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RASD

Requirement Analysis and Specification Document
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1 Introduction

This *Requirements Analysis and Specification Document (RASD)* aims to provide an overview of the eMall project. The following document will help the reader to understand the purpose of the project i.e. in which environment the application operates and which services offers to its users. In particular way it will illustrate goals and how these may be reached, guaranteeing the meeting of certain functional and nonfunctional requirements.

1.1 Purpose

Billions of tons of CO2 are released into the atmosphere every year as a result of coal, oil, and gas production. Human activity is producing greenhouse gas emissions at a record high, with no signs of slowing down. While science tells us that climate change is irrefutable, it also tells us that it is not too late to stem the tide. This will require fundamental transformations in all aspects of society; one of the most debated ones undoubtedly regards the mobility and the increasingly widespread usage of electric vehicles. When it comes to climate change and air quality, electric vehicles are clearly preferable to petrol or diesel ones and the benefits will further increase going forward, as world will adopt more renewable energy sources in the future.

The **e-Mobility for All (eMall)** is a software application designed to support the charging process of electric vehicles. The eMall purpose can be summarized in two main aims:

- Allow drivers to charge easily, quickly and effectively their electric vehicle through out a dedicated user-friendly software interface called **eMobility Service Provider (eMSP)**. This system wants to be an intermediary between the end users and the Charging Point Operators (CPOs). The electric vehicle drivers will find in eMall all the information they need in order to carefully plan, monitor and manage the charging process of their electric vehicle, in such a way that it introduces minimal interference and constraints on their daily schedule.

- eMall wants to be also focused on supporting the Charging Point Operators (CPOs) that own and manage the charging stations. In particular, support is given via a subsystem called **Charging Point Management System (CPMS)**. Every CPO has its dedicated CPMS that administers its IT infrastructure and provide a simple access point to the CPOs operators that want to monitor the charging stations status, make decisions and apply changes. The CPMS handles also the acquisition of energy from the so-called Distribution System Operators (DSOs) and can automatically handle decisions in substitution to the manual intervention of the CPO human operator.

Finally, eMall guarantees an effective and reliable interaction between eMSP and CPMSs, providing full support to users on both sides.

1.1.1 Goals

In this section, we will go to extract the main goals of eMall. The goals indicated below are divided with respect to the eMall system section they belong to.

Users

- [$G.1$] - The system allows Users to register as Drivers in the application.
- [$G.2$] - The system allows Users to visualize the position of the charging stations in a selected area.
- [$G.3$] The system allows Users to visualize "external" data of the charging point, and its sockets, in a selected charging station (e.g. charge price, socket status, socket charging type etc.).
- [$G.4$] - The system allows to differentiate the functionalities dedicated to the Drivers and the functionalities dedicated to Operators.

eMSP

- [$G.5$] - The system allows Drivers to log in the application.
- [$G.6$] - The system allows Drivers to reserve a socket in a selected charging station for a certain time frame.
- [$G.7$] - The system allows Drivers to control (start and stop) the charging process.
- [$G.8$] - The system allows Drivers to visualize the progress of the charging process.
- [$G.9$] - The system allows Drivers to pay for the charging service.

CPMS

- [$G.10$] - The system allows Operators to log in the application.
- [$G.11$] - The system allows Operators to visualize data about the "internal" status of a selected charging station (e.g. station battery percentage, number of charging vehicles, amount of absorbed power etc.).
- [$G.12$] - The system allows Operators to visualize data about DSOs.
- [$G.13$] - The system allows Operators to select from which DSO buy electric energy.
- [$G.14$] - The system allows Operators to set the price of a charging and set special offers in a selected charging station.
- [$G.15$] - The system allows Operators to decide whether to use batteries, energy from DSO or a mixture of them for charging electric vehicles.

1.2 Scope

In this section we want to give a brief analysis of the machine, world and shared phenomena.
The Machine is the application software that we want to develop i.e. eMall.
The World is the external environment, namely the part of the real world that is affected by our system.
These two actors communicate and influence each other. World phenomena are events that take place in the real world and taken by themselves do not have a direct impact on the System.

Shared phenomena can be of two kinds: controlled by the Machine and observed by the World, or vice versa controlled by the World and observed by the Machine. In the tables shown below the phenomena are clearly separate in eMSP and CPMS phenomena.

1.2.1 World and Machine Table : eMSP

Phenomenon	**Controlled by**	**Shared**
A Driver wants to charge an electric vehicle	W	No
A Driver does not arrive in time to the socket reserved	W	No
There is a fault in the electrical system	W	No
The machine shows data about the status of a selected charging station	M	Yes
The machine reserves a socket of a charging station for a certain time frame	M	Yes
The machine sends a QR-Code ticket to be scanned by the driver at the charging point	M	Yes
The machine shows data about the charging process of the electric vehicle (e.g. battery percentage, price, kWatts, spent & remaining time)	M	Yes
The machine shows if the payment has been successfully completed or eventually any payment issue occurred	M	Yes
The machine notifies that the charging process is started or finished	M	Yes
A User opens the eMSP application	W	Yes
A User signs up to the eMSP application	W	Yes
A Driver logs in the eMSP application	W	Yes
A User selects a charging station for view its data	W	Yes
A Driver books a socket in a selected charging station	W	Yes
A Driver scans the QR-Code to confirm he is arrived at the socket	W	Yes
A Driver connects/disconnects the electric vehicle to/from the reserved socket	W	Yes
A Driver starts or stops charging the electric vehicle	W	Yes
A Driver inserts data of payment	W	Yes

Table 1: World and Machine table: eMSP

1.2.2 World and Machine Table: CPMS

Phenomenon	**Controlled by**	**Shared**
A DSO changes the price of the energy sold	W	No
The batteries in a certain charging point are empty	W	No
The machine shows data about the "external" status of a selected charging station	M	Yes
The machine shows data about the "internal" status of a selected charging station	M	Yes
The machine shows data about the DSOs	M	Yes
A Operator selects price and offers of sockets of a charging point	W	Yes
A Operator visualizes the list of DSOs	W	Yes
A Operator selects the DSO from which buy energy	W	Yes
A Operator selects where to get energy for charging	W	Yes

Table 2: World and Machine table: CPMS

1.3 Definitions and abbreviations

1.3.1 Acronyms

- **RASD**: Requirement Analysis and Specification Document.
- **eMSP**: e-Mobility Service Provider.
- **CPO**: Charging Point Operator.
- **CPMS**: Charging Point Management System.
- **DSO**: Distribution System Operator.
- **UML**: Unified Model Language.
- **API**: Application Programming Interface.
- **QR-code**: Quick Response-code.
- **EV**: Electric Vehicle.
- **CS**: Charging Station.
- **CP**: Charging Point.
- **FC**: Fiscal Code.

1.3.2 Definitions

- **User**: person or entity who wants to use the application and is not registered to it.
- **Driver**: User who owns an electric vehicle, can use the charging stations for charging purposes and is registered to the application.
- **Charging Point Operator (CPO)**: entity or organization that owns and manages all the EV infrastructure assets.
- **e-Mobility Service Providers(eMSP)**: software functionalities used by Drivers for manage their charging purposes.
- **Charge Point Management System (CPMS)**: software system that manages the charge point infrastructure. It is also an interface that allows CPO Operators to handle technical and economic aspects of the owned charging stations.
- **Operator**: human operator who works into the staff of a CPO and have access the CPMS functionalities.
- **Distribution System Operator (DSO)**: entity responsible for the operation and management of electricity distribution networks, from which the CPOs can buy energy.
- **Charging Station**: station in which Drivers can charge their electric vehicles.

- **Charging Point**: structure of a charging station with sockets where the Drivers can connect their electric vehicle.
- **Fiscal code**: a 16 characters code used in Italy to uniquely identify a person.

1.3.3 Abbreviations

- $[G.n]$ = n-th goal.
- $[R.n]$ = n-th functional requirements.
- $[D.n]$ = n-th domain assumption.
- $[UC.n]$ = n-th use case.

1.4 Revision history

Version	Date	Details
1.0	23/12/22	RASD first deadline draft

Table 3: revision history

1.5 Reference Documents

Title	Authors	Links
The World and the Machine	Michael Jackson	Online PDF
Alloy Official Documentation	MIT Software Design Group	Alloy documentation

Table 4: table of references

1.6 Document Structure

The rest of the document is organized as follow:

Overall Description (Section 2): This section gives an overall description of eMSP and CPMS functionalities that the application eMall offers, underlining the main goals that have been set. Here we also give an introduction about the world in which the system will be collocated, highlighting the boundaries and the interactions between the machine and the world.

Specific Requirements (Section 3): contains an in-depth description and explanation of the system that we want to develop. More in detail, this section provides a class diagram in order to give a general view of the application structure, some state diagrams to explain the evolution of some crucial domain parts, an explanation about different users and finally the domain assumptions we have defined for this application.

Formal analysis using Alloy (Section 4): This section exploits Alloy in order to generate a formal model of some critical parts of the domain. Some images of significant instances of this model are provided.

2 Overall description

2.1 Product perspective

To better understand the peculiarities of the product, it is important to detail the domain for which it is intended. In this chapter a detailed analysis of the shared phenomena and a visual representation of the domain model will help to achieve the scope.

2.1.1 Scenarios

Scenario 1: Charge Leklerk needs to charge his EV which has a low percentage of battery.
Mr.Leklerk decides to try out a new application eMall, that his friend Carlos Jr. suggest to him. Mr.Leklerk downloads the eMall application on his smartphone, opens the app and, from the homepage, selects the Login icon. He has not an account already, so he decides to create one. He is required to insert: name, surname, phone number, email address, fiscal code and a valid password; he proceeds by inserting his personal data and confirms the agreement of eMall terms and conditions. After successfully completed the registration phase, Mr.Leklerk looks for the nearest CSs to his position on the map, selects one of them, visualizes which sockets are available and book one.

Booking is successful, Mr.Leklerk receives the QR-code ticket and visualizes on the screen that he has 15 minutes to reach the reserved socket, to connect the socket and his EV and to scan the QR-code (mandatory in this order) in order not to loose the reservation. After 10 minutes Mr.Leklerk arrives at the socket, connects the socket cable to his EV and successfully scans the QR-code. At this point, Mr.Leklerk visualizes from the screen that he must enter payment data, within 5 minutes, to proceed with the charging of the vehicle, otherwise he will loose the reservation.

In 1 minute of time, without any special problems, Mr.Leklerk enters the data of his prepaid card, saves these data directly and proceeds with the confirmation.

Once the payment data is successfully entered, the system previously freezes €100 from Mr. Leklerk payment method and then the socket starts charging the vehicle. Mr.Leklerk visualizes on his screen all the progress related to the charging process in real time. In particular, he visualizes: the battery status of the EV, the kWatts used, the money for kWatts used, the initial time of the charging process and and the estimated final time to reach 100 % vehicle charge.

Mr.Leklerk then decides to go for a coffee in a nearby bar waiting for his electric vehicle to completely charge. After about 2 hours, Mr.Leklerk receives a notification from the application: the maximum charging capacity has been reached and the charging process is finished.

Once the charge has been successfully completed, the system withdraws the correspondent total charge price from the previously freezed €100. Mr.Leklerk then goes out the bar, reaches the vehicle, safely detaches the cable and goes away, on a new adventure.

Scenario 2: It will be not a good day for Max Van Der Stappen.
After a busy work day, Max leaves the office and after entering the car he realizes that it

is at 15% battery. Without further ado, Max opens the eMall app, logs in as Driver and looks for a CS with available sockets.

Max successfully books a free socket, but the traffic of the city does not allow him to reach it within 15 minutes, so Max loses the reservation. Then, he tries to book the same socket again but notices that its prices are changed and have increased. Then he decides to book another socket of a nearby CS.

In less than 15 minutes, Max arrives in time to the socket booked, connects the vehicle to the socket and successfully scans the new QR-code received.

In a short time, he enters the payment data correctly, selecting the data of a card already saved, and starts the charging process. Max decides to go for a ride in the sports store next to the CS while the vehicle charges. However, after 1 hour he realizes that evening he has the anniversary dinner with his girlfriend and he is late for it. Then, he leaves the store and through the application stops the charging process in advance, visualizing that the battery of the vehicle has reached 80 %.

After that, he disconnects the vehicle to the socket and goes home.

Scenario 3: Riccardo Bensoni's working day at "The Rooster CPO" headquarter will be very demanding.

The IT system that allows the automatic management of the charging stations is down, so some delicate operations need to be handled manually. Firstly, Mr. Bensoni logs in the eMall application using his desktop PC from his office entering his personal business email address, Identification Number and Password and clicks "login".

The first task the company assigned to him is to change another DSO from which to acquire energy due to an unjustified increase of the current DSO price.

Mr. Bensoni, who is already logged in, goes in the "myDSO" section and selects "List of DSO". Ordering the list by price, he selects the "Energy4All" that is not the cheapest one (still cheaper than the current one), but has a high percentage of energy produced with renewable sources. This choice has been made because of internal CPO policy that oblige to choose DSO that provide renewable energy percentage above the 70After some seconds, the DSO confirms the deal and the modification is successfully registered.

The second thing he has been tasked to do is to modify the price of the "FAST" sockets of the charging station in the Lambrate neighborhood, adding a 10% discount in order to encourage the Drivers to use those sockets.

Mr. Bensoni enters the neighborhood in the map view and, for each CS, he adds the offer.

The third task is to modify the supply settings of the Via Golgi 42 charging station. This is because the batteries are about to empty and the current supply settings are set with 70% of energy from batteries and 30% from the DSO line; so it is necessary to set the supply settings to 100% from DSO.

Mr.Bensoni then clicks on "my Charging Stations", inserts the charging station address in the search bar and selects it.

In the CS menu, he selects "Supply Settings", where he finds an overview of the charging station energy providing settings. Then he selects "Line Only" and submits.

2.1.2 Class Diagrams

Below is presented a high-level class diagram of the application.

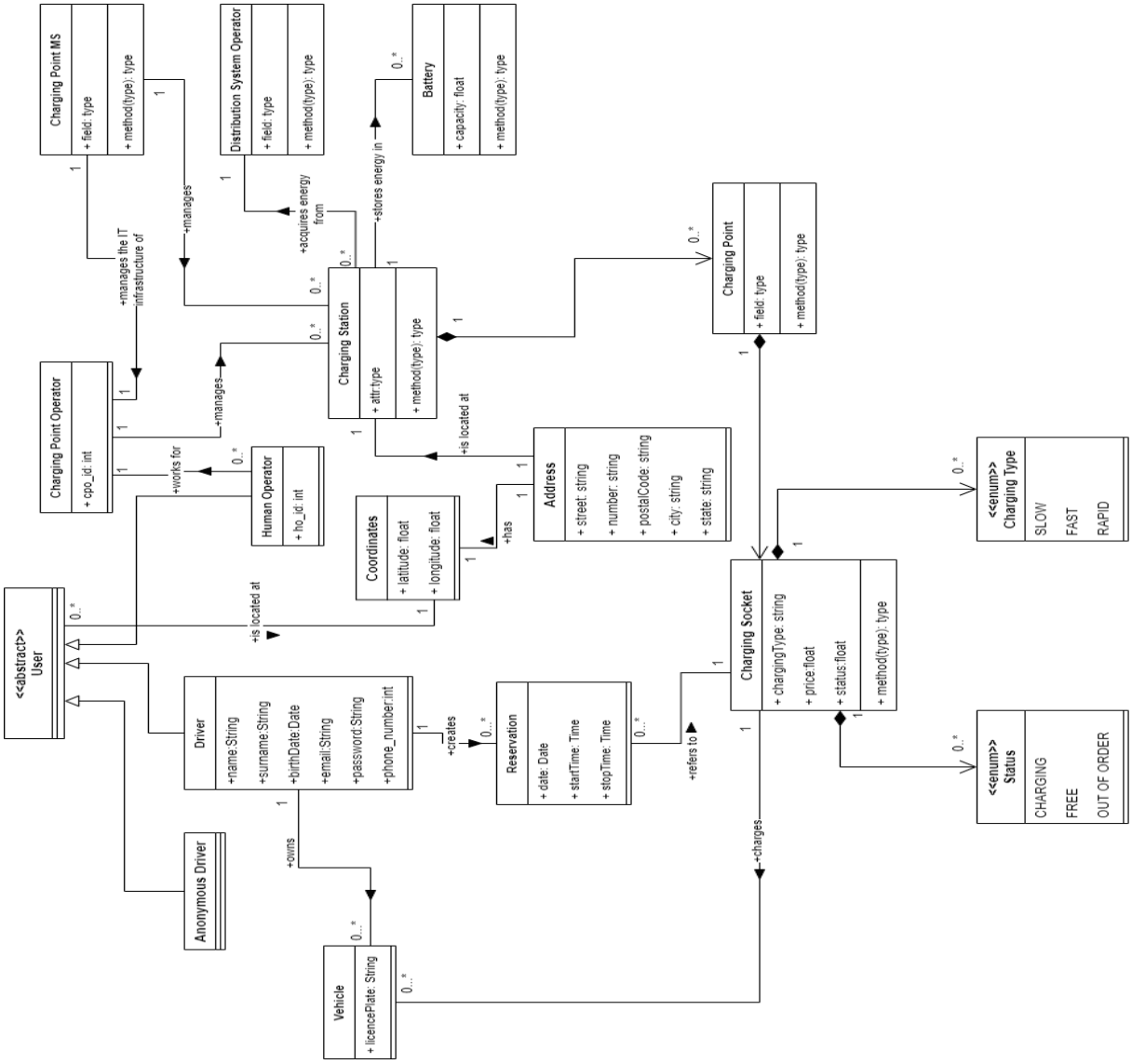


Figure 1: Class Diagram

2.1.3 Statecharts

The statechart diagrams shown below are used to describe the main sequences of events the system handles in its common scenarios.

2.2 Product functions

In this section we will present, in a descriptive way, the main functionalities of the eMall application. Starting from the involved scenarios, the most important requirements will be extracted with the aim of conducting a more precise and formal analysis of them in the next chapter.

2.2.1 Generic functionalities

There are some functionalities of eMall that can be performed by all the Users.

- **Registration and Login**
  In order to use the eMSP booking and charging functionalities, Users must sign up in the application providing name, surname, email address, FC and a valid password. In addition, Users have to agree on Terms and Conditions of Use, that includes for them an agreement on privacy and data collection.
  Drivers, who are already registered, may want to sign in the application. In this case they have to insert email address, FC and the password they have used for the sign up operation.
  Operators that work for the CPO and need to use the CPMS functionalities are required to provide: business email address (provided by their CPO), a valid password and an identification number to log in. A dedicated section of the application will appear and they will be able to exploit the CPMS dedicated features. Due to security reasons, new CPO Operators will be provided with the login credentials by the CPO organization itself, so they do not have to sign up arbitrarily. They will be recognized directly by the CPMS.

- **Visualization of the charging stations on the map**
  Each kind of User, only if they authorize, can be traced by GPS. In this way they can visualize in a map the presence of close CSs to their position or in a selected area (in this second case, the GPS authorization is not strictly required).

- **Visualization of "external" status of a Charging Point**
  Each kind of User can select a certain CS on the map and visualize its "external" data i.e. location, number of CPs, available and occupied charging sockets for each CP, the estimated time when the occupied sockets will be freed, type of each socket (slow/fast/rapid) and cost of each socket.

2.2.2 eMSP functionalities

We will now explain the eMSP functionalities that Drivers can use.

- **Book a socket**
  The Driver can book in advance a socket of a CP. After booking, Driver will receive a QR-code ticket that must be scanned by the socket QR-code reader to confirm the Driver's presence. The Driver has therefore 15 minutes, as per protocol OCPI, to arrive at the booked socket, scan the QR-code ticket and connect the vehicle with the dedicated cable. For those 15 minutes the socket is reserved. If the Driver does not arrive within this time frame, the socket will be freed for other reservations.

- **Payment and start of the charging process**
  In order to launch the charging process, the Driver must insert one valid method of payment in the application. This payment method will be then saved and subsequently usable for the next chargings. After correctly scanning the QR-Code ticket, the Driver will be able to choose a valid payment method among those already added or to add another one, meanwhile, a 5 minutes timer starts. If the Driver does not have a valid payment method yet, it must insert the data about a valid one before the timer expires in order not to lose the reservation. The system will then reserve for the charge an amount of money $x \leq$ €100 and $x \leq$ maximum credit available in the account related to the selected payment method. If the transaction is successful, the charging process will automatically start. In case of payment issues i.e invalid data inserted or no money available in the payment method, the Driver can retry entering again the payment data or choosing another payment method within the five minutes; period of time after which, in case of transaction failure, the reservation expires.

- **Visualization of data during the charging process**
  During the charging process, the Driver can see real-time data about it, such as: kWatts used for charge the EV, price per kWatts used, time spent since the start of the charging process, remaining time to reach 100 % charge.

- **Stop of the charging process**
  The Driver has the possibility to stop in advance the charging process via a button on the application. Otherwise, the charging process stops automatically when the EV reaches 100 % battery.

- **Saving of credit cards**
  The application shall also allow the Driver to save the payment data he prefers, in order to be faster and more effective during the payment phase. In this way, during the payment phase, the Driver will only have to select a payment method already saved to start the charging process in a few seconds.

2.2.3 CPMS functionalities

We will now explain the CPMS functionalities that Operators can use.

- **Visualize the internal status of a charging station**
  The Operators can visualize the "internal" status of a selected charging station, such as: the amount of energy available in its batteries (if batteries are presents), the number of vehicles being charged and, for each charging vehicle, amount of power absorbed and time left to the end of the charge.
- **Setting of DSOs**
  The Operators can visualize: the list of available DSOs, from which they can select a new DSOs from which buy energy; the list of DSOs from which they already buy energy and deselect them.
- **Setting of price and offers**
  The Operators can modify the prices of a selected CP and they can set special offers according to the market needs.
- **Decide where to get energy for charging**
  If batteries are present in a CS, the Operators can decide how to get energy for charging the EV, such as: get energy from station batteries, get energy from DSOs, or a mix of these two modalities.

2.3 User characteristics

- **User**: person who: can download the eMall application, is not registered to it and can only benefit from the Generic functionalities.
- **Driver**: User who owns an electric vehicle, can use the charging stations for charging purposes and is registered to the application. Drivers can benefit from Generic functionalities and also from the so-called eMSP functionalities.
- **Operator**: person who works for a CPO and can make some business choices through dedicated functionalities. Operators can benefit from Generic functionalities and also from the so-called CPMS functionalities.

2.4 Assumption, dependencies and constraints

2.4.1 Domain assumption

Domain assumptions are descriptive assertions assumed to hold in the world.

- $[D.1]$ = Drivers and Operators have different access to the functionalities of eMall.
- $[D.2]$ = The data (FC, email, etc...) provided during registration is truthful and belong to the person who creating the account.
- $[D.3]$ = User's device have to be connected to the Internet to guarantee the proper functioning of the application.
- $[D.4]$ = The Drivers behave civilly with respect to CPOs' infrastructures they use.
- $[D.5]$ = When a Driver arrives at the reserved socket, it is found free.
- $[D.6]$ = The Driver remains in the reserved seat only for the time needed for the charge.
- $[D.7]$ = For safety reasons, the cable that connects the EV to the socket remains blocked for the entire process of charge.
- $[D.8]$ = Each Operator has his own CSs to manage.
- $[D.9]$ = Operators' manual decisions do not conflict with automatic CPMS decisions.
- $[D.10]$ = The interaction between the various providers (eMSPs, CPOs, and DSOs) occurs through uniform APIs.
- $[D.11]$ = There exist uniform API for accurate GPS localization of Drivers and CSs.
- $[D.12]$ = There exist uniform API that manages the payments of the charges.

2.4.2 Constraints

- Each Driver must create only one account.
- Driver can not book more than one socket at a time.
- When a QR-Code ticket is generated, the system doesn't allow to generate another ticket with the same QR-Code.
- Each CS must have at least one DSO which supplies electricity to it.
- Two or more Operators can not intervene in manage the same CS at the same time.
- If the socket does not work, the Driver can not book it.

3 Specific Requirements

3.1 External interface requirements

3.1.1 User interfaces

In this section, we are going to show the user interfaces of eMall application. The eMall application is available for mobile and tablet, so as to be suitable everywhere without excessive limits. In addition, a PC version of eMall is only available for Operators to better manage CPMS functionalities. Graphical interfaces shall have a simple structure and shall be easy to use by all type of users. The interfaces between the system and Users are presented using mockups. Since some functionalities are common to all the Users, others are just for one of the two categories: Drivers and Operators.
For simplicity, we will show only mockups for mobile application.

- **eMall Logo**

Figure 2: eMall Logo

The eMall Logo is composed by: the name of the application "eMall", the slogan "e-mobility for all" and finally a green and light blue car with simple shapes with a lightning bolt inside.
This simple image fully captures the purpose of the service: offer a simple, fast and effective service for the charging of electric vehicles.

- **General homepage: visualization of CSs on the map**

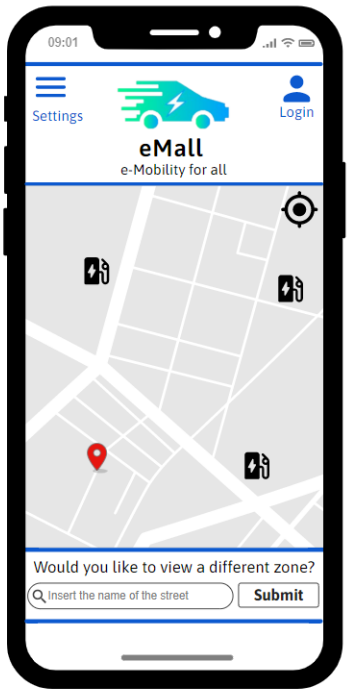


Figure 3: Visualization of CSs on a map

The first screen that a User sees as soon as he enters eMall is the map to search for Css.
It is composed by : a white background; the eMall logo on the top-center; the login icon on the top-right;the settings menu on the top-left; the map at the center, which shows the actual position of the User and the CSs closer to him; the search bar at the bottom-center with the button "Submit" beside. The search bar gives the possibility to the User to select a different zone.

- **Visualization of the external status of the CSs selected**

Figure 4: a) Free Socket, b) Not Free Socket

The User can select a CS on the previous map for visualize its "external" status in that moment. From top to bottom the User can see: a grey background; a exit icon at the top-left, used for return to the map; the icon of a CS with its address position, serial number and the date of today; the bar of the number of the CPs present in the CS from which the User can select a particular CP; the bar of number of sockets present in the CP selects before, from which the User can select a particular socket; the data about the socket selected before, such as the code, the type, if it is free or not, the current price, the booked-time if it was not free and the special offers if presents. In particular way : Figure 4.a shows the interface of a free socket; Figure 4.b shows the interface of a not free socket with its waiting time.

- **Registration and Login**

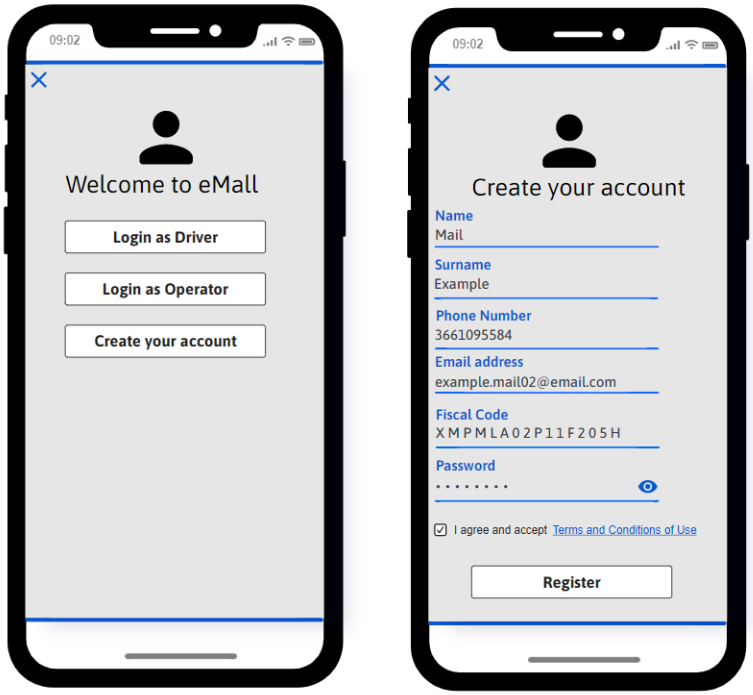


Figure 5: eMall Registration: a) Selection interface, b) Create an account

By clicking on the login icon, the User will see (Figure 5.a): an icon representing a man; an inscription "Welcome to eMall"; three buttons to enter the application as Driver or Operator, and finally a button to register. Buttons have the following functionalities:

- Create your account (Figure 5.b): for sign in the application a User has to provide: name, surname,phone number, email address, FC and a valid password for sign in the eMall application and become a Driver. the User has also to accept the "Terms and Condition of Use".
- Login as Driver (Figure 6.a): the Driver, User already registered, has to insert email address, password and press "Login" button to log in the application. A Driver has also the possibility to recover the password if he forgot it.
- Login as Operator (Figure 6.b): a Operator has to insert: business email address, his identification code, password and press "Login" button to log in the application and use the CPMS functionalities.
  A operator has also the possibility to recover the password if he forgot it.

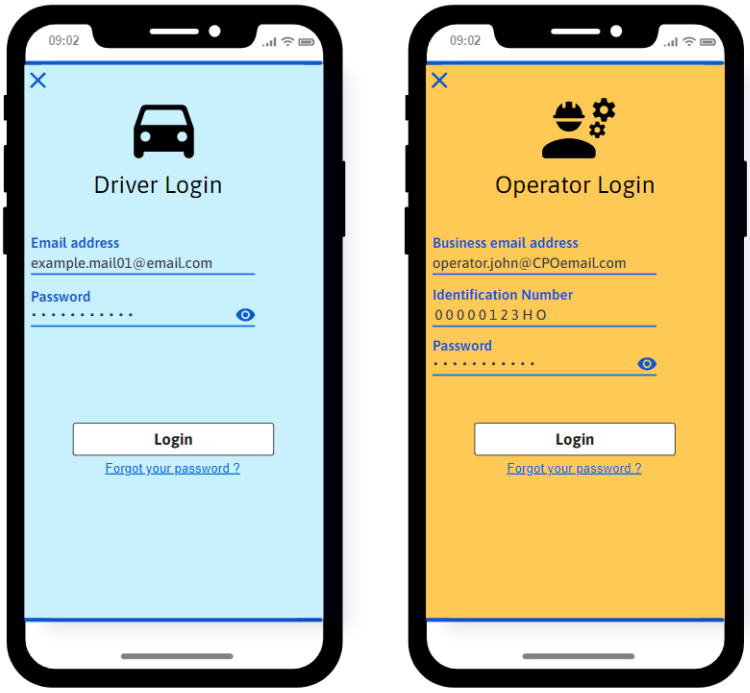


Figure 6: eMall Login: a) Driver, b) Operator

- **Driver homepage** When a Driver logs in the application, he can see an interface (Figure 7.a) similar to the main interface (Figure 3) but with: a light blue background; logout icon at the top-right; the CSs on the map colored by blue and a options menu eMSP at the top-left. By clicking on the eMSP menu, the Driver can visualize some functionalities (Figure 7.b).
  We describe now, in a qualitative way, these options:
  - Profile: the Driver can visualize details about his profile, such as: name, surname, email address etc.
  - Active Charging : the Driver can visualize, if are in progress, data about the charging process.
  - Reservations: the Driver can visualize the booking done before, or in progress, and their details.
  - Payment Options: selecting this, the Driver can visualize the payments done previously and can save a new payment method.
  - Settings: the Driver can visualize and modify some settings of the application, such as: language, change password etc.

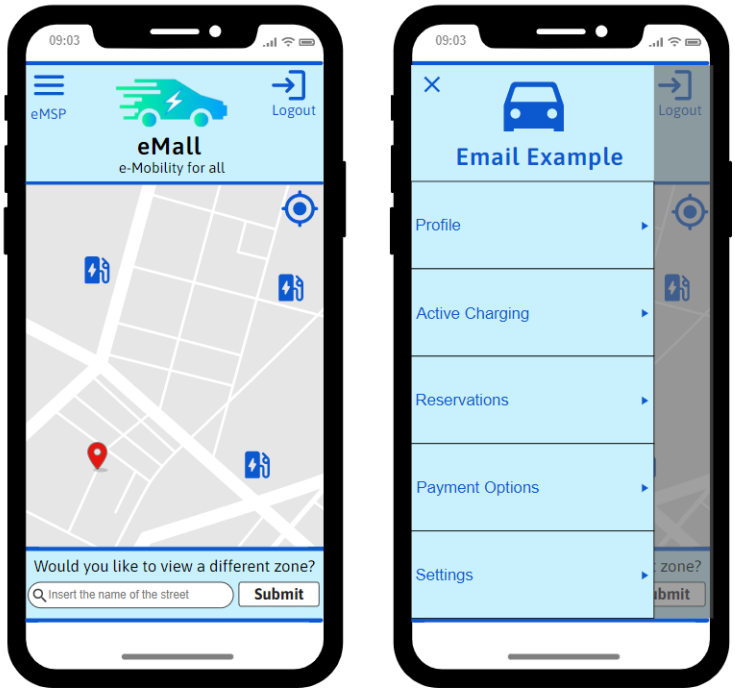


Figure 7: a) Driver principal page, b) Driver options menu

- **Operator homepage**

  When a Operator logs in the application, he can see an interface (Figure 8.a) similar to the main interface (Figure 3) but with: an orange background; the logout icon at the top-right; the CSs on the map colored by blue and a options menu CPMS at the top-left. By clicking on the CPMS menu, the Operator can visualize some functionalities (Figure 8.b).
  We describe now, in a qualitative way, these options:

  – Profile: the Operator can visualize details about his profile, such as: name, surname, business email address etc.

  – myChargingStations: The Operator can enter the main menu that allows him to have access to CPMS functionalities (i.e. view the internal status of the CPs, set price and offers etc...).

  – CPO: the Operator can visualize data about the CPO for which works.

  – DSO: the Operator can visualize the DSO from which the CPO buy electricity and change that DSO with another one via a list of DSOs.

  – Settings: the Operator can visualize and modify some settings of the application, such as: language, change password etc.

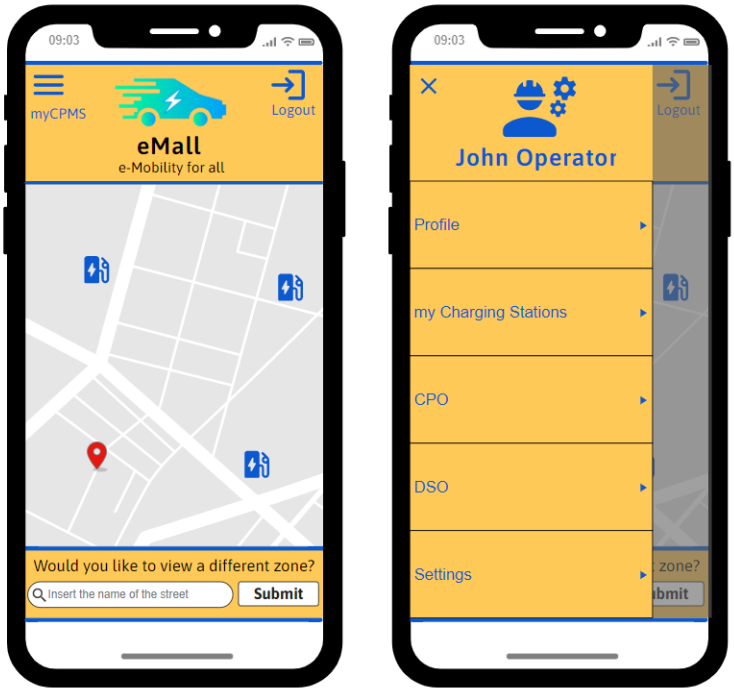


Figure 8: a) Operator principal page, b) Operator options menu

- **Booking a socket**
  We qualitatively describe here the passages of a booking in eMall application:
  - Figure 9.a : clicking on a CS, the Driver can view its "external" status and can, if socket is free, book the socket through the button "Book the socket".
  - Figure 9.b : then, the Driver has 15 minutes to arrive at the socket booked. The application shows to the Driver, from the top to the bottom: data about the CS, a timer, the data about the reservation and a button showing the QR-code ticket to be scanned (Figure 9.d).
  - Figure 9.c : if the Driver does not arrive in time at the socket booked, a notification will appear. This means that the time is expired and the Driver has lost the reservation.

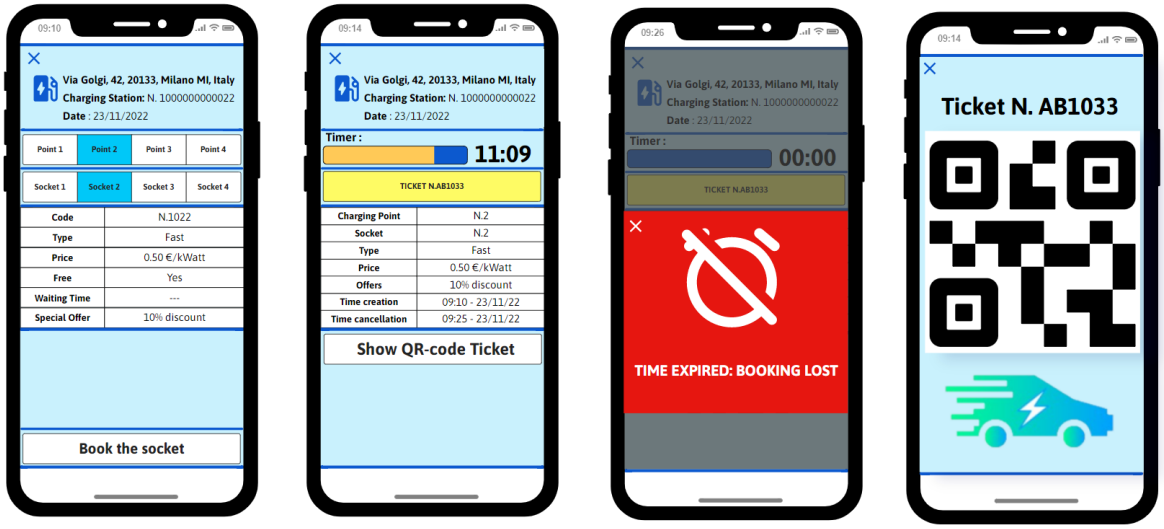


Figure 9: a) External status, b) Booking Status, c) Booking Lost, d) QR-code ticket

Figure 10: a) Past reservations with a ticket, b) Past reservations with no ticket

The Driver can visualize all the reservation selecting "eMSP" and after "Reservations". The Driver will visualize all bookings made in the past, colored green if successfully made and colored red if not happened, with all the details.

Below the list of "Closed Tickets" the Driver can visualize:

- "Open Ticket" (Figure 10.a), in this case clicking on it the Driver will go to visualize the state of the booking (Figure 9.b).
- No socket booked, so no ticket available (Figure 10.b).

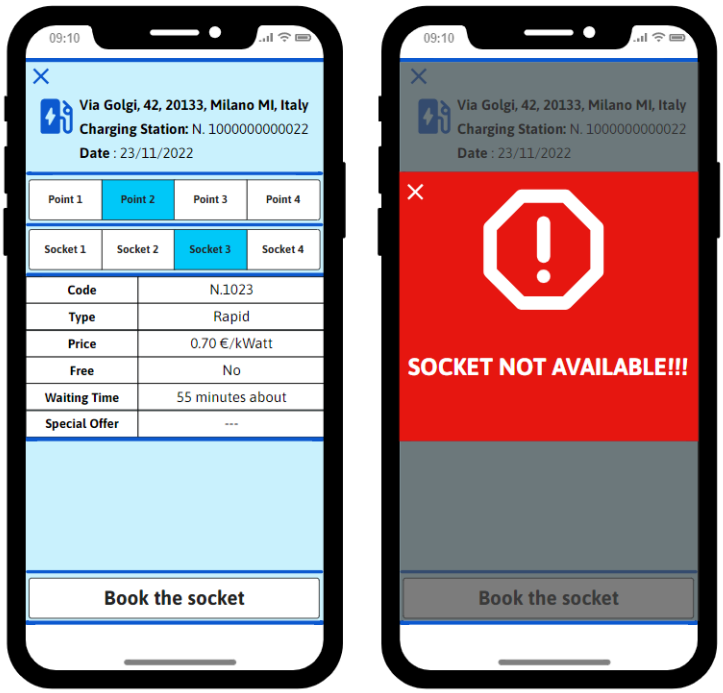


Figure 11: a) External status, b) Booking no available

Finally, the Driver will visualize the message "Socket not available" (Figure 11.b) in cases where:

- The Driver tries to book a busy socket (Figure 11.a).
- Driver tries to book an inoperative socket.
- The Driver tries to book another outlet with a reservation already in place.

- **Payment data and start of the charging process**

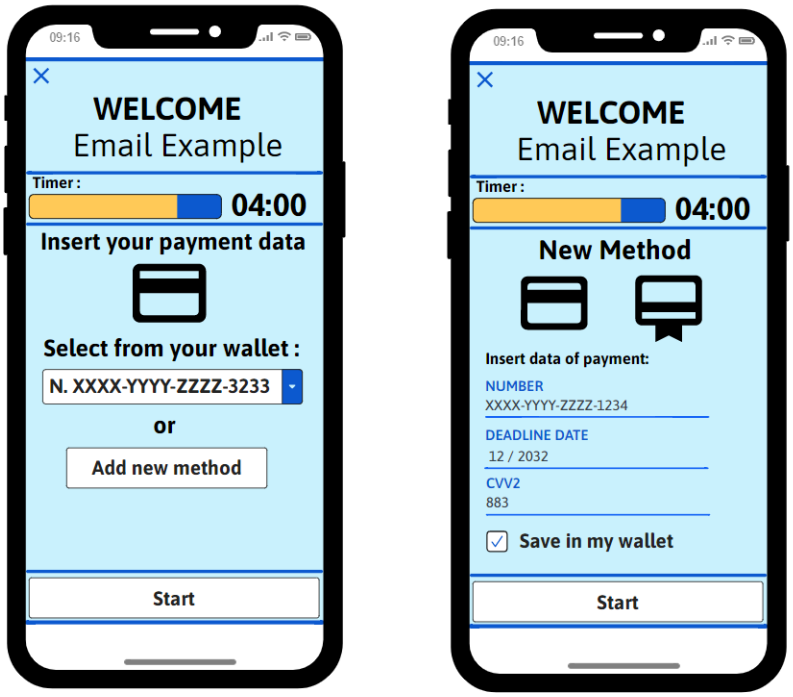


Figure 12: a) Payment Interface, b) Change method interface

After the correct QR-code scan, the Driver have to insert payment data, in less than 5 minutes, for start the charging process. In particular,the Driver can visualize:

- Payment interface (Figure 12.a): the Driver can: choose a credit card previously saved by the wallet, or change payment method clicking on the button "Add new method".
- New Method (Figure 12.b): in this page, the Driver can insert payment data of another credit card o similar, and can save them in the wallet through the appropriate box "Save in my wallet".

After entering the payment data, the Driver have only to click on the "Start" button to start the charging process.
The Driver can visualize also some different notifications of error during the payment process. For example:

- Incorrect payment data inserted (Figure 13.a): if the data of payment are not correct, a notification will appear to point out it.

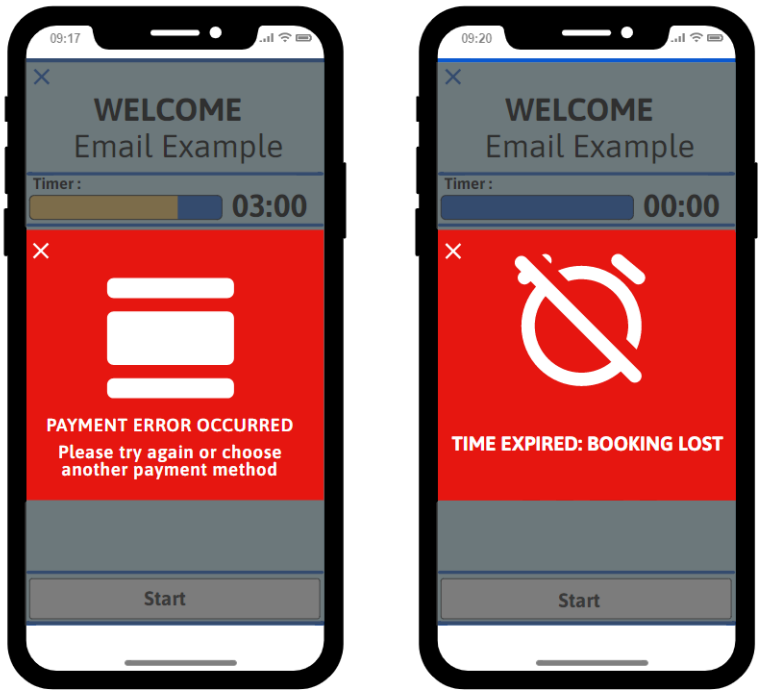


Figure 13: a) Incorrect payment data, b) Payment time expired

– Payment time expired (Figure 13.b) : if the Driver does not insert payment data in time, a notification will appear to point out that he has lost the reservation.

- **Visualization of charging process**

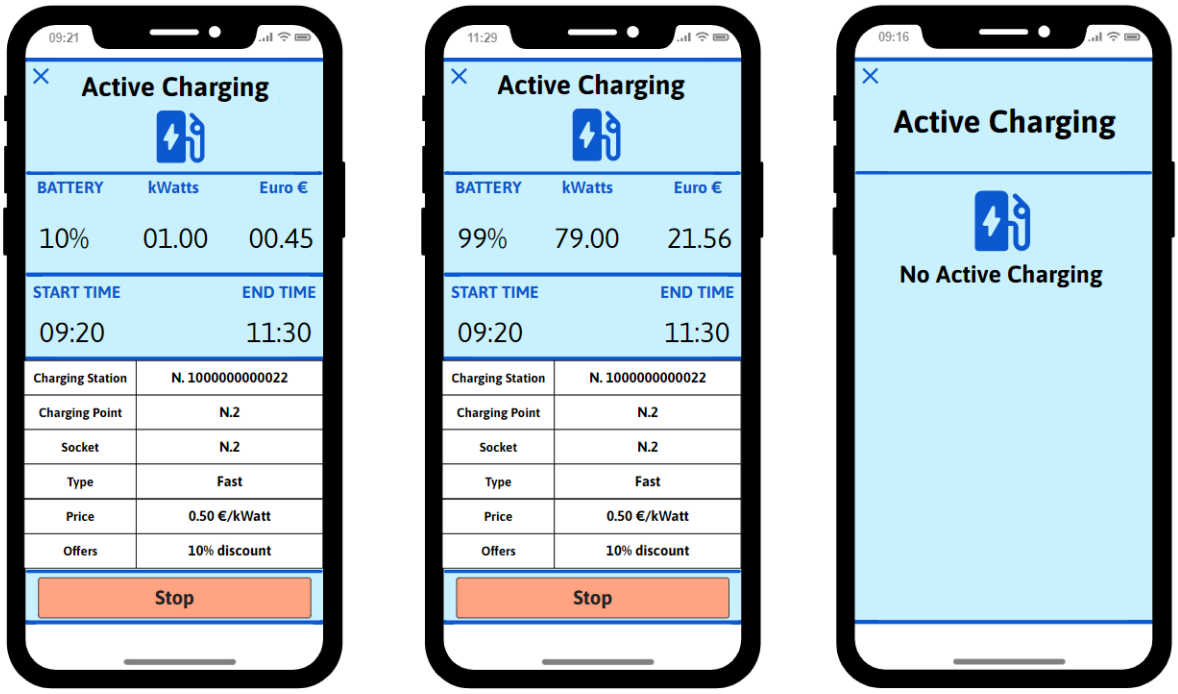


Figure 14: a) Beginning of the charging process, b) End of the charging process, c) No Active Charging

If the payment data is correct, the charging process will automatically start, and the Driver will be able to visualize in real time the progress of the charging process. In particular way, clicking on "eMSP" menu and after on "Active Charging", the Driver will visualize the charging status of the process if it is in place, otherwise the Driver will visualize (Figure 14.c) that there are no Active Charging in place. Talking about the charging process in place, we have:

- Figure 14.a) : the figure shows the initial phase of the charging status of the charging process. It shows: the current battery percentage of the EV, the kWatts inserted, the money per kWatt, the "start time" of the process and the supposed "end time" of the process and the data about the reservation did. The "end time" indicates the time in which the battery will be at 100 %.
- Figure 14.b) : the figure shows the last steps of the charging process.

The Driver can stop the charging process in advance, clicking on the "Stop" button. The Driver is informed of the end of the charging process by a notification (Figure 15.c).

Closing the notification, bu clicking on the icon in top left, the Driver can visualize all the details of the happened charging process, like:

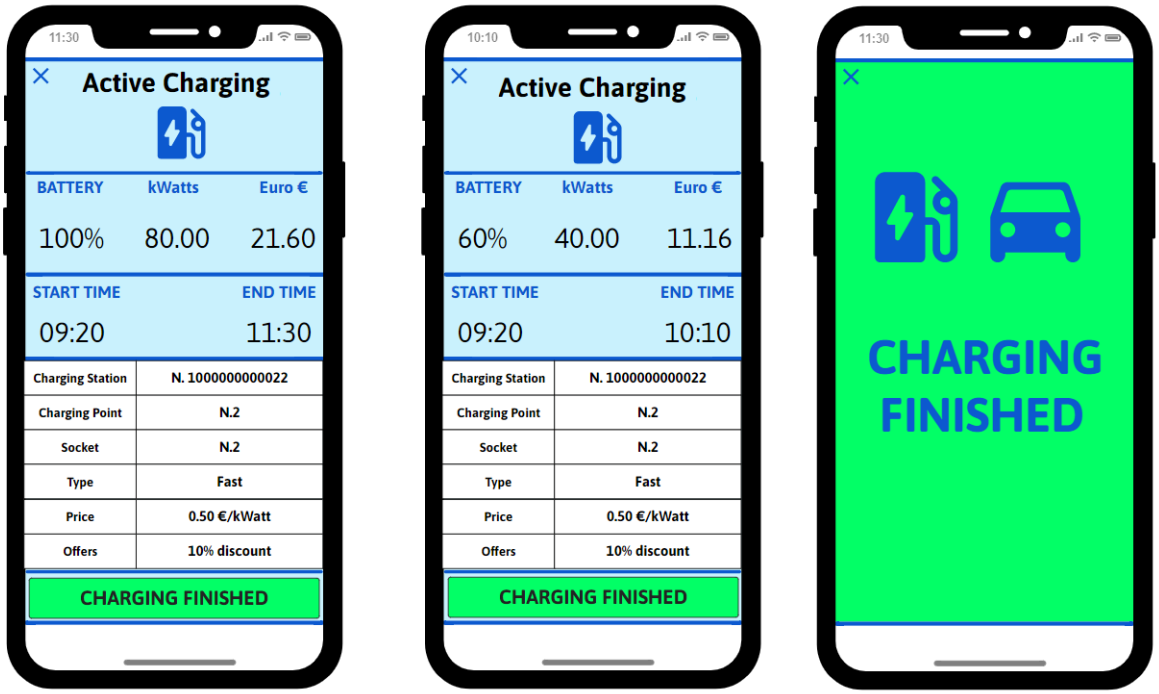


Figure 15: a) 100 % of battery reached, b) Process stopped in advance,c) End of charge notification

- Full charge of battery (Figure 15.a) : the figure shows the end of the process when the battery reachs the 100 %.
- Process stopped in advance (Figure 15.b) : the figure shows the end of the process when the Driver stops in advance the charging process.

It is possible to come back to the map interface either by clicking on the green "Charging Process Completed" button or by clicking on the top left icon.

- **CPMS functionalities : Station Status Menu**

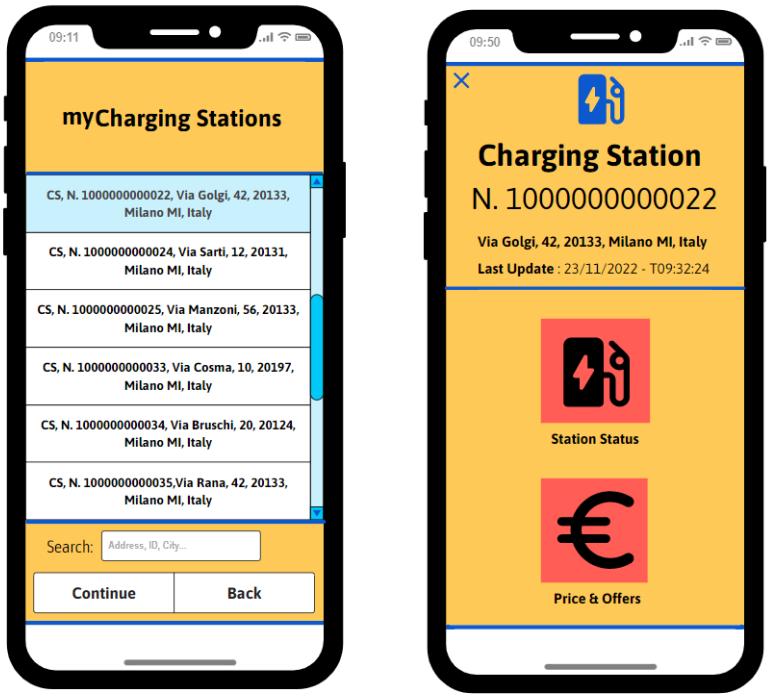
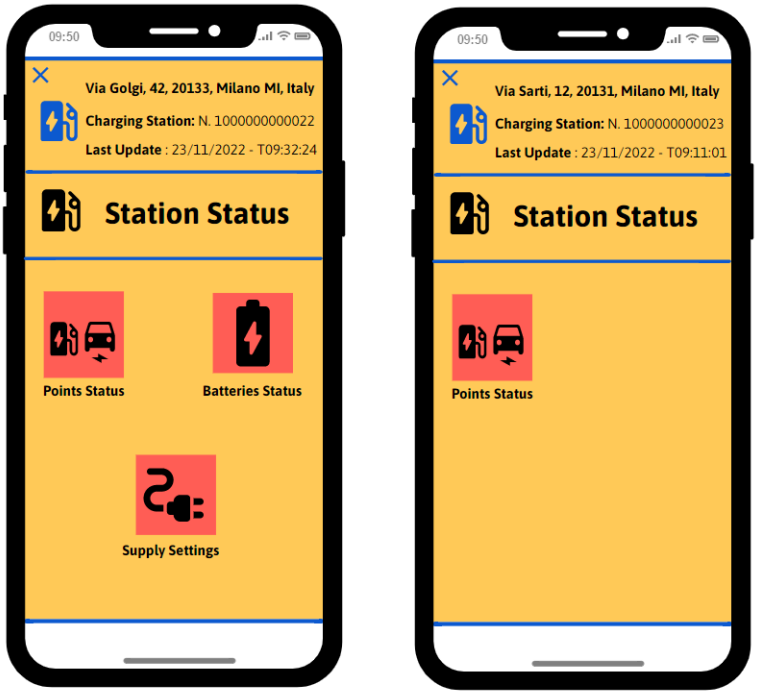


Figure 16: a) Selection of the CS, b) CPMS functionalities menu

By clicking on myCharging Status, the Operator can see the list of CSs (Figure 16.a) that manages and select one, and click on "Continue" button, for visualize its internal data. The Operator can come back to the map by clicking on the "Back" button.

After choosing the CS, the Operator will see a screen (Figure 16.b) with the main data of the CS (serial number, address and the last update done of its settings) and two icons below. The icons represent: Station Status, where the Operator can view and modify some internal parameters of the CS, and Price & Offers, where the Operator can view and modify prices and offers of the charging station.



c) Station Status menu with batteries, d) Station Status menu without batteries

After selecting the "Station Status" icon, the Operator will see a screen (Figure 16.c) with three icons: Point Status, where he can visualize the information concerning each CP of the CS; Batteries Status, where the Operator can visualize data about the batteries present in the CS; Supply Settings, where the Operator can view and change the type of supply of the CS.
If the CS has not batteries, the Operator will see a screen (Figure 16.d) with only the Point Status icon.
The Operator can come back to the previous screen clicking on the "X" icon at the top left of the screen.
The "Last Update" indicates the last change made by either the Operator or the CPMS.

- **CPMS functionalities: Point Status and Batteries Status**

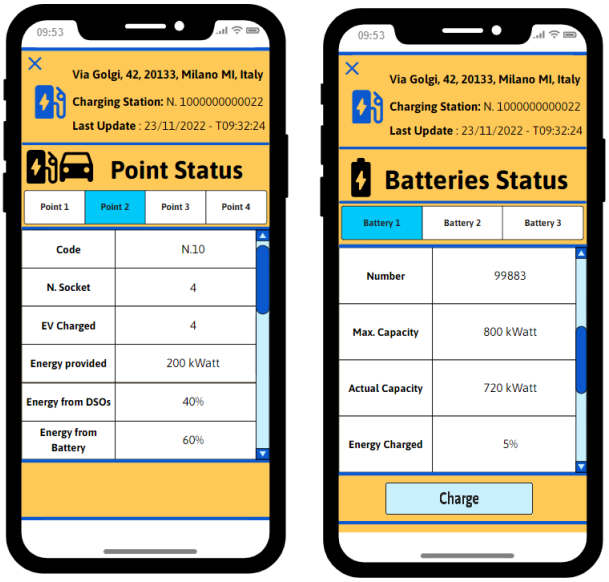


Figure 17: a) Point Status, b) Batteries Status

By clicking on the "Point Status" icon, the Operator can view (Figure 17.a) the features of each CP of the selected CS. For example: the code of the CP, the number of sockets it has, the number of EV connected at that time, how much energy it absorbs and other data. Through a scroll bar, the Operator can see all the features related to CP selected.

By clicking on the "Batteries Status" icon, the Operator can visualize (Figure 17.b) the characteristics of the batteries (if present) of the selected CS. In particular, the Operator can visualize for each battery, for example: the serial number, the maximum capacity, the actual capacity, the energy used for charge EVs, in percentage, in that moment and other data. Through a scroll bar, the Operator can see all the features related to the battery selected.

- **CPMS functionalities: Price & Offers and Supply Settings**

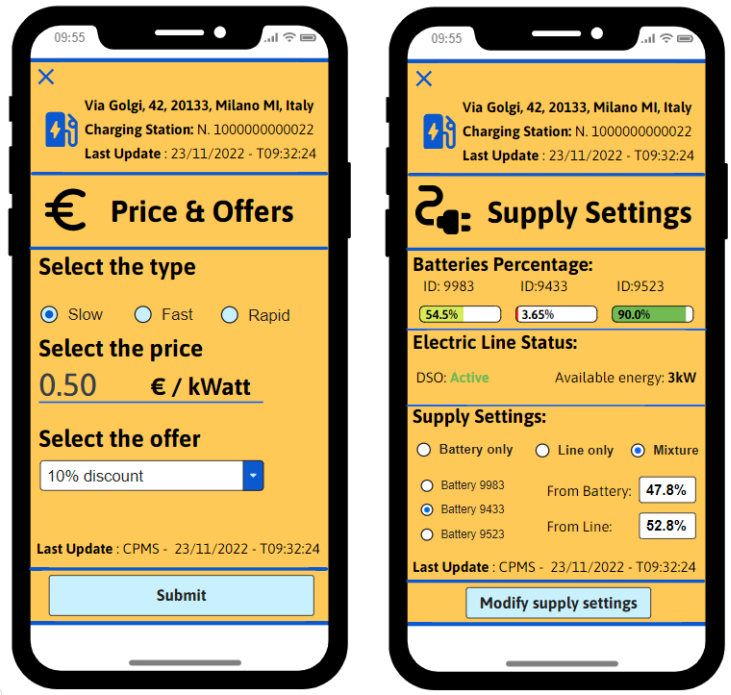


Figure 18: a) Price & Offers, b) Supply Settings

By clicking on the "Price & Offers" icon, the Operator can view (Figure 18.a) a screen related to the price and offers functionalities and can set them. In particular, the Operator: can select which type of socket change (and this change will be applied to all sockets of that type of the CS), and can set the new price for that type of socket. Optionally, the Operator can select a offer for the CS (selecting one from a special menu). For confirm the price and offer chose before, the Operator have to click on the "Submit" button.

By clicking on the "Supply Settings" icon, the Operator can view (Figure 18.b) a screen related to the energy provider functionalities and can set them. The Operator visualizes: the percentage of each battery and the status of the electric line between the DSO and the CS. Below, the Operator can change manually the supply settings. In particular, the Operator can choose three kind of supplies: battery only, DSO (line) only, and a mixture of them. In the mixture setting , the Operator can manually decide from which battery take electric energy and how much electric energy take , in percentage, from the batteries and from the DSO. Clicking on the "Modify supply settings" button, changes will be applied.

In both "Price&Offers" and "Supply Settings",the Operator can see the features of the last update done like: the entity that did the changes (CPMS or Operator), the date and the hour.

- **CPMS functionalities: List of DSOs and myDSO**

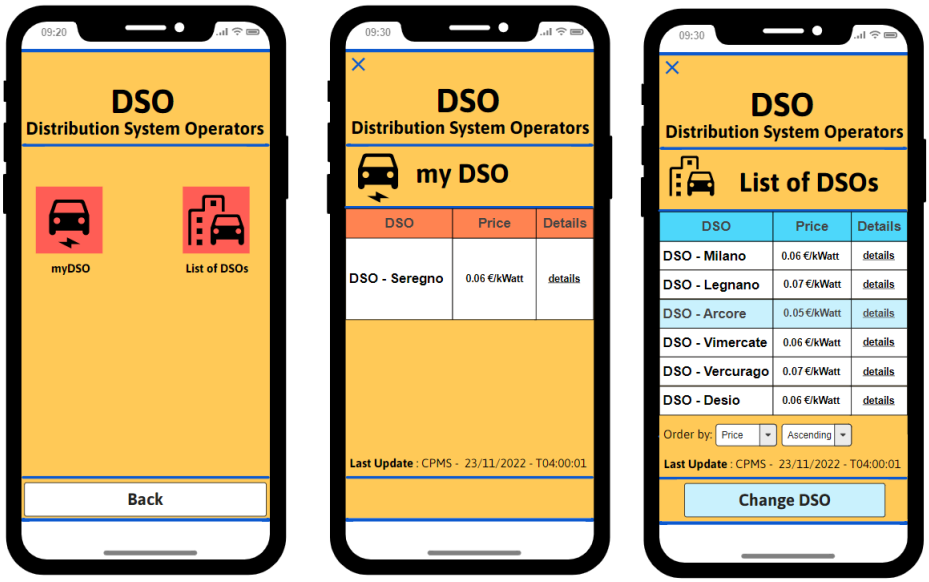


Figure 19: a)DSO menu, b) myDSO, c) List of DSOs

The Operator can manually decide from which DSOs buy electric energy for charge the EVs of the CSs.

By clicking on "myCPMS" and after "DSO" the Operator can visualize the DSO main menu (Figure 19.a) in which he decide the operaton to do. By clicking on the icon "myDSO" the Operator can view the actual DSO that provide electricity (Figure 19.b) to the CSs of the CPO. In particular way, the Operator can visualize the name of the DSO, the price at which it sells electricity and view details about it.

By clicking on the "List of DSOs" icon, the Operator can view the list of DSOs available, their price at which they sell electricity and view details related to them (Figure 19.c). For change the DSO, the Operator have to select the new DSO and click on the "Change DSO" button. The change will take place automatically and the Operator can view the DSO just chosen by going to "myDSO".

In both "myDSO" and "List of DSOs",the Operator can see the features of the last update done like: the entity that did the changes (CPMS or Operator), the date and the hour.

3.1.2 Hardware interfaces

The main hardware interfaces for the system are the sockets of the CSs. These sockets are supposed to be able to: properly scan the QR-code of the User's device, send electricity to the connected vehicle and ensure proper communication between the data of the EVs in charge and the CPMS.

3.1.3 Software interfaces

The system takes advantage of some external services which are necessary to ensure its correct and complete functioning. Since the User can visualize the CS in a specific area and select them, the application requires the usage of a map of the city in which it is being used. One possible option is to use GoogleMaps as it provides accurate real-time information for mapping. Also, the interaction between the various providers (eMall, eMSPs, CPOs, and DSOs) occurs through uniform dedicated APIs.

3.1.4 Communication interfaces

The form of communication used is the HTTPS Protocol: to safely communicate through the internet with the Web Server and the DBMS.

3.2 Functional requirements

3.2.1 Use Case Analysis

1. **RegisterDriver**

Actor	**Driver**
Entry Condition	The Driver has no eMall account, is on the initial view of the application and wants to sign up.
Flow of events	(a) The Driver opens the application and selects "Login" (b) The Driver opens the application and selects "Create your Account" (c) The System responds and presents a form to the Driver. (d) The Driver enters name, surname, email address, FC, phone number and password in the form. (e) The Driver accepts the Terms and Condition of Use and selects "Register". (f) The eMall system processes the acquired data and displays a success message.
Exit Conditions	An account has been successfully created and the System has stored a new Driver account.
Exceptions	(a) The Driver does not fill all the mandatory fields. (b) The entered email address does not exist. (c) The entered data is not valid. (d) The System always notifies the Driver the exception.

Table 5: UC.1

2. **viewChargingStationExternalStatus**

Actor	**Registered or Unregistered Driver**
Entry Conditions	The User is in the initial view of the application.
Flow of events	(a) The User selects a CS on the map view and selects "See Details". (b) The System provides a view with data about the external status of the CS i.e. price for each charging type, the special offers (if any), number of sockets and their type, number of free sockets, if all the sockets of a type are occupied and the amount of time until a socket of that type is freed.
Exit Condition	The view has been correctly presented to the User.
Exceptions	

Table 6: UC.2

3. **LoginDriver**

Actor	**Registered Driver**
Entry Conditions	The Driver is in the initial view of the application and wants to log in
Flow of events	(a) The Driver opens selects "Login" in the initial page of eMall. (b) The Driver selects "Login as Driver". (c) The System responds and presents a form to the Driver. (d) The Driver fills the form with the needed credentials: email address or phone number and password. (e) The Driver selects "Login". (f) The System processes the acquired data and displays the Driver's main page.
Exit Condition	The login has successfully carried out.
Exceptions	(a) The Driver does not insert all the mandatory data. (b) The entered email or phone number and/or the entered password are incorrect. (c) eMall always notify the Driver the exception, if occurred.

Table 7: UC.3

4. **ReserveSocket**

Actor	**Registered Driver**
Entry Conditions	The Driver is in the initial view of the application and wants to reserve a socket
Flow of events	(a) The Driver chooses a charging station on the map view. (b) The System responds with a view of the external status of the selected charging station. (c) The Driver selects a socket and selects on reserve. (d) The System registers the data about the reservation.
Exit Condition	(a) The reservation of the socket has been successfully carried out. (b) The System generates a QR-Code to be scanned at the charging socket's appropriate QR-Code Reader.
Exceptions	(a) The Driver tries to reserve an already reserved, occupied or unavailable socket. (b) eMall always notify the Driver the exception.
Special Requirements	(a) The generated QR-Code is available no later than 30 seconds after a successful reservation. (b) The generated QR-Code expires in 15 minutes. (c) At the moment of the reservation, the price of the energy is locked and can not be modified until the Driver completes the charge or the reservation expires.

Table 8: UC.4

5. **StartCharging**

Actor	**Registered Driver**
Entry Conditions	The Driver is at the charging station and wants to start a charge.
Flow of events	(a) The Driver approaches a QR-Code to the charging point QR-Code Reader. (b) The System scans the QR-Code and provides in the application a view with the Driver's payment methods. (c) The Driver selects a payment method and selects "Start". (d) The System reserves a fixed maximum amount of money from the Driver's chosen payment method. (e) The System unlocks the reserved charging socket. (f) The Driver plugs the socket in the electric vehicle.
Exit Condition	The charging process of the Driver's electric vehicle successfully starts.
Exceptions	(a) The selected payment method is expired or has no money in it. (b) The Driver tries to scan the QR-Code more than 15 minutes after the reservation. (c) eMall always notify the Driver the exception.
Special Requirements	(a) The unlocking of the reserved socket occurs no longer than 15 seconds after the successful money transaction. (b) The Driver has a timer of 5 minutes from the QR-Code scan to choose the payment method and to start the charging.

Table 9: UC.5

6. **InsertPaymentMethod**

Actor	**Registered Driver**
Entry Conditions	The Driver is logged in eMall and on the initial view.
Flow of events	Case 1: Adding a method out of the charging process. (a) The Driver selects on "My eMall" and then on "Payment". (b) The System responds with the view of the already added payment methods, if any. (c) The Driver selects "add a new payment method". (d) The System responds sending a form to fill with the data of the new payment method. (e) The Driver inserts the new payment method data and selects "Submit". (f) The System processes the acquire data and stores the new payment method information. Case 2: Adding a method after QR-Code scan at the charging point. (a) The Driver selects on "insert method". (b) The System responds sending a form to fill with the data of the new payment method. (c) The Driver selects "add a new payment method". (d) The Driver inserts the new payment method data, choose whether to save the new method in the wallet or not and selects "Submit". (e) The System processes the acquire data and stores the new payment method information.
Exit Condition	The new payment method has been successfully added.
Exceptions	(a) The Driver does not fill the form with all the mandatory data. (b) The Driver fills the form with non valid data i.e. expired payment method, incorrect number and/or CVV2. (c) The System can not establish a connection with the bank related to the payment method. (d) eMall always notify the Driver the exception.
Special Requirements	

Table 10: UC.6

7. **StopCharging**

Actor	**Registered Driver**
Entry Conditions	The Driver is logged in eMall, on the initial view, and has an active charging.
Flow of events	(a) The Driver selects on "My eMall" and then on "Active Chargings". (b) The System responds with the view of the status of the active charging. (c) The Driver selects on "Stop". (d) The System withdraws the amount of money corresponding to the provided quantity of energy. (e) The System shows to the Driver the report of the occurred charging process. (f) The System responds with a message of successful interruption of the charging process. (g) The Driver unplugs the socket from the EV and puts it in place. (h) The System updates the status of the socket, setting it as "Free".
Exit Condition	The payment for the charging has been successfully performed.
Exceptions	(a) An error with the payment process occurres. (b) eMall always notify the Driver the exception.
Special Requirements	

Table 11: UC.7

8. **OperatorLogin**

Actor	**Registered Operator**
Entry Conditions	The Operator is in the initial view of the application and wants to log in.
Flow of events	(a) The Operator selects "Login" in the initial view of eMall. (b) The Operator selects "Login as Operator". (c) The System responds and presents a form to the Operator. (d) The Operator fills the form with the needed credentials: email address, identification number and password. (e) The Operator selects "Login". (f) The System processes the acquired data and displays the Operator's main page.
Exit Condition	The login operation has been successfully carried out.
Exceptions	(a) The Operator does not insert all the mandatory data. (b) The entered data is incorrect. (c) eMall always notify the Driver the exception, if occurred.
Special Requirements	

Table 12: UC.8

9. **ViewChargingStationPointsStatus**

Actor	**Registered Operator**
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	(a) The Operator selects "myCPMS" in the initial view. (b) The Operator selects "my Charging Stations". (c) The System responds with a list of the CSs the Operator is tasked to manage. (d) The Operator choose a charging station and then selects "Continue". (e) The Operator selects "Station Status" and then "Points Status". (f) The System provides a view of the internal status of each charging point of the charging station i.e. number of vehicles being charged, amount of power absorbed by each vehicle and estimated time left to the end of the charge.
Exit Condition	The System shows correctly the internal status information of the charging station.
Exceptions	
Special Requirements	

Table 13: UC.9

10. **ViewChargingStationBatteriesStatus**

Actor	**Registered Operator**
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	(a) The Operator selects "myCPMS" in the initial view. (b) The Operator selects "my Charging Stations". (c) The System responds with a list of the CSs the Operator is tasked to manage. (d) The Operator choose a charging station and then selects "Continue". (e) The Operator selects "Station Status" and then "Batteries Status", that is available only if the selected CS is provided of any battery. (f) The System provides a view of the internal status of the charging station i.e. battery ID, maximum capacity, actual capacity and energy charged.
Exit Condition	The System shows correctly the battery status information of the charging station.
Exceptions	
Special Requirements	

Table 14: UC.10

11. **ModifyPriceAndOffersOfAChargingStation**

Actor	**Registered Operator**
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	(a) The Operator selects "myCPMS" in the initial view. (b) The Operator selects "my Charging Stations". (c) The System responds with a list of the CSs the Operator is tasked to manage. (d) The Operator choose a charging station and then selects "Continue". (e) The Operator selects "Station Status" and then "Price and Offers". (f) The System provides a view where to set the price of each type of socket and to set any special offer. (g) The Operator sets the prices and, eventually, a special offer.
Exit Condition	The System processes the data and sets prices and, eventually, special offers for the selected charging station.
Exceptions	(a) The Operator inserts incompatible price or/and a special offer (e.g. negative price or negative percentage discount). (b) eMall always notify the Driver the exception, if occurred.
Special Requirements	

Table 15: UC.11

12. **ChooseDSO**

Actor	**Registered Operator**
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	(a) The Operator selects "myCPMS" in the initial view. (b) The Operator selects "myDSO". (c) The System shows data (i.e. name, energy price) about the DSO that is now providing energy. (d) The Operator selects "Choose another DSO". (e) The System shows a list of the available DSOs with their prices and details. (f) The Operator selects a DSO and then presses "Choose this DSO". (g) The System processes the acquired data and establishes a connection with the chosen DSO.
Exit Condition	The DSO choice has been successfully completed.
Exceptions	(a) The System does not receive any answer from the DSO, so it can not establish the connection. (b) eMall always notify the Driver the exception, if occurred.
Special Requirements	

Table 16: UC.12

13. **viewAndSetSupplySettings**

Actor	**Registered Operator**
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	(a) The Operator selects "myCPMS" in the initial view. (b) The Operator selects "my Charging Stations". (c) The System responds with a list of the CSs the Operator is tasked to manage. (d) The Operator choose a charging station and then selects "Continue". (e) The Operator selects "Supply Settings". (f) The System shows: • data about the state of the charging station's batteries, if any, and about the energy line from which the DSO provides electricity i.e. battery charge percentage, DSO state (active/unavailable) and, if active, the energy it is providing. • percentages of energy provided by the DSO and by the CS battery. (g) The Operator selects "100% battery" (if any battery is available) or "100% DSO" or "Mixture", indicating, in this case, the percentages. (h) The Operator selects "Submit". (i) The System processes the acquired data and sets new supply settings for the selected CS.
Exit Condition	The supply settings modification has been successfully completed.
Exceptions	(a) The Operator presses "Submit" without selecting any supply method. (b) The Operator has chosen "Mixture" but with a sum of percentages different from 100%. (c) eMall always notify the Driver the exception, if occurred.
Special Requirements	

Table 17: UC.13

3.2.2 Use Case Diagrams

3.2.3 Sequence Diagrams

3.2.4 Requirements, Domain Assumptions, Goals Matrix

Requirements

- $[R.1]$ = The system shall allow a User to register an account as a Driver.
- $[R.2]$ = The system must allow registered Drivers to login.
- $[R.3]$ = The system must allow registered Operators to login.
- $[R.4]$ = The system shall allow a User, Driver and Operator, to see the map of CS.
- $[R.5]$ = The system shall allow a User, Driver and Operator, to view the external status of a CS.
- $[R.6]$ = The system shall allow a Driver to book a socket of a selected CS.
- $[R.7]$ = The system shall allow a Driver to receive a unique QR-code ticket for the reservation done.
- $[R.8]$ = The system shall give a timer of 15 minutes to the Driver in order to connect the EV to the socket and to scan the QR-code (otherwise, the booking is rejected).
- $[R.9]$ = The system shall be able to correctly associate the socket with the Driver who booked it.
- $[R.10]$ = The system shall allow a Driver to insert, or to select, payment data.
- $[R.11]$ = The system shall give a timer of 5 minutes to the Driver in order to insert valid payment data (otherwise, the booking is rejected).
- $[R.12]$ = The system shall allow a Driver to visualize correct and real-time data about the charging process.
- $[R.13]$ = The system shall allow a Driver to stop the charging process.
- $[R.14]$ = The system shall allow the Driver to book a socket if and only if the Driver has no active reservations.
- $[R.15]$ = The system shall allow the Driver to book a socket if and only if the socket is free.
- $[R.16]$ = The system shall allow the Operator to visualize the "internal status" of the CSs.
- $[R.17]$ = The system shall allow the Operator to visualize the status of the batteries, if any, in the CS.
- $[R.18]$ = The system shall allow the Operator to select the price and the offers of a socket.
- $[R.19]$ = The system shall allow the Operator to select how to supply the EVs of the CSs.

- $[R.20]$ = The system shall allow the Operator to visualize the list of DSOs, with their prices, from which the CPO can select the one from which to buy energy.
- $[R.21]$ = The system shall allow the Operator to visualize the current DSO from which the CPO already buys electric energy.
- $[R.22]$ = The system shall allow the Operator to change the current DSO with another one from the list of available DSOs.
- $[R.23]$ = The system shall allow a correct and coherent communication between the automatic actions of the CPMS and the manual decisions handled the Operators.
- $[R.24]$ = The system shall be able to notify Drivers or Operators of incorrect actions.
- $[R.25]$ = The system shall be able to distinguish the functionalities to offer according to the User who logs in.
- $[R.26]$ = The software of the sockets must be consistent with the system.

Goals Matrix

GOALS	**DOMAIN ASSUMPTIONS**	**REQUIREMENTS**
G.1	D.1, D.2, D.3, D.10	R.1, R.2, R.3, R.24, R.25
G.2	D.3, D.10, D.11	R4, R.24
G.3	D.3, D.10, D.11	R4, R5, R24
G.4	D.1, D.2, D.3, D.10	R1, R2, R3, R.24, R.25
G.5	D.3, D.10, D.11	R1, R2, R4, R5, R6, R7, R8, R.9, R14, R15, R.24, R.25
G.6	D.3, D.4, D.5, D.6, D.7, D.10	R.1, R.2, R.4, R.5, R.6, R.7, R.8, R.9, R.10, R.11, R.12, R.13, R.14, R.15, R.24, R.25, R.26
G.7	D.3, D.4, D.5, D.6, D.7, D.10	R.1, R.2, R.4, R.5, R.6, R.7, R.8, R.9, R.10, R.11, R.12, R.14, R.15, R.24, R.25, R.26
G.8	D.3, D.4, D.5, D.6, D.7, D.10, D.12	R.1, R.2, R.4, R.5, R.6, R.7, R.8, R.9, R.10, R.11, R.14, R.15, R.24, R.25, R.26
G.9	D.3, D.8, D.9, D.10	R.3, R.16, R.17 R.23, R.24, R.25
G.10	D.3, D.8, D.9, D.10	R.3, R.20, R.21, R.23, R.24, R.25
G.11	D.3, D.8, D.9, D.10	R.3, R.20, R.21, R.22, R.23, R.24, R.25
G.12	D.3, D.8, D.9, D.10	R.3, R.16, R.17, R.18, R.23, R.24, R.25
G.13	D.3, D.8, D.9, D.10	R.3, R.16, R.17,R.19, R.23, R.24, R.25

Table 18: Goal Matrix table

3.3 Performance requirements

In this section we will specify some of the static and dynamic numerical requirements of the system and of the interaction between human user and the application. eMall system have to manage a lot of booking requests from different Drivers at the same time, so there will be a continuous stream of information that must be properly managed. Taking into account this large number of booking requests, the system will be able to store historical data. At the beginning we should guarantee that our system will be able to process requests for up to 100'000 active individual Users but we need to guarantee scalability if the number of registered Users increases. We prefer a step-by-step approach in order not to unnecessarily allocate resources.

3.4 Design constraints

3.4.1 Standards compliance

The standard longitude and latitude measures are used for the position. Regarding sensitive data the users provide to the application, the entire application is subject to the General Data Protection Regulation (GDPR), EU regulation on the processing of personal data and privacy, in order to legally protect our Users. Therefore the system ensures that only the name and location of any CS will be exposed. The same compliance will be adopted in order to ensure the registered customers data protection.

3.4.2 Hardware compliance

eMall application should be designed in order to be employed on smartphones, tablets and PCs. In particular, eMall application for Personal Computers is only available for Operators in order to have access to CPMS functionalities from their office. In order to ensure the system usage to different Users, the application must work independently of the hardware where it runs. Each device must meet the screen requirements for correct QR code scanning of charging socket's scanners. In addition, it must use the GPS positioning with the only purpose of localizing the User position and retrieving the position of any CS. Devices, CSs and monitoring stations must have a working internet connection (Wi-Fi, 5G/4G/3G) in order to submit any request to the system. In addition, very old devices can not run the application (but this point is better explained in Portability paragraph).

3.4.3 Other constraints

An important aspect to manage is the conflict that can arise between the reservation status of the sockets and the changes of some parameters by the Operators or by the CPMS.
When a socket is booked, its prices and any offers are blocked.
If a price or offer change is made, that change will be saved in a "next state" of the sockets. The change will be not apply immediately to the reserved sockets, but in a second moment, when the sockets are released.
When a socket is released (for the end of a charge or for a time expired) its status will be updated.

Every CPO must verify that the sockets of each CS work properly, regarding both the correct scanning of tickets and the internet connection. The monitoring of the correct functioning of CSs must be constant and carried out by authorized and competent workers.

3.4.4 Software system attributes

3.4.5 Reliability

The reliability of eMall should be high enough, in order to give continuity to the system and operate properly for a long period of time. These needs are related to the fact that a new booking could be received at any time, or the CPMS could make automatic choices that could influence the future decisions of Drivers.

3.4.6 Availability

The system needs real time responses in order to complete booking and charging processes and to show correct data about the sockets of the CSs. With this constraint, the system availability must be ensured at least for 99.9 % or three-nines, that corresponds to an approximated system downtime of 8.76 hours per year. Is preferred to perform the maintenance during the night.

3.4.7 Security

Security is very important for our application, in particular because it exchanges and stores many sensitive data. All information regarding Drivers and Operators is sensitive. The system must prevent any attack that could steal data (especially data about credit cards stored in the application) or make the service unavailable. The data exchanged will also be encrypted to prevent any interception. The system will never expose sensitive data to external actors without consent.

3.4.8 Maintainability

The IEEE Standard Glossary of Software Engineering Terminology defines maintainability as: "The ease with which a software system or component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment." The system development must ensure modification in order to fix any problem. It also must be suitable for future functionality extensions and supplements. This purpose is reached with a well commented, clean and readable implementation, using coherent design patterns. The system will also respond to major technological innovations.

3.4.9 Portability

In order to allow a large number of users (Drivers and Operators) to use our services, eMall mobile application should be developed for the most popular Operative Systems:

Windows, OSX, Android and iOS. Since the computational burden of our application is enough high, in developing-phase we will not consider old devices.

4 Formal analysis using Alloy

In this section a formal description of the domain of the system and its properties is given using Alloy.
First of all, we will focus on some critical aspects that are essential for the correct functioning of the application. Next, we will show a unique Alloy code in which we will link all the previous aspects. Attention has been given to the following aspects:

- How Users are managed by the system:
  - Two different Drivers cannot have the same Fiscal Code.
  - Two different Drivers cannot have the same email address.
  - Two different Operators cannot have the same Identification Number (OperatorID).
  - Two different Operators cannot have the same business email address.
  - All inserted Fiscal Codes correspond to a registered Driver.
  - All inserted OperatorIDs correspond to a registered Operator.
  - An inserted email address corresponds to a registered Driver.
  - An inserted business email address correspond to a registered Operator.
  - A password is always associated to a Driver or Operator.
  - A position (indicated by coordinates) is always associated to a User.
- How reservations are managed by the system:
  - Two or more Drivers can not have the same Reservation.
  - One Driver can have one or more Reservations.
  - Two or more Reservations can not have the same Time.
  - Each Time is different and has only one Reservation.
  - Each Reservation has only one Socket.
  - Two or more Socket can have more Reservations.
- How the connection between the Charging Stations and Operators are managed by the system:
  - Each CS is managed by only one Operator.
  - Each Operator manage one or more CSs.
  - Each CS can have one or more CP.
  - Each CP has only one CS.
  - Each Socket has only one CP.

- Each CP can have one or more Sockets.
- Each CS can have zero or more batteries.
- Each battery has only one CS.

User :

```
open util / integer

//* * * Signatures * * *

sig CF{}
sig OperatorID{}
sig Email{}
sig BusinessEmail{}
sig Password{}

sig Coordinates{
        coordinates: some User,
}

abstract sig User{
        coordinates : one Coordinates,
}

sig Driver extends User{
        cf: one CF,
        email : one Email,
        password : one Password,
}

sig Operator extends User{
        operatorID : one OperatorID,
        businessEmail : one BusinessEmail,
        password : one Password,
}


// * * * * * * * * * * Facts * * * * * * * * * *

//There are no CFs duplicates (each Driver can register just once)
fact CFNODuplicates{
all d1,d2: Driver, thiscf: CF |
thiscf in d1.cf and thiscf in d2.cf implies d1 = d2
}

//There are no email duplicates(each Driver can register just once)
fact EmailNODuplicates{
all d1,d2: Driver, thisemail:  Email |
thisemail in d1.email and thisemail in d2.email implies d1 = d2
}

//There are no OpertorID duplicates
fact OperatorIDNoDuplicate{
all o1,o2: Operator, thisid : OperatorID |
thisid in o1.operatorID and thisid in o2.operatorID implies o1 = o2
}

//There are no business email addresses duplicates
fact BusinessAddressNODuplicates{
all o1,o2: Operator, thisbe:  BusinessEmail |
thisbe in o1.businessEmail and thisbe in o2.businessEmail implies o1 = o2
}

//All OperatorIDs have to be associated to an Operator
fact IDOperatorConnection{
all id : OperatorID | some o:Operator | id in o.operatorID
}
```

```
//All business email address have to be associated to an Operator
fact BusinessEmailOperatorConnection{
all bemail : BusinessEmail | some o: Operator | bemail in o.businessEmail
}

//All CFs have to be associated to a Operator
fact CFDriverConnection{
all c: CF | some d: Driver | c in d.cf
}

//All Email Address have to be associated to an Operator
fact EmailDriverConnection{
all e : Email | some d: Driver | e in d.email
}

//All Password have to be associated to a Driver
fact PasswordDriverConnection{
all p: Password | some d: Driver | p in d.password
}


//All Password have to be associated to a Operator
fact PasswordOperatorConnection{
all p: Password | some o: Operator | p in o.password
}


//Coordinates have one or more Users, and User has only one coordinates
fact MoreUsersCoordinates{
all c : User , u: Coordinates | c in u.coordinates ⟺ u in c. coordinates
}


//* * * * * * * * * Predicates* * * * * * * * * *
pred show{
#Operator ≥2
#Driver ≥2
}

run show for 5
```

The following figure (Figure 20) shows an example of how Users are managed.

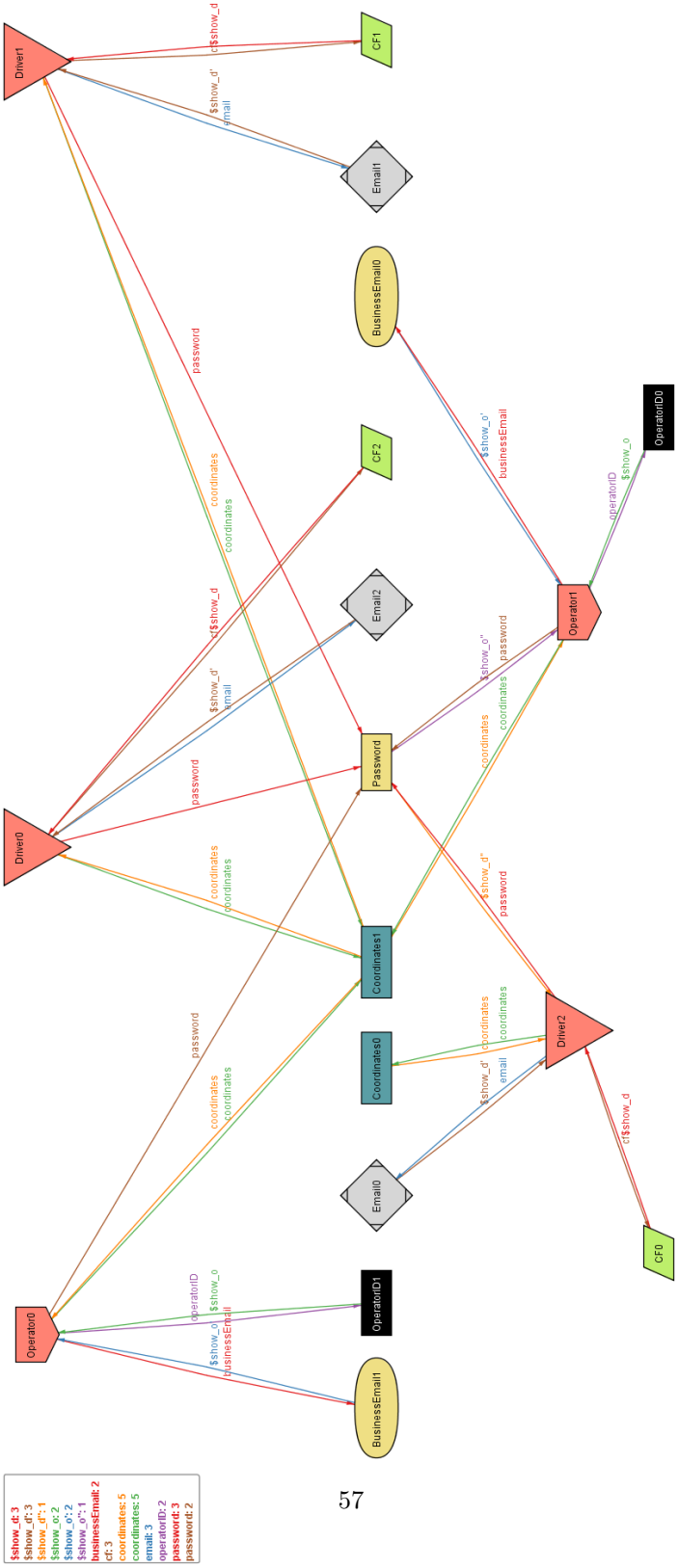


Figure 20: User Alloy Model

Reservations :

```
open util / integer

//* * * Signatures * * *

sig Time{reservation: some Reservation}

sig Driver{ reservation : some Reservation}

sig Socket{reservation : some Reservation}

sig Reservation{
        rd: some Driver,        //rd = reservation for drivers
        rs: some Socket,        //rs = reservation for sockets
        time: one Time
}

// * * * * * * * * * * Facts * * * * * * * * * *

//There are not many Drivers that have the same reservation
fact reservationsNODuplicatesDriver{
all d1,d2: Driver, r: Reservation |
r in d1.reservation and r in d2.reservation implies d1 = d2
}

//There are not many Sockets that have the same reservation
fact reservationsNODuplicatesSockets{
all s1,s2: Socket, r: Reservation |
r in s1.reservation and r in s2.reservation implies s1 = s2
}

//There are no many Times that have the same reservation
fact reservationsNODuplicatesTime{
all r1,r2: Reservation, t: Time |
t in r1.time and t in r2.time implies r1 = r2
}


//Connection between Time and Reservation: Time must have one Reservation
fact connectionTimeReservation{
all t : Time , r: Reservation |  r in t.reservation ⟺ t in r.time
}

//Connection between Drive and Reservation
fact connectionDriverReservation{
all d : Driver , r: Reservation | d in r.rd ⟺ r in d.reservation
}

//Connection between Socket and Reservation
fact connectionSocketReservation{
all s : Socket , r: Reservation | s in r.rs ⟺ r in s.reservation
}
//* * * * * * * * * Predicates* * * * * * * * * *
pred show{
#Socket ≥5
#Driver ≥5
}
run show for 10
```

The following figure (Figure 21) shows an example of how Reservations are managed.

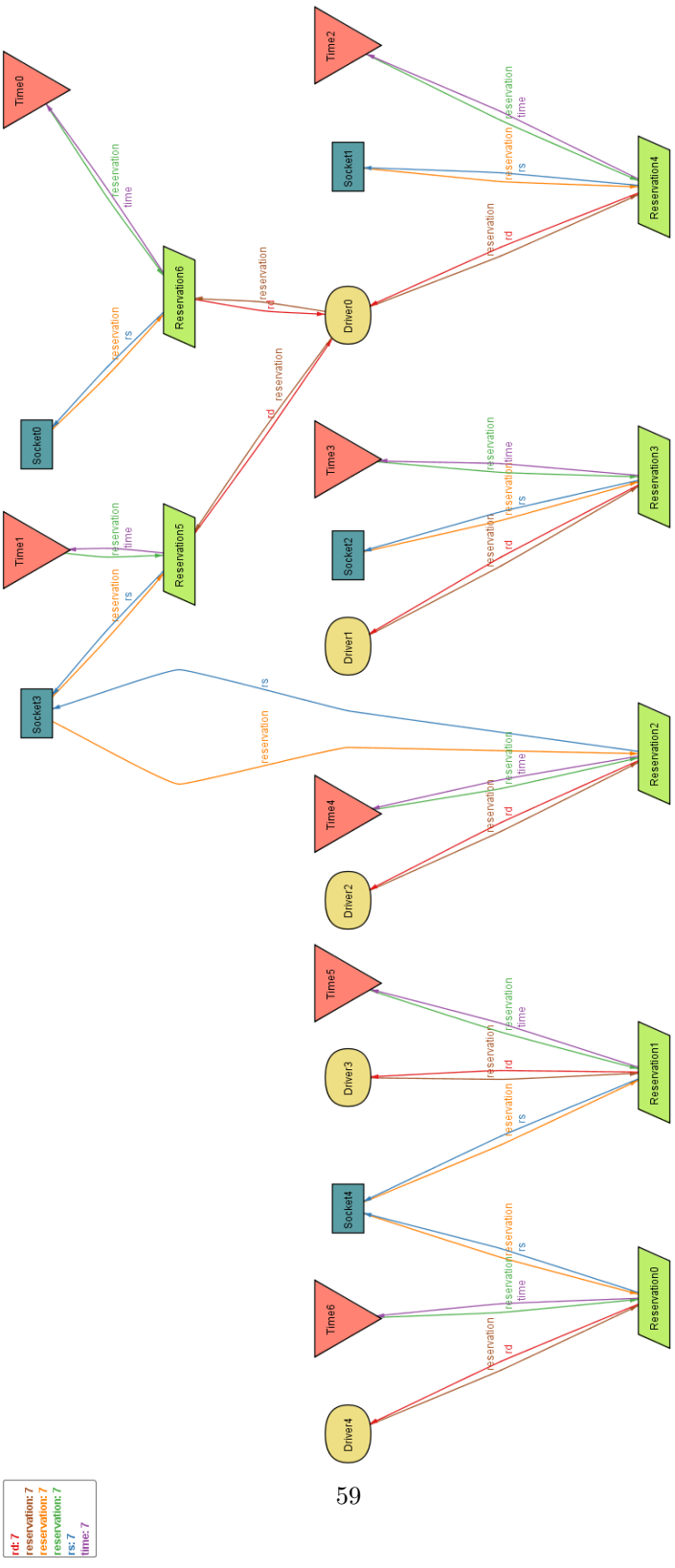


Figure 21: Reservation Alloy Model

Charging Stations :

```
open util / integer

//* * * Signatures * * *

sig CPO{
operator: some Operator,
mydso: one DSO,
}

sig Operator{
cpo: one CPO,
cs: some CS,
}

sig CS{
operator : one Operator,
cpo: one CPO,
dso: one DSO,
cp: some Point,
battery: set Battery,
}

sig DSO{
        cpo: some CPO,
}

sig Socket{}
sig Battery{cs: one CS}
sig Point{
socket: some Socket,
cs : one CS
}

/* * * * FACTS * * * * */

//Every CS has one DSO from the same CPO
fact CStoDSOsameCPO{
all s: CS, c: CPO |
c in s.cpo implies s.dso = c.mydso
}

//Every Operator has only one CPO
fact oneOperatortoCPO{
all c1,c2: CPO, o: Operator |
o in c1.operator and o in c2.operator implies c1=c2
}

//Every DSO has only one CPO
fact oneOperatortoCPO{
all c1,c2: CPO, d: DSO |
d in c1.mydso and d in c2.mydso implies c1=c2
}

//Every CP has one and only one CS
fact operatorNoDuplicatesCS{
all c1,c2 : CS , p: Point |
p in c1.cp and p in c2.cp implies c1=c2
}

//Every Socket has one and only one CP
fact socketCP{
all p1,p2 : Point , s: Socket |
s in p1.socket and s in p2.socket implies p1=p2
}

//Every CP has one and only one CS
fact operatorNoDuplicatesCS{
all c1,c2 : CS , p: Point |
p in c1.cp and p in c2.cp implies c1=c2
```

```
}

//Every Battery has one and only one CS
fact batteriesInCS{
all c1,c2 : CS, b: Battery |
b in c1.battery and b in c2.battery implies c1 = c2
}


//Connection between Operator and CPO
fact connectionOperatortoCPO{
all o: Operator, c: CPO |
o in c.operator ⟺ c in o.cpo
}

//Connection between Operator and CS
fact connectionOperatortoCS{
all o: Operator, c: CS |
o in c.operator ⟺ c in o.cs
}

//Connection between CS and CPO of the same Operator
fact connectionCStoCPO{
all s: CS, o: Operator |
s in o.cs and o in s.operator implies s.cpo = o.cpo
}

//Connection between Operator and CS
fact connectionPointToCS{
all c : CS, p : Point | c in p.cs ⟺ p in c.cp
}
//Connection between Operator and CS
fact connectionBatteriesCS{
all b: Battery | some c: CS | b in c.battery
}

//Connection between batteries and CS
fact batteryAndCS{
all b: Battery, c: CS | b in c.battery ⟺ c in b.cs
}


//There are CPs with at least one Socket
fact moreSocketInCP{
all p: Point | #p.socket ≥2
}
//There are CS with more batteries
fact morebatteriesInCS{
all c: CS | #c.battery ≤3
}

//* * * * * * * * * Predicates* * * * * * * * *


pred show{
#CPO≥3
#Operator ≥3
#CS ≥4
}
run show for 30
```

The following figure (Figure 22) shows an example of how Charging Stations are managed.

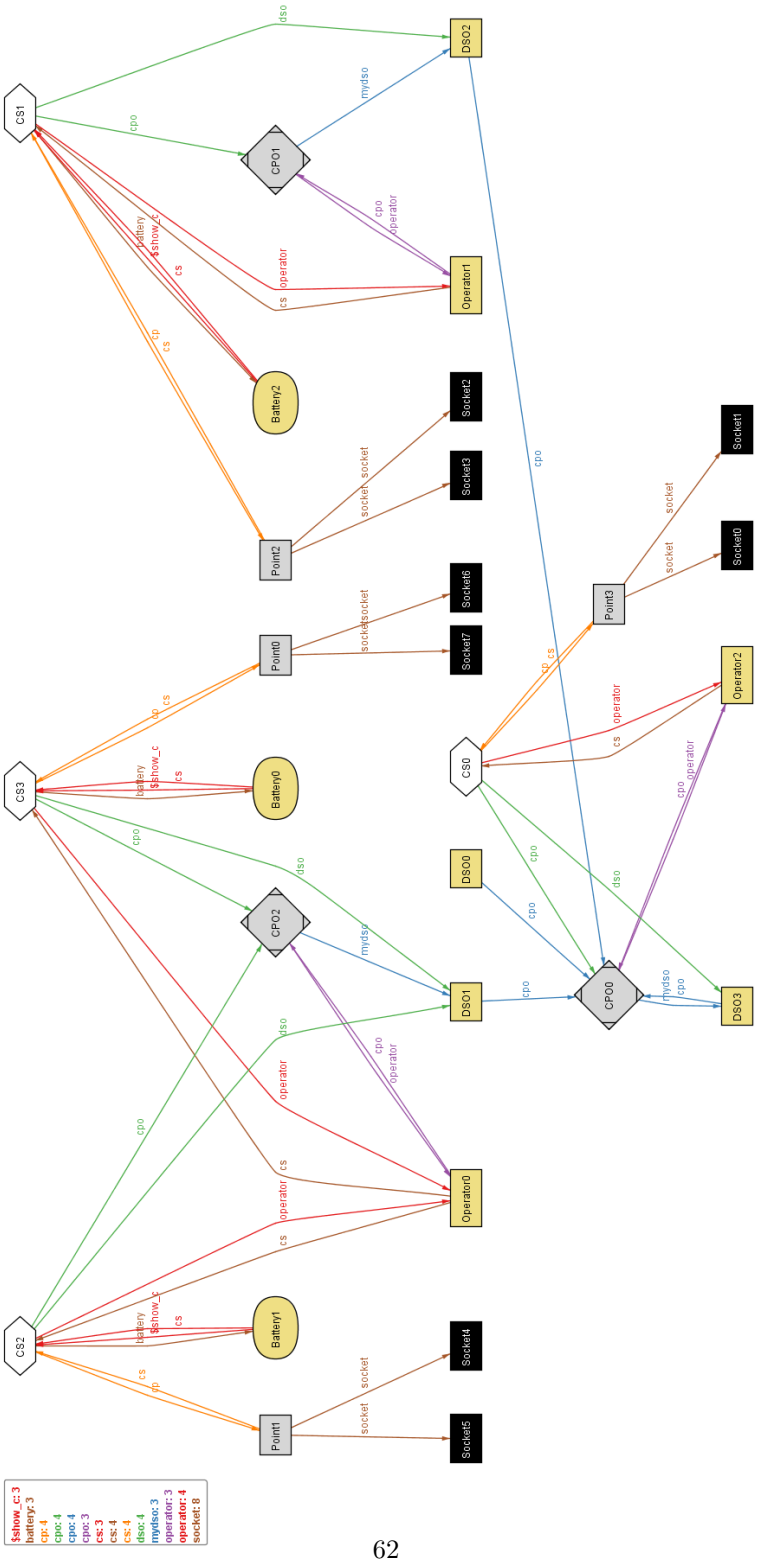


Figure 22: Charging Station Alloy Model

This last model, not being completely clear because of the few instances provided, has been tested through the following assertions to verify its correctness.

The assertion in Figure 23 wants to show that a CPO can have more than one Operator.
The assertion in Figure 24 wants to show that an Operator can manage more than one CS.
The assertion in Figure 25 wants to show that a CPO can have one and only one DSO from which take electric energy.

```
//* * * * * * * * * * Assertions* * * * * * * * * *

//Check if a Operator has more CSs
assert moreCSsInSameOperator{
all o:Operator, s1,s2: CS |
s1 in o.cs and s2 in o.cs implies s1=s2
}
check moreCSsInSameOperator for 10
```

```
Executing "Check moreCSsInSameOperator for 10"
  Solver=sat4j Bitwidth=4 MaxSeq=7 SkolemDepth=1 Symmetry=20
  26190 vars. 1500 primary vars. 43020 clauses. 74ms.
  Counterexample found. Assertion is invalid. 72ms.
```

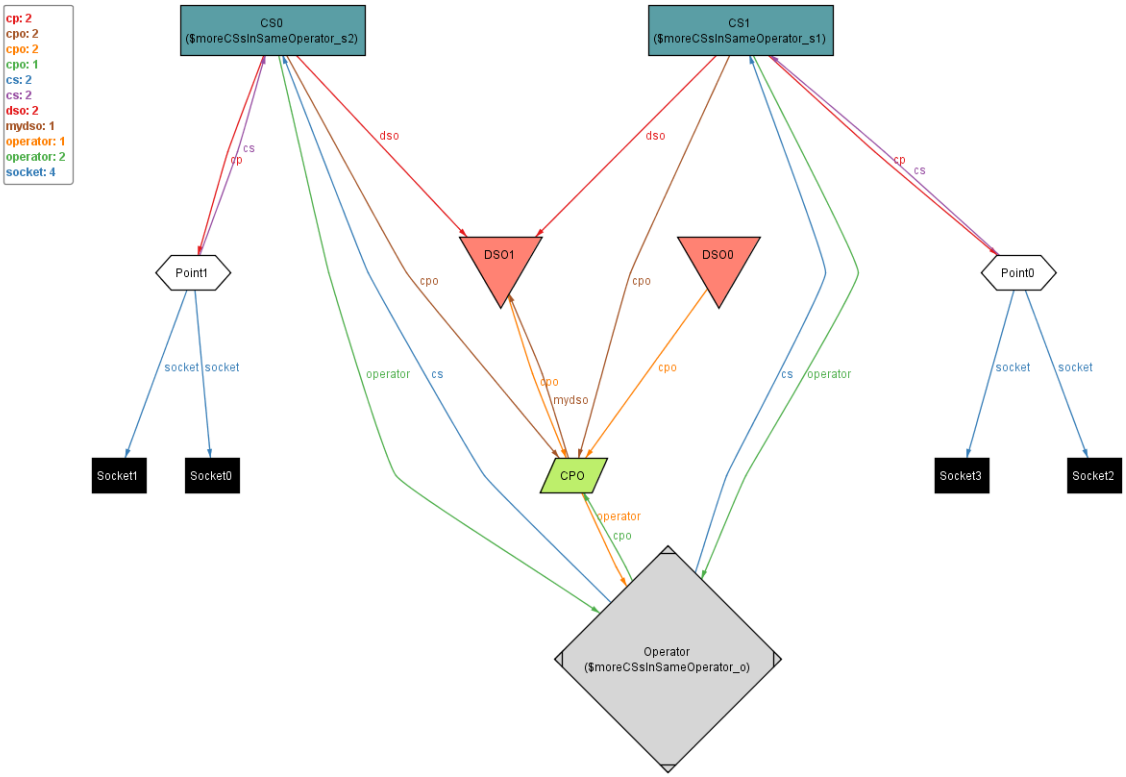


Figure 23: Assertion: CPOs with many Operators

```
//* * * * * * * * * Assertions* * * * * * * * * *

//Check if a CPO has more Operators
assert moreOperatorsInSameCPO{
all c:CPO, o1,o2:Operator |
o1 in c.operator and o2 in c.operator implies o1 = o2
}
check moreOperatorsInSameCPO for 10
```

```
Executing "Check moreOperatorsInSameCPO for 10"
  Solver=sat4j Bitwidth=4 MaxSeq=7 SkolemDepth=1 Symmetry=20
  26190 vars. 1500 primary vars. 43020 clauses. 199ms.
  Counterexample found. Assertion is invalid. 114ms.
```

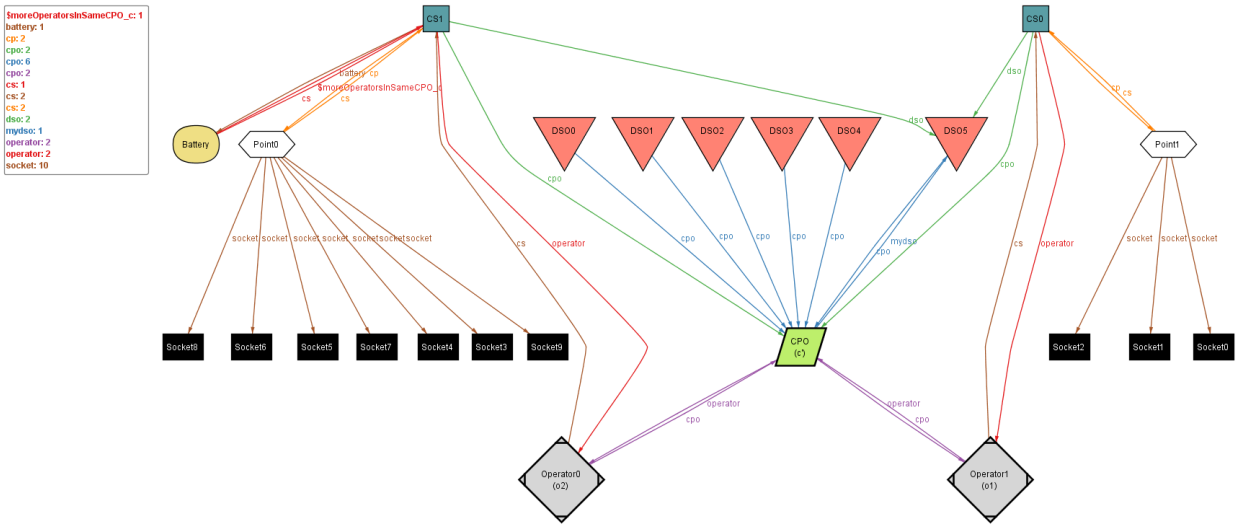


Figure 24: Assertion: Operators with many CSs

```
//* * * * * * * * * Assertions* * * * * * * * * *

//Check if a CPO has more DSO
assert moreDSOtoCPO{
all c1,c2 : CPO, d:DSO |
d in c1.mydso and d in c2.mydso implies c1=c2
}
check moreDSOtoCPO for 10
```

```
Executing "Check moreDSOtoCPO for 10"
  Solver=sat4j Bitwidth=4 MaxSeq=7 SkolemDepth=1 Symmetry=20
  26300 vars. 1500 primary vars. 43230 clauses. 65ms.
  No counterexample found. Assertion may be valid. 8ms.
```

Figure 25: Assertion: CPO with only one DSO

5 Efforts

Individual Work		
	Eutizi Claudio	***Perego Gabriele***
Tasks	**Hours**	**Hours**
Introduction (chapter 1)	4	8
Overall description (chapter 2)	12	9
Specific requirements (chapter 3)	10	9
Formal analysis using Alloy (chapter 4)	0	6
Final Revision	0	0
Total	**26**	**32**

Table 19: Time spent by each team member

6 References

- R&DD Assignment AY 2022-2023
- Alloy references: https://www.csail.mit.edu/research/alloy