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CLup project

Requirements Analysis and Specifications (RASD)

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1 Introduction

1.1 Purpose

This document has the purpose of guiding the developer in the realization process of the **CLup** software, an innovative application to manage queues digitally.

Due to the Coronavirus emergency grocery shopping needs to follow strict rules: supermarkets need to restrict access to their stores which typically results in long lines forming outside. The goal of this project is to develop an easy-to-use application that allows store managers to regulate the influx of people and that saves people from having to crowd outside of stores.

The application releases a number that gives the position in the queue and gives information about the time when that number is called, in this way the user is able to arrive to the supermarket and enter immediately.

CLup allows also the user to book a slot to enter the supermarket indicating the expected time to shop, or alternatively the application itself can infer it.

Finally the application can suggest different slots to visit the store, based on stores crowdedness, and slots in alternative stores, based on the day/hour preferences of the user.

1.1.1 Goals

G1	Anybody is guaranteed possibility to make shopping at any supermarket in reasonable time (def. reasonable)
G2	Users can get to know the least crowded time slots
G3	Fair users can make a reservation to enter in a supermarket
G4	Stores can easily monitor fluxes
G5	Only authorized users can access
G6	Crowds are dramatically reduced outside supermarket stores
G7	CLup should not decrease customer affluence beyond a reasonable level w.r.t. to normal (→ define reasonable)
G8	Same shopping capabilities guaranteed to offline users
G9	Find the best (less crowded, soonest available) alternative among local supermarket stores (of same franchise only?)
G10	Supermarkets do not overcrowd

Table 1: Goal list

1.2 Scope

1.2.1 World Phenomena

WP1	User leaves home to go to the supermarket
WP2	Users crowd outside the store
WP3	User arrives at the supermarket
WP4	User enters the supermarket
WP5	User does the grocery shopping
WP6	User exits the supermarket
WP7	Supermarkets restrict accesses in stores
WP8	User buys products of a non booked category

Table 2: World phenomena list

1.2.2 Shared Phenomena

SP1	User lines up using the application
SP2	User makes a reservation
SP3	User keeps track of how line evolves
SP4	User validates the entrance with a QR code
SP5	User receives suggestion for less crowded time slots
SP6	User receives suggestion for less crowded stores
SP7	CLup assigns a time slot
SP8	CLup signals max number of customers inside the store has been reached
SP9	CLup signals customer for improper behavior
SP10	Offline customer interacts with physical totem
SP11	User confirms booking
SP12	User confirms ticket reservation

Table 3: Shared phenomena list

1.3 Definitions, Acronyms, Abbreviations

1.3.1 Definitions

- **Check-in procedure:** the process of getting inside the store. It starts from when the user approaches the entrance, includes the QR ticket scan and ends as soon as the turnstile is passed.
- **Reserve entrance:** the process of booking a future entrance (starting from the day next to the current one)
- **Malicious user:** someone committed for any reason to CLup malfunction and/or unavailability, shopping disservices.
- **Quick ticket:** the actual ticket granting access to the stores. We call it «quick» to emphasize the difference between booking and lining up.
- **Totem:** a desktop based PC with advanced input functionalities (touchscreen), with external hard shell protection, stand mount, (optional) integrated printer.
- **Big screen:** a huge screen panel to be located outside the store, in visible placement, used for announcements to offline customers.
- **CLup core system:** CLup innermost back-end functionality providing queueing control, access to already enqueued users, access control, big screens operativeness

1.3.2 Acronyms

- **EWT:** Expected Waiting Time
- **ASAP:** As Soon As Possible
- **WRT:** With Respect To

1.3.3 Abbreviations

1.4 Revision History

- **v1.0:** First version of the document
- **v1.1:** Section 4 revision
- **v1.2:** Sections 3.3, 3.4 revision
- **v1.3:** Section 4.2 revision, sequence diagrams upscaling
- **v1.4:** Front page addition, minor syntax revisions

1.5 Reference Documents

This documents has been designed by taking the **ISO/IEC/IEEE 29148** as primary reference.[\[3\]](#)

Other documents of sources have been cited along the way whenever needed.

1.6 Document Structure

Chapter 1 gives an introduction about the purpose of the document and the development of the application, with its corresponding specifications such as the definitions, acronyms, abbreviation, revision history of the document and the references.

The structure of the document is also analyzed.

Chapter 2 contains the overall description of the project. In the product perspective are included the state-charts of the main application functions, the overall Class Diagram and a brief description for it.

In user characteristic application target is further analyzed, as well as the functionalities of the application.

Finally, the taken domain assumptions are exposed.

Chapter 3 exposes interface requirements including: user, hardware, software and communication interfaces. This section contains the core of the document, specifications over functional and non-functional requirements.

Functional requirements are paired with a list of use cases and the corresponding sequence diagrams, plus some scenarios. Non-functional requirements include performance, design and security constraints.

Chapter 4 includes the alloy code and the automated worlds generated, together with model testing results.

Chapter 5 delineates the effort spent in creating each section of this Document, per author.

Chapter 6 is an overall list of the main source references.

2 Overall Description

2.1 Product Perspective

2.1.1 UML description

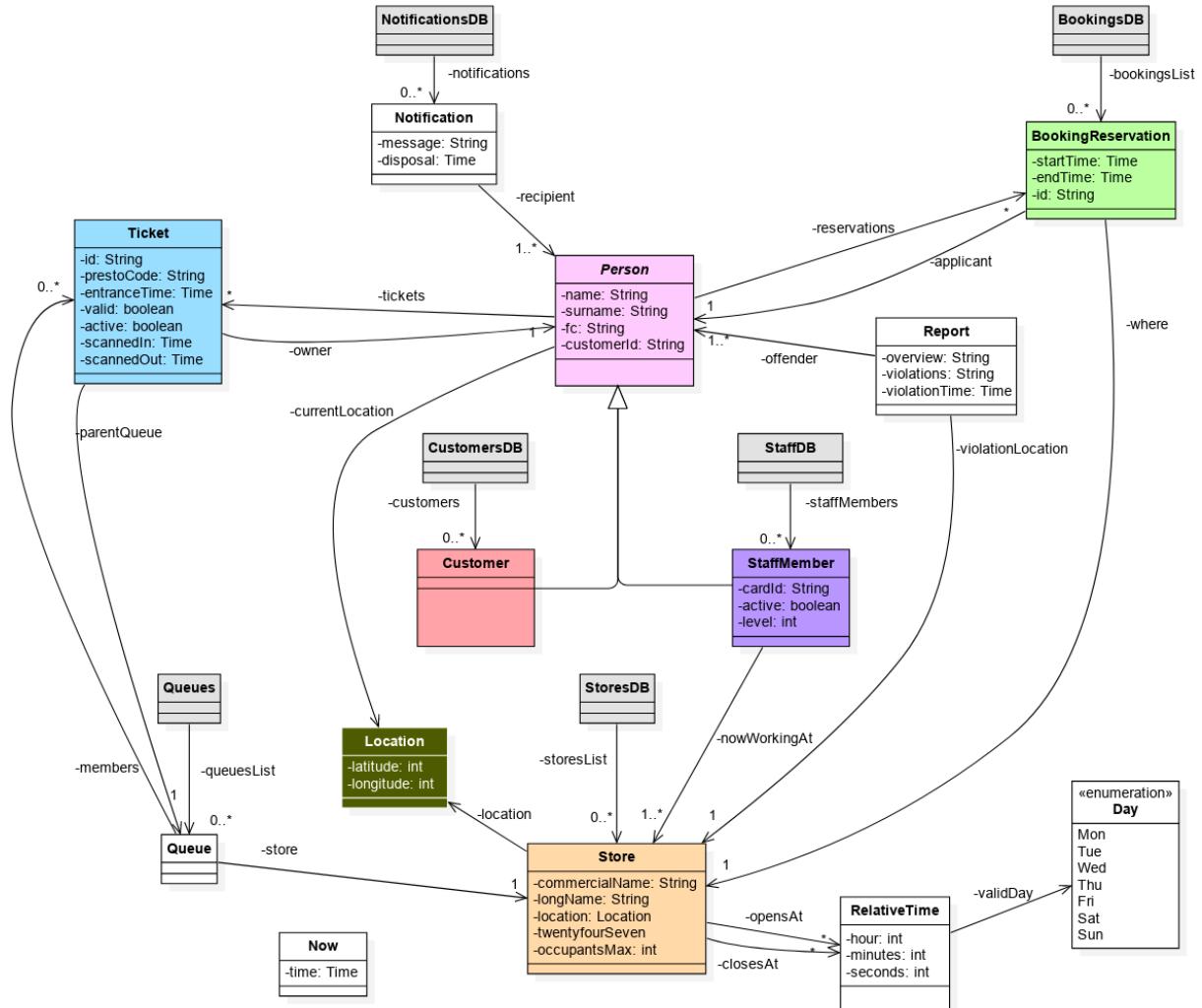


Figure 1: UML: class diagram.

Primary components overview By first glance at Figure 1 you may see in light coloured shade the main components of the CLUp application. In particular:

- Person class, which is abstract, and models the general entity with common characteristics to both customers and staff members
- Store class, modeling a single store facility, with chain attribute.
- BookingReservation class, which models a single reservation instance, including time and store for the reservation as well as - of course - an associated applicant
- Ticket class, referring to the so called QuickTicket 1.3.1 entity, which collects every useful piece of information to enqueue, track and allow users inside the stores.

In light gray shade, you may then notice the database classes, which provides a hint on a possible database displacement for storing the aforementioned classes.

2.1.2 State charts

In this section some state diagrams are being used to better model and visualize the core functionalities of the application.

As we can see in Figure 2, the process to virtually get in the queue of a store begins with Clup's home, where the main menu is displayed. When the virtually queue function is selected, the application state become the local store state: in this state Clup ask the customer his expected shopping duration and will consequently show the user all supermarkets nearby and their current status. If the user selects a store a confirmation dialog is prompted and if he confirms, the application will make a transition to the reserving state.

This state is the most complex one and it is out of the scope of this document to analyse it, what it is important to know is that in this state Clup is processing the ticket request, generating the QR code and updating the relative store line. Assuming that the process is successful, the application will display the ticket alongside real time information about the supermarket line, this state can also be reached by the home but if and only if there is a valid ticket to display.

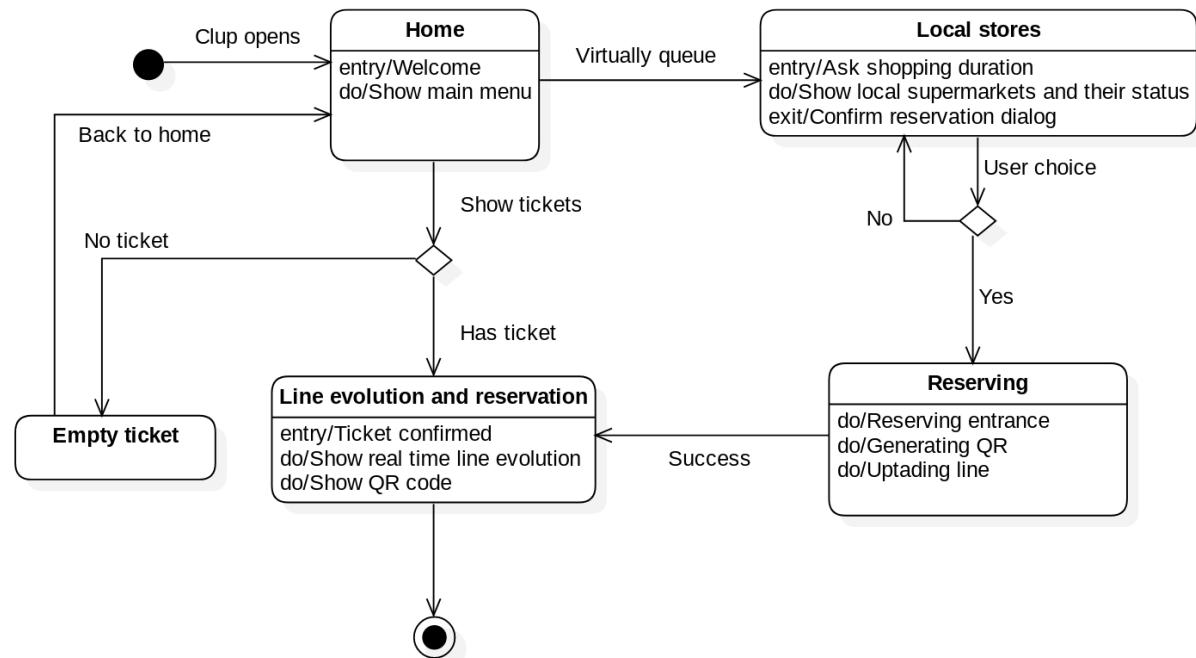


Figure 2: Statechart diagram: Virtually queue.

Another important function to describe is the booking of the entrance; despite its similarities with the previous one it is worth to analyse it anyway from Figure 3: from the Clup home, once selected the book entrance function, the application will ask the use for his shopping time and will show supermarkets inside the filter range. When a store is selected, in accordance with the shopping duration, a calendar of the available time slots is displayed.

If the calendar shown does not satisfies the user it possible to rollback to the store list and change supermarket. When the user decides a time slot and confirms the pop-up, the processing state for the reservation is reached: also in this case we are not interested in details, Clup

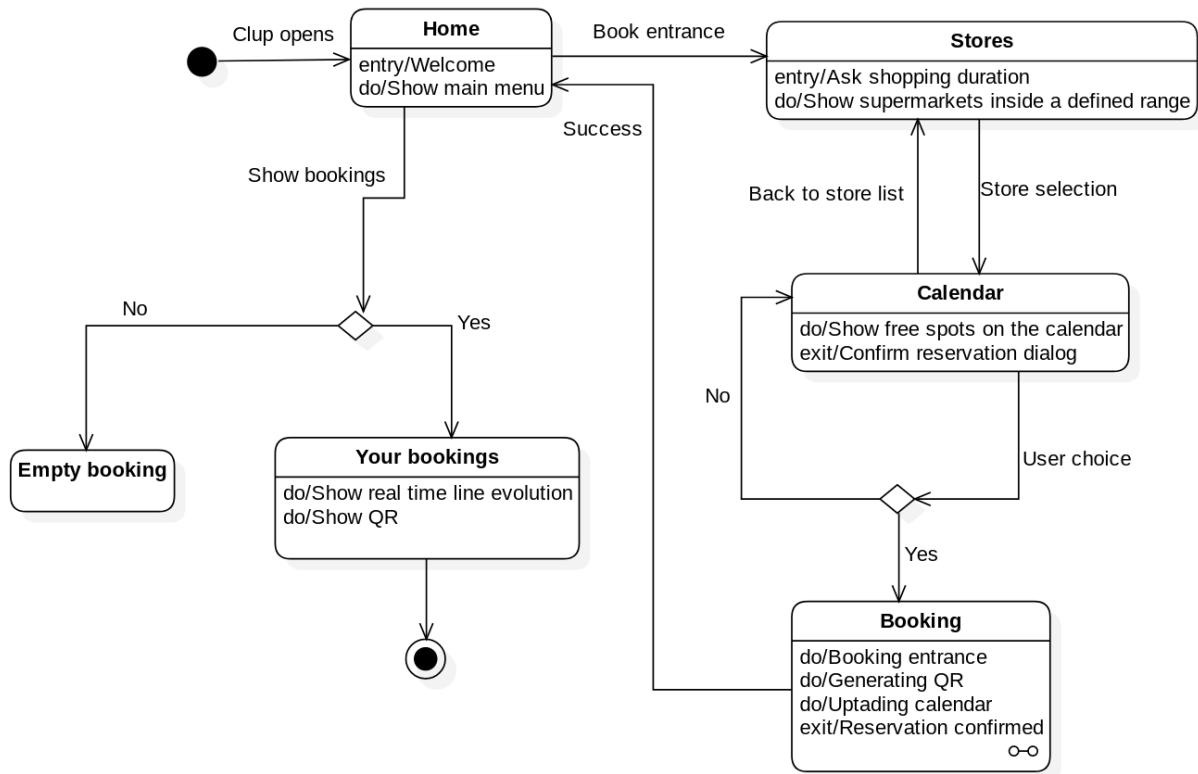


Figure 3: Statechart diagram: Book Entrance.

processes the reservation and updates the calendar.

Assuming the process successful, in average the reservation will be at least a day ahead in time so it would be useless to switch to a state in which the application shows the reservation, instead Clup will return to the home and, if the user wants to see his bookings, assuming that he has at least one, he could reach it from the home.

2.1.3 Scenarios

Scenario 1 Single user of the CLup platform, Bob, decides it's time to go shopping. Bob lives in Milan and this means he's currently in reach of **5 different supermarkets** belonging to the CLup network.

Bob then opens the app, checks the status of the current queue and notices the nearest supermarket has free room, 13 entrances left out of 55 total. It's fine for Bob, he starts walking towards it.

As soon as he approaches the supermarket (Bob's on foot), he checks the app and start the **check-in procedure**. It's not rush hours and 8 entrance are still left, so everything goes ok and Bob gets a **QR ticket**. He approaches the entrance, has his code **scanned by an automatic turnstile** and gets inside the supermarket.

In 36' time, Bob completes his shopping. He proceeds towards the exit, where another turnstile **scans his QR code once again to confirm exit**. He's now free to get home.

Scenario 2 Clara, mother of three children, now needs to go shopping. She's just downloaded CLup and has not figured out how to use it yet.

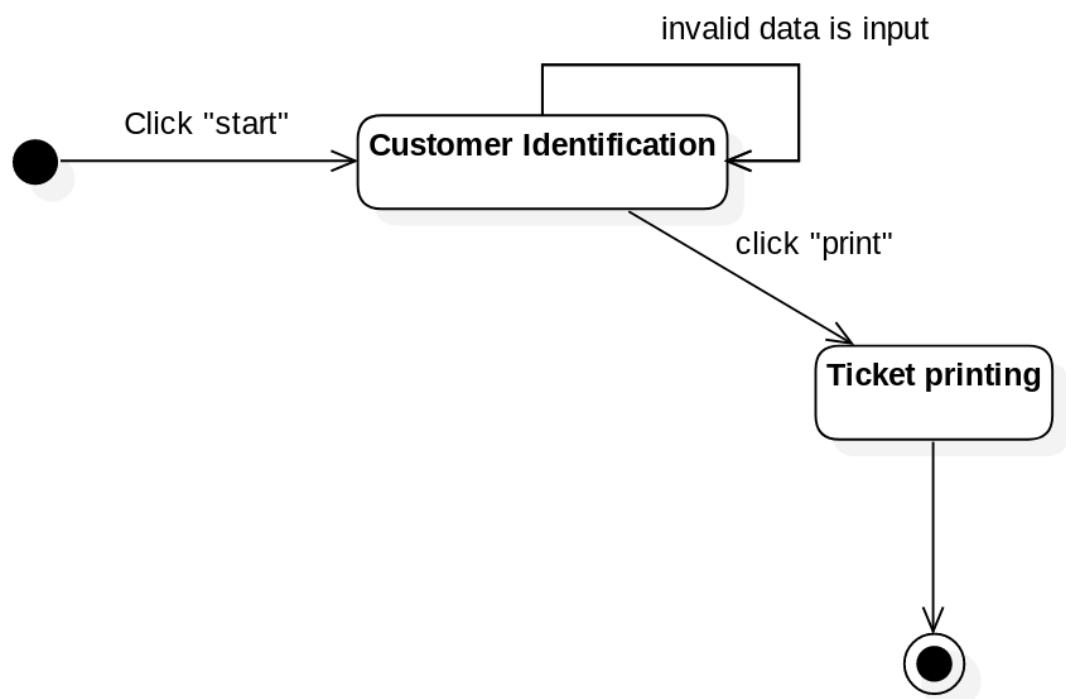


Figure 4: Statechart diagram: Physical ticketing.

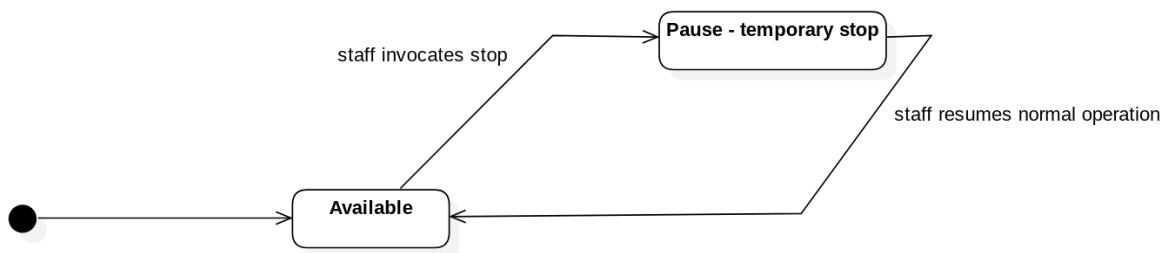


Figure 5: Statechart diagram: Store backend.

Clara decides to have a try right now, on the fly, and opens the app to check for local available supermarkets.

Unfortunately it's now **rush hours**, hence 2 of the 3 local supermarket show no currently available entrances and an **e.w.t. of 35 minutes**. Young mother decides to click on "Reserve entrance" and notices she has **15 minutes left to enter the store**. This is done in order to minimize false reservations impact on the service's availability.

Clara has to travel a 4 Km distance in her home town which seems reasonable, but since it's rush hours, **actually requires 25 minutes of time** to be travelled by car: her QR code has expired.

Fortunately, she checks CLup and can now see new free accesses in the other 2 CLup powered supermarkets, the nearest of which is only a kilometer away. She then reserves an access, reaches the supermarket in 10' time and is now free to do her shopping.

Scenario 3 James is a young unemployed man, living in the west, outer side of Rome. His **not particularly wealthy** condition does not overcome his strong medical conceptions, so that he's **particularly committed in avoiding queues** and other possible ways of contracting Covid-19 in general.

His fridge is starting to starve, so James - who still relies on a well aged Nokia 3310 for its calls and messaging - decides to go shopping. Despite being «less tech-ready» than average, James has nonetheless heard about a new app (a new way) of shopping and decides to give CLup powered supermarkets a try. Those with the lit CLup mark outside.

The nearest of the two eligible supermarkets in James' reach is 900m away and he's on foot. **Owning no smartphone**, James considers a reasonably not crowded time to go, 3 p.m., and walks towards the store.

Unfortunately James' guessing is wrong and the supermarket is **full**: a **big screen notifies no entrance is allowed for now**, and everybody has to stay clear of the entrance. He knows no alternative store as he owns no smartphone, but notices the big screen at the entrance has advices for him: next to the entrance, there's a **self service area** - enclosed by barriers and accessed by automated turnstiles - where James can have a ticket printed. **Only one person at a time** is allowed in, so that James and anybody else has nothing to worry about.

Right after printing its QR, James can notice the big screen now shows information about it, giving him (better, its ticket number, which reads AX625RQ) advice to **come back in 20 minutes** for entrance. He then goes for a walk.

25 minutes later James approaches the supermarket and a **green line** on the big screen says the owner of ticket AX625RQ is allowed to enter the store for another 10 minutes.

James happily heads towards the entrance door, has its paper ticket scanned at the turnstiles and enjoys its queue-less shopping.

Scenario 4 Sara is another young, unemployed woman who lives in an outer borough of Naples. She does own a smartphone, even though it's a bit **old and sometimes sluggish** in the use. She uses it primarily for texting even though CLup is installed and seems to work.

It's 10 am and Sara needs to go shopping, so opens up CLup and reserves an entrance to the nearest store. She reaches the entrance, looks for her QR code and notices **her smartphone is suddenly misbehaving**, randomly rebooting and not letting her accomplish the task. She could have memorized her *presto code* but she actually did not, and asking for a manual check-in is not an option since human interactions have to be avoided - the staff would not let her in.

Sara feels annoyed, and decides she has no time to spend waiting for her smartphone to get back to normal, so she will try and access **like an offline customer**. The store is almost empty but some other offline customers are to get their tickets.

She looks at the big screen over the entrance, someone is currently occupying the self area but that particular store has room for 5 consecutive offline customers, so she enters the fenced area, stopping at «one turnstile distance» from the guy currently occupying the self area. In 2 minutes approximately, Sara is able to reach the self machine, have a new ticket printed and get back out.

The big screen announces both the offline tickets are allowed in (there's few persons inside), hence Sara heads towards the turnstiles and gets inside the supermarket, on her way to buying her next smartphone.

Scenario 5 Michael's family lives outside Messina, in a nice cottage by the sea. Panorama is beautiful, going shopping though requires some effort.

Either Michael or his wife, Laura, have to take the car and travel 25 kilometers of state road to the city. This typically requires up to 1 hour in rush hours, and 35 minutes on average.

This is the type of situation in which the possibility of **booking** an entrance comes in handy. It's 11.30 a.m.: Laura opens CLup and books an entrance at 5 p.m., providing an estimated shopping time of 1 hour.

CLup's **alternative stores functionality** also plays a fundamental role for Laura and her family, as they often head towards Ganzirri - another city on Sicily's east coast, opposite direction than Messina - to do their shopping. There are other shopping districts down there, typically less crowded and easier to reach. Today's best alternative happens to be a supermarket in Messina city though.

At 4.10 pm, Laura gets in the car and heads towards the booked store. She arrives at 5.05 p.m, has her QR booking code scanned and gets in.

However, children are usually hungry and Laura's three kids make no exception to this. She hurries getting the job done quickly, but she inevitably ends up **exceeding the 1 hour slot she had booked**.

Right now the store is full, and this apparently concerning problem leads CLup system to **alert with reasonable notice one user**, whose entrance would have been right after Laura's exit, that he will have to wait an additional 15 minutes before entering the store.

In the end, Laura manages to get outside the supermarket 65 minutes after she got in.

Had she required more than that, at 71st minute CLup would have warned the aforementioned user to add another 10 minutes delay to his entrance, and so forth. So that everybody stays safe and **no overcrowding** takes place.

Straightforwardly enough, Laura's **delay inevitably becomes root of possible discomfort**. Nonetheless, CLup engine makes note of Laura's behaviour and adds her last shopping time to her personal data: this is going to be taken into account the next time she books a visit, and over time the system will become able to **forecast her actual shopping time**, thus reducing consequent discomforts.

It is worth noting that this really unfortunate situation generates a problem since Laura's delay occurs specifically when the store is full, condition without which the problem would not have been so concerning.

Also, comparing CLup management of the situation with standard management indicates a fairly good improvement: without CLup, the next customer could not have booked its visit (much less, being warned about delays), but instead he would simply have reached the store at 7 p.m and crowded to wait an indeterminate amount of time outside the store.

Scenario 6 Valerio is a tech oriented grandfather, whose grandson is committed about technology and pushes him towards the use of electronic devices.

Everything tends to go well, except sometimes Valerio *mis-taps* something on its smartphone. Today Valerio is trying to get used to the new shopping app his grandson has provided him

with, and accidentally makes a booking for late afternoon, at 6 o'clock, at a superstore near his house.

Valerio seems not to notice his mistake, and simply closes the app. Hence the booking remains valid.

We again find ourselves in the very unfortunate situation in which, at 6 o'clock the superstore is full and Valerio's booking means one less entrance for someone who needed it. This actually represents a problem for the very next 15 minutes after 6 p.m., since at 6.16 the booking is automatically cancelled and the next user in current queue is notified he can proceed.

Also, system makes note of Valerio's mistake and reports it to the superstore's Staff. They will be presented a comprehensive report, reading which they will be able to decide whether to contact Valerio for explanations or simply ignore the incident, taking into account factors only humans can evaluate (like Valerio's age).

However, CLup's reservation procedure includes an explicit confirmation dialogue, which is aimed at reducing this type of inconvenience.

Scenario 7 Let's now talk about Alex. He's a young man, living with some sort of anxiety: he's always worried of being late, loosing his seat, and so on. Today's day is going to be full of engagements and despite being roughly 7 o'clock a.m, Alex is now making a booking for a shopping during the evening.

Alex opens up CLup, clicks on the booking section and he's immediately presented with a list of 10 supermarkets available in Norcia, where he lives. Alex *chooses not to choose*: he books a slot at 7 p.m. at each one of the 10 supermarkets.

Now, this is a perfectly common situation, potentially induced by other factors - many of which being far less innocent than Alex's.

However, CLup's booking **system prevents booking more than two entrances on the same day**, hence preventing Alex's behaviour. He is in fact given negative response after the second booking, with a kind informative message explaining the situation.

The reasons behind this are straightforward. CLup aims at **improving, safening and optimizing the shopping experience** in general for the end user. This of course translates into the possibility of **shopping planning**, but has to **prevent prevarication** of some users over others as well.

Alex's behaviour, without this kind of policies, would inevitably reduce the number of persons allowed to go shopping at the same time, failing aforementioned purposes and possibly worsening the user experience w.r.t. the current situation.

Scenario 8 Middle-aged woman Debora also happens to be incline to «compulsive booking», but in a slightly different manner than Alex.

She is used to book services she will not have time to take advantage of in the end, and this also applies to CLup shopping booking. In the last 7 days, she booked a staggering total of 10 different slots, actually never going to the supermarket afterwards.

Again, this kind of situation can be avoided. CLup integrates a customizable policy about **fake booking prevention** that each store can configure according to their likes.

Between a minimum of 3 and a maximum of 10 fake bookings will result in CLup **shutting off user's ability to make bookings**, leaving only the "line up" functionality available for use. The booking feature may then be restored after manual intervention or a preset amount of time.

Note how this is not going to prevent anyone from shopping - since lining up is always allowed, just like normal - thus guaranteeing goals G7, G9 and G10; at the same time though, it helps the booking feature works at its best by reducing disruptions, possibly increasing the overall stores' throughput.

2.2 Product Functions

CLup has NNNN main functionalities, each one of them is essential to reach the goals of the application.

2.2.1 Virtually queue in stores

This is the core of CLup, this function allows the user to virtually queue with a ticket to enter, as soon as possible, the supermarket he chooses. To do this the user needs to set his starting location, his preferred store chains and the distance range in which the application should look for stores. Furthermore CLup will ask the user his expected shopping duration, this is done to avoid inserting many quick tickets who need 1 hour, 10 minutes before a an already booked slot. After this step, Clup will present the stores located inside the chosen range either as a sorted list or in a map with supermarkets highlighted. The list specifies for each store the distance from the starting location, the EWT to enter based on the size of the store and the number of people who already have a ticket for it, the number of people who are already inside and the maximum occupancy. The alternatives sorting system will be discussed later. The information displayed in the list is also visible from the map if the user selects a supermarket. When the user selects a store the application will show him the current EWT to enter and remind him that he has 15 minutes after his turn has come before the ticket definitely expires. Finally it will ask him if he is sure to reserve the entrance. This confirmation dialog is mainly useful to make sure that the user is aware of the timings and he can organize his commitments to go shopping in time. On the other hand, having a confirmation dialog is useful to prevent unintentional reservations by distracted or non-techy users. After the reservation is done, the user can follow the evolution of the line from the application which will give him real time information: the numbers of the tickets that are supposed to enter, the number of people ahead of the user and the estimated wait time. At this point the user should have enough information to arrive at the supermarket neither too early nor too late: in the first case he must wait in the car or away from the store, in the second one his ticket could expire and he would have to get a new one and wait again for his turn. When the time comes, CLup notifies the user that he should enter within 15 minutes. At the entrance the customer scans his QR code, or inserts the code of his ticket, and the turnstile lets him in. Obviously, if the store is not full and it is the turn of many customers to enter CLup allows them to access in any order, if a customer tries to scan the QR at the wrong time, ticket expired or that ticket has not been called yet, the turnstile won't let him pass. When the shopping is finished the customer scans again his QR code, or inserts the code, notifying the CLup system that there is one more entrance available in that store. People who do not have the app can still virtually queue by getting a ticket printed from the physical totems near CLup powered stores where there is also a big screen showing the entering ticket numbers. On the printed ticket it is specified the EWT but of course they will miss the possibility to be updated on the queue status because it is forbidden to wait in front of the store, also the totems give tickets only for the store where they are located. To get more accurate estimations, through the entering and exiting turnstiles, the system stores the shopping time of each user in order to build statistics. To avoid abuses of this function, it is not possible to reserve more than one entrance at the same time, the user will be able to reserve another entrance on the same day only after he left the first store. For the same reasons it will be later described that the store managers can prevent users from making new reservations if they let too many tickets expire..

2.2.2 Book entrance

This feature allows the user to book a ticket to enter in a specific time slot of a specific day, it is available in the mobile app and targets users who want to schedule their shopping time instead

of just going as soon as possible. Just as for the previous function, the user needs a little setup for the starting location and eventually other filters, then he should insert the expected shopping duration and finally he can visualize the matching solutions starting either from a list or a map, or starting from a calendar. Either of the starting views then takes the user to the other one (general calendar -> map/list for that day, general map/list -> calendar for that store) and after selecting both the store and the day a list of time slots for that day will be shown. Once the user decides the combination of store, day and time he can go on with the booking procedure and book his slot by giving confirmation. The application will process his request and, when the time comes, the application will generate the QR code (and notify the user) one hour in advance, from there the user will have 1:15 hours to enter the store before the ticket expires. If the user arrives early, even if the store is empty, the QR will only be valid for the chosen time. From this point on, the functioning is just as in the previous feature.

Also in this case abuses are discouraged: it is not possible to book more than an entrance per day and a ban mechanism is implemented, CLup counts the number of times a user reserves an entrance and then does not go to the store, if this value exceeds a threshold selected by the supermarket the user can not book an entrance to that supermarket until the number of booking absence is reset two weeks after .

2.2.3 Suggestions among different stores and times

This function was actually anticipated in the previous ones and aims at balancing the flux of people between stores and between different hours but, while the previous ones had a dedicated interface button, this one works in background: when the user wants to book or reserve an entrance, if he chooses to visualize stores in list mode, the list is accurately sorted with the purpose of putting in first place the least crowded stores and those with fewer probability of being chosen by other customers based on the statistics. If the user chooses the map visualization each store will have associated a color that indicates its crowdedness. In any case CLup will notify the user if there is a better solution outside of the set filters.

2.2.4 Store management

This function is only for the store managers, it allows them to:

- **view affluence statistics:** the manager can see the status of the supermarket crowdedness, the line to enter, the calendar with all the booked entrances and the throughput. However store managers
- **stop new entrances:** temporarily prevent coming users with valid tickets from entering the store
- **change current store capacity:** set the maximum capacity of the store at a certain time so that the automatic queuing system can plan the queue accordingly
- **inspect misbehaving user automatically generated reports:** The system automatically generates reports from users who miss their reservations or take too long shopping in the supermarket, these are then merged into statistics that allow the managers to use in an informed manner the next feature in this list
- **block or unblock users from accessing CLup for a certain store:** given the reports it is possible to prevent some users from reserving tickets, or also it is possible to let a user reserve again after an eventual clarification with him. It is also possible to set thresholds for which the system automatically blocks or unblocks users

2.3 User Characteristics

The application targets two different entities: users and store managers.

- **Users** are the main concern of CLUp, they represent every customer of supermarkets and actually differentiate between registered and offline users, they need to shop and they need to do it safely. They want to shop at stores without waiting outside and by spending as little time as possible using the application or totem, for this reason the application is very simple and intuitive.
- **Store managers** are supermarket accountants willing to find safer shopping solutions for their customers and their staff.

2.4 Assumptions, Dependencies and Constraints

2.4.1 Domain Assumptions

Follows a list of assumptions made about the domain CLUp focuses on.

D1	Accesses to the store can be monitored
D2	Exits from the store can be monitored
D3	One customer per authorization given is allowed in by the Staff
D4	Users are reasonably able to manage their time while following the queue evolution
D5	Users can estimate the time required to arrive to the store
D6	Users who arrives too early at the supermarket don't wait in front of the entrance
D7	Customers keep the safe distance
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D9	Users insert the right starting location or their GPS works
D10	Store managers give the right information about supermarkets
D11	Staff guarantees access control systems operativeness

Table 4: Domain assumptions list

3 Specific Requirements

3.1 External Interface Requirements

CLup is an application aimed at decreasing the probability of contracting COVID-19 (diseases in general) when going shopping to a supermarket. There are two fundamental components: the main one targets customers of supermarkets while the second one is available for store managers.

3.1.1 User Interfaces

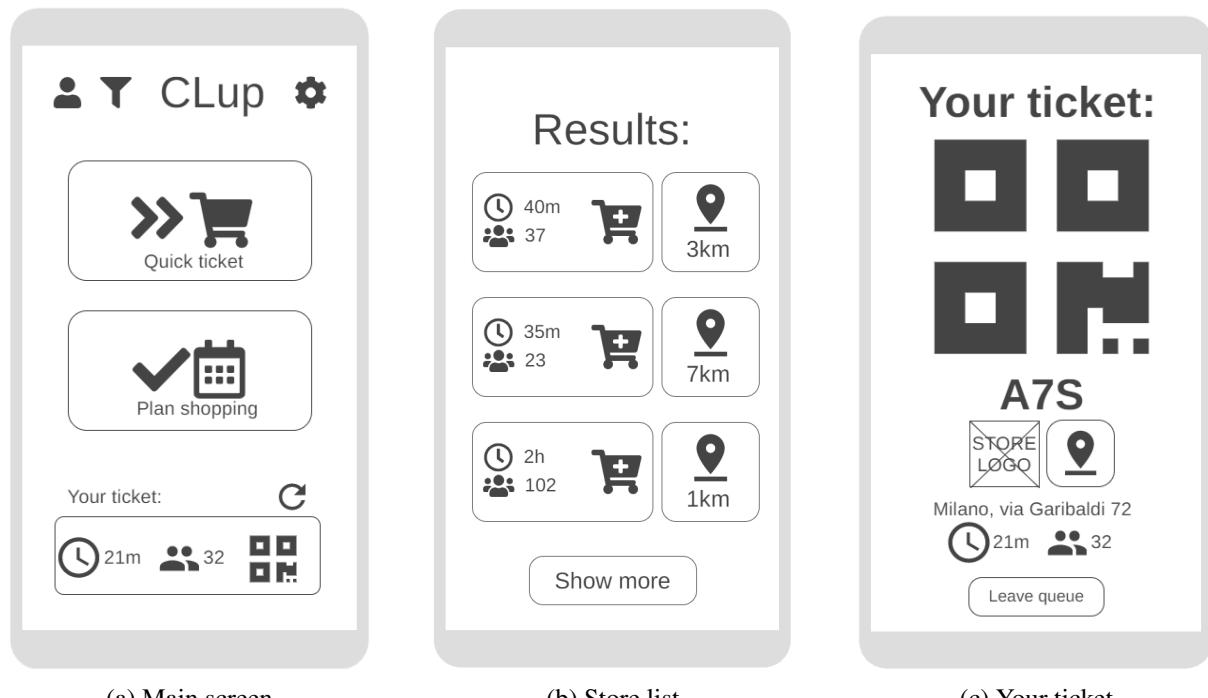


Figure 6: Clup wireframes

End user functionalities Regarding the first target - customers - they will be required to register to the service the first time they use it by inserting their full name, email address, ID card, phone number and a password. The customer will also be requested to specify his physical address, or to enable the GPS, in order to allow CLup to find stores nearby; this last information can be changed anytime the user needs. If the customer is not willing to register or share his address, the service will not be available.

Once the setup is done, customers will be able to access the homepage of the application, where they can tap on a “Virtually queue” button that will allow them to see a list of stores inside a specified range from their current location: for each store a distance in Kilometers from the user position will be outlined, as well as the number of people inside the store and its maximum capacity; whenever a store is full, the current number of people in line and an *EWT* are displayed.

It is also possible to visualize stores on a map and, by tapping on one of them, to see the same information displayed in the list. Now, if the user chooses to reserve a spot in the line,

the application will open a confirm dialog specifying EWT and the expiration of the ticket. If the user refuses nothing happens, if he accepts instead CLUp will process the request, show his ticket and the real time evolution of the line; the ticket is also visible from a home button. The process is shown in Figure 2.

The distance range in which CLUp will look for supermarkets is specified by the user through the filter button in the homepage, this button will in fact open the filter screen in which, among other parameters, a sliding bar controls the distance and a drop-down list allows the user to filter the chains of supermarkets.

Another important feature is the possibility to book an entrance later in the day or in another day. The user can specify from the filters whether he prefers to choose the day or the store first and he can set the time range in which he wants to book. There is a dedicated button in the app's main screen that redirects the user to either the list/map of supermarkets or the calendar, and once the user chooses he will be respectively shown the calendar or the list/map, this time with colours to indicate the average crowdedness of stores/days given the set time range. When the user chooses the day and supermarket combination, a timetable spanning the chosen time range is shown, divided in 15 minutes time slots each one having again a colour to indicate the crowdedness. The user will be able to check his reservation on the home page and near the entrance time he will be provided an actual ticket.

The access at the supermarket is restricted by turnstiles with QR code readers, a staff member is expected to verify that nobody waits his turn in front of the entrance, jumps the turnstile or does anything irresponsible.

Customers who, for any reason, do not use the app will still be able to queue in CLUp supermarkets by obtaining a printed ticket from a physical totem located near such stores; the functioning of the application will be similar to the "Quick ticket" app function with the difference that the user can only obtain a ticket by using a totem.

The tickets consist of a QR code and an easy to remember alphanumeric code alternative to enter the store. There will also be monitors that show the numbers allowed to enter and, eventually, delays.

Internal use functionalities Another component of CLUp targets store managers: when the store decides to join the CLUp network, ad-hoc credentials to access the web app will be given. Special staff-only functions will then be achieved by the use of a web application, accessible via internal-use terminals.

3.1.2 Hardware Interfaces

Both users and store managers can use the application through a mobile phone or a personal computer. Users unable to do so will use totems provided by stores.

3.1.3 Software Interfaces

- map API
- send ticket/booking requests to CLUp
- send turnstile entrances/exits to CLUp
- query automatically generated reports and obtain their statistics

3.1.4 Communication Interfaces

The only type of communication required by CLUp is a stable internet connection.

3.2 Functional Requirements

3.2.1 List of requirements

R1	Every user can generate a quick ticket for any store
R2	Whenever user makes initiates a booking procedure, CLup must be able to compute a suggested least crowded time slot based on historical data
R3	CLup must elaborate and upload data about current global customer affluence to the store during use
R4	CLup must admit only valid QR codes for entrance
R5	CLup must allow users to know current queue status
R6	CLup must update user on tickets' validity change
R7	CLup must inform offline users about new tickets (un)availability
R8	CLup must allow users to indicate which product category they are going to purchase while booking
R9	CLup must suggest alternative stores when the combination of selected store/time gives no results
R10	CLup must reserve a non null number of paper tickets at any time for offline customers use
R11	CLup must gather all stores' data about entrance fluxes
R12	CLup is able to cross affluence data of any supermarket
R13	CLup keeps track of people who book an entrance and don't come
R14	CLup allows store managers to stop quick tickets availability
R15	CLup is able to generate QR codes
R16	CLup is able to authenticate users
R17	CLup is able to store users' data
R18	CLup is able to process users' data
R19	CLup makes quick ticket invalid after 15 minutes delay
R20	CLup can use stores' data to sort every store by crowdedness
R21	Users can see available day/time slots of a supermarket through CLup
R22	CLup shows to store managers flux data about their supermarket (forse questo è quello che intendeva R3)
R23	CLup must be able to process reservations

Table 5: Requirements list

3.2.2 Mapping

Goals	Requirements	Domain Assumptions
G1	R1, R6, R7, R10, R15, R23	D1, D5, D8
G2	R2, R11, R12, R18, R21	D1, D2, D8, D10
G3	R9, R13, R15, R21, R23	D5, D8, D10
G4	R3, R11, R22	D1, D2, D8, D11
G5	R4, R6, R13, R15, R19	D1, D2, D3, D8, D10, D11
G6	R1, R2, R5, R6	D4, D5, D6, D7, D8, D10
G7	R1, R5, R6, R7, R9, R10, R20, R21, R23	D2, D4, D5, D8, D9, D10
G8	R1, R7, R10	D6, D7, D8, D10
G9	R3, R11, R12, R20	D1, D2, D8, D9, D10, D11
G10	R2, R3, R4, R11, R12, R20	D1, D2, D3, D7, D8, D10, D11

Table 6: Goal mapping summary

G1	Anybody is guaranteed possibility to make shopping at any supermarket in reasonable time (def. reasonable)
R1	Every user can generate a quick ticket for any store
R6	CLup must update user on tickets' validity change
R7	CLup must inform offline users about new tickets (un)availability
R10	CLup must reserve a non null number of paper tickets at any time for offline customers use
R15	CLup is able to generate QR codes
R23	CLup must be able to process reservations
D1	Accesses to the store can be monitored
D5	Users can estimate the time required to arrive to the store
D8	Malicious users are not enough in number or coordination to prevent Clup to work

Table 7: G1 Mapping

G2	Users can get to know the least crowded time slots
R2	Whenever user initiates a booking procedure, CLup must be able to compute a suggested least crowded time slot based on historical data
R11	CLup must gather all stores' data about entrance fluxes
R12	CLup is able to cross affluence data of any supermarket
R18	CLup is able to process users' data
R21	Users can see available day/time slots of a supermarket through CLup
D1	Accesses to the store can be monitored
D2	Exits from the store can be monitored
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D10	Store managers give the right information about supermarkets

Table 8: G2 Mapping

G3	Fair users can make a reservation to enter in a supermarket
R9	CLup must suggest alternative stores when the combination of selected store/time gives no results
R13	CLup keeps track of people who book an entrance and don't come
R15	CLup is able to generate QR codes
R21	Users can see available day/time slots of a supermarket through CLup
R23	CLup must be able to process reservations
D5	Users can estimate the time required to arrive to the store
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D10	Store managers give the right information about supermarkets

Table 9: G3 Mapping

G4	Stores can easily monitor fluxes
R3	CLup must elaborate and upload data about current global customer affluence to the store during use
R11	CLup must gather all stores' data about entrance fluxes
R22	CLup shows to store managers flux data about their supermarket
D1	Accesses to the store can be monitored
D2	Exits from the store can be monitored
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D11	Staff guarantees access control systems operativeness

Table 10: G4 Mapping

G5	Only authorized users can access
R4	CLup must admit only valid QR codes for entrance
R6	CLup must update user on tickets' validity change
R13	CLup keeps track of people who book an entrance and don't come
R15	CLup is able to generate QR codes
R19	CLup makes quick ticket invalid after 15 minutes delay
D1	Accesses to the store can be monitored
D2	Exits from the store can be monitored
D3	One customer per authorization given is allowed in by the Staff
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D10	Store managers give the right information about supermarkets
D11	Staff guarantees access control systems operativeness

Table 11: G5 Mapping

G6	Crowds are dramatically reduced outside supermarket stores
R1	Every user can generate a quick ticket for any store
R2	Whenever user makes initiates a booking procedure, CLup must be able to compute a suggested least crowded time slot based on historical data
R5	CLup must allow users to know current queue status
R6	CLup must update user on tickets' validity change
D4	Users are reasonably able to manage their time while following the queue evolution
D5	Users can estimate the time required to arrive to the store
D6	Users who arrives too early at the supermarket don't wait in front of the entrance
D7	Customers keep the safe distance
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D10	Store managers give the right information about supermarkets

Table 12: G6 Mapping

G7	CLup should not decrease customer affluence beyond a reasonable level w.r.t. to normal (→ define reasonable)
R1	Every user can generate a quick ticket for any store
R5	CLup must allow users to know current queue status
R6	CLup must update user on tickets' validity change
R7	CLup must inform offline users about new tickets (un)availability
R9	CLup must suggest alternative stores when the combination of selected store/time gives no results
R10	CLup must reserve a non null number of paper tickets at any time for offline customers use
R20	CLup can use stores' data to sort every store by crowdedness
R21	Users can see available day/time slots of a supermarket through CLup
R23	CLup must be able to process reservations
D2	Exits from the store can be monitored
D4	Users are reasonably able to manage their time while following the queue evolution
D5	Users can estimate the time required to arrive to the store
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D9	Users insert the right starting location or their GPS works
D10	Store managers give the right information about supermarkets

Table 13: G7 Mapping

G8	Same shopping capabilities guaranteed to offline users
R1	Every user can generate a quick ticket for any store
R7	CLup must inform offline users about new tickets (un)availability
R10	CLup must reserve a non null number of paper tickets at any time for offline customers use
D6	Users who arrives too early at the supermarket don't wait in front of the entrance
D7	Customers keep the safe distance
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D7	Customers keep the safe distance

Table 14: G8 Mapping

G9	Find the best (less crowded, soonest available) alternative among local supermarket stores (of same franchise only?)
R3	CLup must elaborate and upload data about current global customer affluence to the store during use
R11	CLup must gather all stores' data about entrance fluxes
R12	CLup is able to cross affluence data of any supermarket
R20	CLup can use stores' data to sort every store by crowdedness
D1	Accesses to the store can be monitored
D2	Exits from the store can be monitored
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D9	Users insert the right starting location or their GPS works
D10	Store managers give the right information about supermarkets
D11	Staff guarantees access control systems operativeness

Table 15: G9 Mapping

G10	Supermarkets do not overcrowd
R2	Whenever user makes initiates a booking procedure, CLup must be able to compute a suggested least crowded time slot based on historical data
R3	CLup must elaborate and upload data about current global customer affluence to the store during use
R4	CLup must admit only valid QR codes for entrance
R11	CLup must gather all stores' data about entrance fluxes
R12	CLup is able to cross affluence data of any supermarket
R20	CLup can use stores' data to sort every store by crowdedness
D1	Accesses to the store can be monitored
D2	Exits from the store can be monitored
D3	One customer per authorization given is allowed in by the Staff
D7	Customers keep the safe distance
D8	Malicious users are not enough in number or coordination to prevent Clup to work
D10	Store managers give the right information about supermarkets
D11	Staff guarantees access control systems operativeness

Table 16: G10 Mapping

3.2.3 Use cases

1. Registration of new account

Name	Registration of new account
Actors	User
Entry Condition	User installed and opened the app and doesn't have an account or wants to register another one
Event Flow	<ul style="list-style-type: none"> (a) User opens the app. (b) Login screen loads. (c) User taps "Sign up". (d) User fills all registration fields (e) User taps "Create new account"
Exit Conditions	User is back to login screen with the possibility of logging in after confirming his registration by opening the link in the received email
Exception	<ul style="list-style-type: none"> (a) There is no internet when the user presses "create account" "No internet" popup, the user can either wait for internet to come back or discard the incomplete account creation by going back to main screen (b) Username or email already in use Already used credentials popup, user has to try with different ones

Table 17: Use case: User registration

2. User login

Name	User login
Actors	User
Entry Condition	User already has an account
Event Flow	<ul style="list-style-type: none"> (a) User opens the app. (b) Login screen loads. (c) User inputs his credentials and presses “login” (d) Main screen loads
Exit Conditions	User logged in and is now in main screen, from where he can virtually access all of the app's functionalities
Exception	<ul style="list-style-type: none"> (a) Credentials are wrong wrong credentials popup, user stays in login screen (b) There is no internet connection no internet warning pop up, user still logs in if he used previously inserted and saved credentials so he can still edit settings and filters or look at his history

Table 18: Use case: User login

3. Quick ticket request

Name	ASAP ticket request
Actors	User
Entry Condition	User successfully logged in and is in main screen
Event Flow	<ul style="list-style-type: none"> (a) User taps “Show stores” (b) User is taken to “Quick results” screen (c) IF LIST MODE (from settings) <ul style="list-style-type: none"> stores with queue time, size and distance are shown in a list according to setted filters, if show more is pressed more stores are loaded and the list is made scrollable, if location button is pressed a map showing the store’s location is shown IF MAP MODE (from settings) <ul style="list-style-type: none">) stores with queue time, size and distance are shown on a map, if list button is pressed User is taken to the previously described “list mode” case (d) User taps on a store (e) Confirmation pop up is shown (f) If user confirms “Ticket screen” is shown, otherwise he is taken back to 3
Exit Conditions	User has a ticket with updating due time to enter the store
Exception	<ul style="list-style-type: none"> (a) The store blocked ticket requests <ul style="list-style-type: none"> after 5 user is told that the store is no longer available and remains in list/map to make an eventual different choice (b) There is no internet connection <ul style="list-style-type: none"> after 1 user stays in main screen with a dismissible “no internet” pop up (c) User already has a quick ticket <ul style="list-style-type: none"> after 1 user stays in main screen with a dismissible “you can only have one quick ticket”

Table 19: Use case: Quick ticket request

4. Quick ticket request at physical Totem

Name	ASAP ticket request at physical Totem
Actors	User
Entry Condition	User starts interacting with CLUp totem outside the store
Event Flow	<ul style="list-style-type: none"> (a) User identifies (b) CLUp validates id code (c) User inputs the expected amount of time he will be shopping (d) Confirmation for queuing is shown (e) If user accepts CLUp totem prints a ticket associated to user ID
Exit Conditions	User has a ticket that he can scan to enter the store when he comes back at the written date and time
Exception	<ul style="list-style-type: none"> (a) The store blocked ticket requests User can't get a ticket and is asked to come back another time (b) ID not valid User is asked to try to identify again

Table 20: Use case: Quick ticket at physical totem

5. Edit filters

Name	Edit filters
Actors	User
Entry Condition	User pressed filter button from main screen
Event Flow	<ul style="list-style-type: none"> (a) User is in main screen and taps the “filters” button (b) User is in filters screen (c) User changes the filter parameters he wants to change among: <ul style="list-style-type: none"> i. distance range ii. store type iii. default booking time (ignored by ticket request) iv. default calendar or stores first when booking (ignored by ticket request) v. default map or list view when booking (ignored by ticket request) vi. -others- (d) User presses back to main screen button (e) Popup to confirm and save or discard the new filters is shown (f) User presses save
Exit Conditions	New filters are set and they will affect the next ticket request or visit plan, user is now in main screen
Exception	<ul style="list-style-type: none"> (a) User closes the app without saving the filters Filter modifications are lost

Table 21: Use case: Edit filters

6. Plan shopping

Name	Plan shopping
Actors	User
Entry Condition	User successfully logged in and is in main screen
Event Flow	<ul style="list-style-type: none"> (a) User taps “Show stores” (b) User is taken to “Quick results” (c) User inputs the expected amount of time he will be shopping (d) Calendar or store map/list is shown depending on what was loaded given the filter settings (e) User chooses date (from calendar) or store (from map/list) (f) Stores map/list or calendar are shown depending on what was shown already (g) User chooses the store or the day (h) CLUp shows time slots for that store on that day (i) User taps on a time slot (j) Confirmation pop up is shown (k) If user confirms “Booking receipt screen” is shown, otherwise he is taken back to 3
Exit Conditions	User has a booked slot to go shopping that will result in the generation of a ticket, he can access his booking from the main screen
Exception	<ul style="list-style-type: none"> (a) The store blocked ticket requests after 5 user is told that the store is no longer available and remains in list/map to make an eventual different choice (b) There is no internet connection after 1 user stays in main screen with a dismissable “no internet” pop up (c) User has already booked a slot after 1 user stays in main screen with a dismissable “you can only have one booking at a time” (d) Day/store/time slot is full the choice is refused with a pop-up and user has to choose an alternative

Table 22: Use case: Plan visit

7. Enter store

Name	Enter store
Actors	User
Entry Condition	User has a valid QR ticket and is at the store entrance
Event Flow	<ul style="list-style-type: none"> (a) User scans his QR ticket or inputs his alphanumeric code at the turnstile (b) The turnstile informs the user he can enter and unlocks (c) The user enters the store
Exit Conditions	The user is in the store and can start shopping
Exception	<ul style="list-style-type: none"> (a) The ticket expired its 15 minutes validity time The turnstile remains locked and informs the user that his ticket is not valid, the ticket expiration causes a report to be generated for the manager independently from the fact that the user tried to enter anyway (b) The code is wrong The turnstile remains locked and informs the user that the code is not valid

Table 23: Use case: Enter store

8. Exit store

Name	Exit store
Actors	User
Entry Condition	User has a valid QR ticket and is exiting the store
Event Flow	<ul style="list-style-type: none"> (a) User scans his QR ticket or inputs his alphanumeric code or inputs his CLUp email or nickname at the turnstile (b) The turnstile informs the user he can exit and unlocks (c) The user exits the store
Exit Conditions	The user leaves the store
Exception	<ul style="list-style-type: none"> (a) The code is wrong or no code can be provided or credentials are wrong The turnstile informs the user that he has to try again and after the third try it is unlocked anyway, the user exit won't be tracked and will cause a report for the misinterpreted long shopping to be generated for him

Table 24: Use case: Exit store

9. Store manager stops new entrances

Name	Stops new entrances
Actors	Store manager
Entry Condition	Store manager is in management web page
Event Flow	<ul style="list-style-type: none"> (a) Manager clicks on stop new entrances (b) Manager is asked to insert admin password (c) Manager is asked to confirm and he does
Exit Conditions	No new tickets can be issued and currently released tickets are put on hold, meaning that valid tickets won't be accepted by the turnstiles (queue time replaced with a suspended entrances message) The page now offers the possibility to allow entrances again
Exception	None

Table 25: Use case: Store manager stops new entrances

10. Store manager views affluence statistics

Name	View affluence statistics
Actors	Store manager
Entry Condition	The manager is in management web page
Event Flow	<ul style="list-style-type: none"> (a) Manager clicks on "View affluence statistics" (b) A page showing various statistics with customizable filters and options about people affluences is shown
Exit Conditions	Manager knows their customers' behaviours (e.g. affluence and permanence times) and can act accordingly
Exception	<ul style="list-style-type: none"> (a) None

Table 26: Use case: Store manager views affluence statistics

11. Store manager changes store capacity

Name	Change store capacity
Actors	Store manager
Entry Condition	Manager is in management web page
Event Flow	<ul style="list-style-type: none"> (a) Manager clicks on “Change people capacity” (b) A screen which contains a text box to input the people number for store capacity is shown (c) Manager inputs the new number and clicks confirm (d) Admin password is asked to proceed (e) Confirmation is asked and done
Exit Conditions	The number of people that can be let in the store after scanning their code is now set to the amount desired by the store Manager. If more people than store capacity are inside no new people will be let in until the store doesn't empty below the limit; actually clearing the store is outside of the scope of this project
Exception	<ul style="list-style-type: none"> (a) Password is wrong no changes are allowed, password is asked again

Table 27: Use case: Store manager changes store capacity

12. Store manager inspects reports

Name	Store manager inspect reports
Actors	Manager
Entry Condition	Manager is in management webpage
Event Flow	<ul style="list-style-type: none"> (a) Manager clicks on “Inspect reports” (b) Reports page is shown (c) Manager can navigate the complete list of reports and can filter or search them
Exit Conditions	Manager now knows the users infringements and can take informed actions on blocking or unblocking them from queuing in the stores
Exception	None

Table 28: Use case: Store manager inspects report

13. Store manager blocks/unblocks user and set threshold

Name	Store manager blocks/unblocks user and set threshold
Actors	Manager
Entry Condition	Manager is in management web page
Event Flow	<ul style="list-style-type: none"> (a) Store staff clicks on “block/unblock user” (b) A screen with a search box to look for a user and navigate blocked users is shown (c) Manager looks for the user on which they want to take action (d) Manager clicks “block” or “unblock” button near the username of the user in question (e) Admin password is asked to proceed (f) Manager sets threshold (valid for all users) for missed entrances automatic block (g) Admin password is asked to proceed
Exit Conditions	Chosen user is now blocked or unblocked for queuing at the store and automatic block threshold is set
Exception	<ul style="list-style-type: none"> (a) The user doesn't exist (anymore) an error message informs that the action cannot be completed (b) The user is already blocked / unblocked an error message informs that the user is already blocked / unblocked and no action is taken (c) Password is wrong no changes are allowed, password is asked again

Table 29: Use case: Store manager (un)blocks user

14. Store manager login

Name	Store manager login
Actors	Manager
Entry Condition	Manager is in management web page
Event Flow	<ul style="list-style-type: none"> (a) Staff opens the CLup website (b) Staff inserts login store code and password and clicks login button
Exit Conditions	Staff is now in the management web page main screen
Exception	<ul style="list-style-type: none"> (a) Credentials are wrong Error message is shown, it is asked to re insert the credentials (b) Too many login attempts After 3 failed login attempts the login-attempting ip is blocked for some time from trying other logins and if the store code was valid its manager will be notified of the attempt

Table 30: Use case: Store manager login

15. Store Manager registration request

Name	Store Manager registration
Actors	Manager
Entry Condition	Manager is in management web page
Event Flow	<ul style="list-style-type: none"> (a) Manager opens the CLUp website (b) Manager clicks on register new store (c) Manager inputs all the information required and confirms (d) CLUp checks the validity of the data (e) CLUp gives a confirmation message saying the request will be elaborated
Exit Conditions	The store is now applying to join CLUp network and the applier will be contacted to complete the procedure and install the turnstiles and totems at the store
Exception	<ul style="list-style-type: none"> (a) Data is not valid Form not accepted, the Manager can try checking his input again

Table 31: Use case: Store registration

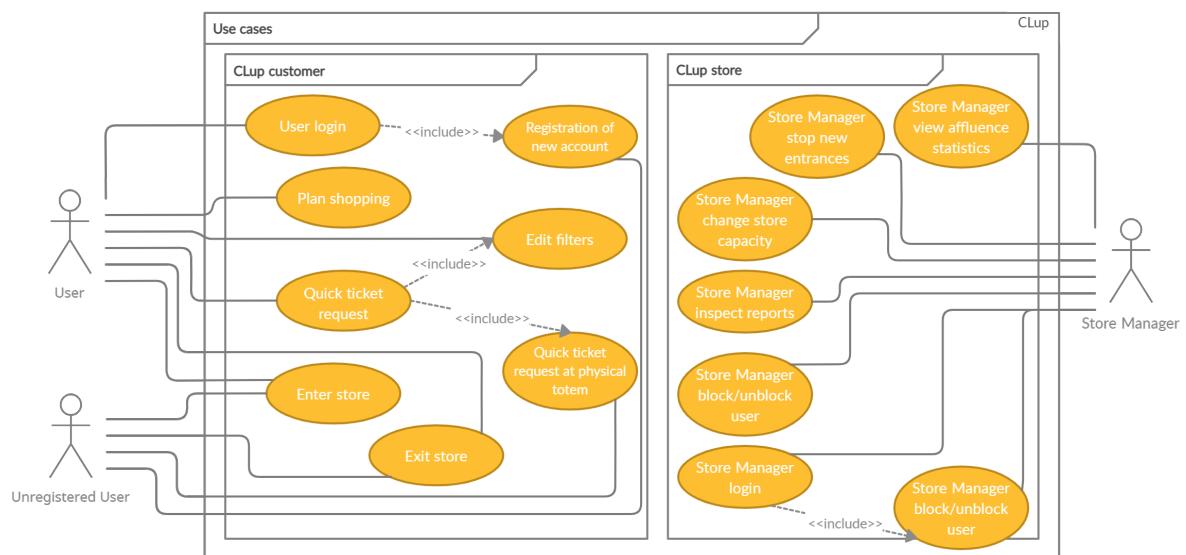


Figure 7: Use case diagram

3.2.4 Sequence diagrams

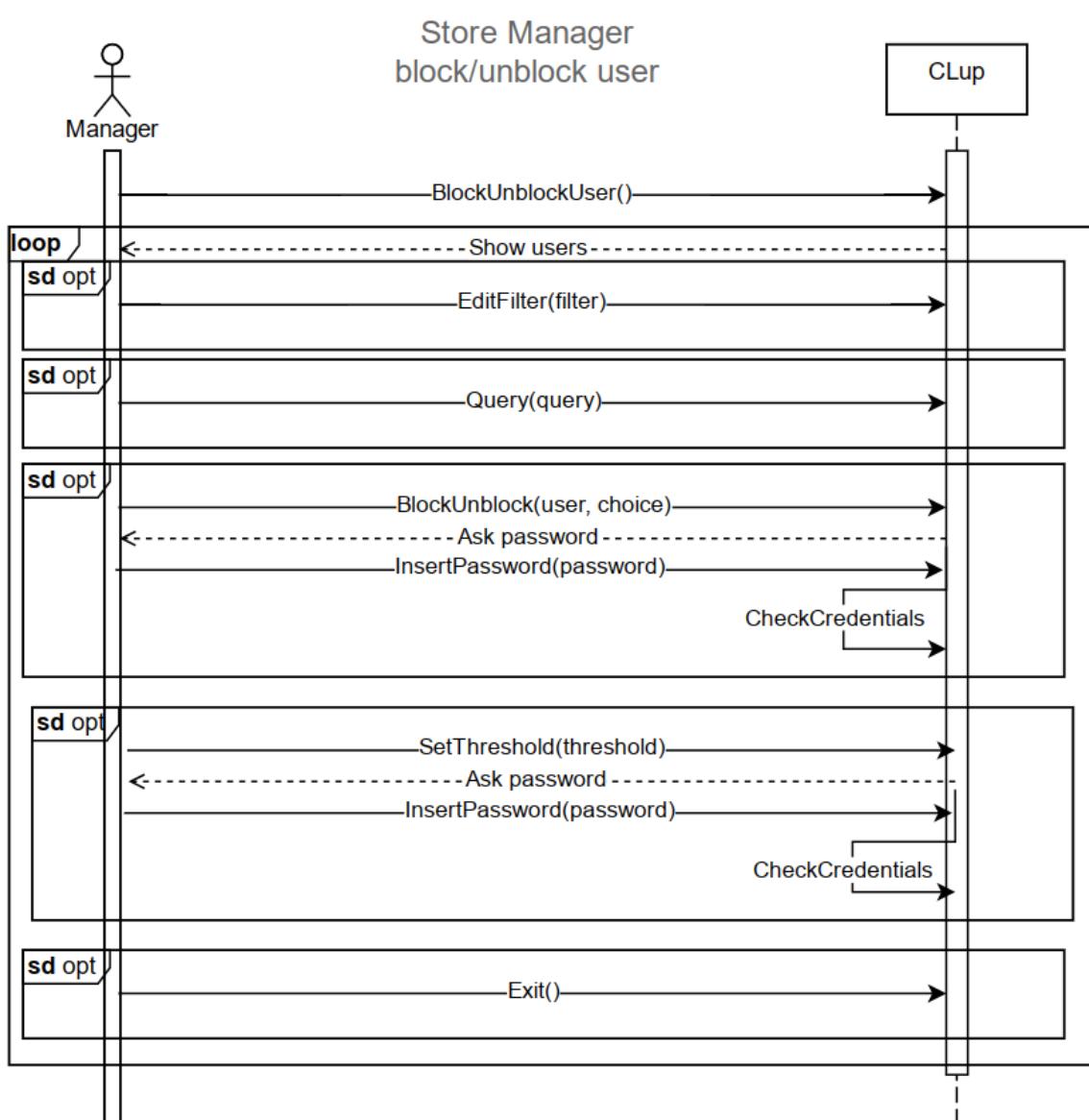


Figure 8: Sequence diagram: Manager (un)block user

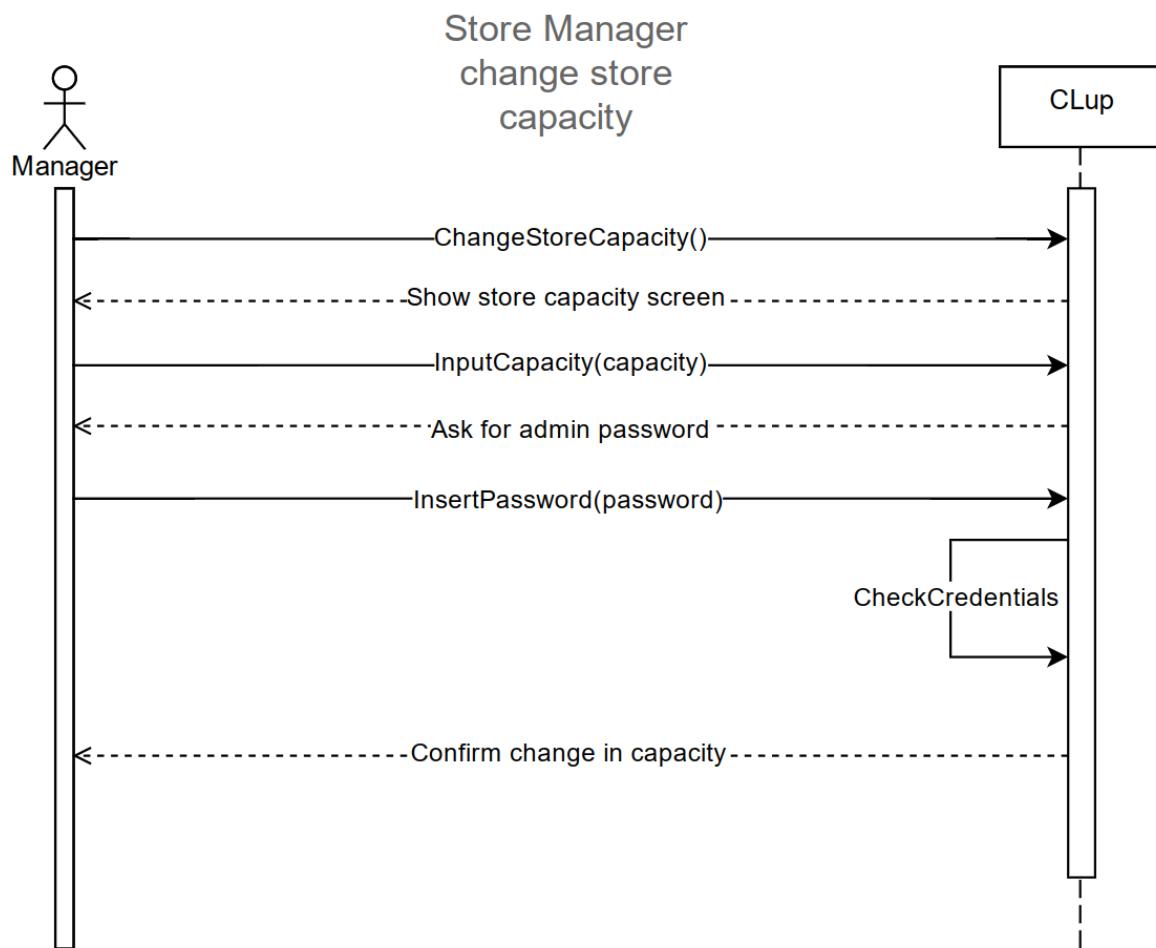


Figure 9: Sequence diagram: Manager changes capacity

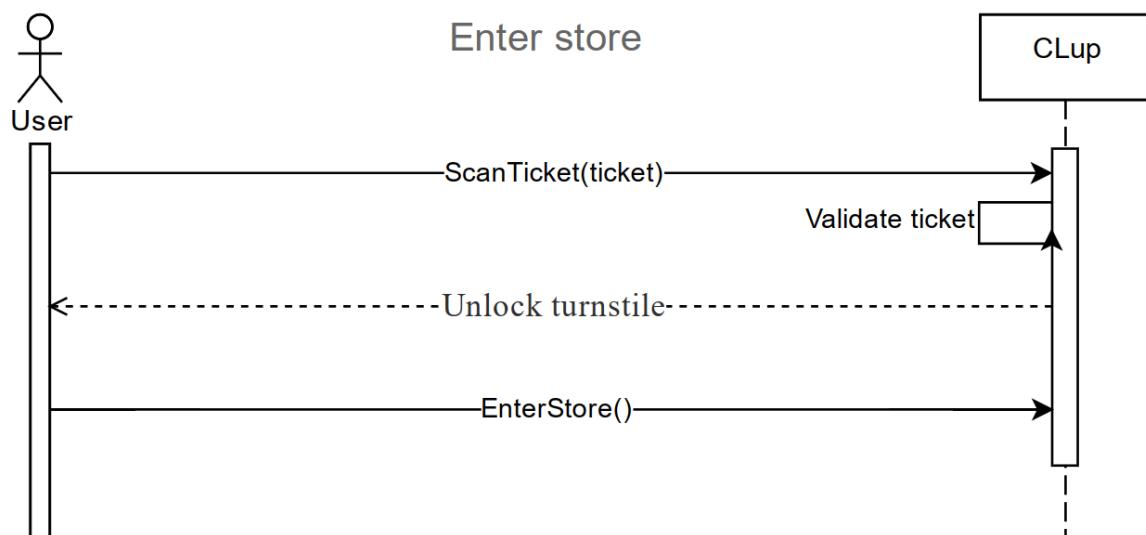


Figure 10: Sequence diagram: Enter store

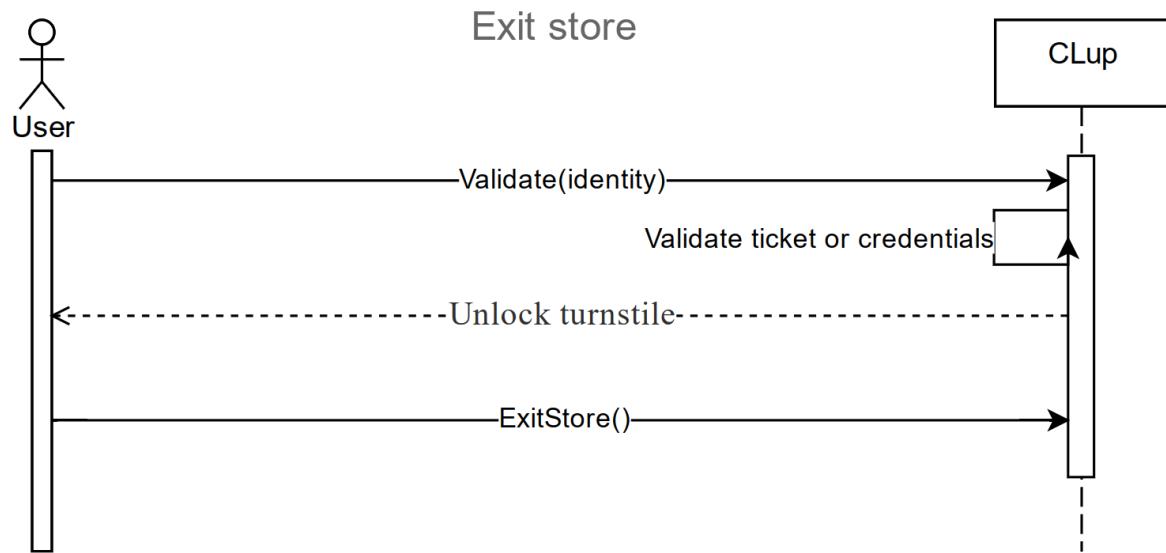


Figure 11: Sequence diagram: Exit store

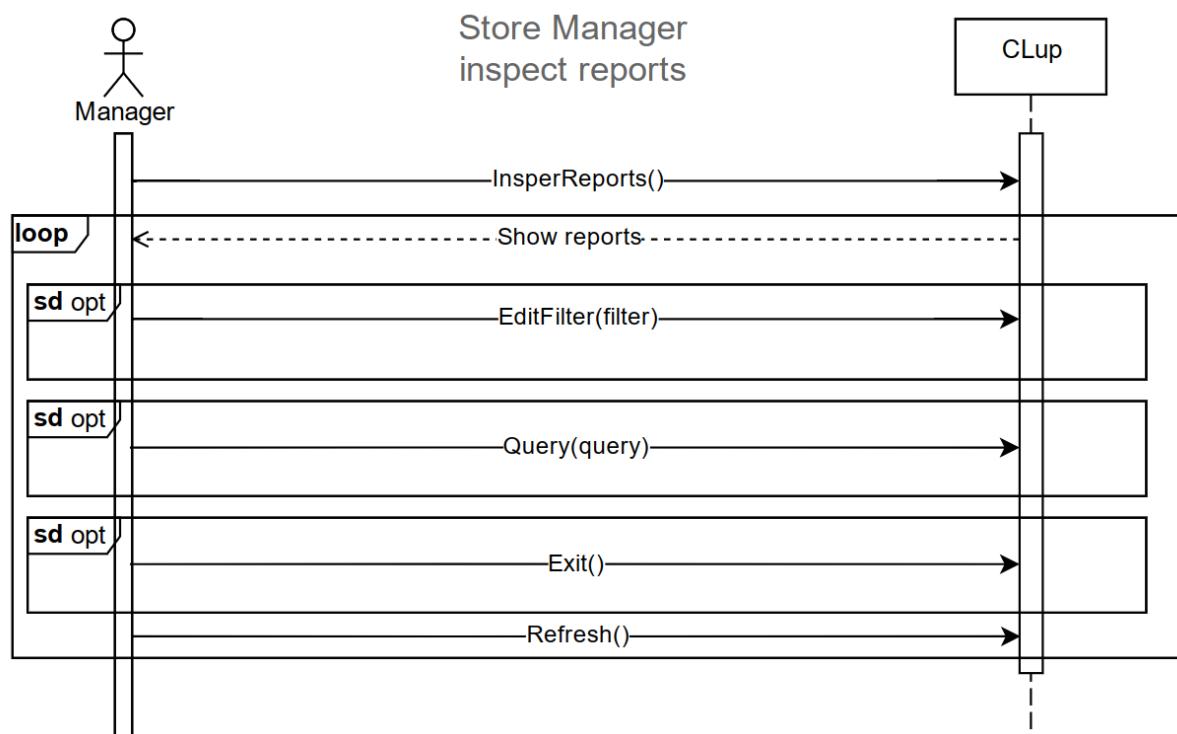


Figure 12: Sequence diagram: Manager inspects report

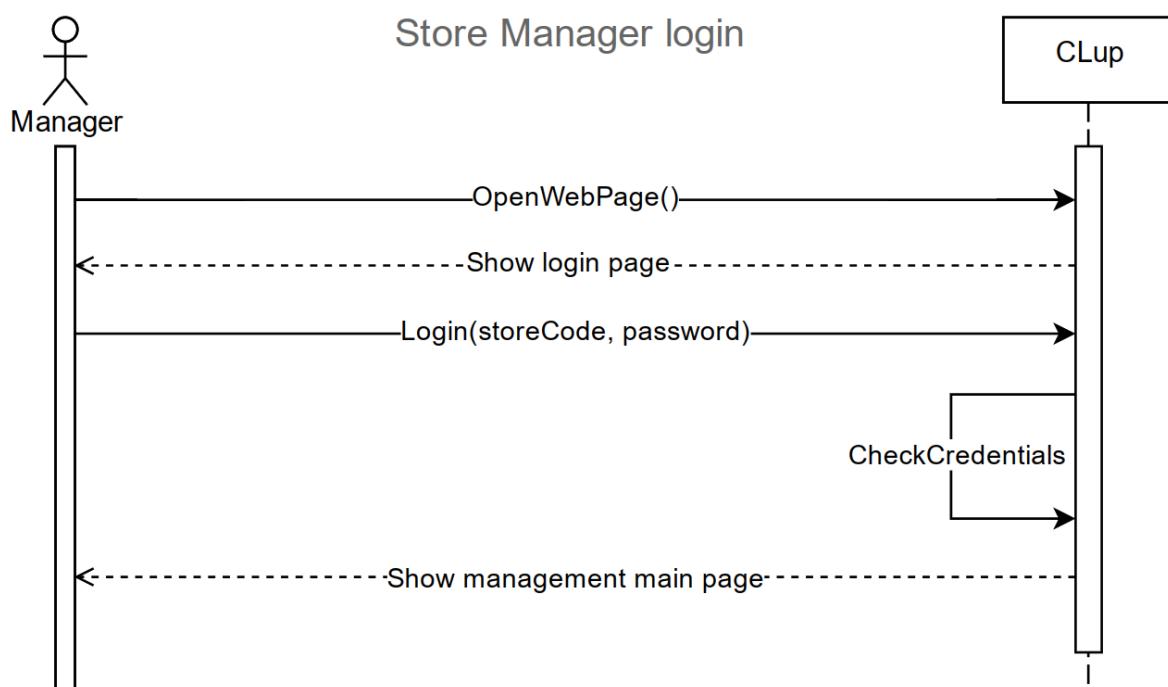


Figure 13: Sequence diagram: Manager logs in

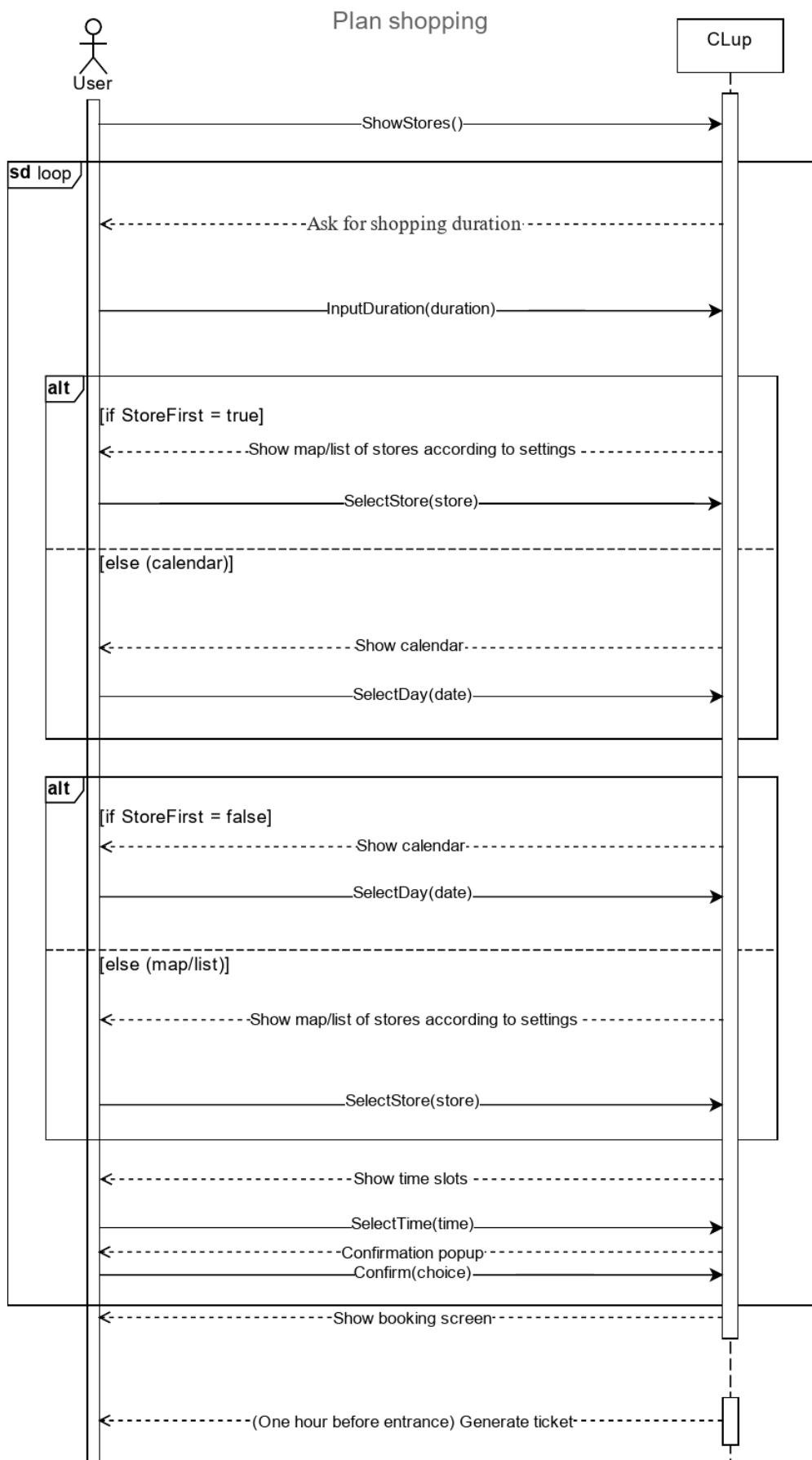


Figure 14: Sequence diagram: User plans visit
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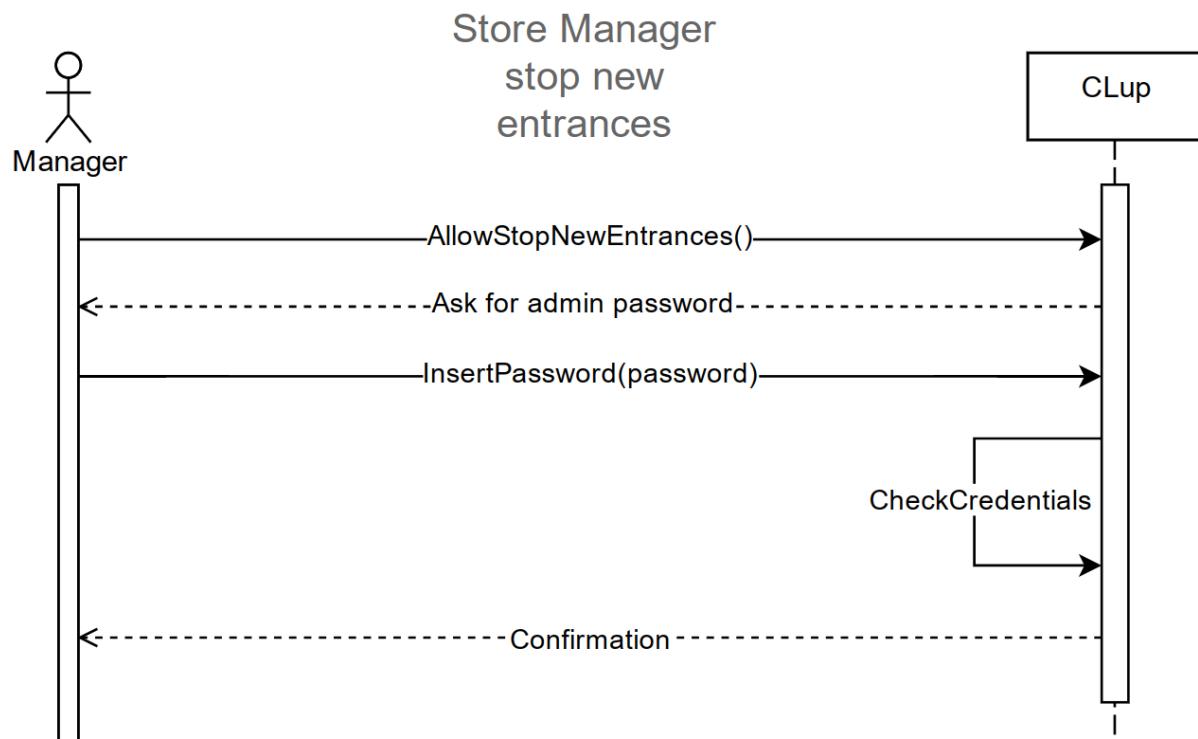


Figure 15: Sequence diagram: Manager stops entrances

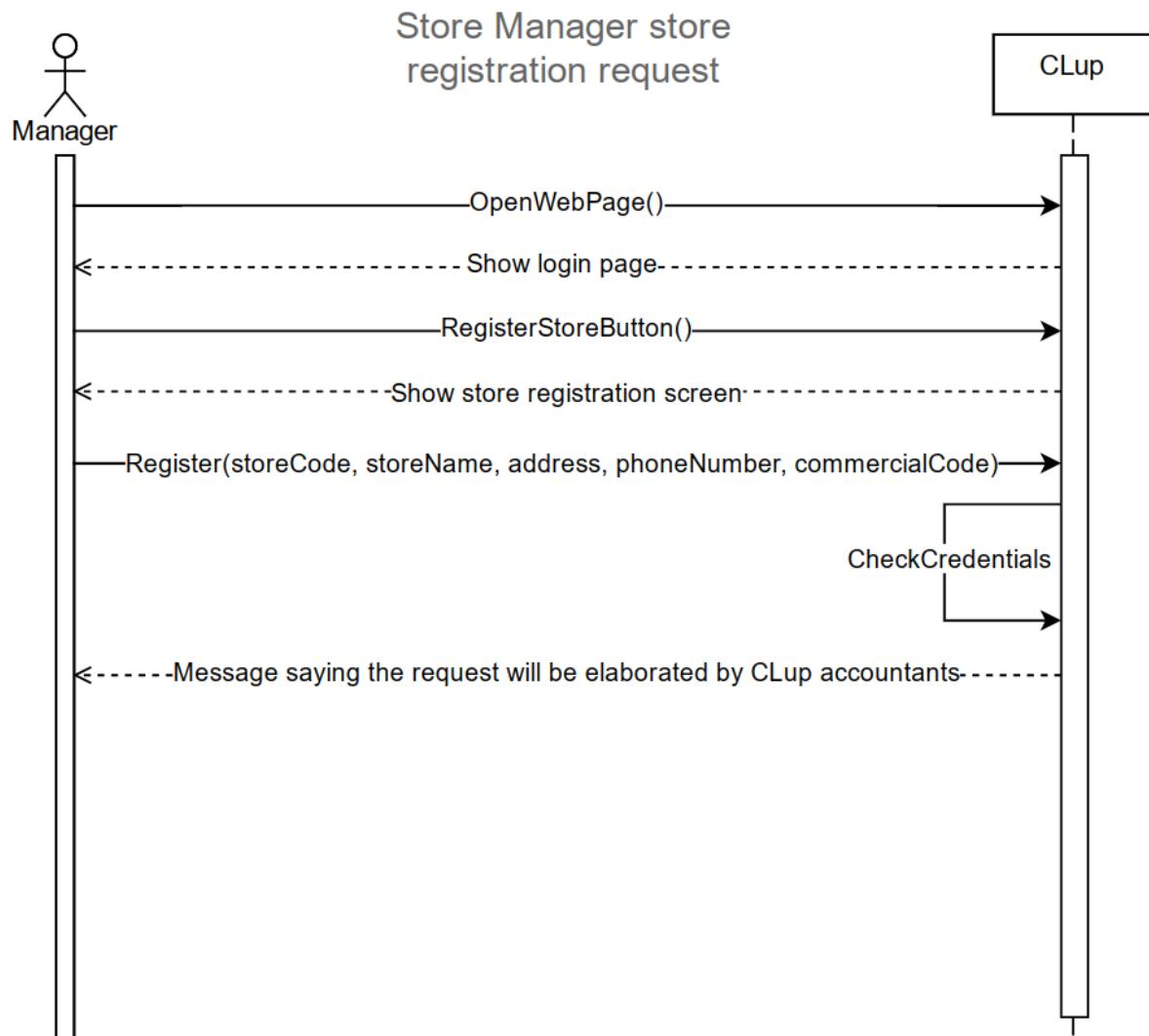


Figure 16: Sequence diagram: Manager registers

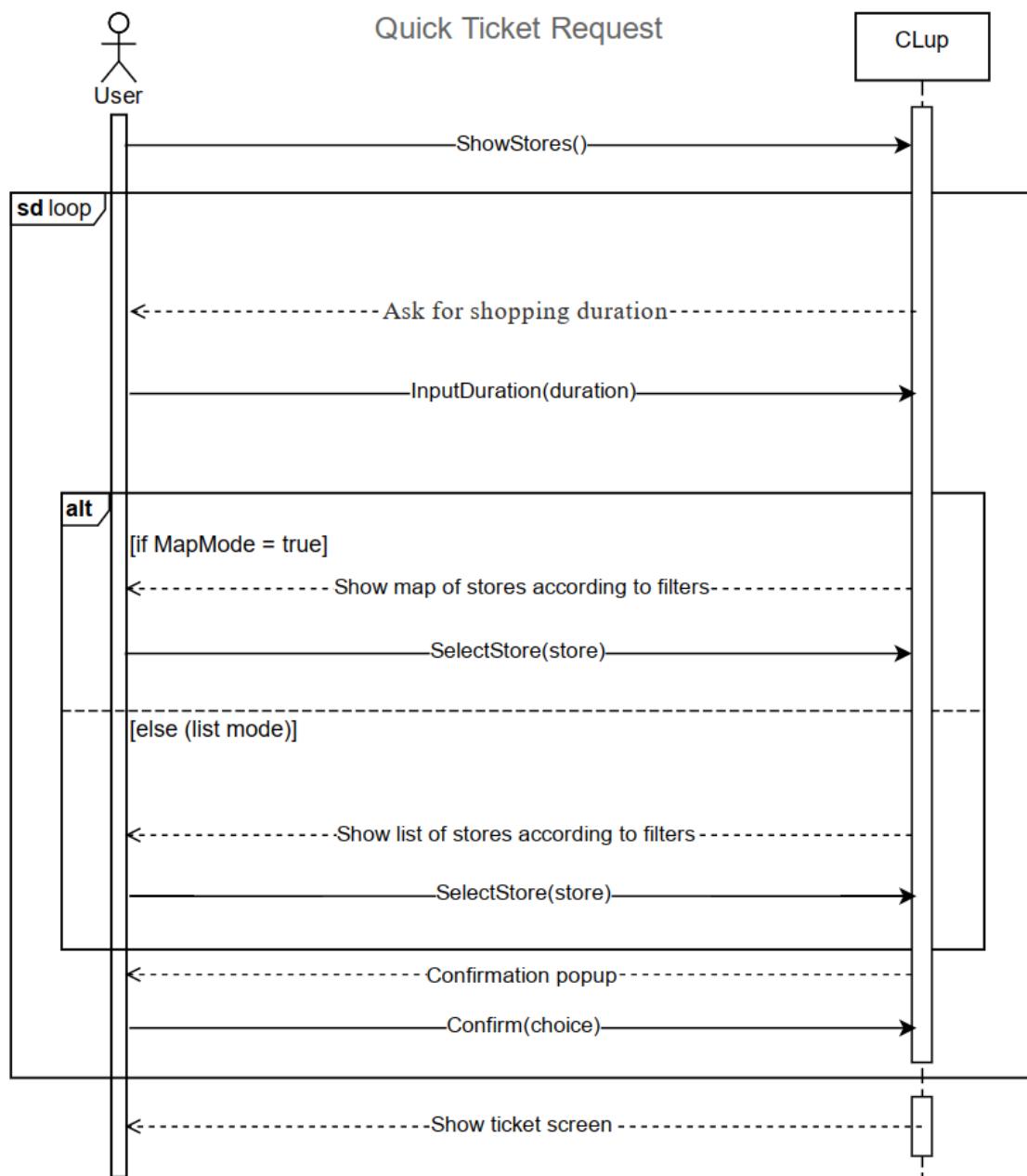


Figure 17: Sequence diagram: Quick ticket request

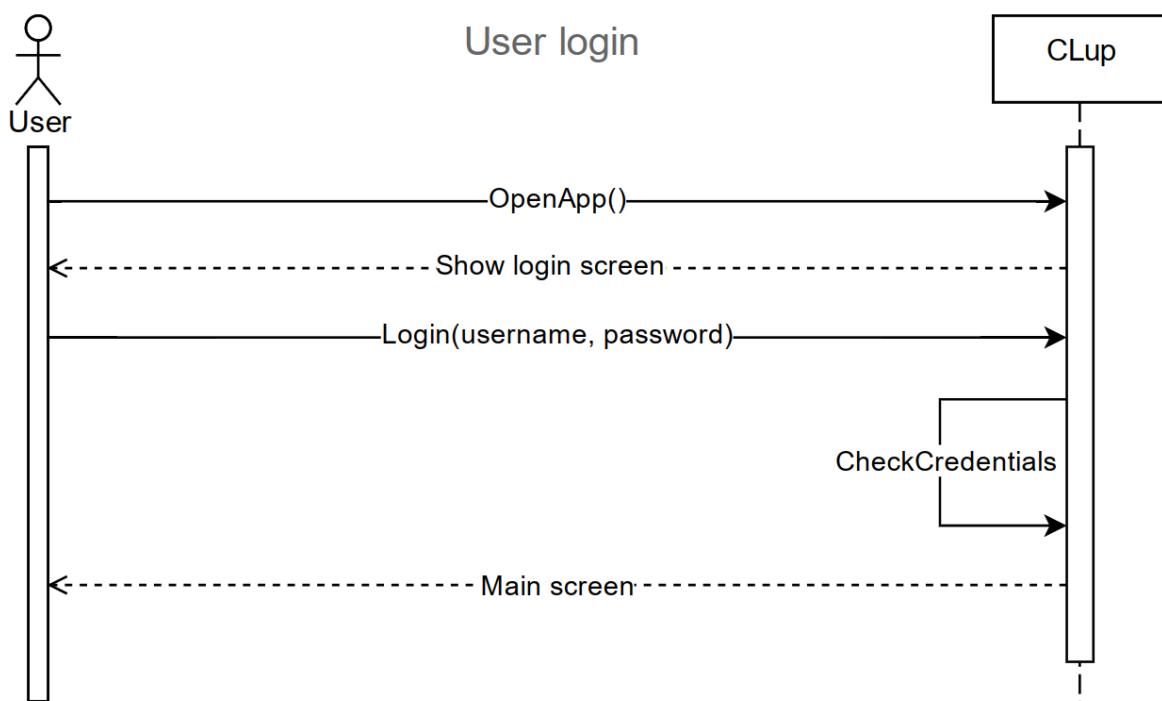


Figure 18: Sequence diagram: User logs in

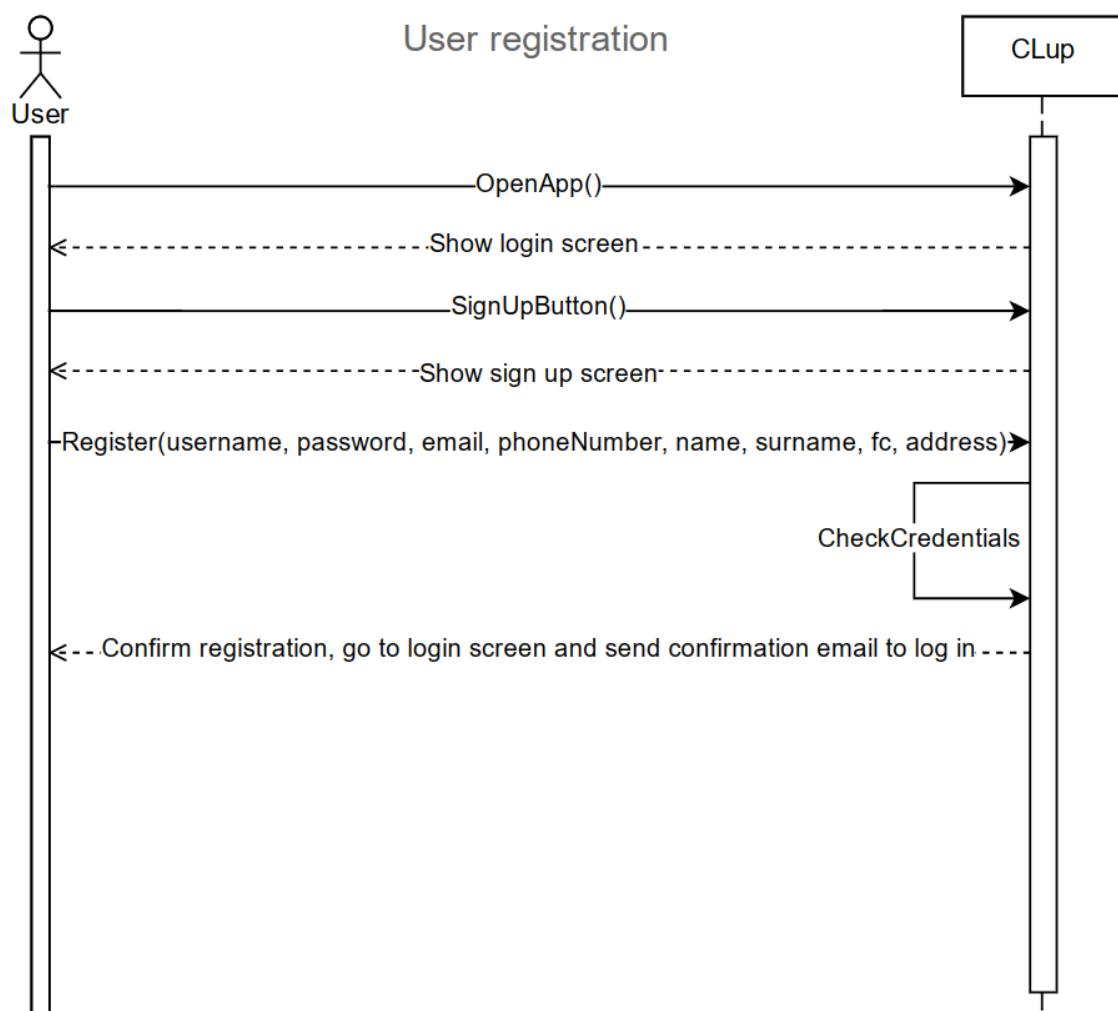


Figure 19: Sequence diagram: User registration

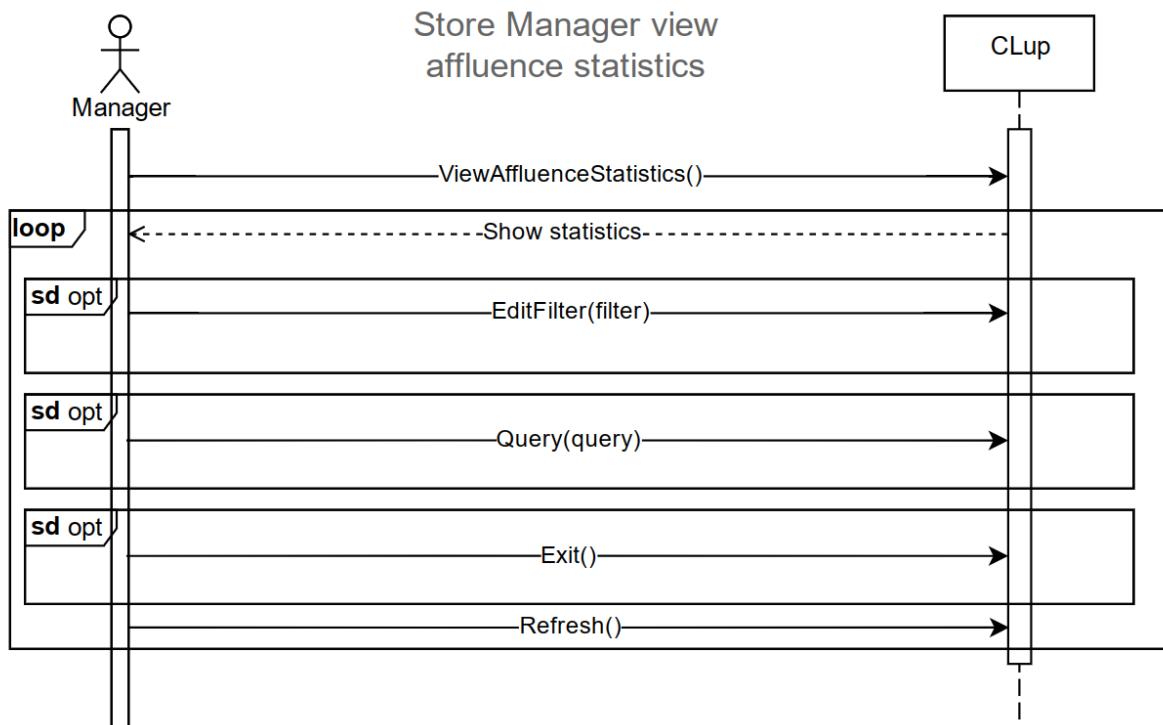


Figure 20: Sequence diagram: Manager views customers statistics

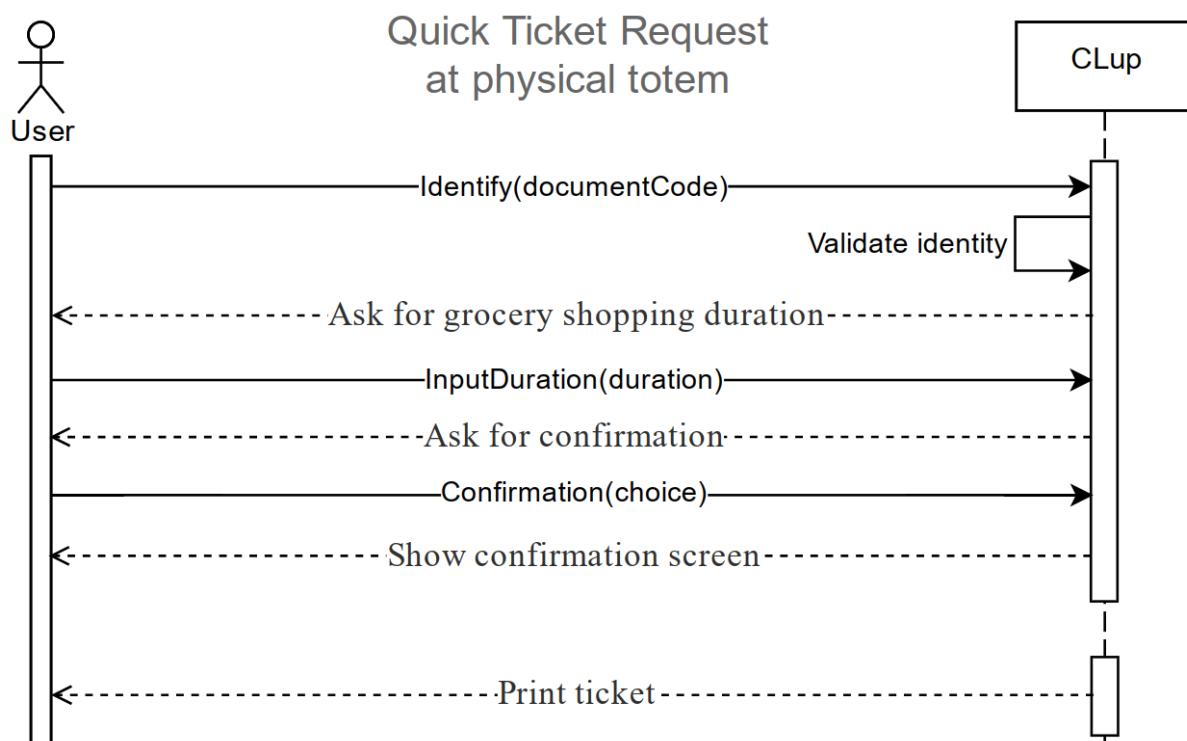


Figure 21: Sequence diagram: Quick ticket at physical totem

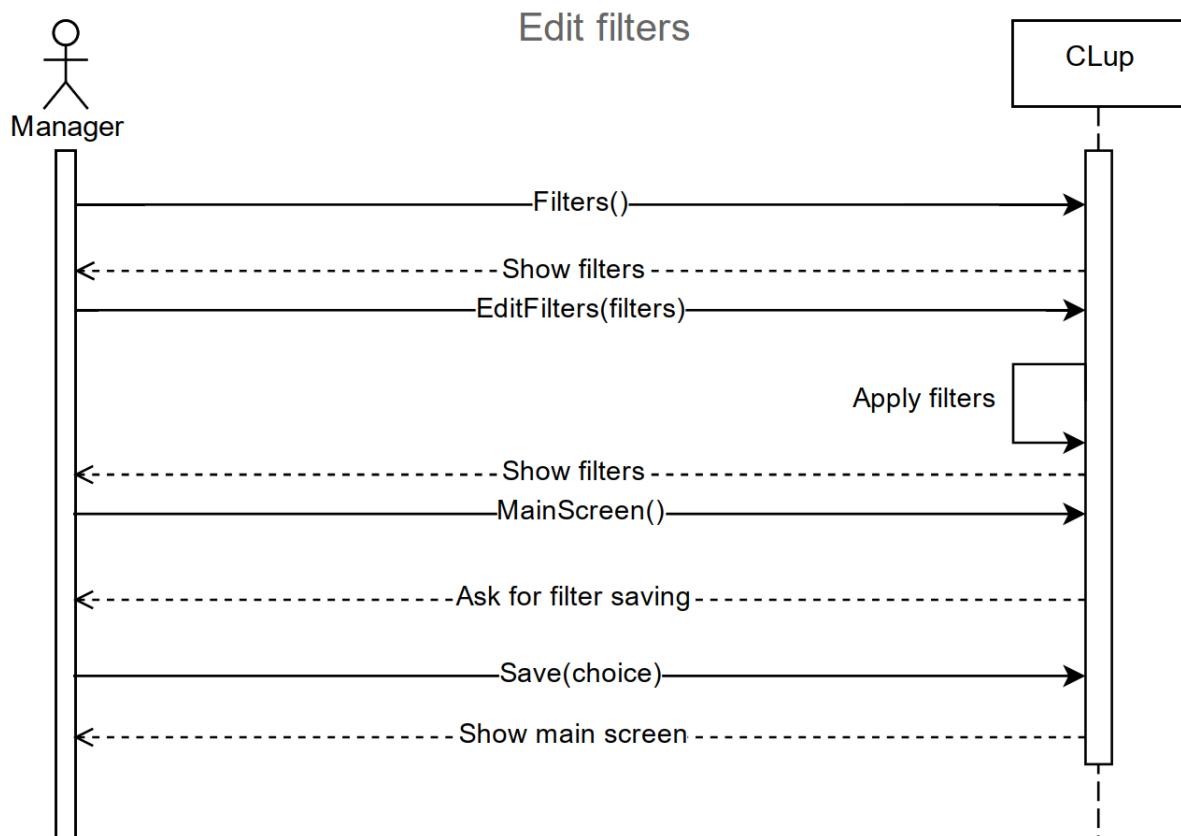


Figure 22: Sequence diagram: Edit filters

3.3 Performance Requirements

Follows a list of critical performance conditions and their associated capabilities.

Dynamic actions Dynamic actions or changes that occur (e.g., rates, velocities, movements, and noise levels).

- 3.3.1.1 CLup totems shall handle multi-touch recognition by a minimum of 2 concurrent touches
- 3.3.1.2 Upon incorrect user data submission, CLup totems must provide user with re-submission prompt in 5 seconds maximum time
- 3.3.1.3 Upon incorrect user data submission, CLup mobile application must provide user with re-submission prompt in 1 second maximum time
- 3.3.1.4 Upon incorrect user data submission, CLup web application must provide staff member with re-submission prompt in 3 seconds maximum time

Endurance capabilities Quantitative criteria covering endurance capabilities of the equipment required to meet the user needs under stipulated environmental and other conditions, including minimum total life expectancy, required operational session duration and planned utilization rate.

- 3.3.2.1 CLup totems shall run a minimum of 240 hours sessions between successive re-boots
- 3.3.2.2 CLup web application backend servers shall process a minimum of 10 requests per minute store-wise or alternatively a minimum of 250K requests per minute country-wise¹
- 3.3.2.3 CLup database servers shall process a minimum of 10K customer sign-up requests per minute, store-wise
- 3.3.2.4 CLup database servers shall process a minimum of 10 staff member sign-up requests per minute, store-wise
- 3.3.2.5 CLup database servers shall handle a minimum of 100 customer-related queries per minute, store-wise
- 3.3.2.6 CLup database servers shall handle a minimum of 10 staff-related queries per minute, store-wise
- 3.3.2.7 CLup database servers shall handle a minimum of 10K bookings-related queries per minute, store-wise.
- 3.3.2.8 CLup web application backend servers shall process a minimum of 10 login sessions per minute, store-wise
- 3.3.2.9 CLup web application servers shall cover a minimum expected lifetime of 5 years each

¹Estimated value calculated over FederDistribuzione data [2]

- 3.3.2.10 CLUp core servers shall cover a minimum expected lifetime of 5 years each
- 3.3.2.11 CLUp outside totems shall cover a minimum expected lifetime of 2 years each
- 3.3.2.12 CLUp outside totems shall withstand a minimum usage rate of 30 quick-ticket generations per hour, or 720 generations per day
- 3.3.2.13 CLUp outside totems shall withstand a minimum ticket generation session of 2 minutes
- 3.3.2.14 Physical turnstiles for access control are requested a minimum throughput of 1 person per second
- 3.3.2.15 CLUp core servers shall process a minimum of 5K queueing requests per hour

Performance requirements for operational phases Performance requirements for the operational phases and modes.

- 3.3.3.1 CLUp totems shall withstand quick ticket printing mode for a minimum of 33% out of the overall up-time
- 3.3.3.2 CLUp big screens shall withstand still queue status graphic elements for a minimum of 98% out of the overall up-time
- 3.3.3.3 CLUp core system functionality shall be guaranteed 99,7% of the requested available time (equivalent to less than 1.1 days of unavailability per year)
- 3.3.3.4 CLUp complete end user functionality shall be guaranteed 99% of the requested available time (equivalent to less than 3.6 days of unavailability per year)

3.4 Design Constraints

Follows a set of constraints on the system design imposed by external standards, regulatory requirements, or project limitations.

3.4.1 Standards compliance

The application requires adhesion to the following standards:

- **Transport Layer Security standard (TLS)** version 1.2 (or higher), [RFC 5246](#)
- **Advanced Encryption Standard** with a 128-bit key or more, [RFC 3394](#)
- 1 February 2015 – Automatic identification and data capture techniques – **QR Code barcode** symbology specification – [ISO/IEC 18004:2015](#)

3.4.2 Hardware limitations

As far as the app version is concerned, CLUp **requires** a device with the following hardware to be operational:

- GNSS (any)

- screen
- pointing input device, such as touchscreens or mice
- internet connectivity
- audio output device

Concerning the **reduced version** to be run on totems outside the stores, the following hardware is **requested**:

- screen
- pointing input device, such as touchscreens or mice
- internet connectivity
- printer device

Finally, the web application for internal use requires:

- screen
- pointing input device, such as touchscreens or mice
- internet connectivity

Given the nature of CLup's primary objectives, implying strong national health concerns, the following requirements have to be fulfilled:

3.4.2.1 Turnstile QR scanning hardware must have a sensitivity value such that **False Acceptance Rate (FAR)** value falls below 5% (righter than Equal Error Rate treshold on figure 23)

3.4.3 Any other constraint

Environmental Constraints

- 3.4.3.1.1** CLup totems shall withstand temperatures between -20° C and +50° C
- 3.4.3.1.2** CLup totems shall withstand winds below 50 km/h
- 3.4.3.1.3** CLup totems shall withstand relative humidity of at least 95%
- 3.4.3.1.4** CLup totems shall withstand solar radiation for a minimum of 1KW² per square meter, 4 hours non-stop
- 3.4.3.1.5** CLup big screens shall withstand temperatures between -20° C and +50° C
- 3.4.3.1.6** CLup big screens shall withstand relative humidity of at least 95%
- 3.4.3.1.7** CLup big screens shall withstand solar radiation for a minimum of 1KW per square meter, 4 hours non-stop

²Calculated by taking into account the Woods Hole O.I. data[5]

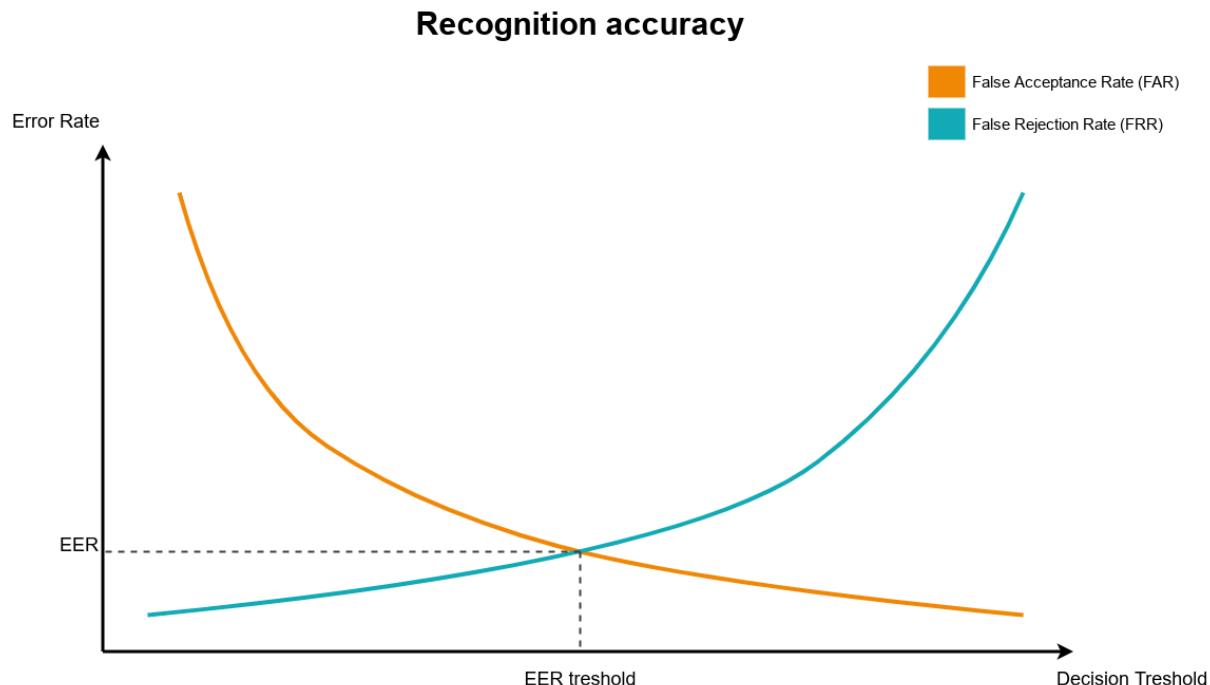


Figure 23: False Acceptance and Rejection Rates (qualitative plot)

Power supply constraints

3.4.3.2.1 CLup core system³ shall operate in case of power failure

3.4.3.2.2 Backup power systems shall provide sufficient backup power capacity for guaranteeing CLup core system functionality 4 hours and up

3.5 Software System Attributes

3.5.1 Reliability

Given the nature of CLup's primary objectives, implying strong national health concerns, the following requirements have to be fulfilled.

3.5.1.1 CLup shall compute current number of occupants with an accuracy equal or higher than 99.999999% (equivalent to 1 wrong computation out of 1 million computations total)

3.5.2 Availability

CLup targets the broadest group of individuals possible, given it's aimed at use for everyone as in depth explained in the previous sections. This indeed strains the availability constraints over the application which must be:

3.5.2.1 Given the presence of 24/7 stores, as additionally specified inside the Alloy Specification sect. (4), the system must have a guaranteed uptime of 24 hours a day, 7 days a week.

³See 1.3.1 for details

3.5.2.2 available to people living inside slow connection areas, thus requiring a minimum 100Kb/s bandwidth to be operational

3.5.2.3 available to old and/or low-end devices, being operational on a minimum configuration of:

- Android version 5.0 or higher
- 1.5 GHz dual core CPUs for Android devices
- 50 MBytes of minimum available storage memory for Android devices
- 512 MBytes minimum of system memory for Android devices
- iOS version 8.0 or higher

3.5.2.4 The staff-operations web application must be able to operate on any modern, HTML5 compliant web-browser, OS-independently

No support for deprecated, unsupported operating system (such as Microsoft ® Windows Phone ®) is being required as the overall market share of those system is below 0.1% [1]

3.5.3 Security

CLup does not require best-in-class security measures given the mainstream nature of its main objectives, yet requires standard security measures to guarantee the following requirements:

3.5.3.1.1 User data AES-128 (or stronger) encryption over the entire user database, as per sect. 3.4.1

3.5.3.1.2 Connection encryption between clients and servers to guarantee authentication and integrity

- Transport Layer Security version 1.2 or higher, as per sect. 3.4.1

3.5.3.1.3 Strong 2-factor authentication (or stronger) must be required for Staff operations, as they imply non-negligible consequences on store operativeness and availability to end users.

3.5.3.1.4 Keep 6+ months old logs about internal staff operations and related authentication sessions.

3.5.3.1.5 Application-level (or more) firewall over database and staff-operations related applications.

3.5.3.1.6 Implementation or outsource use of *anti-DoS* (Denial of Service) techniques/software components.

Physical Security There also are some pretty usual requirements over physical security of the hardware components hosting the CLup software.

3.5.3.2.1 CLup servers shall be enclosed in a secure facility for authorized personnel only.

3.5.3.2.2 There shall be validation and authentication upon entering the servers facility.

3.5.3.2.3 CLup servers facility shall log physical access attempts.

3.5.4 Maintainability

CLUp is inevitably open to great expansion and innovation opportunities due to its potential broad use, hence the need for a highly maintainable and scalable system. The following aspects are necessarily required:

- 3.5.4.1 Code modularity
- 3.5.4.2 Manual code writing privileging over automated generation, eventually privileging code maintainability and stability over eye-candiness and *nice-to-haves* richness.
- 3.5.4.3 Accurate and up-to-date documentation, with a maximum 5% of already implemented, undocumented code rate over total
- 3.5.4.4 Long term support software development kits usage
- 3.5.4.5 Long term support external services usage
- 3.5.4.6 CLUp core system's hardware Mean Time To Repair (MTTR) shall not exceed 2.0 hours
- 3.5.4.7 CLUp core system's hardware Mean Time Between Failures (MTBF) shall be greater than 6200 hours (258.3 days)

3.5.5 Portability

Given its broad spectrum target, CLUp needs to be operational on the largest number of device-/operating system configurations possible. Virtually no device should be eligible for no support by CLUp, however this would potentially lead to infeasibility issues, ultimately slowing down or inhibiting CLUp development.

Therefore, the following minimum requirements are requested for maximised portability:

- 3.5.5.1 A maximum of 10% host-dependant code
- 3.5.5.2 A maximum of 20% elements based on host-dependant code
- 3.5.5.3 Use of HTML5 for static web content
- 3.5.5.4 Use of CSS for web styling
- 3.5.5.5 Use of Java or C++ or C for core application functionalities
- 3.5.5.6 Use of PHP for web application backends
- 3.5.5.7 Use of Linux/Unix based OSs on all servers and end-user totems
- 3.5.5.8 No use of Adobe ® Flash ® technologies

4 Formal Analysis Using Alloy

The next section presents an Alloy Model for CLUp. Just as a remainder, the model has been developed with the following objectives in mind:

- Clarity
- Focus on primary relevance aspects
- Conciseness

Subsequently, a trade-off between completeness and comprehensibility was necessary to render the model either easy at first-glance and unambiguous.

This also means some less relevant factors may have been left uncovered whereas some other pretty much basic (or predefined) elements, such as time-related ones, may have been rewritten and expanded.

The alloy code has been written by taking advantage of the official Alloy Documentation [4].

You may find comments along the way whenever needed. This particularly helps in achieving the clarity goal of the section while preserving conciseness and preventing the need to model elements out of the scope of this Document.

4.1 Alloy code

```
enum Day{Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday}

abstract sig Bool{}
one sig True extends Bool{}
one sig False extends Bool{}

sig Char{} -- using this to comfortably write constraints on strings length
sig Float{
    integer: Int,
    decimal: Int
} {
    decimal>0
}

sig Date{
    year: Int,
    month: Int,
    day: Int,
} {
    year>0
    --year<=3000 //we can't say this with <=10 bits for Int
    month>0
    month<13
    day>0
    day<32
}

sig Time{
    date: Date,
    hour: Int,
    minutes: Int,
    seconds: Int,
} {
    hour<24
    hour≥0
    minutes<60
    minutes≥0
    seconds<60
}
```

```

        seconds≥0
}

sig RelativeTime{
    validDay: one Day,
    hour: one Int,
    minutes: one Int,
    seconds: one Int,
}{{
    hour<24
    hour≥0
    minutes<60
    minutes≥0
    seconds<60
    seconds≥0
}

sig Location{
    latitude: one Float,
    longitude: one Float
}/*{ --this section is left commented out to help keeping the Int bitwidth down
    latitude.integer<85
    latitude.integer>-85
    longitude.integer<180
    longitude.integer>-180
}*/ 

sig Store{
    commercialName: seq Char,
    longName: seq Char,
    location: one Location,
    opensAt: set RelativeTime,
    closesAt: set RelativeTime,
    twentyfourSeven: one Bool,
    occupantsMax: one Int
}{

    twentyfourSeven=False implies (#opensAt>0 ∧ #closesAt>0 ∧ #opensAt=#closesAt)
    twentyfourSeven=True implies (#opensAt=0 ∧ #closesAt=0)
    occupantsMax>0
}

abstract sig Person {
    name: seq Char,
    surname: seq Char,
    fc: seq Char,
    customerId: seq Char,
    tickets: set Ticket,
    reservations: set BookingReservation,
    currentLocation: lone Location //used for timed notifications
}{

    #name>2
    #surname>2
}

one sig Now{
    time: one Time
}

sig Customer extends Person{}

sig StaffMember extends Person{
    cardID: seq Char,
    nowWorkingAt: one Store,
    active: one Bool,
    level: one Int
}{

    #cardID>3
    level>0
}

sig BookingReservation {
    applicant: one Person,
}

```

```

startTime: one Time,
where: one Store,
endTime: one Time,
id: seq Char
}{

    aTimeBeforeB[startTime, endTime]
}

sig Ticket{
    owner: one Person,
    parentQueue: Queue, --identifies parent Queue
    id: seq Char,
    prestoCode: seq Char,
    entranceTime: one Time,
    valid: one Bool,
    active: one Bool,
    scannedIn: lone Time,
    scannedOut: lone Time
}{

    #this.@id>0
}

sig Notification{
    recipient : one Person,
    message: seq Char,
    disposal : one Time //when are we sending this notification
}

sig Queue{
    members: seq Ticket,
    store: one Store, -- each queue refers to a specific store, 1 store <--> 1 queue
    id: seq Char, --each queue has an ID
    estimatedNextEntrance: lone Time
}{

    #members>0
    #this.@id>0
}

one sig NotificationsDB{
    notifications: set Notification
}

one sig Queues{
    queuesList: set Queue
}

one sig CustomersDB{
    customers: set Customer
}

one sig StaffDB{
    staffMembers: set StaffMember
}

one sig BookingsDB{
    bookingsList: set BookingReservation
}

one sig StoresDB{
    storesList: set Store
}

--facts-----
fact userAndFiscalCodesUnique{
    all disj pers,pers1 : Person | pers.fc ≠ pers1.fc ∧ pers.customerId ≠ pers1.customerId
}

fact reservationConsistency{
    all r: BookingReservation | r.startTime.date = r.endTime.date ∧ aTimeBeforeB[r.
        ↵ startTime, r.endTime]
}

```

```

fact noDuplicatedCustomers{
    all disj cust,cust1: Person | cust.customerId ≠ cust1.customerId
}

fact dayConsistency{
    all date : Date | (date.month=11 ∨ date.month=4 ∨ date.month=6 ∨ date.month=9) implies
        ↪ date.day<31 ∧
    (date.month=2) implies date.day<30
}

fact noDBMismatch{
    all p : Person | (isCustomer[p] implies !isStaff[p]) ∧ (isStaff[p] implies !
        ↪ isCustomer[p])
}

fact allPeoplesBelongToDB{
    all p: Person | isCustomer[p] ∨ isStaff[p]
}

fact allStoresBelongToDB{
    all s: Store | s in StoresDB.storesList
}

fact allNotificationsBelongToDB{
    all n: Notification | n in NotificationsDB.notifications
}

fact eachStoreOneQueueMax{
    all disj q, q1 : Queue | q.store≠q1.store
}

fact noDuplicatedTickets{
    all q: Queue | !q.members.hasDups
}

fact userHasNoMultipleTicketsSameDay{
    all disj t,t1: Ticket | (t.owner=t1.owner ∧ t.valid=True ∧ t1.valid=True) implies
        (aDateBeforeB[t.entranceTime.date, t1.entranceTime.date] ∨ aDateBeforeB[t1.entranceTime
            ↪ .date, t.entranceTime.date])
}

fact eachTicketHasParentQueue{
    all t: Ticket | one q: Queue | q=t.parentQueue
}

fact eachReservationHasApplicant{
    all r: BookingReservation | one p: Person | p=r.applicant
}

fact twoWayCorrespondanceTicketQueue{
    all t: Ticket | all q: Queue | t.parentQueue=q iff t in q.members.elems
}

fact twoWayCorrespondanceReservationOwner{
    all r:BookingReservation | all p: Person | r.applicant=p iff r in p.reservations
}

fact twoWayCorrespondanceTicketOwner{
    all t:Ticket, p:Person | (t.owner=p implies t in p.tickets) ∧ (t in p.tickets implies
        ↪ t.owner=p)
}

fact onlyOneBookingPerDayPerUser{
    all disj b, b1: BookingReservation | !(b.startTime.date=b1.startTime.date ∧ b.
        ↪ applicant=b1.applicant)
}

fact eachOpeningDayHasAlsoClosing{
    all s:Store | all o:RelativeTime | o in s.opensAt implies
        (one c:RelativeTime | c.validDay=o.validDay ∧ c in s.closesAt)
}

```

```

fact closingTimeAfterOpening{
    all s:Store | s.twentyfourSeven=False implies (all o,c: RelativeTime |
        (o in s.opensAt ∧ c in s.closesAt ∧ o.validDay=c.validDay) implies
            ↪ aRelativeTimeBeforeB[o, c])
}

--functions -----
fun retrieveTicketsStore[t:Ticket]: one Store {
    t.parentQueue.store
}

fun getCurrOccupants[q: Queue]: one Int {
    #t: Ticket | t.active=True ∧ t in q.members.elems
}

fun getBookedOccupants[s: Store, start:Time, end:Time] : one Int{
    #x: BookingReservation | x.where = s ∧ (sameTime[start, x.startTime]∨ aTimeBeforeB[
        ↪ start, x.startTime])
    ∧ (sameTime[x.startTime, end] ∨ aTimeBeforeB[x.endTime, end]))
    //number of reservations whose start time >= start and end time <= end
}

fun computeDisposalTime[ticketTime: Time, userLocation: Location]: one Time{
    {x: Time}
}

--predicates -----
pred isCustomer[p:Person]{
    p in CustomersDB.customers
}

pred isStaff[p:Person]{
    p in StaffDB.staffMembers
}

pred aDateBeforeB[a:Date , b: Date]{
    a.year<b.year ∨ (a.year=b.year ∧ a.month< b.month) ∨ (a.year=b.year ∧ a.month= b.month ∧ a.
        ↪ day<b.day)
}

pred aRelativeTimeBeforeB[a,b:RelativeTime]{
    a.validDay=b.validDay ∧ ((a.hour<b.hour) ∨ (a.validDay=b.validDay ∧ a.hour=b.hour ∧ a.
        ↪ .minutes<b.minutes) ∨
    (a.validDay=b.validDay ∧ a.hour=b.hour ∧ a.minutes=b.minutes ∧ a.seconds<b.seconds))
}

pred aTimeBeforeB[a: Time, b: Time]{
    aDateBeforeB[a.date, b.date] ∨ (a.date=b.date ∧ a.hour<b.hour) ∨ (a.date=b.date ∧ a.
        ↪ hour=b.hour ∧ a.minutes<b.minutes) ∨
    (a.date=b.date ∧ a.hour=b.hour ∧ a.minutes=b.minutes ∧ a.seconds<b.seconds)
}

pred sameTime[a, b : Time]{
    !(aTimeBeforeB[a,b]∨aTimeBeforeB[b, a])
}

pred userHasBooked[p: Person]{
    some r: BookingReservation | r in BookingsDB.bookingsList ∧ r.applicant=p
}

pred hasTicket[p: Person]{
    some q: Queue | some t: Ticket | t.owner=p ∧ t in q.members.elems
}

pred maxOccupantsNotExceeded[s: Store]{
    all q: Queue | q.store = s implies plus[getCurrOccupants[q], 1]<s.occupantsMax
}

pred bookingsNotExceedingMaxOccupants[s: Store, start: Time, end: Time]{
    getBookedOccupants[s, start, end]+1≤s.occupantsMax
}

```

```

pred hasTicketForThisStore[p: Person, s: Store]{
    some t: Ticket | t in p.tickets ∧ retrieveTicketsStore[t]=s
}

pred activateTicket[t : Ticket]{
    t.active=True ∧ t.scannedIn=Now.time
}

pred expireTicket[t: Ticket]{
    t.active=False ∧ t.scannedOut=Now.time ∧ t.valid=False
}

pred allowUserIn[p:Person, thisStore: Store]{
    //ensures we're not going to exceed store's capacity with a new ticket
    maxOccupantsNotExceeded[thisStore] ∧ (some t: Ticket | hasTicketForThisStore[p,
        ↪ thisStore] ∧ t.valid=True
    ∧ activateTicket[t]) //activates ticket to track user's entrance/exit
}

//adding a reservation
pred book[b, b': BookingsDB, a: Person, start:Time, store: Store, end: Time]{
    bookingsNotExceedingMaxOccupants[store, start, end] //ensures we're not going to
    ↪ exceed store's capacity with new bookings
    aTimeBeforeB[Now.time, start] //we don't want reservations in the past
    b'.bookingsList.applicant = b.bookingsList.applicant + a
    b'.bookingsList.startTime= b.bookingsList.startTime + start
    b'.bookingsList.where= b.bookingsList.where + store
    b'.bookingsList.endTime= b.bookingsList.endTime + end
}

pred getQuickTicket[q, q': Queues, a: Person, t:Time, s: Store]{
    q'.queuesList.members.elems.owner = q.queuesList.members.elems.owner + a
    q'.queuesList.members.elems.entranceTime= q.queuesList.members.elems.entranceTime+t
    q'.queuesList.store= q.queuesList.store + s
    (all ticket: Ticket | (ticket.owner=a ∧ ticket.entranceTime=t) implies ticket.valid=True
     ↪ ) //new tickets are valid
    (some v1, v2: NotificationsDB | { //generate notifications accordingly
        v2.notifications.recipient=v1.notifications.recipient + a
        v2.notifications.disposal=v1.notifications.disposal + computeDisposalTime[t, a,
            ↪ currentLocation]
    })
}

pred deleteQuickTicket[q, q': Queues, t: Ticket]{
    q'.queuesList.members.elems.owner = q.queuesList.members.elems.owner - t.owner
    q'.queuesList.members.elems.entranceTime= q.queuesList.members.elems.entranceTime - t
    ↪ .entranceTime
    (#q'.queuesList.members.t≥1) ∨ (q'.queuesList.store= q.queuesList.store -
    ↪ retrieveTicketsStore[t])
    (all ticket: Ticket | (ticket.owner=t.owner ∧ ticket.entranceTime=t.entranceTime)
     ↪ implies ticket.valid=False) //old tickets are invalid
}

pred temporaryStopStore[s: Store]{
    all q: Queue, t : Ticket | (q.store = s ∧ t in q.members.elems) implies t.valid=False
}

pred exitStore[t: Ticket]{
    expireTicket[t] ∧ (some q, q': Queues | deleteQuickTicket[q, q', t])
}

pred notificationDispatch{
    all n: Notification | aTimeBeforeB[n.disposal, Now.time] implies sendNotification[n]
}

pred sendNotification[n: Notification] {}

--assertions-----
assert customersInCustomersDB{

```

```

        all c: Customer | isCustomer[c]
}

assert staffMembersInStaffDB{
    all s: StaffMember | isStaff[s]
}

assert noOrphanTicket{
    no t: Ticket | some p: Person | t.owner=p ∧ !hasTicket[p]
}

assert noTicketNoEntry{
    no p: Person, s: Store | !hasTicketForThisStore[p,s] ∧ allowUserIn[p, s]
}

assert getQuickTicketGrantsEnter{
    all p: Person, t:Time, s:Store, disj q,q': Queues | getQuickTicket[q, q',p, t, s]
        ↪ implies allowUserIn[p,s]
}

assert generateTicketDoesNotExceedMaxOccupants{
    all p: Person, t:Time, s:Store, disj q,q': Queues | getQuickTicket[q, q',p, t, s]
        ↪ implies maxOccupantsNotExceeded[s]
}

assert bookingDoesNotExceedMaxOccupants{
    all p: Person, s,e :Time, st:Store, disj b,b': BookingsDB | book[b, b', p, s, st, e]
        ↪ implies bookingsNotExceedingMaxOccupants[st, s, e]
}

assert neverAllowInMoreThanMax{
    no p:Person, s:Store | allowUserIn[p, s] ∧ !maxOccupantsNotExceeded[s]
}

assert delUndoesAdd{
    all disj q, q', q'': Queues, p: Person, t: Time, s: Store, ticket: Ticket |
        (ticket.owner=p ∧ ticket.entranceTime=t ∧ getQuickTicket[q, q', p, t, s] ∧
            ↪ deleteQuickTicket[q', q'', ticket])
    implies
        (q.queuesList.members = q''.queuesList.members)
}

--commands-----
check delUndoesAdd for 7 Int
check neverAllowInMoreThanMax for 7 Int
check bookingDoesNotExceedMaxOccupants for 7 Int
check generateTicketDoesNotExceedMaxOccupants for 7 Int
check getQuickTicketGrantsEnter for 7 but 7 Int
check customersInCustomersDB for 7 Int
check staffMembersInStaffDB for 7 Int
check noOrphanTicket for 7 Int
check noTicketNoEntry for 7 Int
run {some t: Ticket | t.valid=True} for 7 Int
run hasTicket for 7 Int
run hasTicketForThisStore for 7 Int
run {some p:Person | hasTicket[p] ∧ isCustomer[p]} for 7 Int
run {some p:Person | hasTicket[p] ∧ isStaff[p]} for 7 Int
run {some p:Person, s:Store | allowUserIn[p,s] ∧ isStaff[p]} for 7 Int
run {some p:Person, s:Store | allowUserIn[p,s] ∧ isCustomer[p]} for 7 Int
run userHasBooked for 7 Int
run isCustomer for 7 Int
run isStaff for 7 Int
run aDateBeforeB for 7 Int
run book for 7 Int
run getQuickTicket for 7 Int
run {some s, s1: Store | s.twentyfourSeven=True ∧ s1.twentyfourSeven=False} for 7 Int
run aTimeBeforeB for 7 Int
run maxOccupantsNotExceeded for 7 Int
run temporaryStopStore for 7 Int
run notificationDispatch for 7 Int
run exitStore for 7 Int
run deleteQuickTicket for 7 Int

```

4.2 Alloy generated worlds

Follows a list of the most relevant, automatically generated worlds by using the Alloy Tool. First of the list is the *Metamodel*.

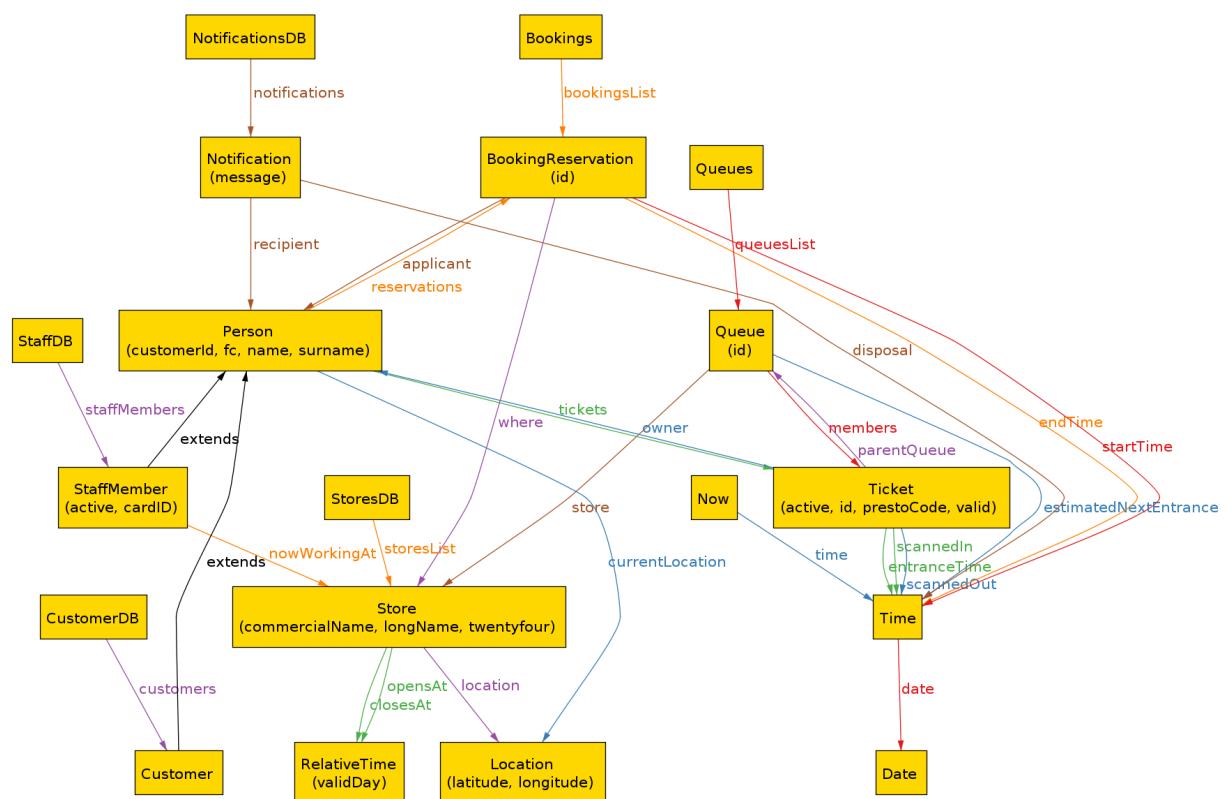


Figure 24: The Alloy Metamodel

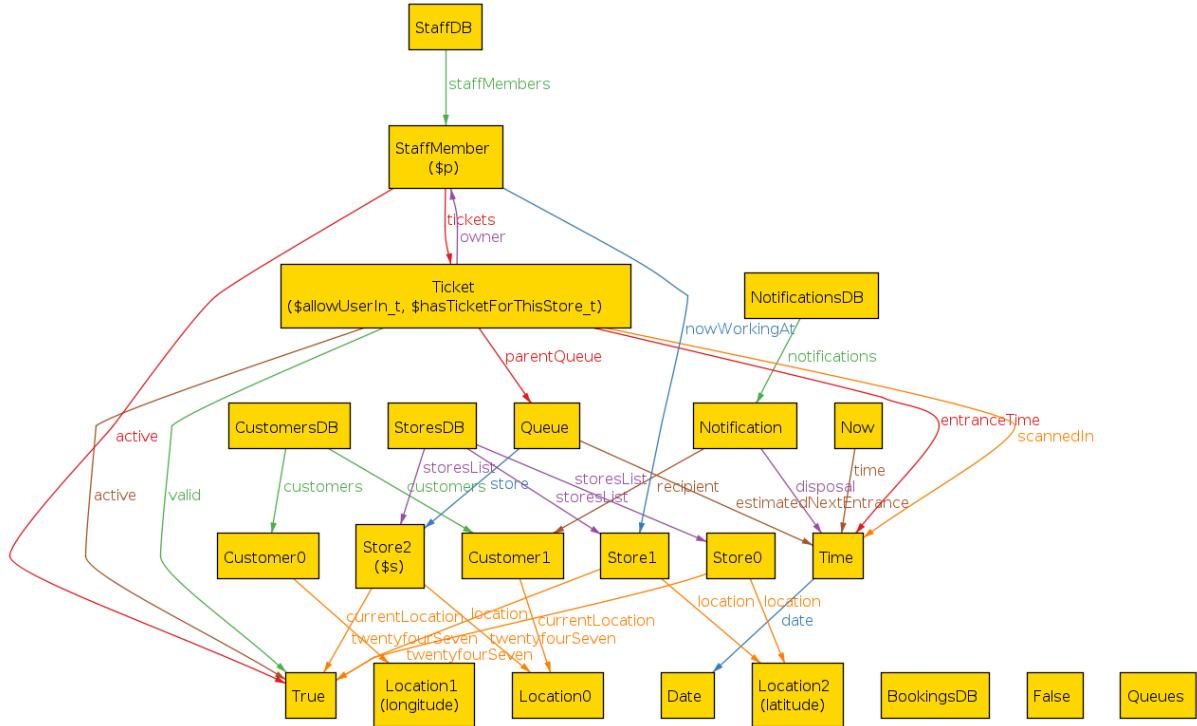


Figure 25: A staff member is allowed inside the store for shopping, hence being treated as a customer

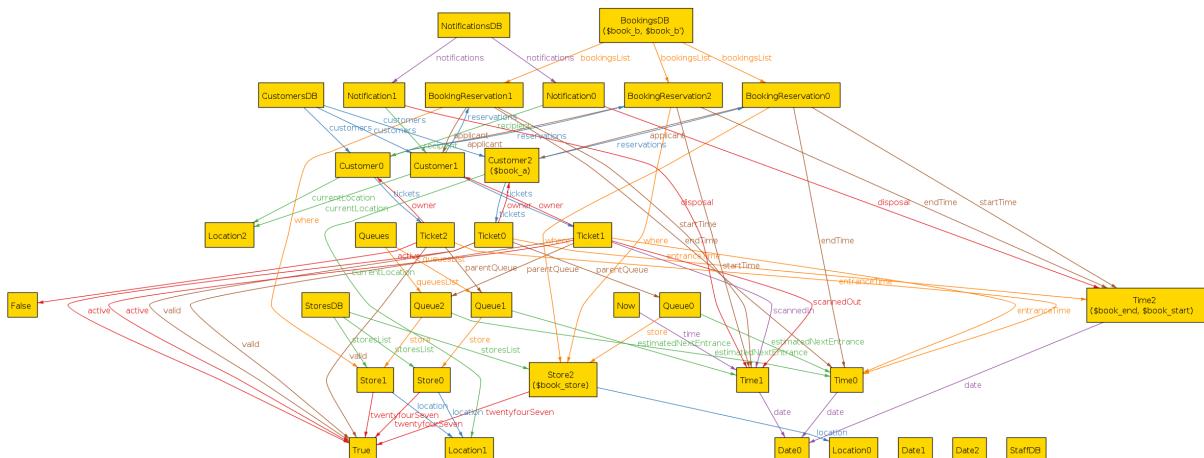


Figure 26: A booking procedure takes place

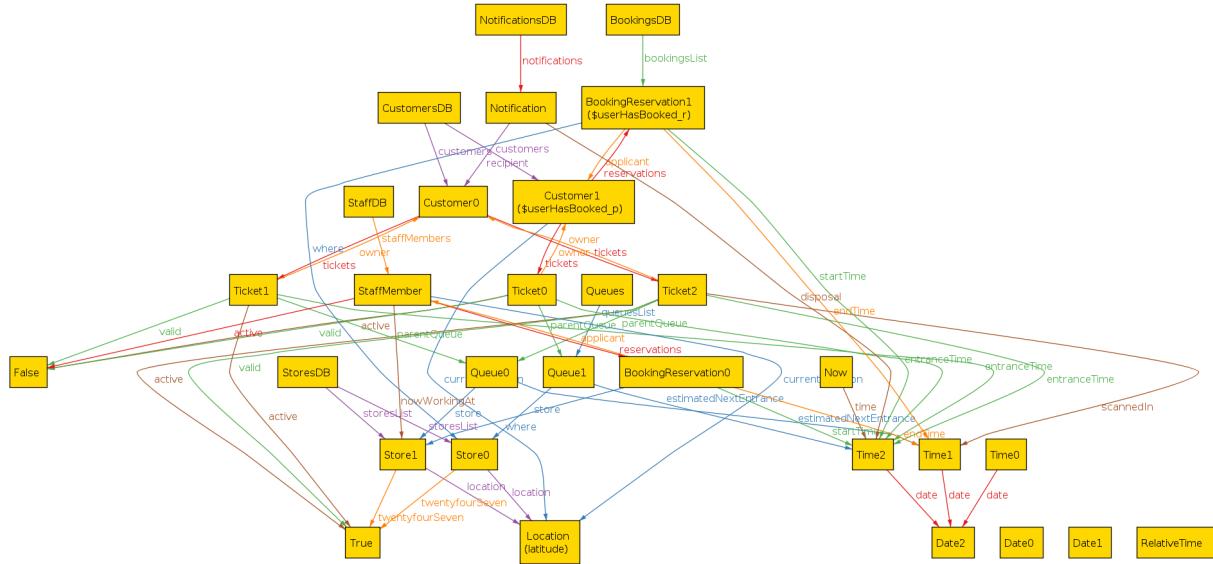


Figure 27: User has made a reservation

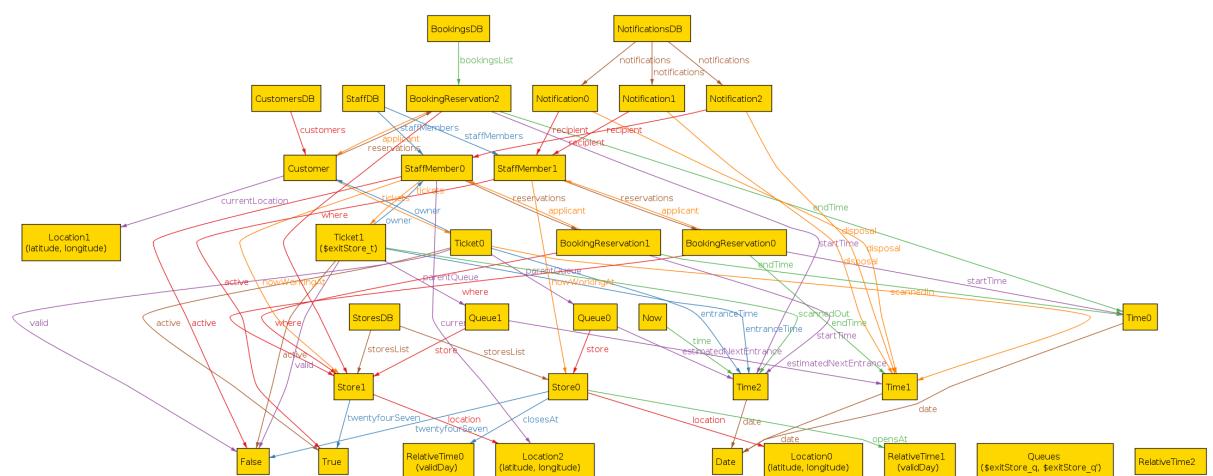


Figure 28: User exits the store after shopping, causing ticket deletion

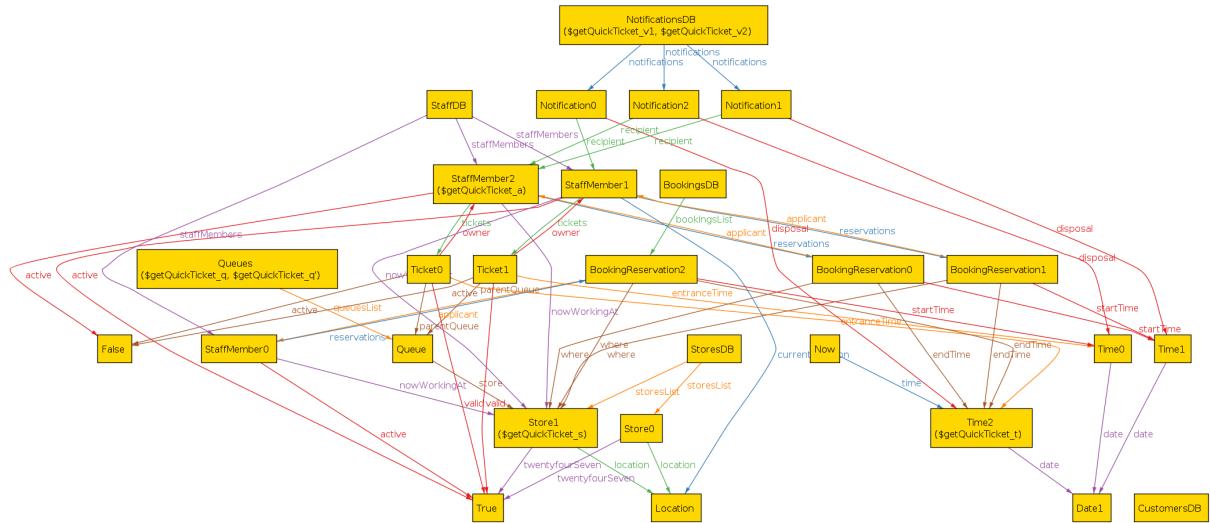


Figure 29: User gets a new quick ticket by using the mobile application

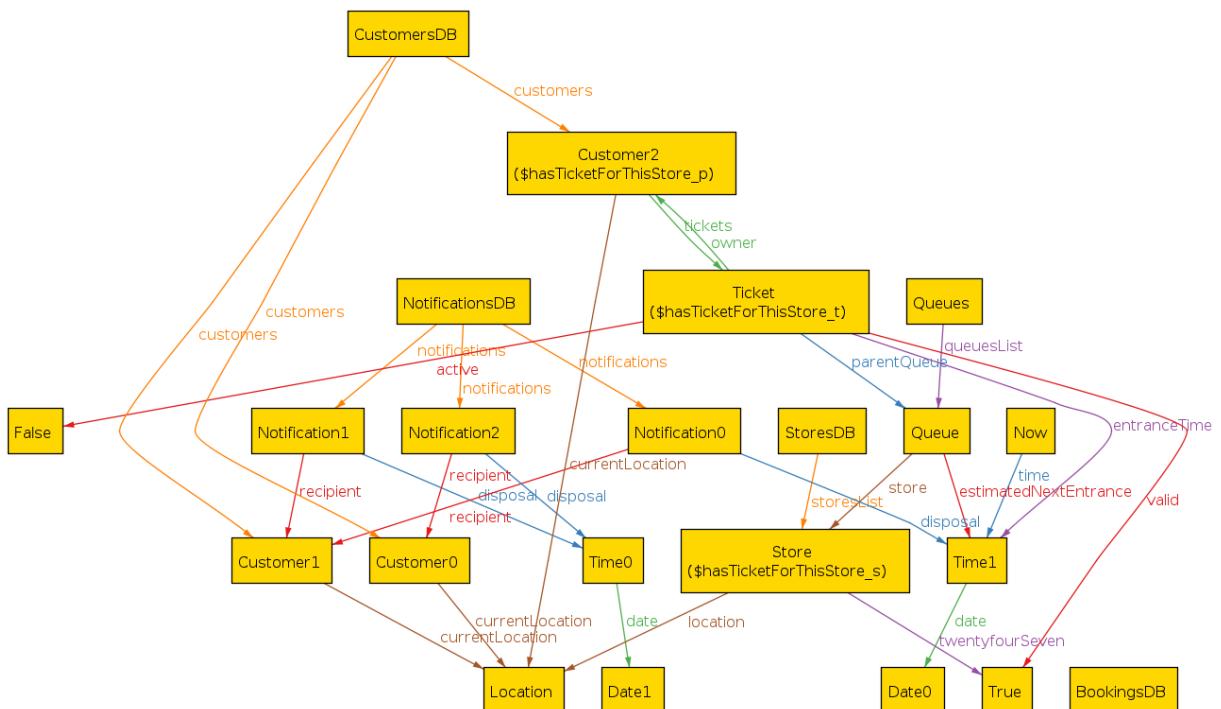


Figure 30: User has a valid ticket for entrance

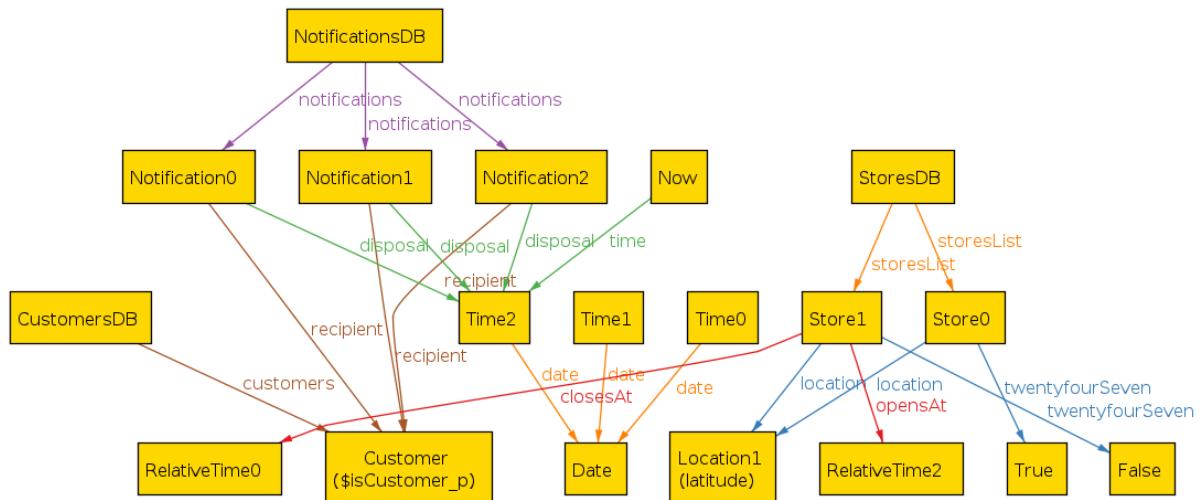


Figure 31: A new customer

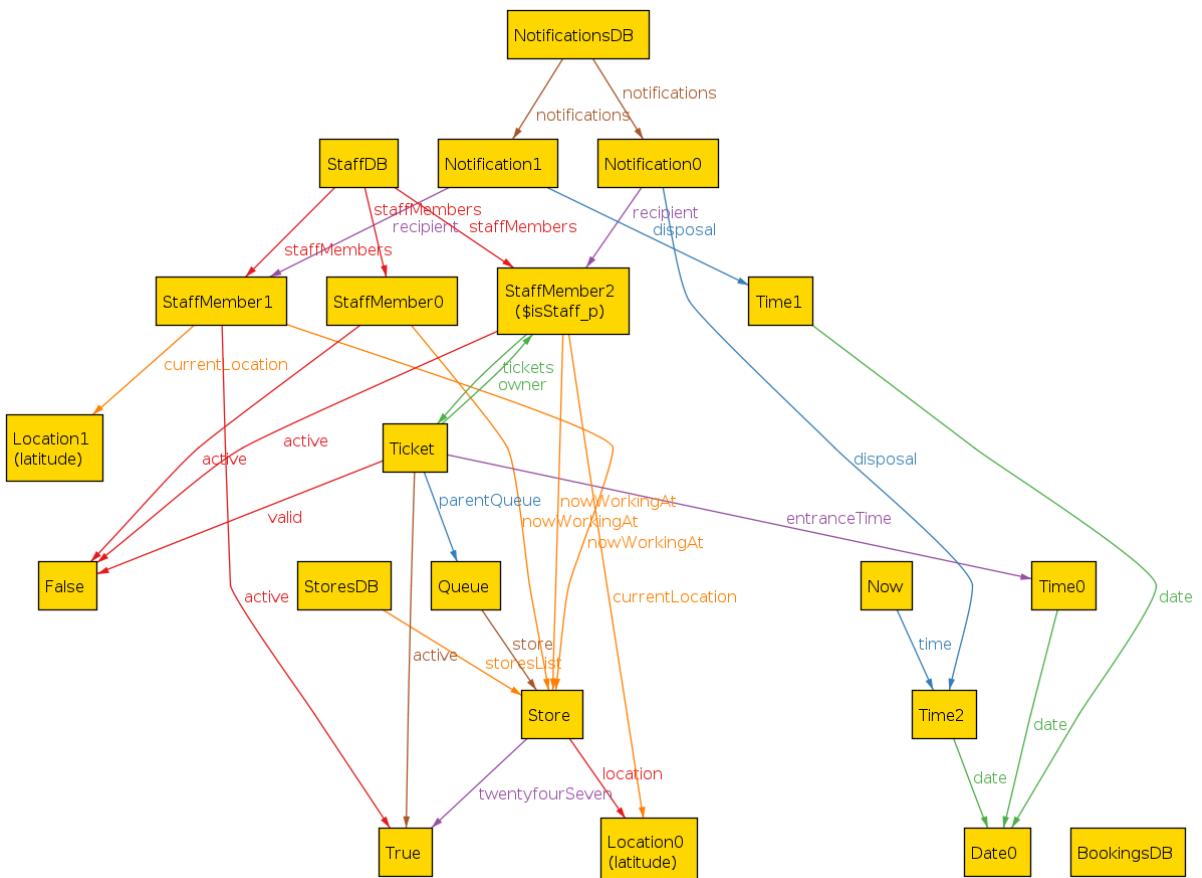


Figure 32: A new staff member

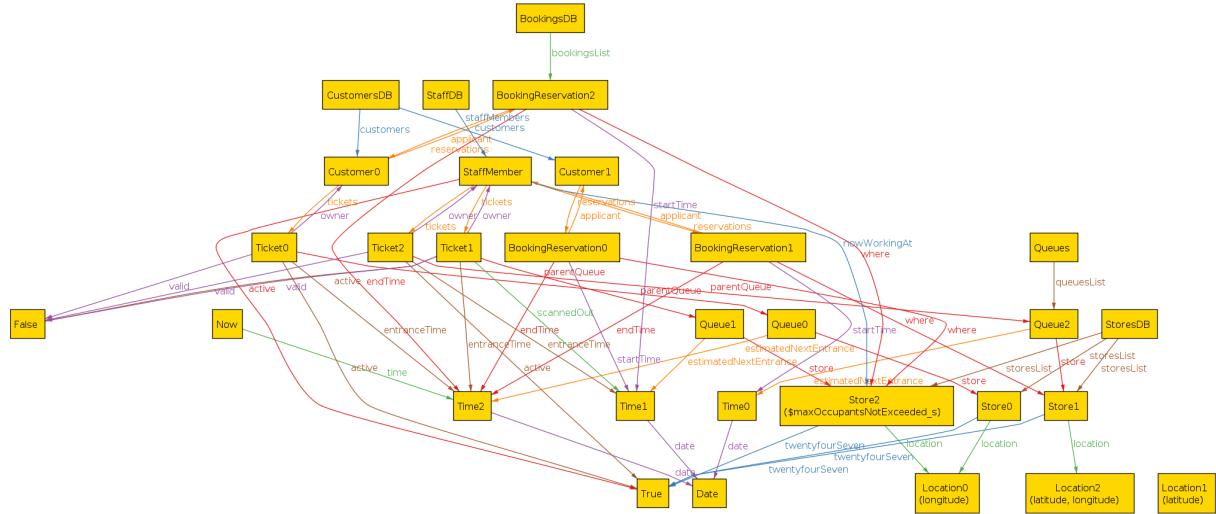


Figure 33: Showing it is possible not to exceed the max capacity of a store

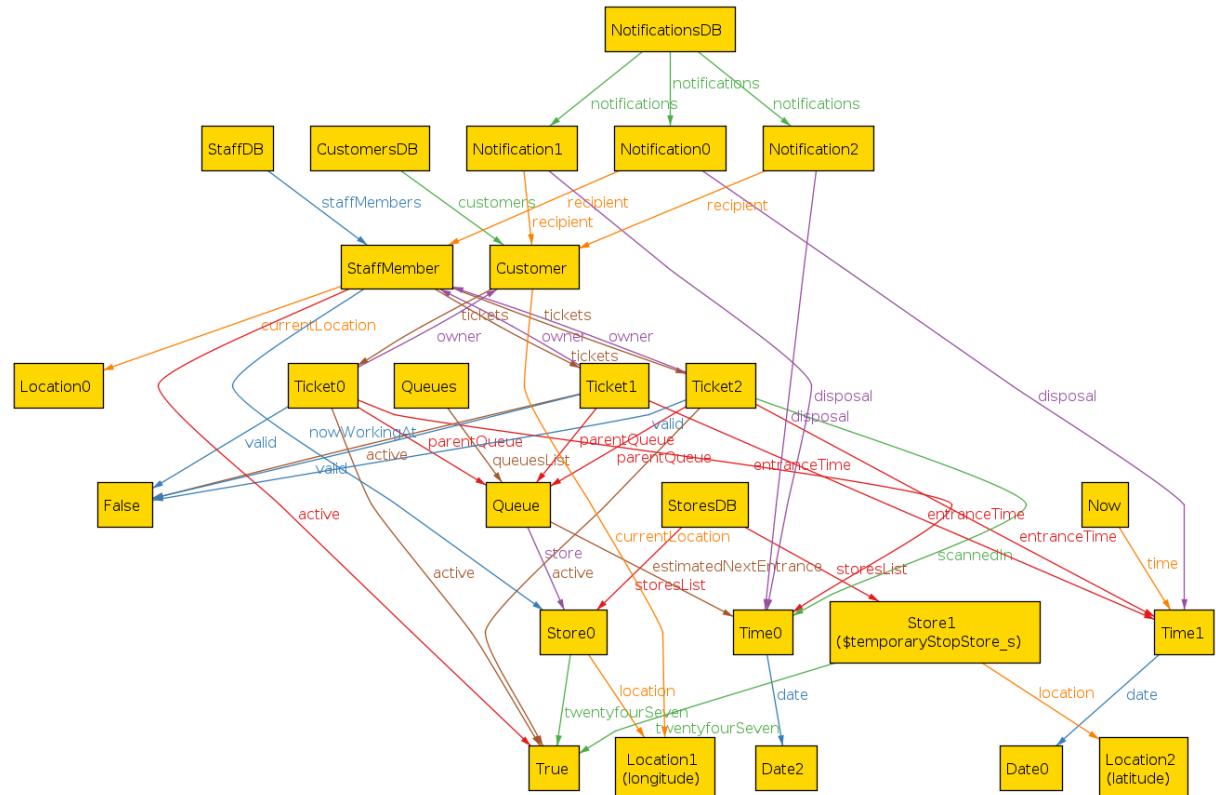


Figure 34: Demonstrating the possibility of temporary interrupting store public access by the staff

4.3 Model test results

The following extracts represent the results from testing the Alloy model with the automated tool.

```
Alloy Analyzer 5.1.0 built 2019-08-14T18:53:58.297Z

Executing "Check delUndoesAdd for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
215328 vars. 5789 primary vars. 779152 clauses. 1083ms.
No counterexample found. Assertion may be valid. 17ms.

Executing "Check neverAllowInMoreThanMax for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
217432 vars. 5787 primary vars. 787947 clauses. 777ms.
No counterexample found. Assertion may be valid. 239ms.

Executing "Check bookingDoesNotExceedMaxOccupants for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
275695 vars. 5786 primary vars. 1024493 clauses. 1278ms.
No counterexample found. Assertion may be valid. 35ms.

Executing "Check generateTicketDoesNotExceedMaxOccupants for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
217556 vars. 5788 primary vars. 788373 clauses. 645ms.
No counterexample found. Assertion may be valid. 29ms.

Executing "Check getQuickTicketGrantsEnter for 7 but 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=7 SkolemDepth=1 Symmetry=20
622401 vars. 17504 primary vars. 2200810 clauses. 3132ms.
No counterexample found. Assertion may be valid. 76ms.

Executing "Check customersInCustomersDB for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214573 vars. 5775 primary vars. 777236 clauses. 608ms.
No counterexample found. Assertion may be valid. 34ms.

Executing "Check staffMembersInStaffDB for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214573 vars. 5775 primary vars. 777236 clauses. 571ms.
No counterexample found. Assertion may be valid. 32ms.

Executing "Check noOrphanTicket for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214665 vars. 5778 primary vars. 777395 clauses. 602ms.
No counterexample found. Assertion may be valid. 85ms.

Executing "Check noTicketNoEntry for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
217366 vars. 5784 primary vars. 787514 clauses. 593ms.
No counterexample found. Assertion may be valid. 82ms.
```

Figure 35: Test results, part 1

```

Executing "Run run$10 for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214594 vars. 5775 primary vars. 777272 clauses. 537ms.
Instance found. Predicate is consistent. 859ms.

Executing "Run hasTicket for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214690 vars. 5781 primary vars. 777443 clauses. 581ms.
Instance found. Predicate is consistent. 1111ms.

Executing "Run hasTicketForThisStore for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214661 vars. 5781 primary vars. 777414 clauses. 555ms.
Instance found. Predicate is consistent. 645ms.

Executing "Run run$13 for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214695 vars. 5781 primary vars. 777451 clauses. 675ms.
Instance found. Predicate is consistent. 1604ms.

Executing "Run run$14 for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214695 vars. 5781 primary vars. 777451 clauses. 543ms.
Instance found. Predicate is consistent. 933ms.

Executing "Run run$15 for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
217300 vars. 5784 primary vars. 787331 clauses. 571ms.
Instance found. Predicate is consistent. 912ms.

Executing "Run run$16 for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
217300 vars. 5784 primary vars. 787331 clauses. 555ms.
Instance found. Predicate is consistent. 754ms.

Executing "Run userHasBooked for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214617 vars. 5778 primary vars. 777323 clauses. 554ms.
Instance found. Predicate is consistent. 1578ms.

Executing "Run isCustomer for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214573 vars. 5775 primary vars. 777235 clauses. 784ms.
Instance found. Predicate is consistent. 1149ms.

Executing "Run isStaff for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214573 vars. 5775 primary vars. 777235 clauses. 538ms.
Instance found. Predicate is consistent. 3523ms.

```

Figure 36: Test results, part 2

```

Executing "Run aDateBeforeB for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
229846 vars. 5778 primary vars. 835307 clauses. 558ms.
Instance found. Predicate is consistent. 1718ms.

Executing "Run book for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
275691 vars. 5786 primary vars. 1024432 clauses. 774ms.
Instance found. Predicate is consistent. 5723ms.

Executing "Run getQuickTicket for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214978 vars. 5785 primary vars. 778298 clauses. 753ms.
Instance found. Predicate is consistent. 1373ms.

Executing "Run run$23 for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214624 vars. 5778 primary vars. 777320 clauses. 695ms.
Instance found. Predicate is consistent. 703ms.

Executing "Run aTimeBeforeB for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
245124 vars. 5778 primary vars. 893425 clauses. 587ms.
Instance found. Predicate is consistent. 1380ms.

Executing "Run maxOccupantsNotExceeded for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
217178 vars. 5775 primary vars. 787084 clauses. 613ms.
Instance found. Predicate is consistent. 1883ms.

Executing "Run temporaryStopStore for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214652 vars. 5775 primary vars. 777353 clauses. 524ms.
Instance found. Predicate is consistent. 2096ms.

Executing "Run notificationDispatch for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
276924 vars. 5772 primary vars. 777223 clauses. 801ms.
Instance found. Predicate is consistent. 896ms.

Executing "Run exitStore for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214996 vars. 5777 primary vars. 778376 clauses. 538ms.
Instance found. Predicate is consistent. 2425ms.

Executing "Run deleteQuickTicket for 7 int"
Solver=minisat(jni) Bitwidth=7 MaxSeq=4 SkolemDepth=1 Symmetry=20
214952 vars. 5777 primary vars. 778285 clauses. 551ms.
Instance found. Predicate is consistent. 1035ms.

```

Figure 37: Test results, part 3

5 Effort Spent

In this section we provide an overview about how many times each section requires us to be made.

Section 1.1.1	1 hour
Section 1.2.1	0.5 hours
Section 1.2.2	0.5 hours
Sections 1.3, 1.4, 1.5	0.5 hours
Section 2.1.1	0.3 hours
Section 2.1.3	2 hours
Section 2.4	0.5 hours
Section 3.2.1	1 hour
Section 3.2.2	1 hour
Section 3.2.4	0.5 hours
Section 3.3	1 hour
Section 3.4	2.5 hours
Section 3.5	3.5 hours
Section 4	20 hours
Section 5	0.5 hours
Section 6	1.2 hours
Diagrams	4 hours

Table 32: Pozzi's work overview

References

- [1] **Mobile Operating Systems market share.** Technical report, Statcounter, 2020. URL: <https://gs.statcounter.com/os-market-share/mobile/worldwide>.
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- [3] Software & Systems Engineering Standards Committee of the IEEE Computer Society. **ISO/IEC/IEEE 29148:2011(E), Systems and software engineering — Life cycle processes — Requirements engineering.** 2011-12-11. URL: <https://ieeexplore.ieee.org/document/8559686>.
- [4] The MIT Software Design Group. **Alloy Documentation & Reference**, 2020. URL: <https://alloytools.org/documentation.html>.
- [5] The Woods Hole Oceanographic Institution. **Solar Radiation.** URL: <https://www.whoi.edu/science/AOPE/mvco/description/SolRad.html>.