Phenomena

In the following table with the word “another CPO” we intend a different CPO from e-Mall.

ID	Description
WP1	The user wants to charge their vehicle
WP2	The user books a certain charging station in a certain timeframe
WP3	The user goes to the selected charging station
WP4	The CPMS of another CPO acquires energy from a DSO, based on the prices the latter offers and the mix of sources it acquires the energy from
WP5	The CPMS of another CPO distributes the energy to the different connected vehicles
WP6	The CPMS of another CPO decides the prices for a specific charging point based on the prices it acquired it from a DSO
WP7	Another CPO decides whether to store energy in the batteries of a charging point (if any)

WP8	Another CPO decides whether to use the energy stored in the batteries of a charging port (if they are available) or to use the one directly purchased from a DSO or a mix of both

1.2.2 – Shared Phenomena

SP1	The user selects a charging port to go charge to
SP2	The user starts the charging process
SP3	The user monitors their charging process
SP4	The user gets notified about the ending of their charging process
SP5	The user pays for the charge
SP6	e-Mall retrieves the information about the external status of a charging station from the CPMS of the CPO which manages it (this includes the number of charging sockets available, their type, their cost, and, if all sockets of a certain type are occupied, the estimated amount of time until the first socket of that type is freed)
SP7	e-Mall retrieves the information about the internal status of a charging station from the CPMS of the CPO which manages it (this includes the amount of energy available in its batteries, if any, number of vehicles being charged and, for each charging vehicle, amount of power absorbed and time left to the end of the charge)
SP8	e-Mall starts and monitors the charging process accordingly to the request of a user through an API provided by the CPMS of the CPO managing a certain charging station
SP9	e-Mall retrieves the information about current energy cost from the CPMS of the CPO which manages a certain charging station
SP10	e-Mall provides the user with smart suggestions about the best charging stations to go charge to (based on their location, schedule and status of charging stations nearby)
SP11	e-Mall CPMS acquires energy from a DSO, based on the prices the latter offers and the mix of sources it acquires the energy from
SP12	e-Mall CPMS distributes the energy to the different connected vehicles
SP13	e-Mall CPMS decides the prices for a specific charging point based on the prices it acquired it from a DSO
SP14	e-Mall decides whether to store energy in the batteries of a charging point (if any)
SP15	e-Mall decides whether to use the energy stored in the batteries of a charging port (if they are available) or to use the one directly purchased from a DSO or a mix of both

1.3 – Definitions, Acronyms, Abbreviations

- eMall – e-Mobility for All
  The system we are analyzing and specifying in this document

- eMPS – e-Mobility Service Provider
  A company (like e-Mall) which offers the user various features regarding the e-Mobility field, from locating a charging station, to starting the charging process and paying for it

- CPO – Charging Point Operator

A company which manages the energy supply and the features of a physical charging station. e-Mall is a CPO as well.

- CPMS – Charging Point Management System
  The backend infrastructure of a CPO, which takes decisions and interfaces with providers of energy

- DSO – Distribution System Operator
  A company which produces and provides electric energy to CPOs

- SPX – Shared Phenomenon X
  A phenomenon related to the system in analysis and the domain which it operates in

- WPX – World Phenomenon X
  A phenomenon happening in the domain which the analyzed system operates in. The specified World Phenomena are relevant for us because system operations derive from them

- GX – Goal X
  A purpose the system wants to be able to reach

- API – Application Programming Interface
  An interface which a system offers for other systems (human beings or softwares) to be able to perform specific operations or retrieve information on it

1.4 – Revision History

- First release: RASD v1.0 **INSERIRE DATA QUA**

1.5 – Reference Documents

- Specification document: "*Assignment_RDD_AY_2022-2023_v3*"
- Alloy code documentation: https://alloy.readthedocs.io/en/latest/language/

1.6 – Document Structure

The document is organized in six well defined sections, which are as well divided into sub sections accordingly to modularity and concept separation.

- **Section 1: Introduction**
  This section provides the context of the problem, the scope, the main goals and the phenomena (either the shared ones and the world ones), summarized in the 2 tables in section 1.2. At the end of section 1 we can also find this paragraph, the reference

documents and the abbreviations and definitions necessary to understand the technical and non sections.

- **Section 2: Overall Description**
  This section provides a high level description of the problem and the system itself. Here we can find various use cases and scenarios that can happen with regard to the application, further details about the shared phenomena and domain assumptions. Furthermore here are specified the requirements about the features the system offers and hardware and software constraints too.

- **Section 3: Specific Requirements**
  In section 3 every aspect mentioned in section 2 is specified with regard to information which can be useful to further development of the application. We can find external interface requirements, functional requirements and performance requirements, as well as design constraints and software attributes.

- **Section 4: Formal Analysis using Alloy**
  In section 4 a formal analysis on the phenomena is performed using Alloy code.

- **Section 5: Effort Spent**
  Section 5 includes a table with the details about the effort spent on each section by each member of the group tackling the project.

- **Section 6: References**
  Here we can find all the reference to documents and web pages used to draw up this document.

2 – Overall Description

2.1 – Product Perspective

In this following section some shared phenomena are explained and detailed with diagrams to help them be understood. Moreover, some scenarios of usage of the application are presented, with regard to user side (entry conditions and user actions) and system side (application responses and communication between its components).

2.1.1 – Scenarios

1. **User wants to start using e-Mall to better handle the charging sessions of their vehicle**
   A user owns an electric vehicle and comes to know about e-Mall through their friend who has owned an electric car for a year, so they decide to sign up.
   They download the app on their phone and open it, seeing as a first screen the sign-up form; they insert their name, surname, email, telephone number and password and then click on the Sign-Up button.
   The system then shows an “email sent” screen and sends a confirmation link to the user email which expires after 30 minutes: if the user clicks it in this timeframe, then the account is validated with the inserted credentials and it is stored in the database (obviously the password is encrypted) and the user gets redirected to the home screen of the application.
   Here, at last, they are asked to let the application access their location and their calendar app (which could be the default one or a third-party one), to know their schedule and make smart suggestions.

2. **The user registers their first vehicle and first payment method**
   A user can link to their account as many vehicles as they want and as many payment methods as they want.
   They want to register their first vehicle so they go in their “My Profile” section and click on the “My vehicles” button: they just see a “+” button with the text “Add Vehicle” (if they had also other registered vehicles, they would have seen all of them and the same “+” button at the end of the list). They then click on it and a pop up, where they can insert a Name for the vehicle, the capacity of the battery and the model, opens. The user then inserts these data (all required) and at the end of the insertion they click on the “Confirm” button, thus saving the insertion of the vehicle; If they changed their mind they could have clicked on the “Cancel” button to abort the operation.
   The application then shows a “Vehicle saved” pop up (for cancel button it would have showed “Operation cancelled”) and then redirects the user to the “My vehicles” section.
   As soon as the user saves their vehicle it is automatically marked as default one, as it is the first, while if they already had some, it would have been put at the end of the list and could have been marked as default by the user (if they wished to) by clicking the “Set as Default” button on the entry of the vehicle itself.
   The process to save the first payment method is basically equal as the one needed to save the first vehicle: the user goes to the “Wallet” section and clicks on the “+” button; as for the vehicles, they only see the + and clicking on it a pop up opens, where the user is able to insert the payment type (Credit Card or PayPal) and the needed data for each one of them

(for example card number, expiry date and CVV for Credit Card or the login credentials for PayPal etc.).
The user clicks on PayPal, gets redirected to the PayPal login page and at the end of the login process they get redirected to the previous screen, where they click on the “Confirm” button to end the registering process (they could have also click on the ”Cancel” button to abort the operation).
As for the vehicles the application then shows a “Payment method saved” pop up (it would have showed “Operation cancelled” if they had pressed the cancel button) and then redirects the user to the “Wallet” section.
Even in this case the inserted payment method is automatically marked as the default, as it is the first, while if they already had some, it would have been put at the end of the list and could have been marked as default by the user (if they wished to) by clicking the “Set as Default” button on the entry of the method itself.

3. **The user wants to retrieve information about their nearby charging locations**
   From the home screen the user can directly see all the charging points near their location. On the first access the user gets asked by the application to let it retrieve the information about their location through the GPS service of their phone: without consent to this, the user will not be able to use this feature.
   Once granted the access, the application centers the map in the user location and shows with different colors all the different charging points managed by different CPOs.
   The user then clicks on some of these marked locations and for each one of them (one at a time) are shown the distance from the current location, the price per kWh, the free charging sockets (if a charging point has no free charging sockets gets marked in grey) of each type and if all of a certain type are occupied also the estimated amount of time until the first socket of that type is freed. Moreover, if there are special offers related to that charging station, those are showed too (with their prices)

4. **The user charges their vehicle**
   When the user arrives at a charging station, from the app they select the correct marked location and a pop up opens with all the information about it and also the “Start charging” button, which only appears if the user is in a 100m range from the station.
   The user then clicks on it and another screen appears, where the user inserts the code of the charging socket (we suppose every single socket has a unique ID): the app then asks for a further confirmation and shows the default vehicle and payment method as selected.
   The user confirms both and sets the time to charge their vehicle until, then they click on the “START!” button which unlocks the socket and lets them physically plug the car; at that point the vehicle is charging and from the app the user can monitor the process, seeing the energy injected in the vehicle, the current amount to be paid in real time and the estimated battery level which the vehicle should be a the end of the process (in alternative they could have selected a target percentage of charge and the app would have shown the estimated amount of time until it was reached).
   The user after 30 minutes gets bored and decides to leave even if he had previously set the charge timer to 40 minutes: he opens the recharge popup in the homepage of e-Mall application, clicks on the “STOP” button and unplugs vehicle from the socket; the application takes the money the user owes from the selected payment method and shows a “Charge ended” pop up.

5. **The user wants to book a charging point for a certain timeframe**
   The user decides to schedule a charging session for the next day to better organize their day.
   So, they open app and tap on the “Schedule” section: a calendar opens up, where they select the desired day and the desired timeframe (they select the 9:00 – 11:00 frame as they have a charging station pretty close to the office they work at) and the desired charging station and socket type (Fast, Rapid or Slow), based on availability.
   The app then asks for a future confirmation ad then shows, default vehicle and payment method as selected, the estimated amount of money for the charge and also a red text which says:

   > “Be aware that half of the estimated amount of money due for the charge will be pre-authorized from the selected payment method.
   > You can delete your reservation from the “My reservation” section in your account.
   > If you fail to delete it before 2 hours from the starting time the half of the pre-authorized amount will be taken”.

   The user then confirms the vehicle and the payment method and at the end clicks on the “Reserve your spot” button; the application shows a “Socket booked” pop up and redirects the user to the “My reservations” section (if the user had wanted to abort the operation they could have clicked on the “Cancel” button and the application would have showed an “Operation cancelled” pop up without redirecting the user).

6. **The user receives a suggestion**
   The user receives a notification from the e-Mall application:
   > “We have a suggestion from you!”

   The user then clicks on it and the application on their phone opens directly in the “My Suggestions” section. Here they can see a list of all past suggestions and the new one at the top of the list marked with a “NEW” green text at the right of the entry.
   The user clicks on this new suggestion and a new screen opens, where some information appear: the application has indeed found that the user has a charging station near the restaurant he has planned to go to that evening between 20:00 and 23:00 and so it shows that same charging station, its prices and the fact that there are free rapid charging sockets for the 20 – 23 timeframe (it shows the rapid sockets because they are the cheapest ones due to a special weekend offer)
   The user has the possibility, from this page itself, to click on a “Accept suggestion” that will book that same charging station, in rapid charge mode, in that same timeframe, so they click it and the application shows a “Reservation confirmed” pop up. If they would have not liked it and not clicked it then the user could have clicked on the “X” at the top right of the screen to go back to the “My suggestions” section, where this new suggestion would not have been marked as new anymore.

7. **The system CPMS decides which DSO to acquire energy from and sets the prices for the users**

e-Mall CPMS contacts through the provided APIs a list of DSOs to acquire energy: each one of them offers a different price and some of them offer a monthly and bi-monthly solution to be more competitive, still making money out of it obviously.
After receiving all the answers from the DSOs and after an attentive evaluation, e-Mall decides to acquire the energy for the next three months from *E-Distribuzione SpA*, the biggest one in Italy for 0.21€/kWh.
Knowing this, the e-Mall CPMS is able to compute the prices for the end users, so it decides to go for 0.35€/kWh for Slow charging sockets, 0.42€/kWh for Rapid charging sockets and 0.55€/kWh for Fast charging sockets.
The CMPS then sets these prices in their database and updates the user application with the current values in real time.

8. **The System decides to charge a connected vehicle at the "Piazza del Duomo" charging station through the energy stored in the batteries of the station itself**
The CMPS of e-Mall has seen that many users in Milan tend to charge their vehicles at the Piazza del Duomo charging station, since they are able to reach the station by car and then have a walk in the city center while it charges.
To better handle the workload and the amount of energy to be dispensed, the station has been previously provided with batteries (providentially) that are charged during the night from the energy acquired from a DSO at a discounted price.
Once a new car arrives, the system then checks the level of the battery of the charging station and since they are more than 80% full, the CMPS decides not to charge it through the energy coming in real time from the DSO, but through the batteries.
The CPMS then through and API switches the incoming source of energy from DSO to batteries and the vehicle charges as nothing happens; this decision is completely transparent to the end user themselves, they indeed do not need to do anything different on their interface, nor about what they physically need to do at the charging station.

2.1.2 – Class Diagrams

The UML diagram below gives an overview of all the components needed to describe the system. In the following lines a brief description of the main entities is provided.
A *User*, in addition to all the contact information – that have to be verified - needed to minimize the probability that automated or unofficial clients can access the functionalities of e-Mall, has a *currentLocation* attribute, updated in real time in order to show the user the charging stations closer to him, one or more saved *PaymentMethod*s, one or more electrical *Vehicle*s, a list of active *Prenotation*s and *Suggestion*s – based on any discount on energy price offered by some CPO or on the *Appointment*s of the user.
A *CPO* communicates with many *DSO*s through its CPMS and, according to the data retrieved from them, many decisions can be taken. For example, observing the fluctuation of the energy price and other internal and external factors, it can update the energy price of the *ChargingStation*s it owns, offering discounts if some conditions hold, or decide whether to store energy in the batteries of the most popular stations.
It's important to clarify that all the decisions associated to the CPMS entity can be taken automatically by the system (which schedules periodical tasks to check DSO prices or batteries levels and performs actions based on their results) or manually by a human operator, who interacts with the backend through a desktop application installed only on e-

Mall's computers. Note that all the operations performed by humans have higher priority than the corresponding ones done by the automated software; in addition, an agent can validate, cancel or delay any order carried out by the system. The order is automatically validated in absence of an explicit decision by an operator within 15 minutes: the reason why the order is automatically processed – rather than rolled back – is that if no one takes an explicit decision, then the operation is based on the trust on the software, which is able to individuate favorable buy-pattern.
A *ChargingStation* is composed of many *ChargingSocket*s, each one possibly associated to multiple *Suggestion*s and *Reservation*s, but at most to an active *ChargingSession*, that is paid with the provided *PaymentMethod*.

2.1.3 – State Diagrams

Qui mettere il BPMN

2.2 – Product Functions
In this section the main functionalities of the e-Mall system are explained in a more orderly manner.

2.2.1 – Control of the charging process
The system will allow end-users to manage the whole charging process of their electric vehicle. It will be able to show every available location in certain area, along with specific details about each of those.

If the user is near the selected station, it will allow them to immediately begin the charging process. It will also let them reserve a charging spot at a given time on a given day.
While the vehicle is charging, the system shows the status and the remaining time to completion (based on the battery capacity provided by the user). When the charging process is finished, the system proceeds to make the user pay.

To make it faster for the end-user to compete the former steps, the system will have the possibility to remember payment methods, details about the vehicle and other personal information the user will provide.

Additionally, the system can store details about the user's vehicle, like the model, battery capacity and charging adapter, so that only compatible stations are shown.

2.2.2 – Energy management in every charging station
The system will allow to make decisions regarding many aspects of energy management in a certain charging station. This will consist mainly of two aspects:
- Being able to select the current best DSO (based on the price of energy offered, the mix of sources they produce energy from…) and set the prices for end-users accordingly.
- Being able to strategically use the batteries that may be present at a charging station, based on what is most convenient at a given time.

All the functions described above can be either automatically fulfilled by e-Mall's CPMS or manually by a human operator, which can directly interact with the system itself.

2.2.3 – Proactive prediction of end-user needs

The system will be able to identify which course of action best fits the user needs, based on the information it has (if the user grants access to them):
- current position
- calendar schedule
- battery level of the vehicle

The system will then communicate with the end-user with personalized notifications, who can then either accept the suggestion or dismiss it.

2.3 – User Characteristics

There are three types of users considered in the e-Mall system.

1. Unregistered end-user
   A user that has not registered yet in the e-Mall system. In order to use its functionalities, they first have to sign-up.

2. End-user
   A user that has successfully completed the registration process and can have full access to the system's functionalities, with which they interact using the e-Mall app.

3. E-Mall admin
   A person within the company e-Mall that is responsible to directly modify data (as described above) in e-Mall's CPMS. They interact with the system using a command line interface or a GUI developed outside of this project's scope (giusto?).

2.4 – Assumptions, Dependencies and Constraints

2.4.1 - Domain assumptions

ID	Description
D1	The end-user has an active Internet connection.
D2	The vehicle's details about the battery capacity are true and exact.
D3	
D4	The end-user does not input fraudulent information (e.g., fake reservations to disturb other users).
D5	
D6	Each external CPO provides an API to communicate with the system.
D7	Data provided by other CPOs is valid and trustworthy.
D8	
D9	The information upon which the system provides suggestions (location, calendar…) is valid and reflects the user's real status.
D10	