



**POLITECNICO**  
**MILANO 1863**



## **RASD**

**Requirement Analysis and Specification Document**  
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## 1 Introduction

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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 CO<sub>2</sub> 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
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	<a href="#">Online PDF</a>
Alloy Official Documentation	MIT Software Design Group	<a href="#">Alloy documentation</a>

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

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### 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:** Charles Leklerk needs to charge his EV which has a low percentage of battery.

**Scenario 2:** It will be not a good day for Max Van Ser Dtappen.

**Scenario 3:** Riccardo Bensoni's working day will be very demanding.

**Scenario 4:** serve? Voledo si, altrimenti no, LOL

### 2.1.2 Class Diagrams

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

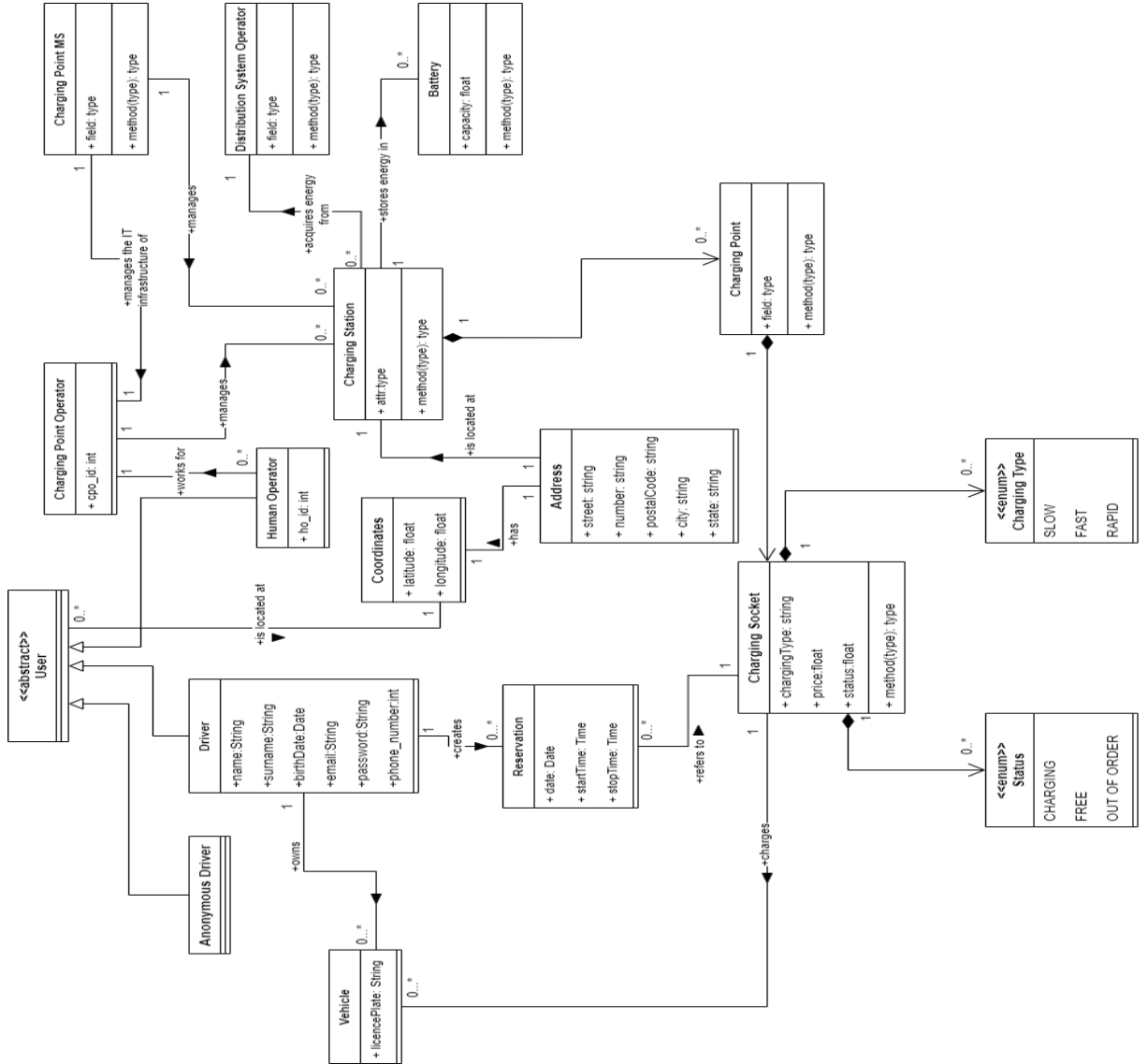


Figure 1: Class Diagram

### 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  $x \leq \text{€}100$  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.
- [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

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### 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.

- Visualization of CSs on the map

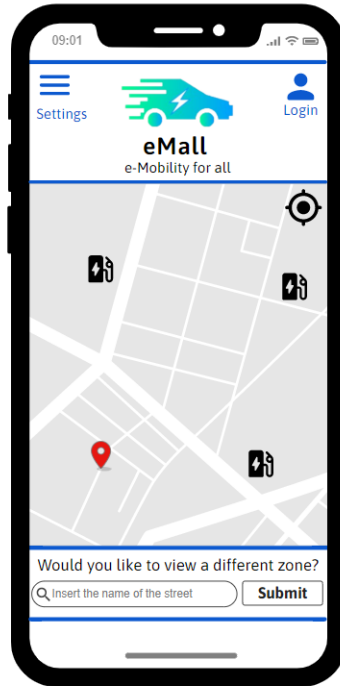


Figure 3: Visualization of CSs on a map

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**

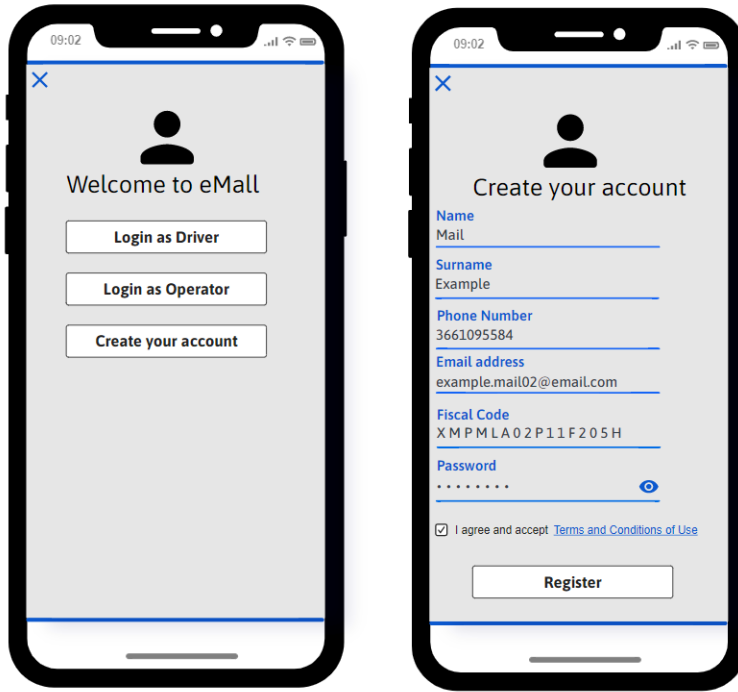


Figure 5: eMall Registration: a) Selection interface, b) Create an account

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.

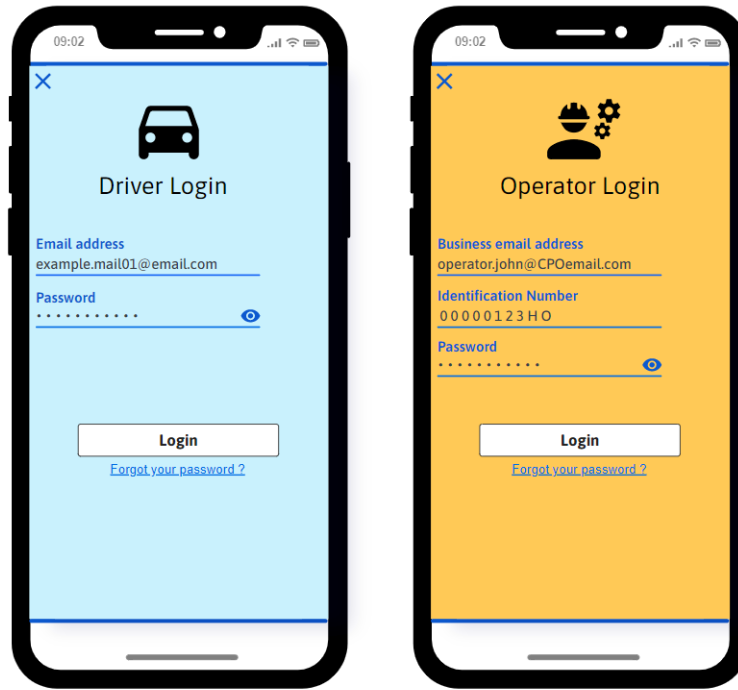


Figure 6: eMall Login: a) Driver, b) Operator

- **Driver principal page** 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.

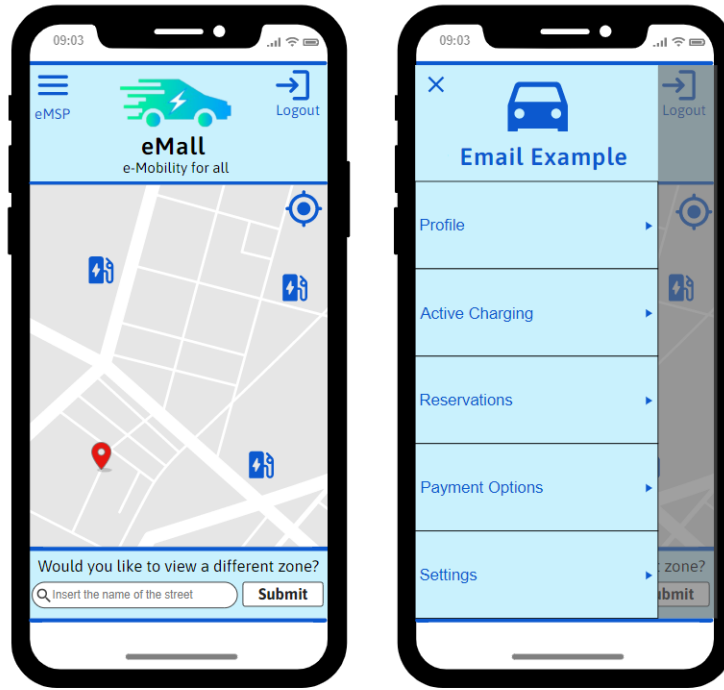


Figure 7: a) Driver principal page, b) Driver options menu

#### • Operator principal page

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.

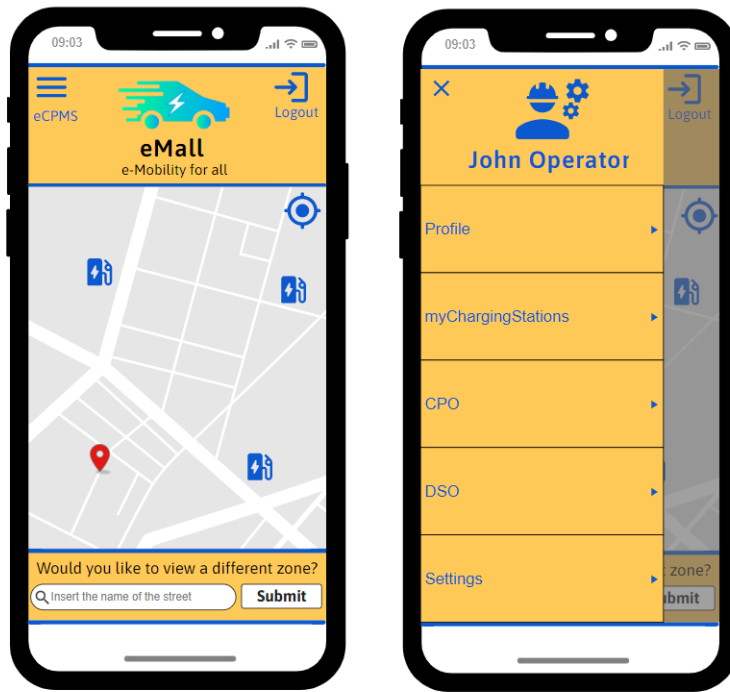


Figure 8: a) Operator principal page, b) Operator options menu

- **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

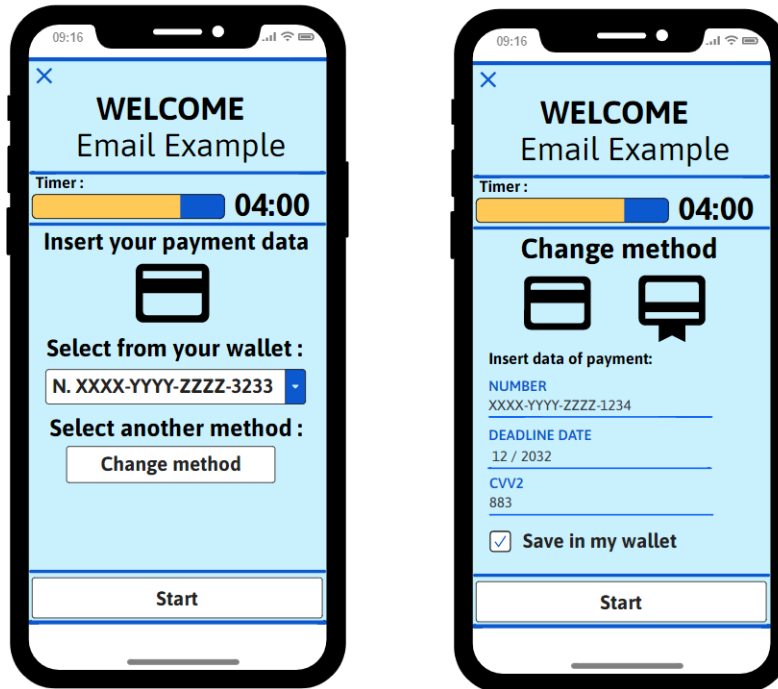


Figure 12: a) Payment Interface, b) Change method interface

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 "Change method".
- Change method (Figure 12.b): in this page, the Driver can insert payment data of another credit card or 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:

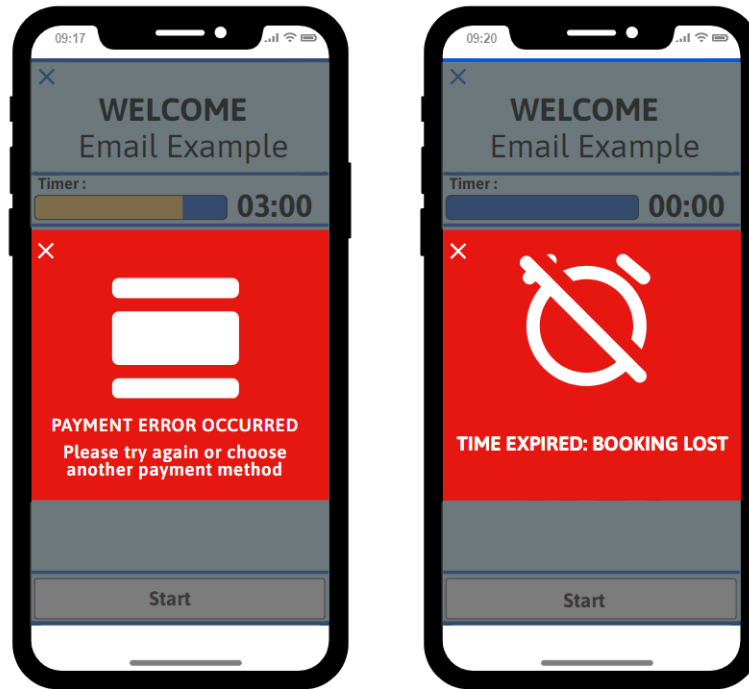


Figure 13: a) Incorrect payment data, b) Payment time expired

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



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

- Figure 15.a : the figure shows the end of the process when the battery reaches the 100 %.
- 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 : Internal Status, Batteries Status, Supply Settings and Price & Offers

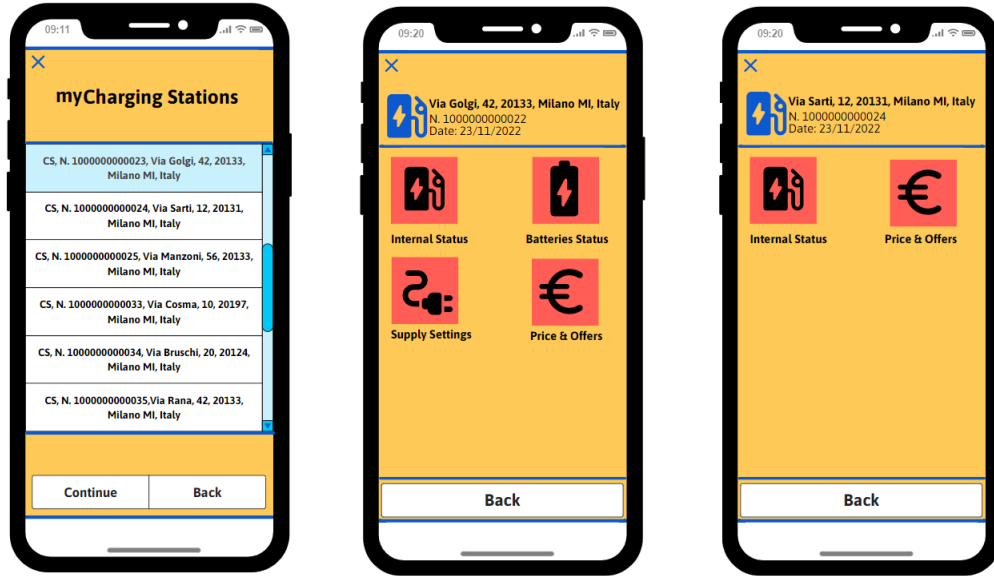


Figure 16: a) Selection of the CS, b) CPMS functionalities menu, c) menu with no batteries

Clicking on "CPMS" menu and then on "myChargingStations", the Operator will visualize a screen (Figure 16.a) on which there are all the CSs that he manages. By selecting one of them and then clicking on "Continue" button, the Operator will be able to visualize a screen (Figure 16.b) showing: data about the CS selected (address, serial number and date of today) and below the main menu with some of the eCMPS functionalities of eMall. It is possible to return to the previous screen simply clicking on the "Back" button. Otherwise, to return to the map, simply click on the exit icon on the top-left of the screen.

Figure 16.c shows how the interface is presented if the CS selected has no batteries.

- CPMS functionalities: Internal Status and Batteries Status



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

By clicking on the "Internal Status" icon, the Operator can view (Figure 17.a) the internal characteristics of each CP of the selected CS. In particular, the Operator can visualize: 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 view (Figure 17.b) the characteristics of the batteries (if present) of the selected CS. In particular, the Operator can visualize for each battery: the serial number, the maximum capacity, the actual capacity, the energy used, in percentage, for charge EVs 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

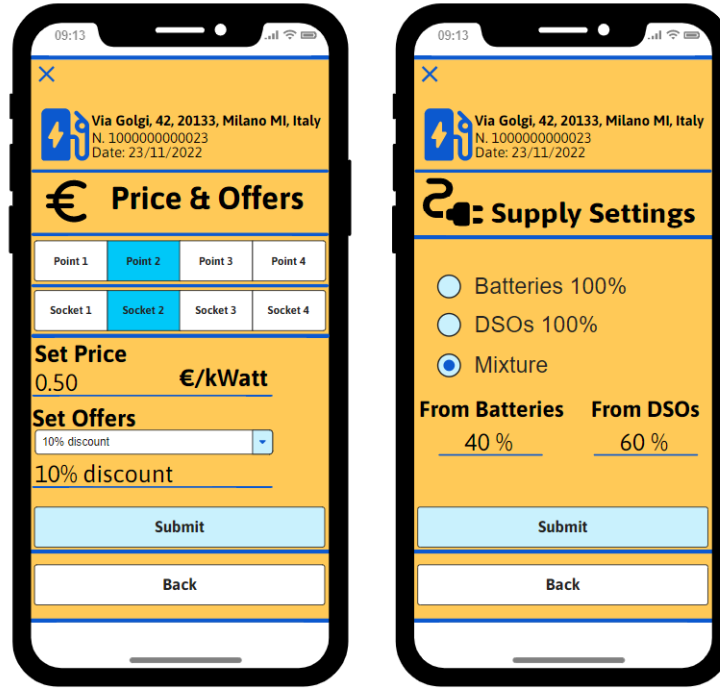


Figure 18: a) Price & Offers, b) Supply Settings

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 a socket of a CP and set manually the price and select a special offer from a combo box. 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. In particular, the Operator can choose from where to take electricity to supply the vehicles connected to the selected CS. Between the modalities, the Operator can choose: to charge the vehicles only through batteries (if present); to charge only through DSO, or if to adopt a hybrid approach. In the latter case, the Operator can choose how much electricity (as a percentage) to take from the batteries and how much from the DSO. To confirm these choices, the Operator must click on the "Submit" button.



- CPMS functionalities: List of DSOs and myDSOs

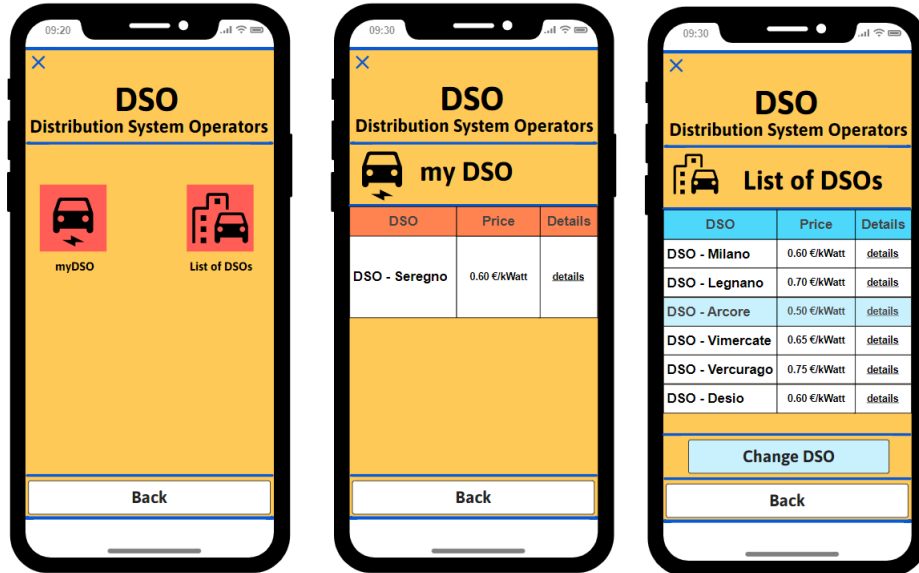


Figure 19: a)DSO menu, b) myDSOs, c) List of DSOs

The Operator can also 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 operation 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.b). 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".

### **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	<ul style="list-style-type: none"><li>(a) The Driver opens the application and taps "Login"</li><li>(b) The Driver opens the application and taps "Create your Account"</li><li>(c) The System responds and presents a form to the Driver.</li><li>(d) The Driver enters name, surname, email address, FC, phone number and password in the form.</li><li>(e) The Driver accepts the Terms and Condition of Use and taps "Register".</li><li>(f) The eMall system processes the acquired data and displays a success message.</li></ul>
Exit Conditions	An account has been successfully created and the System has stored a new Driver account.
Exceptions	<ul style="list-style-type: none"><li>(a) The Driver does not fill all the mandatory fields.</li><li>(b) The entered email address does not exist.</li><li>(c) The entered data is not valid.</li><li>(d) The System always notifies the Driver the exception.</li></ul>

Table 5: UC.1

## 2. viewChargingStationExternalStatus

Actor	Registered or Unregistered Driver
Entry Conditions	The Driver is in the initial view of the application.
Flow of events	<ul style="list-style-type: none"><li>(a) The Driver selects a CS on the map view and selects "See Details".</li><li>(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.</li></ul>
Exit Condition	The view has been correctly presented to the Driver.
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	<ul style="list-style-type: none"><li>(a) The Driver opens taps "Login" in the initial page of eMall.</li><li>(b) The Driver taps "Login as Driver".</li><li>(c) The System responds and presents a form to the Driver.</li><li>(d) The Driver fills the form with the needed credentials: email address or phone number and password.</li><li>(e) The Driver taps "Login".</li><li>(f) The System processes the acquired data and displays the Driver's main page.</li></ul>
Exit Condition	The login has successfully carried out.
Exceptions	<ul style="list-style-type: none"><li>(a) The Driver does not insert all the mandatory data.</li><li>(b) The entered email or phone number and/or the entered password are incorrect.</li><li>(c) eMall always notify the Driver the exception, if occurred.</li></ul>

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	<ul style="list-style-type: none"><li>(a) The Driver chooses a charging station on the map view.</li><li>(b) The System responds with a view of the external status of the selected charging station.</li><li>(c) The Driver selects a socket and taps on reserve.</li><li>(d) The System registers the data about the reservation.</li></ul>
Exit Condition	<ul style="list-style-type: none"><li>(a) The reservation of the socket has been successfully carried out.</li><li>(b) The System generates a QR-Code to be scanned at the charging socket's appropriate QR-Code Reader.</li></ul>
Exceptions	<ul style="list-style-type: none"><li>(a) The Driver tries to reserve an already reserved, occupied or unavailable socket.</li><li>(b) eMall always notify the Driver the exception.</li></ul>
Special Requirements	<ul style="list-style-type: none"><li>(a) The generated QR-Code is available no later than 30 seconds after a successful reservation.</li><li>(b) The generated QR-Code expires in 15 minutes.</li></ul>

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	<ul style="list-style-type: none"> <li>(a) The Driver approaches a QR-Code to the charging point QR-Code Reader.</li> <li>(b) The System scans the QR-Code and provides in the application a view with the Driver's payment methods.</li> <li>(c) The Driver selects a payment method and taps "Start".</li> <li>(d) The System reserves a fixed maximum amount of money from the Driver's chosen payment method.</li> <li>(e) The System unlocks the reserved charging socket.</li> <li>(f) The Driver plugs the socket in the electric vehicle.</li> </ul>
Exit Condition	The charging process of the Driver's electric vehicle successfully starts.
Exceptions	<ul style="list-style-type: none"> <li>(a) The selected payment method is expired or has no money in it.</li> <li>(b) The Driver tries to scan the QR-Code more than 15 minutes after the reservation.</li> <li>(c) eMall always notify the Driver the exception.</li> </ul>
Special Requirements	<ul style="list-style-type: none"> <li>(a) The unlocking of the reserved socket occurs no longer than 15 seconds after the successful money transaction.</li> <li>(b) The Driver has a timer of 5 minutes from the QR-Code scan to choose the payment method and to start the charging.</li> </ul>

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	<p>Case 1: Adding a method out of the charging process.</p> <ul style="list-style-type: none"> <li>(a) The Driver taps on "My eMall" and then on "Payment".</li> <li>(b) The System responds with the view of the already added payment methods, if any.</li> <li>(c) The Driver selects "add a new payment method".</li> <li>(d) The System responds sending a form to fill with the data of the new payment method.</li> <li>(e) The Driver inserts the new payment method data and taps "Submit".</li> <li>(f) The System processes the acquire data and stores the new payment method information.</li> </ul> <p>Case 2: Adding a method after QR-Code scan at the charging point.</p> <ul style="list-style-type: none"> <li>(a) The Driver taps on "insert method".</li> <li>(b) The System responds sending a form to fill with the data of the new payment method.</li> <li>(c) The Driver selects "add a new payment method".</li> <li>(d) The Driver inserts the new payment method data, choose whether to save the new method in the wallet or not and taps "Submit".</li> <li>(e) The System processes the acquire data and stores the new payment method information.</li> </ul>
Exit Condition	The new payment method has been successfully added.
Exceptions	<ul style="list-style-type: none"> <li>(a) The Driver does not fill the form with all the mandatory data.</li> <li>(b) The Driver fills the form with non valid data i.e. expired payment method, incorrect number and/or CVV2.</li> <li>(c) The System can not establish a connection with the bank related to the payment method.</li> <li>(d) eMall always notify the Driver the exception.</li> </ul>
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	<ul style="list-style-type: none"> <li>(a) The Driver taps on "My eMall" and then on "Active Chargings".</li> <li>(b) The System responds with the view of the status of the active charging.</li> <li>(c) The Driver taps on "Stop".</li> <li>(d) The System withdraws the amount of money corresponding to the provided quantity of energy.</li> <li>(e) The System shows to the Driver the report of the occurred charging process.</li> <li>(f) The System responds with a message of successful interruption of the charging process.</li> <li>(g) The Driver unplugs the socket from the EV and puts it in place.</li> <li>(h) The System updates the status of the socket, setting it as "Free".</li> </ul>
Exit Condition	The payment for the charging has been successfully performed.
Exceptions	<ul style="list-style-type: none"> <li>(a) An error with the payment process occurs.</li> <li>(b) eMall always notify the Driver the exception.</li> </ul>
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	<ul style="list-style-type: none"><li>(a) The Operator taps "Login" in the initial view of eMall.</li><li>(b) The Operator taps "Login as Operator".</li><li>(c) The System responds and presents a form to the Operator.</li><li>(d) The Operator fills the form with the needed credentials: email address, identification number and password.</li><li>(e) The Operator taps "Login".</li><li>(f) The System processes the acquired data and displays the Operator's main page.</li></ul>
Exit Condition	The login operation has been successfully carried out.
Exceptions	<ul style="list-style-type: none"><li>(a) The Operator does not insert all the mandatory data.</li><li>(b) The entered data is incorrect.</li><li>(c) eMall always notify the Driver the exception, if occurred.</li></ul>
Special Requirements	

Table 12: UC.8

## 9. ViewChargingStationInternalStatus

Actor	Registered Operator
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	<ul style="list-style-type: none"> <li>(a) The Operator selects "myCPMS" in the initial view.</li> <li>(b) The Operator selects "my Charging Stations".</li> <li>(c) The System responds with a list of the CSs managed by the CPO the Operator works with.</li> <li>(d) The Operator choose a charging station and then selects "Continue".</li> <li>(e) The Operator selects "Internal Status".</li> <li>(f) The System provides a view of the internal status 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.</li> </ul>
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	<ul style="list-style-type: none"> <li>(a) The Operator selects "myCPMS" in the initial view.</li> <li>(b) The Operator selects "my Charging Stations".</li> <li>(c) The System responds with a list of the CSs managed by the CPO the Operator works with.</li> <li>(d) The Operator choose a charging station and then selects "Continue".</li> <li>(e) The Operator selects "Batteries Status", that is available only if the selected CS is provided of any battery.</li> <li>(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.</li> </ul>
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	<ul style="list-style-type: none"> <li>(a) The Operator selects "myCPMS" in the initial view.</li> <li>(b) The Operator selects "my Charging Stations".</li> <li>(c) The System responds with a list of the CSs managed by the CPO the Operator works with.</li> <li>(d) The Operator choose a charging station and then selects "Continue".</li> <li>(e) The Operator selects "Price and Offers".</li> <li>(f) The System provides a view where to set the price of each type of socket and to set any special offer.</li> <li>(g) The Operator sets the prices and, eventually, a special offer.</li> </ul>
Exit Condition	The System processes the data and sets prices and, eventually, special offers for the selected charging station.
Exceptions	<ul style="list-style-type: none"> <li>(a) The Operator inserts incompatible price or/and a special offer (e.g. negative price or negative percentage discount).</li> <li>(b) eMall always notify the Driver the exception, if occurred.</li> </ul>
Special Requirements	<ul style="list-style-type: none"> <li>(a) The price modification can occur maximum once a day at an established moment.</li> </ul>

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	<ul style="list-style-type: none"> <li>(a) The Operator selects "myCPMS" in the initial view.</li> <li>(b) The Operator selects "myDSO".</li> <li>(c) The System shows data (i.e. name, energy price) about the DSO that is now providing energy.</li> <li>(d) The Operator selects "Choose another DSO".</li> <li>(e) The System shows a list of the available DSOs with their prices.</li> <li>(f) The Operator selects a DSO and then presses "Choose this DSO".</li> <li>(g) The System processes the acquired data and establishes a connection with the chosen DSO.</li> </ul>
Exit Condition	The DSO choice has been successfully completed.
Exceptions	<ul style="list-style-type: none"> <li>(a) The System does not receive any answer from the DSO, so it can not establish the connection.</li> <li>(b) eMail always notify the Driver the exception, if occurred.</li> </ul>
Special Requirements	

Table 16: UC.12

### 13. setSupplySettings

Actor	Registered Operator
Entry Conditions	The Operator is logged in and in the initial view of the application.
Flow of events	<ul style="list-style-type: none"><li>(a) The Operator selects "myCPMS" in the initial view.</li><li>(b) The Operator selects "my Charging Stations".</li><li>(c) The System responds with a list of the CSs managed by the CPO the Operator works with.</li><li>(d) The Operator choose a charging station and then selects "Continue".</li><li>(e) The Operator selects "Supply Settings".</li><li>(f) The System shows the percentages of energy provided by the DSO and by the CS battery.</li><li>(g) The Operator selects "100% battery" or "100% DSO" or "Mixture", indicating, in this case, the percentages.</li><li>(h) The Operator selects "Submit".</li><li>(i) The System processes the acquired data and sets new supply settings for the selected CS.</li></ul>
Exit Condition	The supply settings modification has been successfully completed.
Exceptions	<ul style="list-style-type: none"><li>(a) The Operator presses "Submit" without selecting any supply method.</li><li>(b) The Operator has chosen "Mixture" but with a sum of percentages different from 100%.</li><li>(c) eMall always notify the Driver the exception, if occurred.</li></ul>
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 current booking.
- [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 they are present 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 its prices, from which the CPO can buy electric energy.
- [R.21] = The system shall allow the Operator to visualize the current DSO from which the CPO already buy 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 of the Operators.
- [R.24] = The system shall be able to notify to Drivers or Operators of incorrect actions.
- [R.25] = The system shall be able to distinguish the functionalities to be offered according to the User who logs in.

#### 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
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
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
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**

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 to use our services, eMall mobile application should be developed for the most popular Operative Systems: Android and iOS. Since the computational burden of our application is enough high, in developing-phase we won't consider old devices.

## 4 Formal analysis using Alloy

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In this section a formal description of the domain of the system and its properties is given using Alloy.

Some critical aspects that are essential for the correct functioning of the application are represented. 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 User (Driver or Operator).
- 
- 
-

```

open util/integer

/* ** Signatures ** */

sig CF{}
sig OperatorID{}
sig Address{}
sig BusinessAddress{}
sig Password{}

abstract sig User{
password : one Password,
}

sig Driver extends User{
cf: one CF,
address : one Address,
}

sig Operator extends User{
operatorID : one OperatorID,
businessAddress : one BusinessAddress,
}

/* ** 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 addresses duplicates(each Driver can register just once)
fact EmailAddressNODuplicates{
all d1,d2: Driver, thisadd: Address |
thisadd in d1.address and thisadd in d2.address implies d1 = d2
}

//There are no OperatorID 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, thisbadd: BusinessAddress |
thisbadd in o1.businessAddress and thisbadd in o2.businessAddress 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 BusinessAddressOperatorConnection{
all badd : BusinessAddress | some o:Operator | badd in o.businessAddress
}

//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 AddressDriverConnection{
all add : Address | some d:Driver | add in d.address
}

//All Password have to be associated to a User
fact PasswordUserConnection{
all p:Password | some u:User | p in u.password
}

/* ** Predicates ** */

pred show{
#Operator >=2
#Driver >=2
}

run show for 5

```

## 5 Efforts

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Individual Work		
	<i>Eutizi Claudio</i>	<i>Perego Gabriele</i>
Tasks	Hours	Hours
Introduction (chapter 1)	4	8
Overall description (chapter 2)	7	8
Specific requirements (chapter 3)	8	9
Formal analysis using Alloy (chapter 4)	0	0
Final Revision	0	0
<b>Total</b>	<b>18</b>	<b>25</b>

Table 19: Time spent by each team member

## 6 References

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