POLITECNICO
MILANO 1863

Customer Line Up RASD

REQUIREMENTS ANALYSIS AND SPECIFICATION DOCUMENT

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CLup

Customer Line up

1. INTRODUCTION

A. Purpose

This document has the purpose to clearly define the functionalities that the system-to-be will provide, the goals it strives to achieve, indicate general use cases and describe its limitations as to guide the engineers' job and the stakeholders' decision making.

The system tries to put an end to overcrowding inside common spaces and physical queues as much as possible, as to reduce the possibility of getting infected by Covid-19 while doing a daily activity such as grocery shopping. It will incentivize its users to line up virtually to go to said shops and permit to the shop managers to check how many people are inside at any time.

These goals are formally defined as the following:

- Store Manager related:

G1	The store manager should track how many people are inside the store at any point in time.
G2	The store manager should regulate the influx of people that can enter inside the store.

- Store stakeholders and users related

G3	Everybody should be able to maintain social distancing inside the stores.
G4	Everybody should be able to maintain social distancing in front of the stores.
G5	Stores should allow as many customers inside as permitted by law

- Customers related

G6	Anyone who wants to book a visit to any store should decide their desired time to go.
G7	Anyone who wants to go in any store should not need to stand in queue in front of it.

As subgoals of these last two goals we would have:

Sub-G8: "Customers should have the ability to know which stores are available to go to."

Sub-G9: "Customers should reach the shop at the arranged time."

B. Scope

In the following tables are listed the most relevant world and shared phenomena. In this application, it is critical to consider, among world phenomena, the behavior of the user, since there are some factors (e.g. W1,W2,W5,W6) that if not considered and handled, can create problems that may lead to unwanted situation, as the creation of a line in front of the store.

B.1 World Phenomena

W1	User reaches the shop
W2	User lines up in front of the shop
W3	User maintains social distancing
W4	User gets into a corridor to get a product
W5	User takes physical ticket with him
W6	User loses physical ticket

B.2 Shared Phenomena

		Controlled by
S1	Virtual User gets ticket through the app	World
S2	Virtual User books a visit through the app	World
S3	Physical User requests ticket from the dispenser	World
S4	Physical User retrieves ticket from the dispenser	Machine
S5	User scans QR code at entrance	World
S6	User scans QR code at exit	World
S7	Turnstile unlocks	Machine
S8	Turnstile locks	Machine
S9	Virtual User is notified about his coming turn	Machine
S10	Virtual User registers providing requested info	World
S11	Virtual User queries available markets	World
S12	Shop manager queries statistics on shop entrances	World
S13	User pushes turnstile	World

C. Definitions, Acronyms, Abbreviations

Physical user: the person who goes directly to the market without using the application.

Virtual user: any person who uses the app to line up virtually and asks for a ticket.

User: Either a physical user or a virtual user.

Ticket: QR code that permits to enter inside the market at a certain time written on the ticket.

Store, Market, Supermarket, Shop: Any building that provides goods and services in return for money and are connected to the CLup application.

Social distancing: the personal space to any single person as an area of radius 1m.

Front of stores: the area that is property of the store and in which people queue up to wait for their turn.

Authorized Account: Account associated to a Shop Manager, formally authorized through adequate procedures.

Inactive User: a virtual user that does not click on any button in the *"Get a ticket"* or *"Book a visit"* page.

D. Revision history

Group meetings:

1st meeting: Defined a very high level of what we want our application to be and what it will provide, by brainstorming scenarios and possible stakeholders' needs and wants.
Duration: 1.5h, 14/10/2020

2nd meeting: Defined scenarios and some key World and Shared Phenomena. We categorized the shared phenomena into World/Machine controlled.
Duration 1.5h, 17/10/2020

3rd meeting: Revised the R&DD document of the last year's group.
Duration 1.5h, 24/10/2020

4th meeting: Defined Functional Requirements, Domain Assumptions and Goals
Duration 1.5h, 14/11/2020

5th meeting: Defined Use Cases
Duration 2h, 21/11/2020

6th meeting: Reviewed Goals and defined all the External Interfaces
Duration 1.5h, 25/11/2020

7th meeting: Reviewed Use Cases and defined new Requirements
Duration 1.5h, 01/12/2020

8th meeting: Added sections of Alloy code into the document
Duration 1h 06/12/2020

E. Reference documents

1) ISO/IEEE standards for the engineering of requirements for systems and software products: https://standards.ieee.org/standard/29148-2018.html

2. OVERALL DESCRIPTION

A. Product perspective:

A.1. Scenarios

1) Hajsen wishes to buy groceries but remembers that the nearest market is small, and he would probably have to wait for an hour. Instead of going downstairs and waiting in line:
   - He opens the app on his device and clicks on the button to *"Get a ticket"*
   - He chooses the market "Eurospim" from a map
   - The system shows the first available time slot to enter the market
   - Hajsen decides to go at that time and clicks on *"Confirm"*
   - The system sends a notification to remind him about his appointment, and Hajsen gets ready to go
   - He arrives in the market in the assigned time and opens his app again
   - He clicks on the "Show ticket" and scans it in the apposite machine
   - After he finishes buying the groceries and paying for it, he opens the app and shows the ticket to the cashier
   - Now he can exit the market

2) Giulio has just remembered that he promised to her fiancée a special dinner the following day. Since it is too late and he has no time to do the shopping, he decides to book a visit to the nearest supermarket to his home for the following day:
   - He opens the app on his device and clicks on the button to *"Book a visit"*
   - He selects "18:00" as time slot
   - He selects the store "Ellelunga" from a map between the stores provided by the app
   - The system asks Giulio an estimate of how much time his visit will last and a list of items (or categories of items) he intends to buy. Since Giulio has not a clear idea of what he will purchase and how much the visit will take, he clicks on *"Confirm"* leaving the two previous fields empty
   - The following day the system sends a notification to remind him the visit, so Giulio gets ready to go
   - He arrives in the market in the assigned time and opens his app again
   - He clicks on the "Show ticket" and scans it in the apposite machine
   - After he finishes to do the shopping and paying for it, he opens the app and shows the ticket to the cashier
   - He proceeds to exit the market

3) Alberto B. hates technology, so he gambles his luck and tries to enter inside the market, unfortunately there are no available places to enter so he takes a ticket from the dispenser.

- He gets to the ticket dispenser in front of the shop and presses the button to get a ticket
- Reading the ticket, he sees the time slot in which he can enter the market
- Since the time slot assigned is 2 hours later, he decides to do other things he had to do instead of queuing in front of the shop
- When the time is getting close to the appointment time, he gets back to the shop
- He retrieves the ticket from his pocket and scans it in the apposite machine, that lets him enter the market
- After he finishes buying the groceries and paying for it, he shows the ticket to the cashier
- Now he can exit the market

- Francesco wants to make a delicious dinner with pasta and tuna. Unfortunately, in the afternoon, he discovers that he is run out of pasta. Since he works until evening, he decides to book a visit for the current day:
- He opens the app on his device and clicks on the button to *"Book a visit"*
- He selects the time slot "20:00"
- Between the received available stores from the application, he is unable to make a choice because there is not a store he likes
- While he is inactive thinking about the stores, the applications notifies Francesco that there are further available stores
- Francesco clicks on the notification, hopeful to find his preferred store
- After received the further stores, Francesco selects immediately "SicilianPasta" store
- The system asks Francesco an estimate of how much time his visit will last and/or a list of items (or categories of items) he intends to buy. Since he is eager to eat pasta and tuna, he inserts just "pasta" as product he intends to buy and "15 minutes" as estimation time. Finally, he clicks on the *"Confirm"* button
- The system sends a notification to remind him the visit, so Francesco gets ready to go
- He arrives in the market in the assigned time and opens his app again
- He clicks on the "Show ticket" and scans it in the apposite machine
- After he takes 10 packs of pasta and pays for them, he opens the app and shows the ticket to the cashier
- He proceeds to exit the market and run at home to cook his loved pasta and tuna.

4) It is Monday, Francesco M. is taking a break from his intense day at work. While he is eating a sandwich, he receives a notification from the application, being informed that his preferred store "The Good Goods" has an available time slot at 18:00 the following day. Since he usually does the shopping at 18:00 on Tuesday, he decides to book a visit. After he completes the procedure to book a visit and receives the virtual ticket, he continues to eat his sandwich before to come back at work.

5) Silvia loves doing the shopping at "W-Food" but unfortunately, due to the great popularity of the store, she sometimes does not manage to get a ticket or book a visit at the desired time slot. To avoid further similar situations, she decides to activate the periodic notification on the availability of "W-Food". In particular:
   - She opens the application on her device
   - She open the notification panel
   - She insert "W-Food" as the store she wants to be notified about
   - She selects "Monday, Tuesday, Wednesday, Sunday" as days and "from 14:00 to 20:00" as time range
   - Since she wants to be notified every hour, she inserts "1 hour" as periodic time notification
   - She clicks on the *"Confirm"* button
   - She receives a confirmation about the successful update of the periodic notification system

6) Shalini is the manager of one of the grocery shops of the chain "Ellelunga" and she wants to check on peak times how many people are entering inside the shop:
   - She connects to the application on her device
   - She logs in with the credentials of her authorized account
   - On the home page she sees the button "Statistics and Diagnostics" and presses it
   - In front of her there are number of effective and expected entrances for the current week

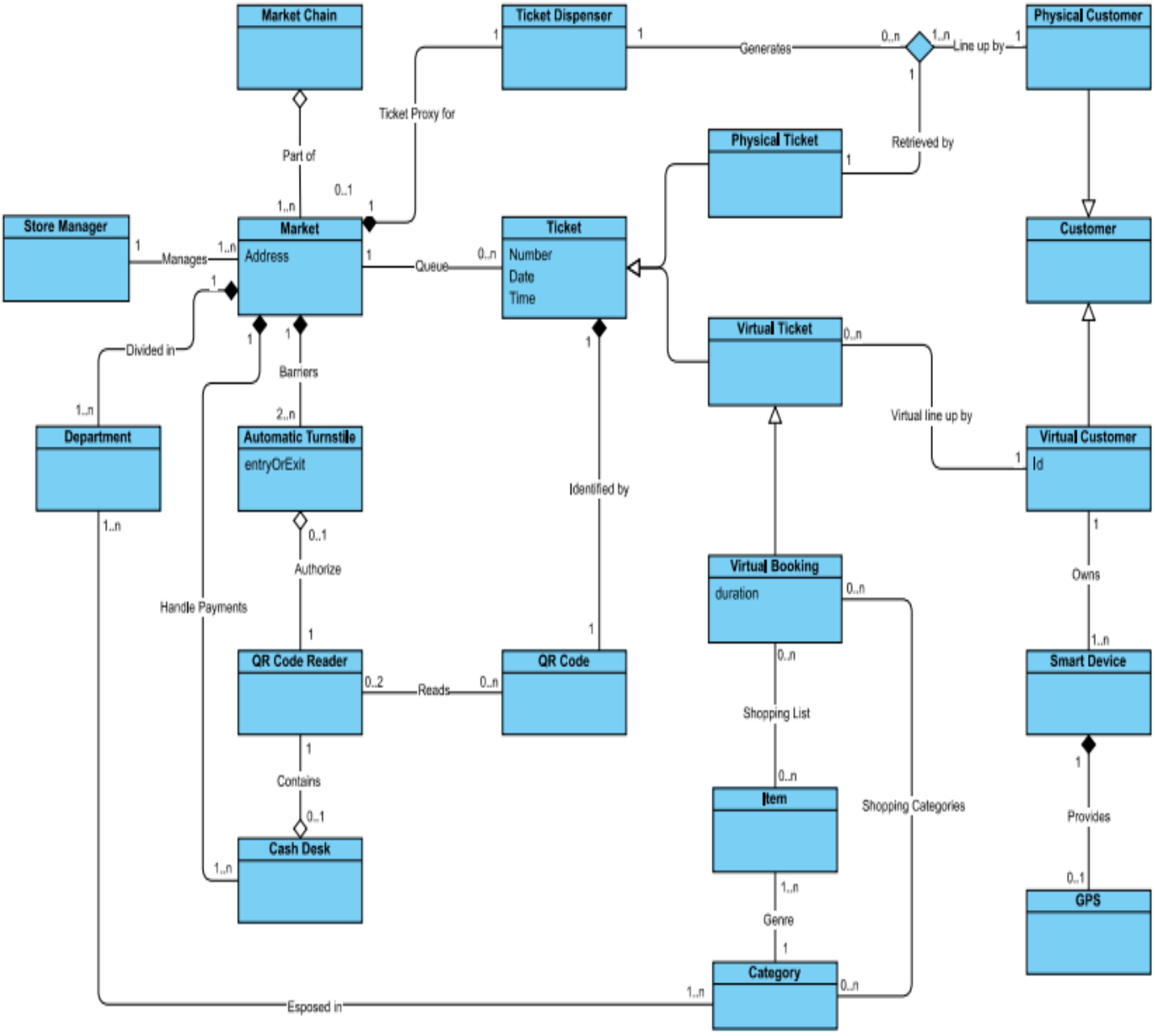
7) Etion, who is the manager of one of the grocery shops of the chain "Carre-4", wants to register a further store in CLup. In particular:

- He connects to the application on his device
- He logs in with the credentials of his authorized account
- On the home page he presses the button "Register Store" and presses it
- The system provides him a form where he can insert all the mandatory information
- Etion inserts:
  - "Carre-4" as name
  - "Via Pino Daniele, 35 (Milan)" as location
  - "630 m^2" as dimension
  - Which categories of goods are available into the store
- Etion receives the notification confirming the successful registration of the store and goes to take a coffee

8) Cristian, who is the manager the grocery shop "Love&Food", is currently at work controlling how many people are inside the store. After he notices that some bottles of wine were broken and consequently the wine department will be unavailable for 30 minutes, he decides to regulate the influx of people to guarantee the social distancing inside the store.

- He connects to the application on his device
- He logs in with the credentials of his authorized account
- On the home page he presses the button "Regulate Influx" and presses it
- He selects the store "Love&Food" where he is at the moment
- Cristian decreases the parameter regulating the influx of people in order to temporarily permit a number of entrances less than usual
- After he has received confirmation of the successful change of the parameter, he goes to the wine department to check how much the cost damage is and at which point is the cleaning of the department.

A.2. *Class Diagram*



The diagram shows the system's view of the world, showing different important aspects:

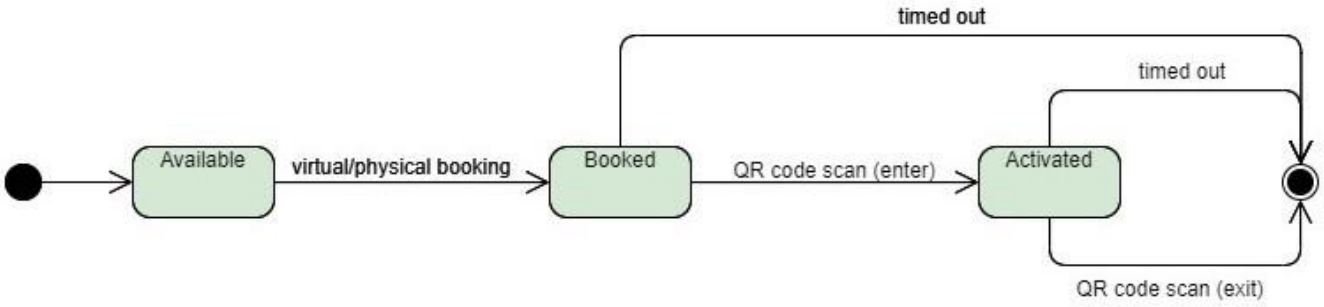
- the organization of markets (used to optimize estimated times).
- The presence of QR code readers at entrances and exits.
- Visits (called Virtual Booking) are treated exactly as virtual tickets, the only differences are that they have a user decided time slot, while normal tickets assign

the first available timeslot, and that on visits users may insert their shopping list and/or the estimated duration of their visit.

- Both virtual tickets (including visits) and physical tickets are conceptually treated equally when optimizing queues and finding available timeslots. This is clear from the "extends" relation on Ticket. This allows to correctly consider, in the queue and optimization of timeslots, physical tickets taken by non-users of CLup.

A.3. Statecharts

A.3.1. Ticket's status



Tickets are crucial to guarantee the virtual (and physical) lining up mechanism. An *"Available"* ticket becomes *"Booked"* when it is booked, or when a user requires to get a ticket either virtually or physically. In order to enter the store ("Activated" state), the user must scan the *"Booked"* ticket at the indicated time slot or within a brief time variation taking into account a small human error, otherwise the ticket will expire and become unusable. The user, who owns the ticket, after scanning it to enter the store, will use the same ticket to exit. If the user's ticket becomes unavailable (e.g., the physical ticket is lost, the user's device has low battery) while he is shopping, the user is allowed to exit the store anyway after asking for assistance from a cashier or a manager inside the store. In this case, the *"Activated"* ticket will expire after a time equal to the system's estimated average duration of a grocery shop trip from the indicated time slot and it will be considered scanned anyway.

B. Product functions

The most important aspects of the system-to-be are the regulation and management of the entrances in stores as seen in the above scenarios. These are critical, as they not only depend on the correct handling of tickets, but it is paramount to consider the uncertainty brought by human behavior.

Queue managing is applied through the means of time slotted (in fractions of an hour) tickets. Every ticket or booked visit will allow users to enter in the store only in the time slot written on the ticket, plus a brief time variation as not to be extremely strict and as to take into account for a small human error, that if not considered could lead again to the creation of a physical queue. The system will use time slots as not to have many entrances at the same time and create a virtual queue for the entrance. Afterwards the system will consider the user as being inside a store until the scan in exit is carried out or until a time calculated considering to the system's estimated average duration of a grocery shop trip passes.

The system should also consider fallback options for non-users of CLup, that may be people unable to use digital devices or that do not want to. To consider them correctly when optimizing the queue and the timeslots, the system should offer a physical proxy, in order to grant them access to shops.

The system-to-be should inform its users of what stores are available to go to and allow them to take a ticket and line up without needing to be in presence in front of the store, also generating customized suggestions based on user's search. The system will allow its registered virtual users to input the products they are willing to buy. The system will consider the average time it takes for its registered users to shop and will use that time to infer how long a shop trip will last based on what products the user plans on buying, allowing better optimization of the queue and timeslot system.

The system should help the user in reminding his tickets and visits, as to reduce the risk of users getting tickets and then not presenting.

The system should also be a guidance of help to the store managers by providing information about the number of people who have entered said stores and allowing them to regulate the influx too.

C. User Characteristics

Virtual User: A person who has a smartphone or any smart device that can connect to the internet and the application as to virtually line up or book a visit. He will have to show the QR code of the ticket of his appointment in the right place in the entrance of the store.

Physical User: A person who goes directly to the shop and takes, from a dispenser, a ticket where are indicated: the date, the time, the store's name, the store's location, the QR code. He will have to show the QR code of the ticket of his appointment in the right place in the entrance of the store.

Cashier: An employee of the shop who will provide with the correct scanning of the ticket before the exit of a Physical/Virtual User. If the market has a self-check-out department, the turnstile will serve as the aforementioned employee.

Manager: An employee of the shop who is interested in checking the number of entrances or exits and in regulating them as needed. He will have the possibility to use our application for the statistics of entrances and exits.

D. Assumptions, dependencies and constraints

A1	Users will take the shortest path to shops
A2	User which specified a shopping list will spend 90% of their time within that visit in the departments related to the declared list
A3	Data about the store's location, store departments and items collocation in departments are correct
A4	Users will abide to local norms on social distancing
A5	Only one person will enter the store per ticket
A6	90% of people who are in front of the store have an appointment to enter the store within the next timeslot

Since the system is a critical part of the defense against the further spread of the virus, it is crucial to have some assumptions on undesired behaviors on which the system has no control and cannot check: (**A1**) regards the correct notification of users by the system about their suggested departing time and their distance to the shop; (**A2** and **A3**) allow the system to optimize the space inside the market knowing where the user will be during his visit; (**A4**) is crucial as one of the main goals of the system is user's safety; (**A5**) instead deals with the correct behavior of people entering the turnstiles, that could be misused, and cannot be checked automatically by the system. (**A6**) Deals with another undesired behavior: since system allows to line up virtually, users have no need to stand in queue in front of the store, and logically they should not unless their turn is coming. Plus, (**A6**) is needed to consider the eventual presence of other people in front of the store for eventual other reasons, since we cannot assume that each store is completely isolated.

3. SPECIFIC REQUIREMENTS

A) External Interface Requirements:

A.1) User Interfaces:

I. Mobile App, that must be easy to use as it will have to be used from people of all ages, this means that the interface must be very minimal and intuitive. The app will allow virtual users to get a ticket, book visits, as well as monitor their tickets and visits, either if the virtual user has an account or not. If user does not login, the app will just consider him as a guest. The app will allow user to define first either the shop or the date and time, in the case of "Book a visit". In the case of "book a visit", after the shop selection, the app will allow registered virtual users to select their shopping list.

II. Physical ticket dispensers, that will be installed in front of each shop, acting as proxies for the system. Physical ticket dispensers will allow physical users to get a ticket for the shop to which the dispenser belongs to.

III. Admin interface, that will be a more statistics-oriented panel, accessible through a desktop app (requiring an Authorized Account), and will allow the shop manager to login from an authorized device and monitor entrances and statistics as the average duration of a visit.

A.2) Hardware Interfaces:

I. Virtual Users must have a device that can download and run the app. To use all the functionalities, as the notifications about the traveling time to a shop when the time is close to user's turn, the device must have GPS turned on.

II. Dispensers must have at least a screen to display the first available time slot for a ticket and to ask for confirmation. There must also be two clearly distinguishable buttons for accepting or declining tickets, as to allow for an easy interaction with the customers, there could be then other types of interface to provide more accessibility.

III. Shop entrances must have devices to communicate to users the tickets allowed to enter in that moment.

IV. The users of the system-to-be will have to interact with turnstiles gates in entrance and possibly in exit, in special cases documented above. In addition, the turnstiles gates will have a QR code scanner.
V. The cash register will have a QR code scanner for all the users who are about to exit from the store.

A.3) Software Interfaces:

I. The system will need to access to some external APIs to access to maps, needed for user localization, user-to-store distance and time estimation and to find stores near a given address.
II. The system will require an interface with a memory storage unit to manage store and ticket data and to allow lookups.

A.4) Communication Interfaces:

I. Virtual user devices connect to the system via Internet.
II. Ticket dispensers can connect to system via ethernet cable or by a wireless connection.
III. Shop manager's device connects to the system via Internet.

B) Functional Requirements and mapping

B.1.1) Users and Customers Requirements:

R1	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, virtually
R2	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, physically
R3	**The system shall** allow users to book a visit virtually with their desired store.
R4	**The system shall** allow users to look up on a map available registered stores where to go to
R5	**The system shall** ask users how much he or she thinks the trip to the store will last
R6	**The system shall** allow users to be identified by their device unique ID
R7	**The system shall** allow users to be identified by a username of their choosing
R8.1	**The system shall** notify the user who is inactive while on the confirmation page of booking a visit on other available stores he could go to and other timeslots of the same store
R8.2	**The system shall** notify the user who is inactive while on the confirmation page of getting a ticket on other available stores he could go to
R9	**The system shall** allow its users to insert information about which categories or items they want to buy
R10	**The system shall** infer how long it will take for "Book a Visit" customers to buy the expressed shopping list
R11	**The system shall** store data about registered virtual users' visits durations and expressed shopping lists
R12.1	**The system shall** inform users periodically of the available time slots in the store for which he subscribed to the service
R12.2	**The system shall** allow its users to select which store(s) to get informed about
R12.3	**The system shall** allow its users to select which time slots he is interested to get informed about
R12.4	**The system shall** allow its users to select how often to get notified
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R14	**The system shall** allow the user to scan its QR code in exit through the turnstiles or cash register
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R15.2	**The system shall** unlock turnstiles after a unique QR code scan in exit
R15.3	**The system shall** lock the turnstiles after a push has occurred

R16	**The system shall** map the QR code of a scan to the virtual user who owns the QR code
R17	**The system shall** send a reminder to the user when it is time for him to leave so that he can arrive at the store in time
R18	**The system shall** calculate the time it takes the user to go to a shop in which he has an appointment
R19	**The system shall** manage how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store
R20	**The system shall** calculate the maximum number of people allowed inside each store, as to allow for social distancing to take place

There is a subtle difference between the last two functional requirements, in which the last provides the social distance inside stores, so customers might have their personal space while the second to last provides the social distance outside stores, in the sense that people enter divided in sections as to not have crowds outside of the store.

B.1.2) Store Managers Requirements:

R21	**The system shall** count the number of entrances and exits each day for each market
R22	**The system shall** store the number of daily entrances and exits for each market
R23	**The system shall** manage how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store hourly, without exceeding the maximum calculated by the system
R24	**The system shall** allow store managers to see how many customers have entered the store in any day.
R25	**The system shall** allow store managers to register their stores
R26	**The system shall** allow store managers to input the store's location
R27	**The system shall** allow store managers to input what categories of goods and what products are contained in the store
R28	**The system shall** allow store managers to input the dimensions of the store

The most important functional requirements for store managers are allowing them to register their stores and input their location and further details as to allow users to see the store on the map and to allow the system to provide its functionalities towards users.

B.1.3) Functional Requirement and Goal Mapping

G1	The store manager should track how many people are inside the store at any point in time, within one week
A5	Only one person will enter the store per ticket
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R14	**The system shall** allow the user to scan its QR code in exit through the turnstiles or cash register
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R15.2	**The system shall** unlock turnstiles after a unique QR code scan in exit
R15.3	**The system shall** lock the turnstiles after a push has occurred
R21	**The system shall** count the number of entrances and exits each day, for each market
R22	**The system shall** store the number of daily entrances and exits for each market
R24	**The system shall** allow store managers to see how many customers have entered the store in any day.

Supposing that for each ticket only one person will physically enter the store (**A5**), the system shall allow the person to enter inside the store through the requirements **(R13 - R15.3**), count these entrances (and successive exit) through the requirement (**R21**), store the sum of all entrances and exits per day and display them to the store manager having fulfilled goal (**G1**).

G2	The store manager should regulate the influx of people that can enter inside the store.
A5	Only one person will enter the store per ticket
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R14	**The system shall** allow the user to scan its QR code in exit through the turnstiles or cash register
R14	**The system shall** give out tickets and visits per timeslot, to each store at most equal to the difference of the maximum number of people allowed inside the store and people currently inside the store
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R15.2	**The system shall** unlock turnstiles after a unique QR code scan in exit
R15.3	**The system shall** lock the turnstiles after a push has occurred
R19	**The system shall** manage how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store
R20	**The system shall** calculate the maximum number of people allowed inside each store, as to allow for social distancing to take place
R23	**The system shall manage** how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store hourly, without exceeding the maximum calculated by the system

Assuming that (**A5**) one person enters in the store per ticket, we force entrances only after the QR code has been scanned (**R13 - R15.3**) equal to the number of people allowed inside the store either by the manager's decision (**R23**) or the law's maximum number of people allowed inside the same area (**R19**, **R20**). In this way the system accomplishes goal (**G2**).

G3	Everybody should be able to maintain social distancing inside the stores.
A2	User which specified a shopping list will spend 90% of their time within that visit in the departments related to the declared list
A4	Users will abide to local norms on social distancing
A5	Only one person will enter the store per ticket
R1	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, virtually
R2	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, physically
R3	**The system shall** allow users to book a visit virtually with their desired store.
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R15.2	**The system shall** unlock turnstiles after a unique QR code scan in exit
R15.3	**The system shall** lock the turnstiles after a push has occurred
R16	**The system shall** map the QR code of a scan to the virtual user who owns the QR code
R19	**The system shall** manage how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store
R20	**The system shall** calculate the maximum number of people allowed inside each store, as to allow for social distancing to take place
R23	**The system shall manage** how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store hourly, without exceeding the maximum calculated by the system
R27	**The system shall** allow store managers to input what categories of goods and what products are contained in the store
R28	**The system shall** allow store managers to input the dimensions of the store

We suppose that (**A2**, **A4**) users and employees will try to avoid staying close as to not maintain social distancing to any other user and employee inside the store. It is important that only one person enters the store per ticket (**A5**) so that the system can keep track of the number of people inside stores (**R13** – **R15.3**) through the scans and forced entrances and exits. The system forces entrances with the help of the planned visits of the store (booking or getting a ticket, (**R1-R3**).), maps the users to their QR code (**R16**, important for booked visits), whilst not exceeding the maximum number of entrances allowed in the store (**R19**, **R20**, **R23**) which is calculated with the help of the input from (**R27**, **R28**) the store manager, as to realize goal (**G3**).

G4	Everybody should be able to maintain social distancing in front of the stores.
A4	Users will abide to local norms on social distancing
A6	All people who are in front of the store have an appointment to enter the store within the next 10 minutes
R1	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, virtually
R2	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, physically
R3	**The system shall** allow users to book a visit virtually with their desired store.

Requirements (**R1**, **R3**) incite the users to not stand in front of the store needlessly and furthermore requirement (**R2**) in addition with the assumption (**A6**) that no person will stand in front of the store for more than 10 minutes prior to an expected entrance and that (**A4**) they will want to stand far enough from other people, as to have their own personal space. In this way the goal (**G4**) is fulfilled.

G5	Stores should allow as many customers inside as permitted by law, or as chosen by the store manager
A2	User which specified a shopping list will spend 90% of their time within that visit in the departments related to the declared list
A3	Data about the store's location, store departments and items collocation in departments are correct
R1	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, virtually
R2	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, physically
R3	**The system shall** allow users to book a visit virtually with their desired store.
R5	**The system shall** ask users how much he or she thinks the trip to the store will last
R9	**The system shall** allow its users to insert information about which categories or items they want to buy
R10	**The system shall** infer how long it will take for "Book a Visit" customers to buy the expressed shopping list
R11	**The system shall** store data about registered virtual users' habits of expenses
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R15.2	**The system shall** unlock turnstiles after a unique QR code scan in exit
R15.3	**The system shall** lock the turnstiles after a push has occurred
R23	**The system shall manage** how many people can enter inside the store for each timeslot, as to not exceed the maximum number of people allowed inside the store hourly, without exceeding the maximum calculated by the system
R27	**The system shall** allow store managers to input what categories of goods and what products are contained in the store

The requirements (**R1-R3**) provide a plan for the entrances allowed inside the store, and furthermore the requirements (**R5**, **R10**) will add a finer granularity of detail to the time users will spend inside stores. Other requirements (**R9**, **R11**) will help infer the time users will spend inside the store based on the average time previous users had spent to buy those products, supposing that the assumptions: (**A2**) users will stay in their own lane for most of their time inside the store and (**A3**) the data regarding the position of categories, items and the area surrounding the lane where the products are found, inserted through its related requirement(**R27**), are true. The requirements (**R13-R15.3**) enforce that only people who have QR code tickets will enter. The requirement (R23) verifies that the number of people inside the store will never exceed that applied by the law.

G6	Anyone who wants to book a visit to any store should decide their desired time and available day to go.
R3	**The system shall** allow users to book a visit virtually with their desired store.
R6	**The system shall** allow users to be identified by their phone unique ID
R7	**The system shall** allow users to be identified by a username of their choosing
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R16	**The system shall** map the QR code of a scan to the virtual user who owns the QR code

The requirements (**R3**, **R6**, **R7**) provide for the identification of the user as to allow the correct entrance through the store (**R13**, **R15.1, R16**), having satisfied the goal (**G6**).

G7	Anyone who wants to go in any store should not need to stand in queue in front of it.
R1	**The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, virtually
R3	**The system shall** allow users to book a visit virtually with their desired store.
R6	**The system shall** allow users to be identified by their phone unique ID
R7	**The system shall** allow users to be identified by a username of their choosing
R13	**The system shall** allow the user to scan its QR code in entrance through the turnstiles
R15.1	**The system shall** unlock turnstiles after a unique QR code scan in entrance
R16	**The system shall** map the QR code of a scan to the virtual user who owns the QR code

The requirements (**R1**, **R3**) allow users to skip going physically in front of the stores and instead plan a visit that will allow the user to enter the store (**R6**, **R7**, **R13**, **R15.1**, **R16**).

Sub-G8	The ability to know which stores are available to go to, on request
A3	Data about the store's location, store departments and items collocation in departments are correct
A5	Only one person will enter the store per ticket
R4	**The system shall** allow users to look up on a map available registered stores where to go to
R8.1	**The system shall** notify the user who is inactive while on the confirmation page of booking a ticket, on other available stores he could go to and other timeslots of the same store
R8.2	**The system shall** notify the user who is inactive while on the confirmation page of getting a ticket, on other available stores he could go to
R12.1	**The system shall** inform users periodically of the available time slots in the store for which he subscribed to the service
R12.2	**The system shall** allow its users to select which store(s) to get informed about
R12.3	**The system shall** allow its users to select which time slots he is interested to get informed about
R12.4	**The system shall** allow its users to select how often to get notified
R21	**The system shall** count the number of entrances and exits each day, for each market
R25	**The system shall** allow store managers to register their stores
R26	**The system shall** allow store managers to input the store's location

Supposing that the monitoring of entrances and exits (**R21**, **A5**, **A3**) works correctly as specified in the goals above, the requirements (**R4**, **R8.1**, **R8.2, R12.1-R12.4**) provide to the user a way to check and be notified of all the registered stores (**R25**) that have available spaces and their locations (**R26**). fulfilling sub-goal (**Sub-G8**).

Sub-G9	Customers should reach the shop at the arranged time.
A1	Users will take the shortest path to shops
A3	Data about the store's location, store departments and items collocation in departments are correct
R17	**The system shall** send a reminder to the user when it is time for him to leave so that he can arrive at the store in time
R18	**The system shall** calculate the time it takes the user to go to a shop in which he has an appointment
R26	**The system shall** allow store managers to input the store's location

Assuming that (**A1**) users will take the shortest path to the store, and the location inserted through the requirement (**R26**) is correct (**A3**), the system reminds the user that they need to leave (**R17**) based on the distance between the location of the user and that of the store (**R18**). In this way the sub-goal (**sub-G9**) is accomplished.

B.2) Use Cases

B.2.1) Register Account

Actors	Virtual User
Entry condition	No entry condition
Events flow	1) The user opens the CLup app on his smartphone and clicks on the *"Create account"* button. 2) The user fills all the mandatory fields. 3) The user clicks on the *"Confirm"* button. 4) The user receives a notification confirming the registration.
Exit condition	Virtual User's data are saved into the database and the registration terminates successfully
Exceptions	1) The user chooses an already registered username or email 2) The user does not fill one or more mandatory fields 3) The use inserts not valid information in one or more fields For all the exceptions the system notifies the user that an error has occurred. The *Events flow* starts again from point 2.

B.2.2) Login into Account

Actors	Virtual User
Entry condition	The virtual user is already into the CLup app homepage
Events flow	1) If the user wants to login as a guest, he directly selects either "Get a ticket" or "Book a visit" button, otherwise he inserts username and password into the "Username" and "Password" fields, respectively. 2) The user clicks on the "Login" button. 3) The system redirects the user to the CLup app homepage
Exit condition	The virtual user is successfully redirected to the CLup app homepage
Exceptions	1) The virtual user clicks on the "Login" button but either the username or the password is wrong. The system notifies the user about the error. The Events flow starts again from point 1.

B.2.3) Get Physical Ticket

Actors	Physical User
Entry condition	The user is in front of the ticket dispenser of the store where he would want to do the shopping
Events flow	1) The user clicks on the "Get ticket" button 2) The user visualizes through the ticket dispenser's screen the first available time slot. 3) The user clicks on the "Confirm" button 4) The ticket dispenser gives out to the user the physical ticket containing: a) The provided time slot. b) The store's name and address. c) The QR code to enter (and exit) the store.
Exit condition	The user successfully receives the physical ticket.
Exceptions	1) The user refuses the provided time slot clicking on the "Cancel" button. The ticket is not dispensed. The user either goes away or starts again the procedure to get a physical ticket (Events flow restarts from event 1).

B.2.4) Get Virtual Ticket

Actors	Virtual User
Entry condition	The virtual user is already logged into CLup app or he wants to access as a guest
Events flow	1) The user selects the *"Get a ticket"* button. 2) The system redirects the user to a page where he can select the store where he would want to go (from a map). 3) The user selects a store from the map. 4) The system provides the first available time slot for the selected store. 5) The user clicks on the *"Confirm"* button. 6) The system notifies the user that the procedure has been successfully managed. 7) The system sends to the user the virtual ticket containing: d) The provided time slot. e) The store's name and address. f) The QR code to enter (and exit) the store.
Exit condition	The user successfully receives the virtual ticket.
Exceptions	1) The user refuses the provided time slot clicking on the *"Cancel"* button. The system redirects the user to the homepage (*Events flow* starts again from event 1).

B.2.5) Suggestion Alternative Stores (Get Virtual Ticket)

Actors	Virtual User
Entry condition	The virtual user is already logged into CLup app or he wants to access as a guest
Events flow	1) The first four events are the same of the *"Get Virtual Ticket"* use case. 2) The user becomes inactive 3) The system notifies to the user the possibility to check among a list of further suggested stores. 4) The user clicks on the received notification. 5) The system provides to the user a list with further available stores with an available time slot preceding the already provided one.
Exit condition	The user successfully receives the list of further suggested stores.
Exceptions	1) The user clicks on the *"Confirm"* button without becoming inactive The *Events flow* proceeds from event 6 of *"Get Virtual Ticket"* use case. 2) The user does not click on the notification. The user can only confirm or reject the provided time slot for the selected store (the *Events flow* proceeds from event 5 of *"Get Virtual Ticket"* use case).

B.2.6) Book Visit

Actors	Virtual User
Entry condition	The virtual user is already logged into CLup app or she wants to access as a guest
Events flow	1) The user selects the *"Book a visit"* button. 2) The system redirects the user to a page where she can select the time slot or the store where she would want to go (from a map) 3) a) The user selects the time slot, the system provides, through the map, the stores closest to the user's current position. b) The user selects a store from the map, the system provides the list of available time slots. 4) The user selects either a store from the map (case a) or a time slot (case b), then she clicks on the *"Confirm"* button. 5) The system redirects the user to a page where she can indicate the approximate expected duration of the visit, the exact list of items and the categories of items she intends to purchase. 6) The user optionally fills the previous fields, then she clicks on the *"Confirm"* button. 8) The system notifies the user that the procedure has been successfully managed. 9) The system sends to the user the virtual ticket containing: a) The user's selected time slot. b) The store's name and address. c) The QR code to enter (and exit) the store.
Exit condition	The user successfully receives the virtual ticket.
Exceptions	1) The user clicks on the *"Cancel"* button. The system redirects the user to the homepage (*Events flow* starts again from event 1). 2) The user's GPS is unavailable (case 3.a). The system asks the user to insert an address and provides the stores closest to the user's address (*Events flow* continues from event 4).

B.2.7) Suggestion of Alternative Time Slots (Book visit)

Actors	Virtual User
Entry condition	The virtual user is already logged into CLup app or she wants to access as a guest
Events flow	1) The first three events are the same of the *"Book visit"* use case (the user selects a store: case 3.b). 2) The user becomes inactive 3) The system notifies to the user the possibility to check available time slots of further suggested stores. 4) The user clicks on the received notification. 5) The system provides to the user a list of available time slots of further suggested stores close to selected one.
Exit condition	The user successfully receives the list of available time slots.
Exceptions	1) The user selects a provided time slot without becoming inactive The *Events flow* proceeds from event 5 of *"Book visit"* use case. 2) The user does not click on the notification. The user can only select the initial provided time slots (the *Events flow* proceeds from event 4 of *"Book visit"* use case).

B.2.8) Suggestion of Alternative Stores (Book visit)

Actors	Virtual User
Entry condition	The virtual user is already logged into CLup app or she wants to access as a guest
Events flow	1) The first three events are the same of the *"Book visit"* use case (the user selects a time slot: case 3.a). 2) The user becomes inactive 3) The system notifies to the user the possibility to lookup further available stores for the selected time slot. 4) The user clicks on the received notification. 5) The system provides to the user a list with further available stores.
Exit condition	The user successfully receives the list of further available stores.
Exceptions	1) The user selects a provided store without becoming inactive The *Events flow* proceeds from event 5 of *"Book visit"* use case. 2) The user does not click on the notification. The user can only select the initial provided stores (the *Events flow* proceeds from event 4 of *"Book visit"* use case).

B.2.9) Enter/Exit Store

Actors	User, Cashier
Entry condition	The user, after he has been notified by the app, reaches the store indicated in his ticket
Events flow	1) The user scans his QR code through the QR code reader of the turnstile in entrance. 2) The user enters the store. 3) The user does the shopping. 4) The user pays at the cash register. 5) The cashier scans the QR code of the user's ticket though the QR code reader of the cashier desk 6) The user exits the store
Exit condition	The user successfully enters/exits the store.
Exceptions	1) The user tries to enter in the store by scanning a ticket after the maximum acceptable delay that is indicated in his ticket has passed. The user either gets a physical ticket (see "Get physical ticket" use case) or goes away. 2) The user does not buy anything. The user exits the store scanning his QR code through the QR code reader of the turnstile in exit. 3) After the user enters the store, his physical ticket is lost, or his virtual ticket becomes unavailable. The user exits the store, without scanning the QR code, after asking for assistance from a cashier or a manager inside the store. Moreover, the ticket is considered scanned after a time equal to the system's estimated average duration of a grocery shop trip plus a delay that takes into account for people long-duration trips.

B.2.10) Periodic Notification of Time Slots

Actors	Virtual User
Entry condition	The virtual user is already logged into CLup app or she wants to access as a guest
Events flow	1) The user accesses the notification panel. 2) The user selects one or more stores she wants to be notified about. 3) The user selects a day or a time range. 4) The user selects how often she wants to be notified. 5) The user clicks on the *"Confirm"* button. 6) The system notifies the user that the procedure has been successfully completed.
Exit condition	The user's notification preferences are correctly updated.
Exceptions	

B.2.11) Monitor Entrances

Actors	Store Manager
Entry condition	The store manager access CLup app through an authorized account.
Events flow	1) The store manager selects a store between those he manages. 2) The system redirects the store manager to a page where he can: a) See the statistics about entrances of the selected store. b) Regulate the influx of people entering the store by setting a parameter.
Exit condition	The store manager can see the statistics and regulate the influx of people entering the selected store
Exceptions	

B.2.12) Register Store

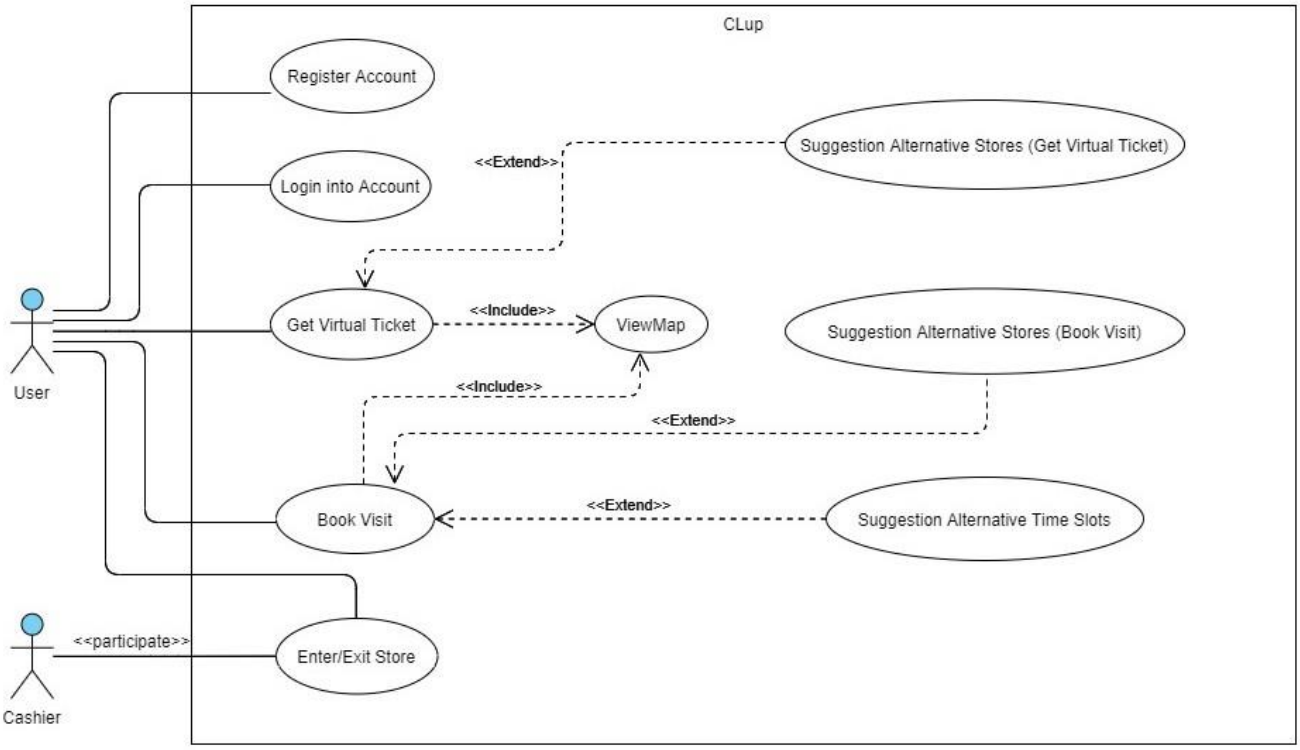
Actors	Store Manager
Entry condition	The store manager access CLup app through an authorized account.
Events flow	1) The store manager clicks on the *"Add store"* button. 2) The system redirects the store manager to a page where he can add a store. 3) The store manager inserts the store's name. 4) The store manager inserts the store's location. 5) The store manager inserts the store's dimension. 6) The store manager inserts what categories of goods and what products are contained in the store. 7) The systems notifies the store manager that the registration has been completed successfully.
Exit condition	The store manager has successfully registered the store.
Exceptions	1) One ore more input inserted by the store manager are invalid. The system notifies the store manager that an error has occurred. The *Events Flow* starts again from event 3.

B.2.13) Use case to functional requirement mapping:

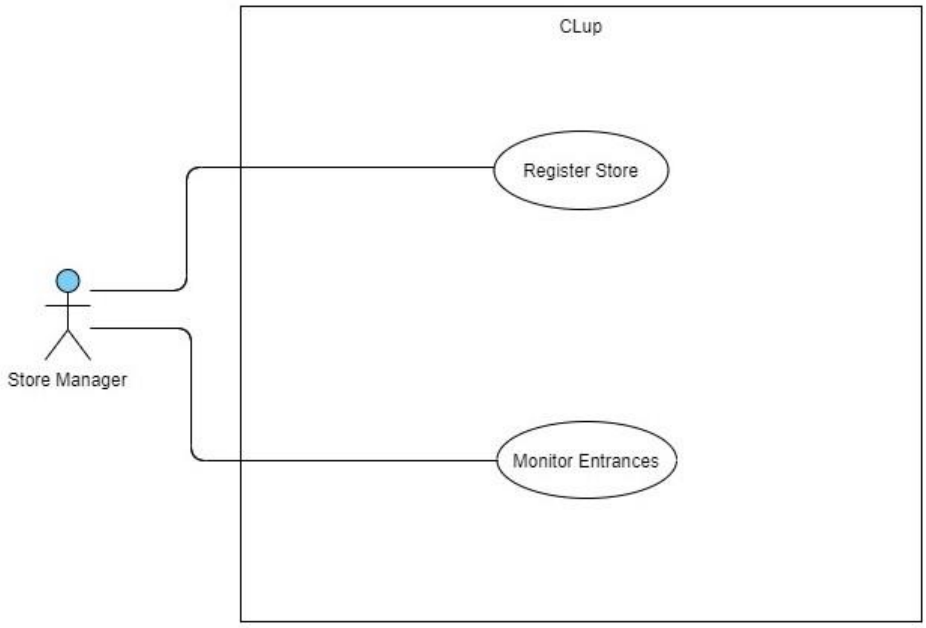
1)Register Account	R7) **The system shall** allow users to be identified by a username of their choosing
2)Login into account	R7) **The system shall** allow users to be identified by a username of their choosing
3)Get Physical Ticket	R2) **The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, physically
4)Get Virtual Ticket	R1) **The system shall** allow users to get a ticket with a date and time that shows when to go to a certain store, virtually R4) **The system shall** allow users to look up on a map available registered stores where to go to
5) Suggestion Alternative Stores (Get Virtual Ticket)	R8.2) **The system shall** notify the user who is inactive while on the confirmation page of getting a ticket, on other available stores he could go to
6)Book Visit	R3) **The system shall** allow users to book a visit virtually with their desired store. R4) **The system shall** allow users to look up on a map available registered stores where to go to R5) **The system shall** ask users how much he or she thinks the trip will last R9) **The system shall** allow its users to insert information about which categories or items they want to buy
7) Suggestion of Alternative Time Slots (Book visit)	R8.1) **The system shall** notify the user who is inactive while on the confirmation page of booking a visit, on other available stores he could go to and other timeslots of the same store
8) Suggestion of Alternative Stores (Book visit)	R8.1) **The system shall** notify the user who is inactive while on the confirmation page of booking a visit, on other available stores he could go to and other timeslots of the same store
9)Enter/Exit Store	R13) **The system shall** allow the user to scan its QR code in entrance through the turnstiles R14) **The system shall** allow the user to scan its QR code in exit through the turnstiles or cash register
10) Periodic Notification of Time Slots	R12.1) **The system shall** inform users periodically of the available time slots in the store for which he subscribed to the service (R12.2, R12.3, R12.4)
11)Monitor Entrances	R22) **The system shall** allow store managers to regulate the number of entrances allowed in the store hourly. R24) **The system shall** allow store managers to see how many customers have entered the store in any day.
12)Register store	R25) **The system shall** allow store managers to register their stores R26) **The system shall** allow store managers to input the store's location R27) **The system shall** allow store managers to input what categories of goods and what products are contained in the store R28) **The system shall** allow store managers to input the dimensions of the store

B.3) Use Case Diagrams

B.3.1) User use case diagram

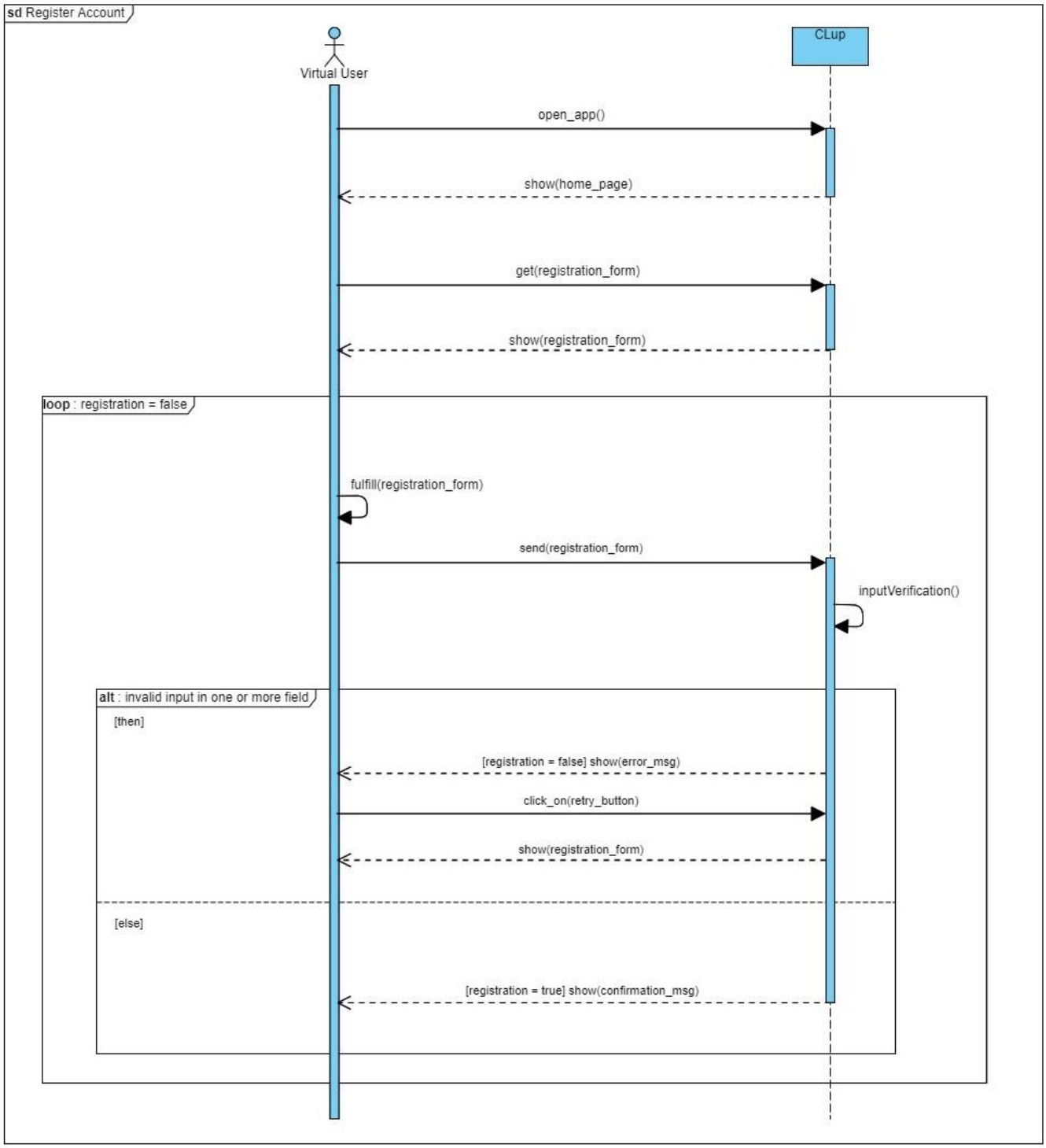


B.3.2) Store Manager use case diagram

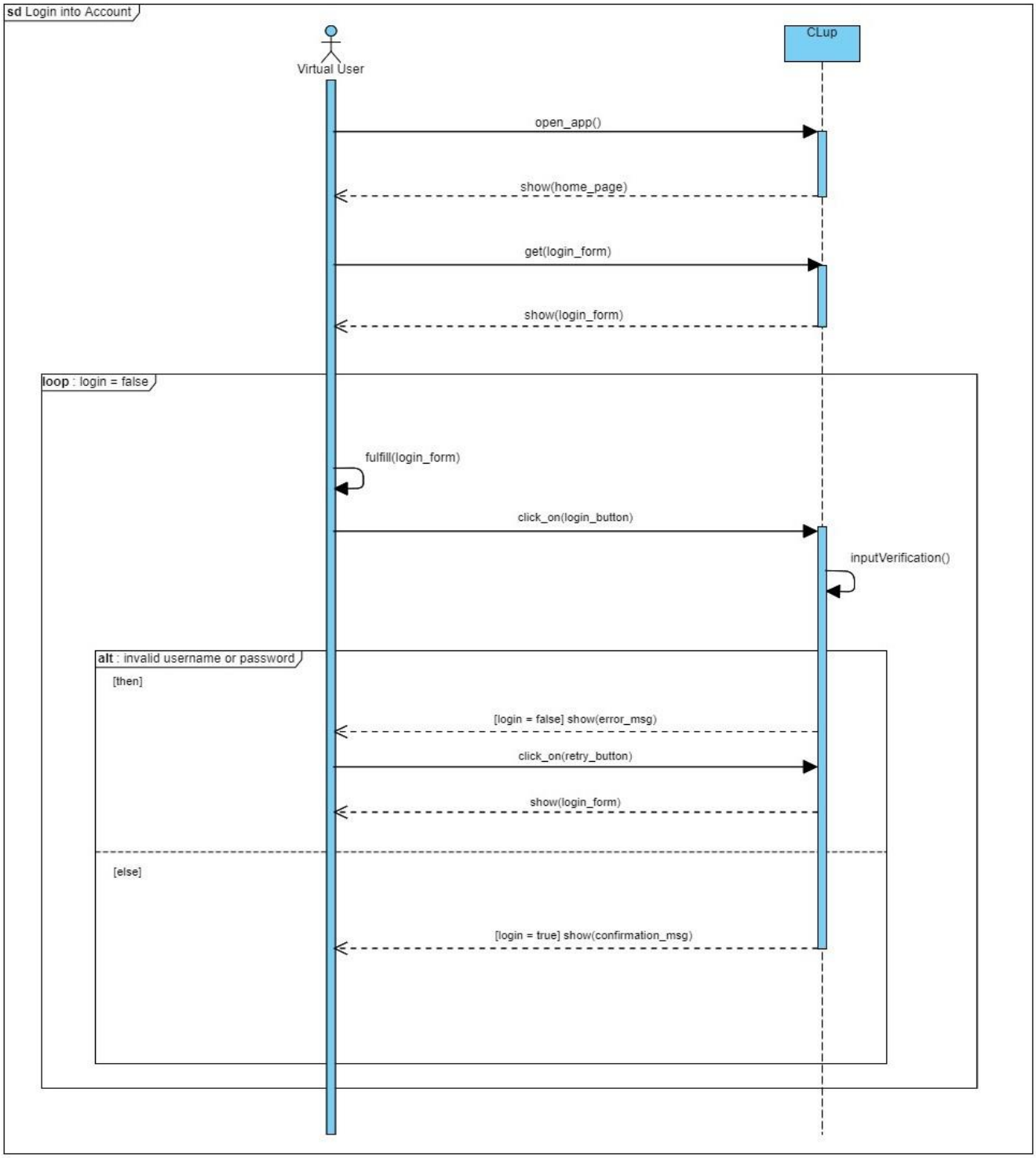


B.4) Sequence Diagrams

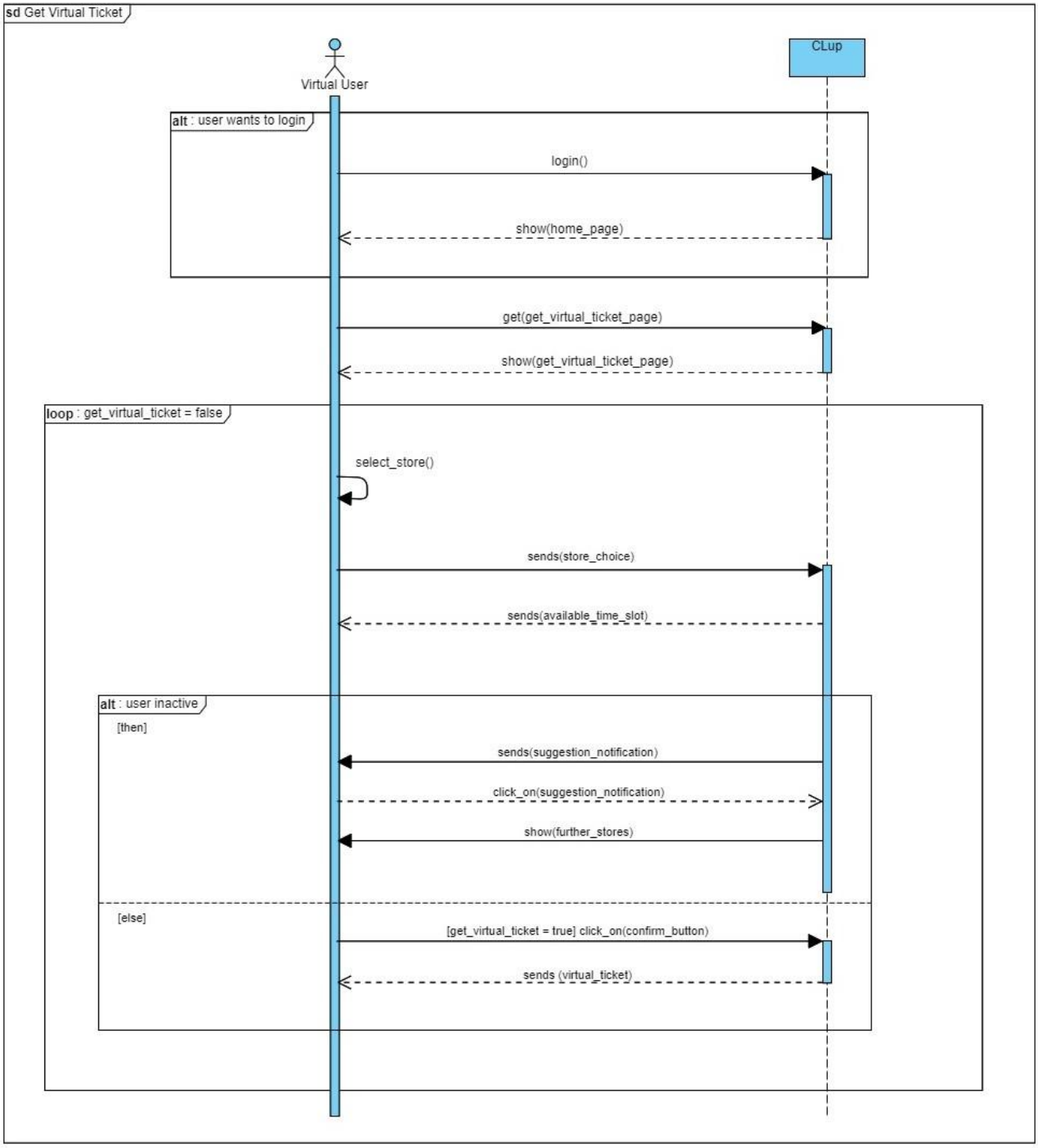
B.4.1) Register Account



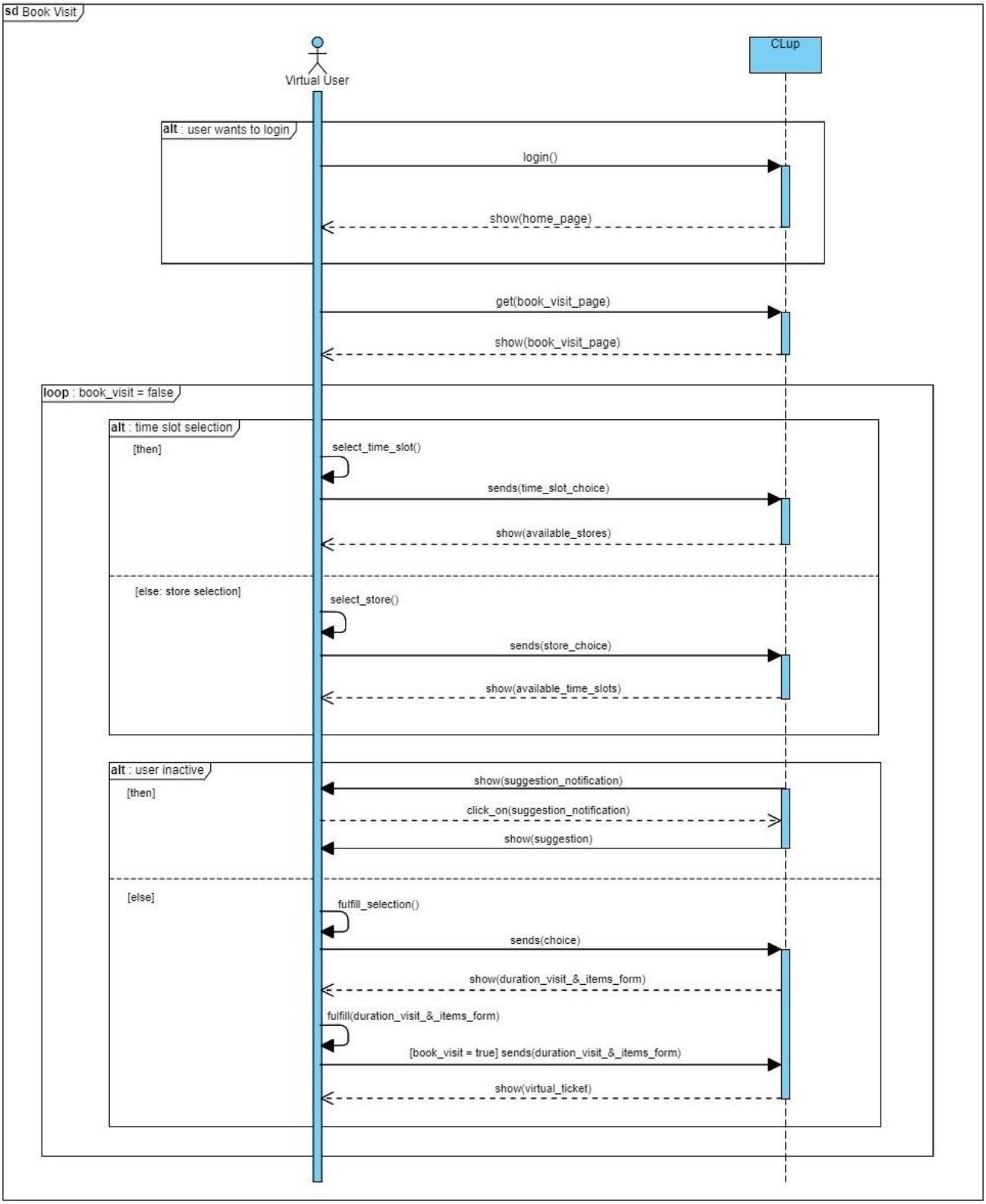
B.4.2) Login into Account



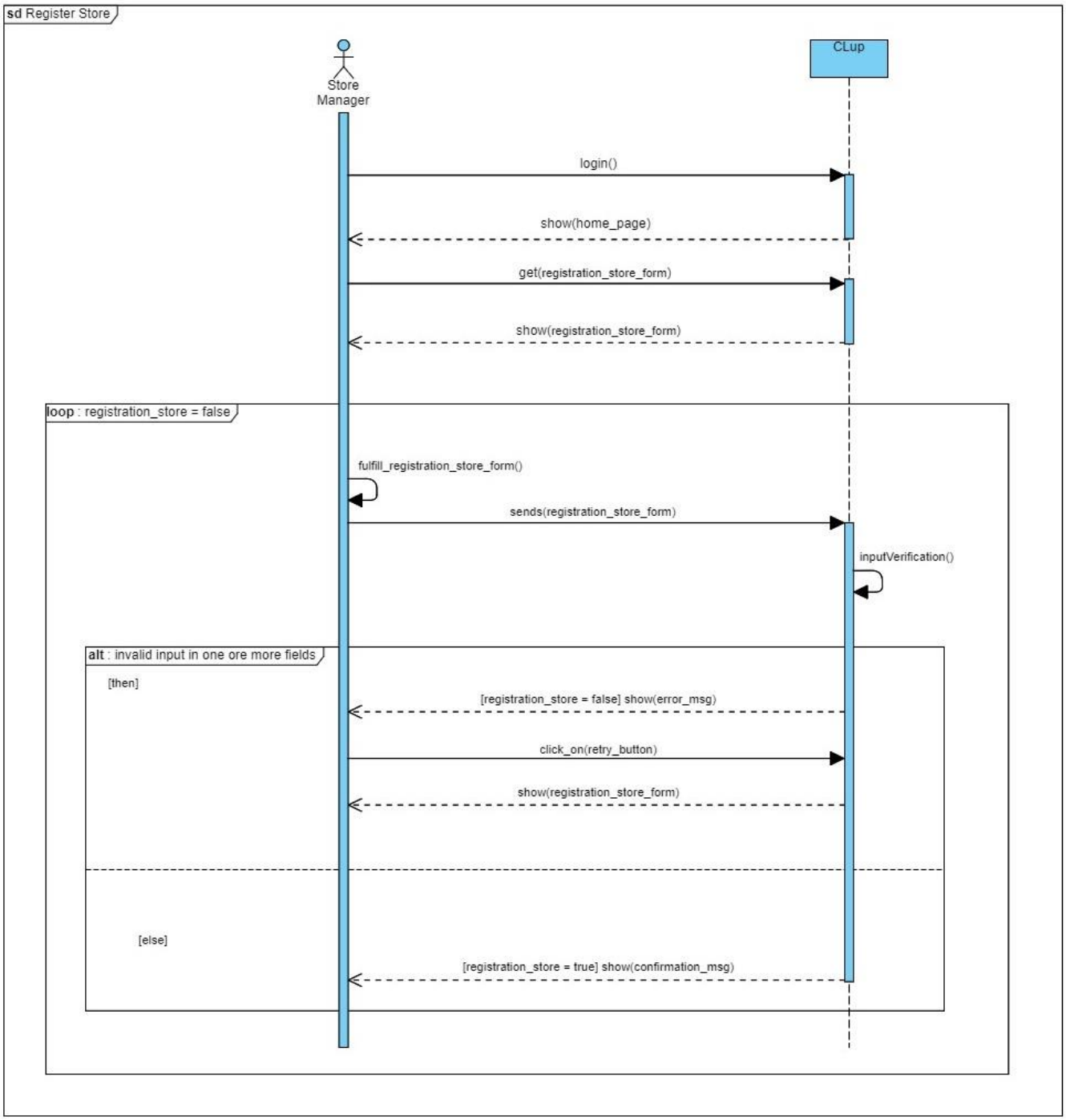
B.4.3) Get Virtual Ticket



B.4.4) Book Visit



B.4.5) Register Store



C) Performance Requirements:

On the basis of studies done by ISTAT on the Italian number of population and by the US government on the habits of customers of grocery shops (references in point 6 of document), we extract some main points needed on the calculation of the performance requirements. These main points are:

i) *There are around 750 thousand families in Milan only.*
ii) *There are around 25 million families in Italy.*
iii) *On average Saturday sees more families go grocery shopping (from 10% to 40% more)*
    (1) *In the US from 29-30 million go on a weekday, while on the weekend 33-41 million families go grocery shopping*
iv) *The average family goes grocery shopping 1.6 times a week as of 2019*

Based on this information we can deduce that on the worst case the system to be will have to manage on peak hours 360 thousand users contemporarily in one hour in Italy.

Since it is important to have fast responses to users' requests, a response time to any request, comprising those of the external API's should be under 0.5 seconds.

D) Design Constraints:

D.1) Software Compliance:

The software will comply with local laws regarding COVID-19 and its safety related regulations.

Furthermore, the software will comply with local laws about data treatment and usage such as the EU General Data Protection Regulation GDPR 2016/679.

D.2) Hardware Limitations:

There are inherent hardware limitations in which the system will find itself. Indeed, it is important for the software to be designed in a way that keeps count of its portability. This way it will need to be run on computationally weak (old) devices too.

E) Software System Attributes:

E.1) Reliability:

The system will have to handle up to 10% more requests with respect to the worst-case scenario defined in the Performance Requirements section.

E.2) Availability:

Because of the system's importance on the provision of social distancing for one of the most crucial aspects of our lives, it will have to be up for 99.9% of the time. (Downtime: less than 9 hours)

E.3) Security:

Security is important for the sole reason of the registered virtual users' passwords that will have to be stored. Since these passwords might be shared with other applications or programs with more sensitive data, the passwords should be encrypted with up-to-date technologies. All data should be stored in compliance with GDPR's regulation.

E.4) Maintainability:

The system-to-be has a strong need of maintainability and extendibility because of its nature. The core system will have to adapt to many different countries' laws so the most important aspect will be its reusability of logical components such as the booking aspect or the queue managing.

E.5) Portability:

Since the goal is to make it easy for all people to use our system-to-be, it must be operatable in different operating system environments.

4. FORMAL ANALYSIS USING ALLOY

4.1 Objectives

The following alloy formal analysis has the goal to prove the correct functionality and the formal proof of some of the defined goals for the proposed system. We focus on:

- (**G3**) The goal of user's safety inside store, modelled as the ability of the system to grant that the maximum number of people inside the store in never exceeded nor tickets are given when the maximum is reached, and given the assumption that people will behave with respect to the local norms (**A4**).
- (**G6**, **G7**) The goals of the users about being able to get tickets and visits in available time slots, so that they do not need to line up in front of the store. These goals are modelled through predicates, showing the correct working of the system, that can give tickets to users both physically through a dispenser and virtually through their devices. Moreover, the advanced functionality of booking a visit is modelled too, with the user choosing both the date and the time slot. The system is shown to work correctly giving tickets only for available time slots.
- (**G1**, **G2**) The goals about the shop manager being able to track and regulate the influx of people in the store. This is modelled through a ticket system, that allows to monitor and regulate the maximum number of people admitted inside the store at each timeslot and the current general situation about tickets.
- The soundness of the proposed system, showing that users cannot shop without having their entrance monitored, thus they cannot shop without a ticket or a visit booked. This is modelled with a predicate. The model also considers possible particular cases as the fact that users could lose their ticket after the entrance, with the system recognizing this and correctly considering concluded such a ticket after the end of its time slot.

4.2 Alloy Code

In the next pages is reported the Alloy code used to generate the world. In the code there are, in order:

- *Signatures*
- *Utilities*
- *Facts*
- *Assertions and Predicates*

```
sig Market{
dispensers: some TicketDispenser,
cashDesks: some CashDesk,
entrances: some QRCodeReader,   //Representing the entrance of the market
freeExit: some QRCodeReader,    //No purchases exit
manager: one StoreManager,
departments: set Department,
ticketManager : one TicketSystem
}{
freeExit & entrances  = none
freeExit & cashDesks.reader = none
entrances & cashDesks.reader = none
}

sig TicketSystem{
maxUsersPerSlot: one Int,
insideMarket: set Ticket,
line: set Ticket,
pastTickets: set Ticket,
currentTimeSlot: one TimeSlot,
currentDate: one Date,
availableSlots: Date -> TimeSlot
}{ //no ticket is in more different states at the same time
#(insideMarket & line)=0
#(insideMarket & pastTickets)=0
#(line & pastTickets)=0
//all tickets insideMarket are tickets booked for the current Date and Time Slot
all t: Ticket |
        t in insideMarket implies (t.ticketDate = currentDate and t.ticketTimeSlot = currentTimeSlot)
//Available Dates and Time Slots are the ones for which the number of tickets is less than the max number admitted and
//that are not Dates or Slots different from the current for which there are already past tickets
all d:Date, ts:TimeSlot |
        (d->ts) in availableSlots iff
                (#((insideMarket + line) &  ticketDate.d & ticketTimeSlot.ts) < maxUsersPerSlot and
        no t: Ticket |
                t in pastTickets and
                (t.ticketDate ≠ currentDate and
                        d=t.ticketDate or
                        t.ticketTimeSlot ≠ currentTimeSlot and
                        d=t.ticketDate and ts=t.ticketTimeSlot))
maxUsersPerSlot > 0
}

sig TicketDispenser{
distributedTickets: set PhysicalTicket
}

sig QRCode{}

sig QRCodeReader{
scanned: set QRCode
}

sig CashDesk{
reader: one QRCodeReader
}

sig StoreManager{}

abstract sig SafetyStatus{}
one sig Safe extends SafetyStatus{}
one sig UnSafe extends SafetyStatus{}

abstract sig User {
userStatus: one SafetyStatus
}
sig VirtualUser extends User{
userVTickets: set VirtualTicket,
userVisits: set Visit,
userDevice: some SmartDevice
}

sig PhysicalUser extends User{
userPTickets: set PhysicalTicket
}

sig Date{}
sig TimeSlot{}

abstract sig Ticket{
ticketDate: one Date,
ticketTimeSlot: one TimeSlot,
ticketCode: one QRCode
}



sig PhysicalTicket extends Ticket{}
sig VirtualTicket extends Ticket{}
```

```
sig Visit extends Ticket{
shoppingListCategories : set Category,
shoppingListItems : set Item
}

sig Item{}

sig Category{
products: some Item
}

sig Department{
categories: some Category
}

sig SmartDevice{
localizationDevice: lone GPS
}

sig GPS{}



//////////////UTILITIES//////////////

//gets all the qr code readers that scanned the given ticket
fun scannedBy[t: Ticket] : set QRCodeReader {
 scanned.(t.ticketCode)
}

//gets all tickets managed by the given ticket system
fun getAllTickets[ts: TicketSystem] : set Ticket {
 ts.insideMarket + ts.line + ts.pastTickets
}

//gets all the visits and tickets of the given virtual user
fun getVUserTicketsAndVisits[u: VirtualUser] : set Ticket {
u.(userVTickets + userVisits)
}

//gets the ticket that manages the given ticket
fun getTicketManager[t: Ticket] : one TicketSystem{
(line + insideMarket + pastTickets).t
}



//checks if the two markets are the result of a new ticket insertion
pred checkEqualStateMarketPlusNewTicket[t: Ticket, m,m1 : Market]{
m1.ticketManager.(pastTickets + insideMarket) = m.ticketManager.(pastTickets + insideMarket)  and
m1.ticketManager.line= m.ticketManager.line + t and
m1.dispensers=m.dispensers and
m1.cashDesks=m.cashDesks and
m1.entrances=m.entrances and
m1.freeExit=m.freeExit and
m1.manager=m.manager and
m1.departments=m.departments
}

//checks if the two users are the result of a new virtual ticket insertion
pred checkEqualStateVUserPlusNewTicket[t: VirtualTicket, u,u1: VirtualUser]{
u1.userVTickets=u.userVTickets + t and
u1.userVisits = u.userVisits and
u1.userDevice = u.userDevice
}

//checks if the two users are the result of a new visit insertion
pred checkEqualStateVUserPlusNewVisit[v: Visit, u,u1: VirtualUser]{
u1.userVTickets=u.userVTickets  and
u1.userVisits = u.userVisits + v and
u1.userDevice = u.userDevice
}

//checks if the two users are the result of a new physical ticket insertion
pred checkEqualStatePUserPlusNewTicket[t:PhysicalTicket, u,u1:PhysicalUser]{
u1.userPTickets=u.userPTickets + t
}

//////////////FACTS//////////////

//No market gives more tickets per time slot than the max allowed by the shop manager
fact{
all m: Market, d: Date, t: TimeSlot |
        let marketTickets=  getAllTickets[m.ticketManager] |
                #(marketTickets & ticketDate.d & ticketTimeSlot.t) ≤ m.ticketManager.maxUsersPerSlot
}
```

```
//definition of user safety
fact{
all vu: VirtualUser |
        vu.userStatus = Safe iff
                (no t: Ticket, ts: TicketSystem  |
                        t ≠ none and
                        t in (vu.userVTickets + vu.userVisits) and
                        t in ts.insideMarket and
                        #(ts.insideMarket) > ts.maxUsersPerSlot )
all pu: PhysicalUser |
        pu.userStatus = Safe iff
                (no t: Ticket, ts: TicketSystem  |
                        t ≠ none and
                        t in pu.userPTickets and
                        t in ts.insideMarket and
                        #(ts.insideMarket) > ts.maxUsersPerSlot )
}

//each ticket can be scanned at most 2 times:
//2 times is a past ticket that has entered and exited
//1 time is only entered
//0 times is in line
fact {
all t:Ticket |
        #scannedBy[t] ≤ 2
        and
        //ticket is past if scanned 2 times, at entrance and at exit
        ((#scannedBy[t]  = 2 ) implies ( let ts = getTicketManager[t] |
                t in ts.pastTickets and
                #(scannedBy[t]  & (ticketManager.ts).entrances) = 1 and
                #(scannedBy[t]  & ((ticketManager.ts).freeExit + (ticketManager.ts).cashDesks.reader)) = 1))
        and
        //ticket is inside if it has been scanned 1 time at entrance
        (#scannedBy[t]  = 1  iff let ts =  getTicketManager[t] |
                t in ts.insideMarket and
                #(scannedBy[t]  & (ticketManager.ts).entrances) = 1 )
        and
        //ticket is in line if it has been scanned 0 times and it is not referring to a past Date:
        //if the latter is true then the ticket is past(ticket invalidated because of user not presenting)
        (#scannedBy[t]  = 0 implies
                ((no t1: Ticket |
                        t1 ≠ t and
                        getTicketManager[t1] = getTicketManager[t]  and
                        t1 in getTicketManager[t1].pastTickets and
                        #scannedBy[t1]  = 2 and
                        (t1.ticketDate ≠ getTicketManager[t1].currentDate and
                                t.ticketDate = t1.ticketDate or
                                t1.ticketTimeSlot ≠ getTicketManager[t1].currentTimeSlot and
                                t.ticketDate = t1.ticketDate and
                                t.ticketTimeSlot=t1.ticketTimeSlot ))
                implies
                t in getTicketManager[t].line
                else
                t in  getTicketManager[t].pastTickets))
}

//each physical ticket is generated by one dispenser belonging to the ticket's market
fact{
all pt: PhysicalTicket |
        one d: TicketDispenser |
                pt in d.distributedTickets and
                dispensers.d = ticketManager.((line + insideMarket + pastTickets).pt)
}

//no same Ticket in two different markets' TicketSystem, in any of the states (inside, past, in line)
fact {
no disj ts1,ts2: TicketSystem |
         #( getAllTickets[ts1] & getAllTickets[ts2]) ≠ 0
}

//no same dispenser/cash desks/departments/ticketManager for disjoint markets
fact {
no disj m1,m2: Market |
        #(m1.dispensers & m2. dispensers +
                m1.cashDesks & m2.cashDesks +
                m1.departments & m2.departments +
                m1.ticketManager & m2.ticketManager) ≠ 0
}

//each ticket has a different QRCode
fact {
no disj t1,t2: Ticket |
         #(t1.ticketCode & t2.ticketCode)≠ 0
}

//each category is associated to a Department in each Market
fact{
all disj d1,d2: Department |
        departments.d1 = departments.d2 implies no c: Category |
                c in d1.categories and c in d2.categories }
```

```
//different markets have no same QRcodeReader
fact{
all disj m1,m2: Market |
        (m1.freeExit + m1.entrances + m1.cashDesks.reader)&(m2.freeExit + m2.entrances + m2.cashDesks.reader) = none
}

//each Device has a different GPS device
fact {
all disj d1,d2: SmartDevice |
        (d1.localizationDevice ≠ none and d2.localizationDevice ≠ none)
        implies
        d1.localizationDevice ≠ d2.localizationDevice
}

//each ticket system is associated to one and only one market
fact{
all t: TicketSystem |
        #(ticketManager.t) = 1
}

//eachQRCodeReader is associated to a desk, an entrance or an exit
fact {
all qr: QRCodeReader | #(freeExit.qr + entrances.qr + reader.qr) = 1
}

//each QRCode is associated to one ticket
fact{
all c: QRCode | #(ticketCode.c) = 1
}

//each ticket dispenser is associated to one market
fact{
all td: TicketDispenser | #(dispensers.td) = 1
}

//each category is associated at least to one department
fact{
all c: Category | #categories.c ≥ 1
}

//each cashDesk is associated to one market
fact{
all cd: CashDesk | #(cashDesks.cd) = 1
}

//each department is associated to one market
fact{
all d: Department | #(departments.d) = 1
}

//each item is associated to one category
fact{
all i: Item | #(products.i) = 1
}

//each GPS is associated to a SmartDevice
fact {
all g: GPS | #(localizationDevice.g) =1
}

//each SmartDevice is associated to a Virtual User
fact {
all sd: SmartDevice | #(userDevice.sd) =1
}

//each ticket of any type belongs to a correct type of user
fact{
all vt: VirtualTicket |  #(userVTickets.vt) = 1
all pt: PhysicalTicket | #(userPTickets.pt) = 1
all vs: Visit | #(userVisits.vs) = 1
}
```

```
//////////////ASSERTIONS AND PREDICATES//////////////

//G3. User inside stores are safe
assert allUsersInsideStoresAreSafe{
all u: User | u.userStatus= Safe
}

//G5.   If there are avavilable time slots in the current date, user can get a ticket and be put in line
pred vUserGetsTicket[m,m1: Market, u,u1: VirtualUser]{
some ts: TimeSlot |
        ts in m.ticketManager.currentDate.(m.ticketManager.availableSlots) and
        some t: Ticket | t.ticketDate = m.ticketManager.currentDate and
        t.ticketTimeSlot = ts and
        t in m1.ticketManager.line and
        checkEqualStateMarketPlusNewTicket[t, m,m1] and
        checkEqualStateVUserPlusNewTicket[t, u,u1]
}

//G5.   If there are available time slots in the current date, physical user can get a ticket from the dispenser
pred pUserGetsTicket[m,m1: Market, u,u1: PhysicalUser]{
some ts: TimeSlot |
        ts in m.ticketManager.currentDate.(m.ticketManager.availableSlots) and
        some t: Ticket |
                t.ticketDate = m.ticketManager.currentDate and
                t.ticketTimeSlot = ts and
                t in m1.ticketManager.line and
                m1.dispensers.distributedTickets = m.dispensers.distributedTickets+t and
                checkEqualStateMarketPlusNewTicket[t, m,m1] and
                checkEqualStatePUserPlusNewTicket[t, u,u1]
}

//G6.   If the selected date and time slot are available, virtual user can book a visit in that date and time slot
pred vUserBooksVisit[m,m1: Market, u,u1: VirtualUser,ts: TimeSlot, d: Date]{
        (d->ts) in m.ticketManager.availableSlots and
        some v: Visit |
                v.ticketDate = d and v.ticketTimeSlot = ts and
                checkEqualStateVUserPlusNewVisit[v,u,u1] and
                checkEqualStateMarketPlusNewTicket[v,m,m1]
}

//User cannot shop whitout having registered their entrance scanning QRCode
assert  noExitWithoutEntering{
no t: Ticket |
        (one qrReader: QRCodeReader |
                t.ticketCode in qrReader.scanned and
                qrReader in (Market.freeExit + Market.cashDesks.reader)) and
                no qrReader: QRCodeReader |
                        t.ticketCode in qrReader.scanned and
                        qrReader in Market.entrances
}

run vUserGetsTicket for 5
run vUserBooksVisit for 5
run pUserGetsTicket for 5
check noExitWithoutEntering for 5
check allUsersInsideStoresAreSafe for 5
```

4.3 Results

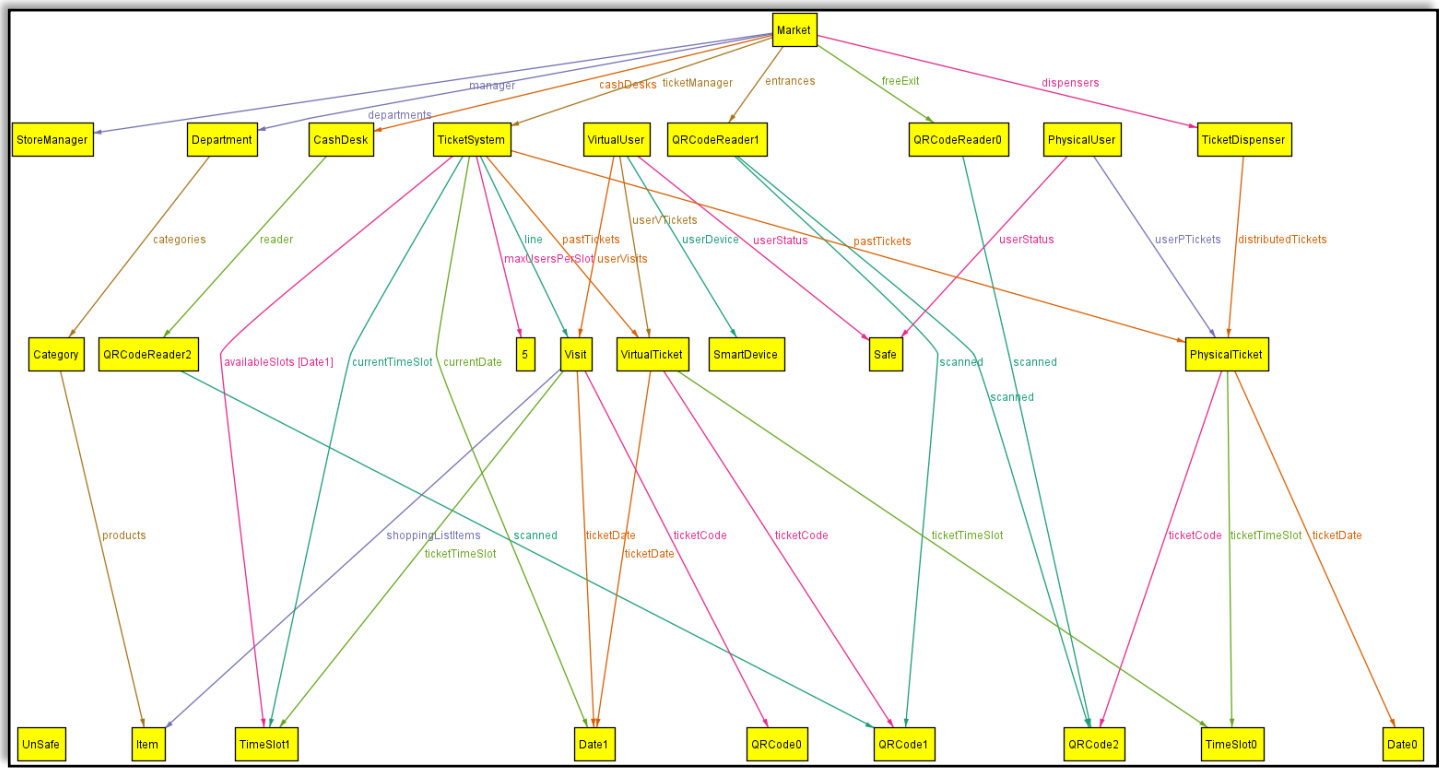
run vUserGetsTicket for 5
run vUserBooksVisit for 5
run pUserGetsTicket for 5
check noExitWithoutEntering for 5
check allUsersInsideStoresAreSafe for 5

5 commands were executed. The results are:

#1: Instance found. vUserGetsTicket is consistent.
#2: Instance found. vUserBooksVisit is consistent.
#3: Instance found. pUserGetsTicket is consistent.
#4: No counterexample found. noExitWithoutEntering may be valid.
#5: No counterexample found. allUsersInsideStoresAreSafe may be valid.

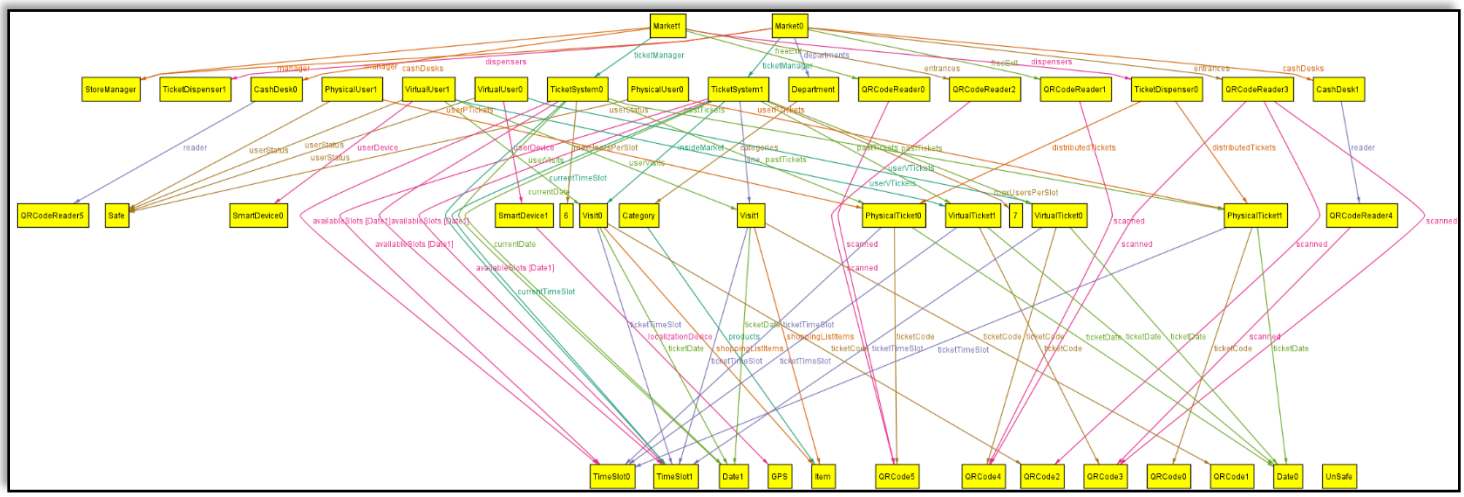
4.4 Generated World

Here we report a simple and a more complex world generated by the alloy model. The simple one is easy to understand, and highlights the properties mentioned in paragraph 4.1:



it is clear the association between tickets and users, either physical or virtual, and the correct modelling of the situation of the market (only one market reported for ease of reading).

The model can also generate more complex and multi-market worlds, of more difficult reading, but still correct. Here is reported one example:



5. EFFORT SPENT

- *As a group:*

Date	*Topic*	*#Hours*
14-10-2020	Brainstorming of what we want our system to be	1.5
17-10-2020	World and Shared Phenomena, Scenarios	1.5
24-10-2020	R&DD revision of last year's assignment	1.5
14-11-2020	Domain assumptions & Goals	2
21-11-2020	Functional requirements and use cases	1.5
25-11-2020	External Interfaces and Goal revision	1.5
01-12-2020	Missing functional requirements and use cases	1.5
06-12-2020	Alloy	1
NA	Total	12

- Etion Pinari

Topic	*#Hours*
Functional Requirements	8
Scenarios, state charts	1
Non-functional requirements	1.5
Domain assumptions & Goals	1.5
Use cases	0.5
External Interfaces	1.5
Functional Requirements and goal mapping	6
Alloy	1
Sequence Diagrams	1
Research on various topics	3
Writing on Word and formatting	5
Total	30

- Giorgio Romeo

Topic	*#Hours*
Functional Requirements	3
Scenarios, state charts	4
Non-functional requirements	1.5
Domain assumptions & Goals	1.5
Use cases	8
External Interfaces	1
Functional Requirements and goal mapping	3
Alloy	2
Sequence Diagrams	5
Research on various topics	3
Total	32

- Cristian Sbrolli

Topic	*#Hours*
Functional Requirements	3
Scenarios, state charts	1
Non-functional requirements	1.5
Domain assumptions & Goals	2
Use cases	0.5
External Interfaces	2
Functional Requirements and goal mapping	2
Alloy	15
Sequence Diagrams	2
Research on various topics	2
Total	31

6. *REFERENCES*

- How often families go grocery shopping per week : https://www.statista.com/statistics/251728/weekly-number-of-us-grocery-shopping-trips-per-household/
- How many families are there in Milan: https://www.tuttitalia.it/lombardia/18-milano/statistiche/popolazione-andamento-demografico/
- Which day is the busiest for grocery shopping: https://www.forbes.com/sites/joanverdon/2020/04/08/best-time-for-grocery-shopping-tips-from-in-store-traffic-data/#:~:text=The%20busiest%20days%3F,box%20stores%2C%E2%80%9D%20he%20said.
- How many families go grocery shopping on weekends in respect to weekdays: https://www.insider.com/best-time-to-go-grocery-shopping-2018-3
- How many families are there in Italy: https://www.istat.it/it/files/2018/12/C03.pdf

- Web App used to generate mockups: https://bubble.io/home

- Web App used for diagrams: https://online.visual-paradigm.com/diagrams/