Computer Science and Engineering
Software Engineering 2 Project - Prof. Elisabetta Di Nitto

CLup – Customers Line-up

Requirement Analysis and Specification Document

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Contents

1. Introduction

1.1 Purpose

This document represents the Requirement Analysis and Specification Document (RASD). It contains the description of the main goals, the domain and its representation through some models, the uses cases that describe the scenario, the list of functional and non-functional requirements, and specifications that characterize the software described in the following subsection. It also includes the revision history to better understand the development of this document. This document is addressed to the developers who will have to implement the described system and it has the purpose to guide them through the development process.

1.2 Scope

The system aims to provide a solution to reduce overcrowding both inside and outside grocery stores. Due to the coronavirus emergency supermarkets need to restrict access to their stores to avoid having crowds inside, but at the same time, they must avoid long queues outside which are themselves a potential risk.

The application would work as a digital counterpart to the common situation where people who are in line for a service retrieve a number that gives their position in the queue. The system should provide both the possibility to line up remotely (for example through a mobile phone) and at the grocery store for those customers who do not have access to the required technology (**Line up functionality**). Each customer that lined up should receive a number. Users should wait until his/her number is being called (or close to being called) to approach the store. This should reduce overcrowdings outside supermarkets. Users can also scan a QR code when entering the grocery store, enabling the store manager to monitor entrances.

In addition to lining up directly, an advanced function is offered. Customers can also book a visit to the supermarket, similarly to booking a slot for visiting a museum. The system should be able to schedule customer visits correctly given that each visit will last differently from the others. CLup can ask the customer details about his/her visit or it can compute an estimated duration from previous visits of the same user (**Book a visit functionality**).

Ultimately, the system will have to be easy-to-use given that everyone needs to do grocery shopping and the more users will use the system remotely the more CLup will be effective.

1.2.1 World Phenomena

WP1	Customer wants to go grocery shopping at that time
WP2	Customer wants to go grocery shopping in the future
WP3	Customer wants to line up
WP4	Customer wants to book a visit in the future
WP5	Customer goes to the supermarket and he/she has a booking/lined up
WP6	Customer goes to the supermarket and he/she does not have a booking/didn't line up
WP7	Grocery store has a limited capacity due to the Covid19 restrictions
WP8	The store manager wants to monitor and control entries in his/her store
WP9	Customer exits the store
WP10	Customer who has lined up at the store entry point is called by the employee

1.2.2 Shared Phenomena

SP1	Customer books a visit
SP2	Customer specifies what he/she will buy (or the shop departments he/she will mostly go to) in his/her next visit
SP3	Customer lines up remotely
SP4	Customer lines up at the grocery store
SP5	Customer is called by the CLup system
SP6	Customer shows his/her number entering the store
SP7	Customer shows his/her QR Code entering the store
SP8	Customer shows his/her visit booking entering the store
SP9	Store employee uses CLup to check entrances and insert exits

1.2.3 Goals

G1	Everyone can use and interact with the CLup system accordingly with its features and processes
G2	All customers who reserve a place in the queue will be called
G3	Allow customers to enter the store once their number has been called or if they have booked a visit for that time slot
G4	Customers who go to the supermarket without a number/booking are allowed to line up at the store
G5	Inside the grocery store it must be feasible to follow Covid19 regulations
G6	Outside the grocery store there must not be long queues or overcrowding
G7	Customer is allowed to book a visit through the CLup system
G8	Customer is allowed to line up through the CLup system
G9	The store manager is allowed to monitor entrances of customers that used the QR Code
G10	Customer is allowed to approach the store in time with respect to his position in the queue

1.3 Definitions, Acronyms, Abbreviations

1.3.1 Definitions

QR code	A QR code is a type of matrix barcode, that is a machine-readable optical label that contains information about the item to which it is attached
Visit	In this document by "visit" we mean the visit to a supermarket in a specific time slot
Line up	In this document by "line up" we mean the line up to enter in a supermarket

1.3.2 Acronyms

RASD	Requirement Analysis and Specification Document
QR	Quick Response
GPS	Global Positioning System
COVID-19	COronaVIrus Disease 19

1.3.3 Abbreviations

WPn	World Phenomena number n
SPn	Shared Phenomena number n
Gn	Goal number n
Rn	Requirement number n
Dn	Domain Assumption number n
TAn	Text Assumption number n
LU	CLup "line up" function
BV	CLup "book a visit" function

1.4 Revision history

Date	**Description**
20-12-20	First Version
23-12-20	Final Version

1.5 Reference Documents

- Specification Document : "R&DD Assignment AY 2020-2021"
- Lecture slides

1.6 Document Structure

This document is composed of six chapters :

- **Chapter 1: Introduction.** This chapter includes the goals of the project (*Purpose*) and an analysis of the world and the shared phenomena (*Scope*). It also includes a section where there are all the descriptions, acronyms, and abbreviations in the document. Lastly, there is a revision history and a reference documents list
- **Chapter 2: Overall Description.** This chapter includes scenarios and further details on the shared phenomena and a domain model (class diagrams and statecharts) (*Product perspective*). It also shows the most important requirements (*Product functions*). It clarifies the user needs (*User charateristics*), and lastly, it contains the domain assumptions (*Assumptions, dependencies and constraints*)
- **Chapter 3: Specific Description.** This chapter is the body of the documents. It includes a section for the User, Hardware, Software, and Communication Interfaces (*External Interface Requirements*). It also contains a definition of use case diagrams, use cases, and associated sequence/activity diagrams, and a map on requirements (*Functional Requirements*). Lastly, there are three sections dedicated to non-functional requirements (*Performance Requirements*, *Design Constraints Software System Attributes*)
- **Chapter 4: Formal Analysis Using Alloy.** This chapter includes a brief presentation of the main objectives driving the formal modeling activity, as well as a description of the model. itself, what can be proved with it, and why what is proved is important given the problem at hand. It also includes some worlds obtained by running the formal model and the results of the checks performed on the meaningful assertion
- **Chapter 5: Effort Spent.** This chapter includes information about the number of hours each group member has worked for this document
- **Chapter 6: References.**

2. Overall Description

2.1 Product perspective

2.1.1 Scenarios

- **Scenario 1: The Store Manager discovers the CLup System and decides to use it for his/her store.** John is the Store Manager of the main supermarket in Via Pacini, Milan. With the start of the COVID emergency and the delineation by the government of new rules on the entrances of people into the store, its store has created very long queues for 2 weeks outside the store. John realizes the danger of the situation and decides to look for a system that can regulate the entrances avoiding the creation of long queues, thus finding CLup. Once decided to adopt CLup for the management of queues and entrances he registers via the web app. He inserts information about him, inserts all the store information, and then decides to allow access to the system to his 5 employees: Ellen, Mike, Harry, Louis, and Ricky who will handle the various phases of interaction with the system. These 5 employees are registered and will then be able to log in with their accounts as employees to the system.
- **Scenario 2: A User meets the CLup service and decides to give it a try.** Steve is a young guy, he lives alone in a studio apartment located in the city center of Milan. Every month he has to pay the rent, which is quite expensive, the bills and the other monthly expenses. Every week he goes to his favorite supermarket website to see what are discounts available. While browsing the website Steve sees that the store has enabled a new service, called CLup, to reduce the physical queue present every day outside the store. Every time he goes grocery shopping he loses so much time because he has to wait to get inside the store due to the limited space inside the building. He is very happy and curious about this new service. He downloads the CLup application, opens it, and decides to sign up.
- **Scenario 3: A User who could not reserve a seat in the queue virtually, goes to the store.** Lily is a pretty 80-year-old lady who lives with her 86-year-old husband and buys groceries every week. Unfortunately, Lily doesn't have a smartphone and an internet connection to book a seat in the queue using CLup. Lily shows up at the supermarket and approaches the store entrance to ask if it's possible to enter. Mike, the employee on shift at the supermarket entrance at that moment informs Lily that there is no problem and that he will be the one to reserve a queue for her. Mike, from his computer, requests CLup web app, sees a number being generated and prints it to give it to Lily. He also informs Lily that he can wait outside the store and he will alert her when the time comes to enter.
- **Scenario 4: A CLup customer lines up to go grocery shopping to her favorite store.** Ester is a young housewife. She has two children, one of them is very young and he needs frequent attention during the day. She also has to clean up the big house she lives in with her husband. Ester is very busy during the day doing such duties. She needs to go grocery shopping and she remembers that some time ago she signed up for the digital queue service CLup. She opens the application and finds that her favorite supermarket adopted the CLup system. She selects the store and lines up to go shopping. While she is waiting for her turn she can play with her young son. Once arrived at the supermarket she enters the store directly showing her digital queue number.

- **Scenario 5: A CLup customer books a visit.** Frank opens the food storage and realizes that soon he will finish his stock of pasta. Being a lover of pasta, he knows he will have to buy more but today he has to finish working on a very important project. So Frank decides to book a visit to the supermarket in Via Pacini for tomorrow, he knows it will be short and does not want to wait in line. So Frank picks up his smartphone, opens the CLup app, enters the visits section, and inserts the optional information requested by CLup. In particular, he specifies that he will go to the supermarket exclusively to buy pasta and that he plans to spend a maximum of 5 minutes there. Immediately after confirming this information, he slides through all available time slots in which to book his visit displayed by CLup. So he selects tomorrow at 3:30 PM.
- **Scenario 6: The Store Manager views charts and statistics about entrances.** Mike is the Store Manager of a big supermarket near Porta Vittoria, situated in the metropolitan city of Milan. The Milan city council is collecting data to define the upcoming local ordinance related to the COVID-19 emergency. In particular, the politicians want to know if the supermarkets are "safe" places if they avoid creating long queues and if they are or are not overcrowded places. To retrieve such information they know that in the last month many grocery stores adopted a smart queue service called CLup. Further investigating this innovative platform they discovered that CLup collects metrics and statistics about people entering the stores. After obtaining the necessary legal authorizations the council asks every store manager involved with CLup to report a summary of the data provided by the application. Mike logs in to the store manager administration interface, clicks on "View store charts and statistics" and reports the main information to the city council that asked him.
- **Scenario 7: A CLup customer arrives late to the store and he loses his turn.** Mark is a middle-aged man working for a big tech company in Lombardia, Italy. He works in the sales and marketing department and he is often out of town on business. Today his driving home after a two days trip around Italy. He's stretching his legs after stopping at an auto grill and he decides to line up to go grocery shopping on the way home to see the estimated queue time. He finds that he's perfectly in time to go directly to the store, thus he starts driving again. On the way to the store a car crash slows down his way and he arrives late to the store concerning his turn. He tries to explain what happened to the employee checking entrances, but in end he is not allowed to enter the store because his queue number turn is expired.

2.1.2 Application Domain Model

Here is the application domain model of this project. In particular, this section focuses on the object model (**static information models** and **dynamic class behaviour models**).

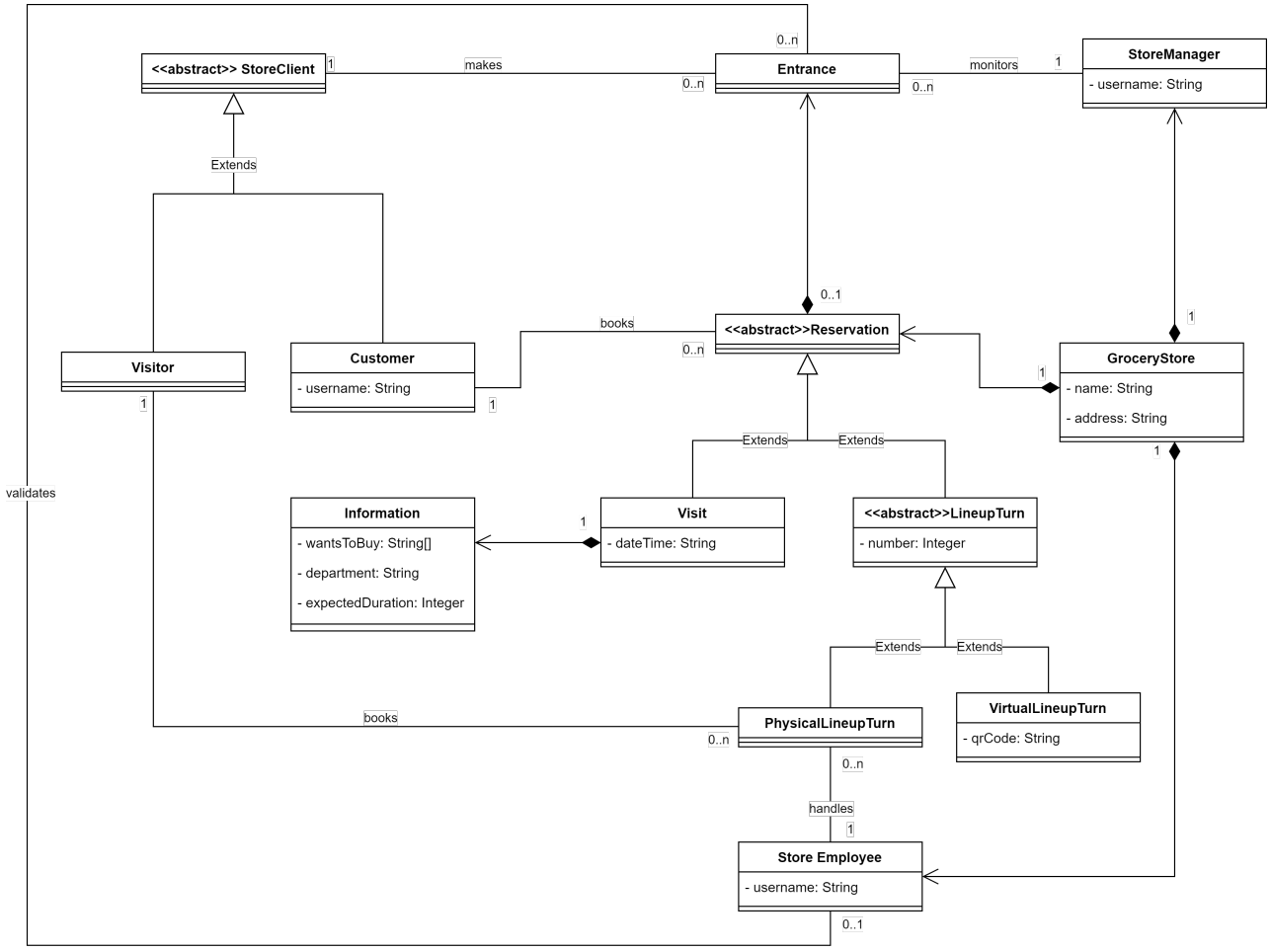
2.1.2.1 Static Information Model

The below high-level diagram provides a static information model of the application domain. Basically, it is the structure of the world, it contains only a few attributes, and it doesn't include every class that will be necessary to define the model of the CLup system.

The main aspects of Clup modeled in the below diagram are:

- The application needs to consider the presence of a visitor who arrives at the supermarket and requires a place in the queue. For this reason, two types of Store Clients (visitor and customer) are distinguished in the diagram
- Given the need to allow the reservation of a seat in the queue to those who do not use the system directly, it is necessary to distinguish between 2 types of Lineup turn (physical and virtual).

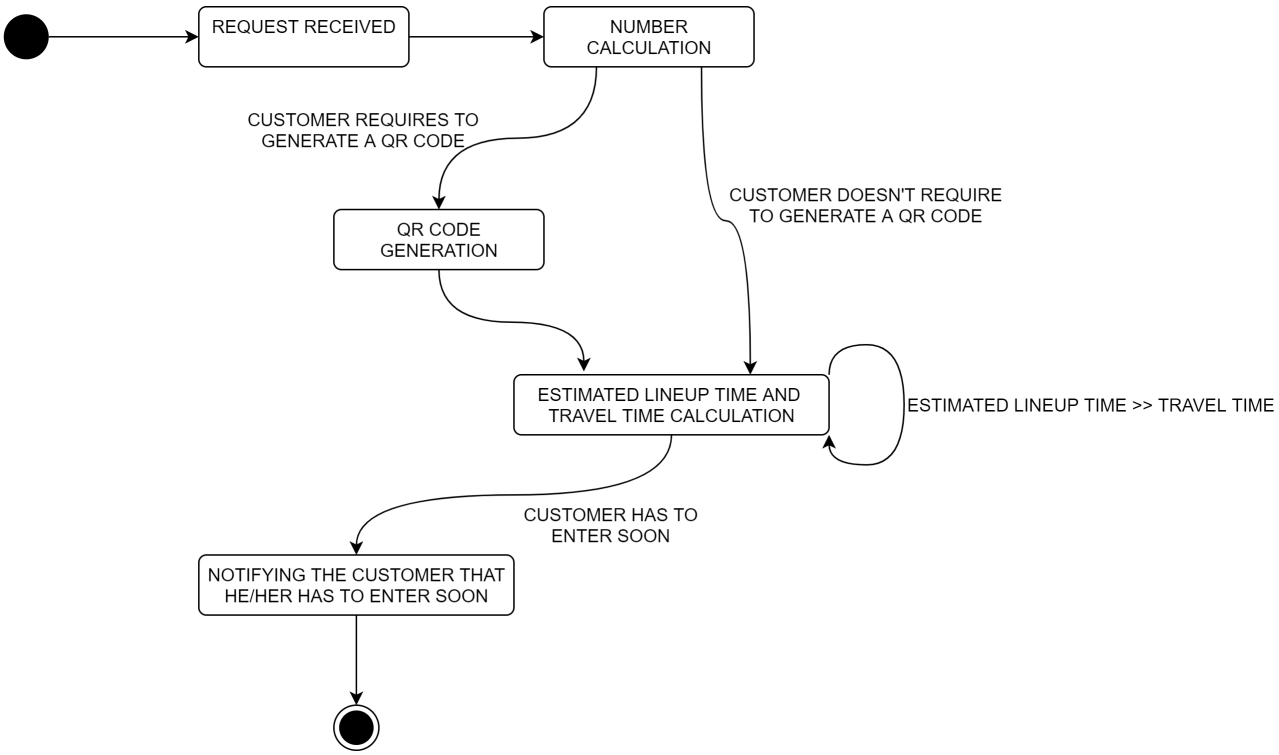
- A customer can book a Visit or a Lineup turn. To facilitate the reading of the diagram these two actions were generalized to an abstract class Reservation extended by Visit class and LineupTurn class. the possibility to generate a QR code associated with a reservation of a seat in the queue is represented in the diagram by the optional attribute "qrCode" of the VirtualLineupTurn class
- A visitor can book only a physical lineup turn. This reservation is handled by a Store employee who will act as a link between the system and the visitor
- Each entrance could be monitored by the store manager



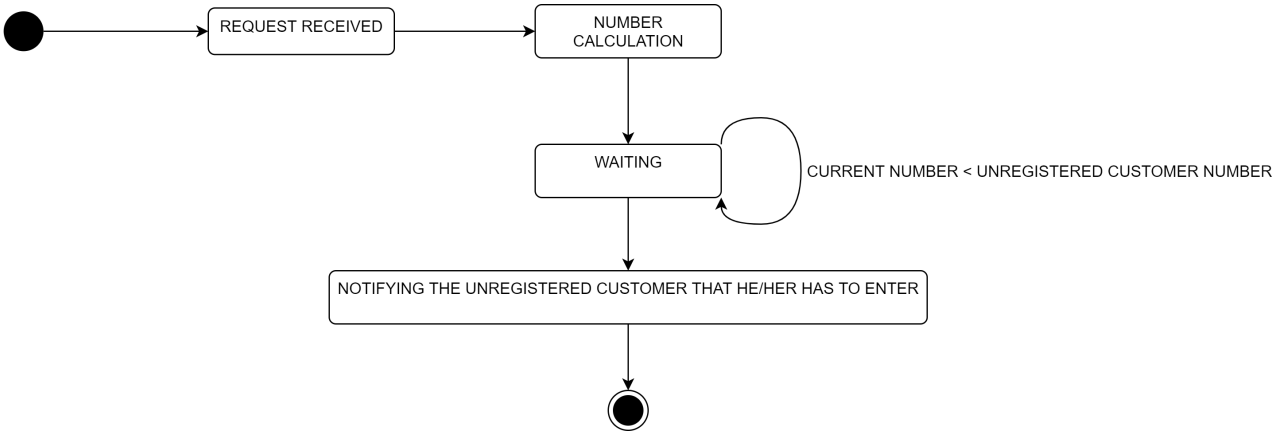
2.1.2.2 Dynamic Class Behaviour Models

The below state diagrams shows some critical aspects of the application, how the behavior of these critical aspects is modeled, and the evolution of their states.

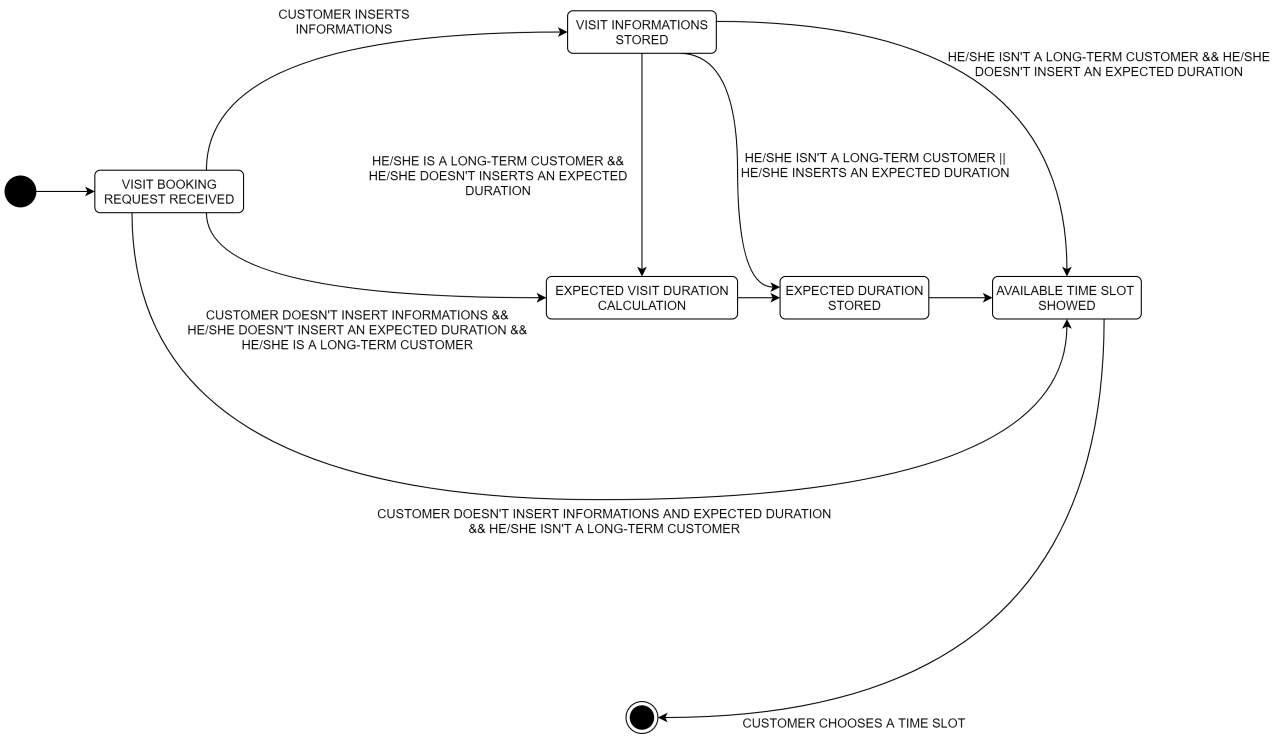
In the first state diagram, we model the behavior our system has to have when there is a new request to reserve a virtual lineup turn. Particular attention is paid to the possibility of generating a QR code and the management of waiting in the virtual lineup.



In the second state diagram, we model the behavior our system has to have when a store employee notifies a new request to reserve a physical lineup turn. Attention is paid to the difference from the previous phenomenon. In this case, the system will limit itself to acquire the demand and to process it with the other demands (also virtual)



In the third and last diagram, we model the behavior our system has to have when there is a new request for booking a visit. Attention is paid to the possibility of following various paths to reach the end of the request. These numerous paths are due to the optional insertion of information related to the visit (department, products to buy, and estimated time). Also, for long-term customers, the estimated time could be calculated by the system based on previous entries.



2.2 Product functions

Here is the description of the major functions that the CLup system has. In particular, we identified four significative functions, they are:

- **Line up:** This is the main function of the CLup system. The application works as a digital counterpart to the common situation where people who are in line for a service retrieve a number that gives their position in the queue.
  To do that, the application allows customers to line up, retrieving a number, for a store that has joined to CLup and it provides to alert the customer when his turn is coming.
- **Book a visit:** Another main functionality the application has, is to book a visit. Similar to booking a slot for visiting a museum, customers can choose a time slot in which to visit the supermarket. The system can schedule customer visits correctly given that each visit will last differently from the others. CLup asks the customer details about his/her visit or it computes an estimated duration from previous visits of the same user
- **Identification of customers at the store entrance:** The system allows customers to generate a QR code for their entrance into the supermarket, it is optional and customers are not obliged to do so. This QR code allows the store to identify the customer is entering the supermarket. For those who do not generate the QR code to enter after a queue, it will not be possible to identify them because their access will be exclusively through the generated number

2.3 User characteristics

The actors of the application are the following:

- **Visitor:** a person who can sign up to the CLup service. If the user doesn't have a compatible device to register to CLup he/she can go to the store and line up there.
- **Customer:** a person passed through the registration process. He/she can line up digitally or to book a visit right from the CLup application.
- **Store employee:** a person who works at a grocery store and is registered to CLup as an employee. He/she can line up customers who arrived at the store without lining up digitally. He/she will then call the customers when it's time to enter the supermarket. He is the one who will be in charge of checking the numbers of people entering a queue and checking the booking information of the visiting people.
- **Store manager:** a person who works at a grocery store as the manager of that shop. He/she can manage the store information on the CLup platform like the opening hours or the store capacity. He can monitor customer information recorded by the system.

2.4 Assumption, dependencies and constraints

2.4.1 Regulatory policies

The CLup application will ask for user personal information like name, surname, email address, and phone number. Phone numbers and email addresses won't be used for commercial purposes. Personal information will be processed in compliance with the GDPR.

Moreover, the system will have to ask for users' permission to retrieve and use their position. GPS positions will be stored for as long it's needed to compute the route to the grocery store.

2.4.2 Hardware limitations

- Mobile application
  - iOS or Android smartphone
  - 2G/3G/4G/Wi-Fi Internet connection
  - GPS
- Web application
  - Modern web browser

2.4.3 Interfaces to other applications

In the first release of CLup no public interfaces will be opened to third party services.

2.4.4 Text assumptions

In the specification document presented by the client, we found some points that lacked precision. To better clarify and to make you understand better the content of this document we decided to introduce those assumptions.

- Entrances monitoring is referred to customers using their QR code.
- QR Code scanning is not mandatory: customers who will scan their QR code when entering the store will contribute to entrances monitoring, those who will not contribute to such statistics.
- Visits durations for long term customers are computed by the CLup system from previous visits details inserted by the users

2.4.5 Domain assumptions

D1	All customers use CLup to access the store
D2	The CLup line up system is enabled only when entrances control is needed
D3	Store has a capacity greater than 0
D4	GPS is enabled between the line up request and the departure to approach the store
D5	The user has a working internet connection
D6	The store has an available employee to serve customers who physically want to line up and retrieve a number
D7	The store has an available employee to check for entrances and to report exits
D8	The store employee who lines up customers will call them when they are allowed to enter the store
D9	Stores are uniquely identified
D10	The customer's device, the store and the CLup system have a syncronized date and time
D11	A QR code scanner will be available entering the store
D12	The store is physically accessible
D13	There is a route from the customer to the store
D14	The estimated time to enter the store is greater than the estimated time to approach the store

D15	The customer stay at the store is limited in time
D16	No two customers have the same number when entering at the same time
D17	The customer who specifies what he/she will buy/what departments he/she will go to will comply with his/her estimations
D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

3. Specific Requirements

3.1 External Interface Requirements

3.1.1 User Interfaces

The application in use by the customer will let the user line up, book a visit, and view the details about the queue or the booked visit. The web application in use by the store manager will let him view store information and statistics. The employee will use the web application to line up on behalf of visitors, to call them, to check entrances, and report exits. Functional requirements are fully described in the next subsection.
The following mockups represent a basic idea of what the mobile app and the web app will look like.

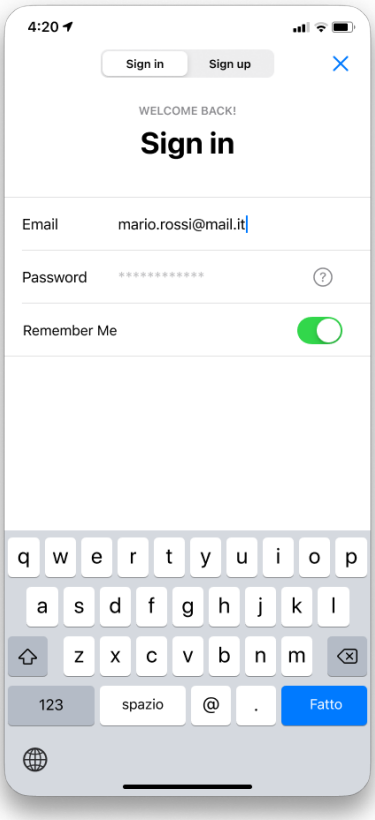


Figure 3.1: Sign in

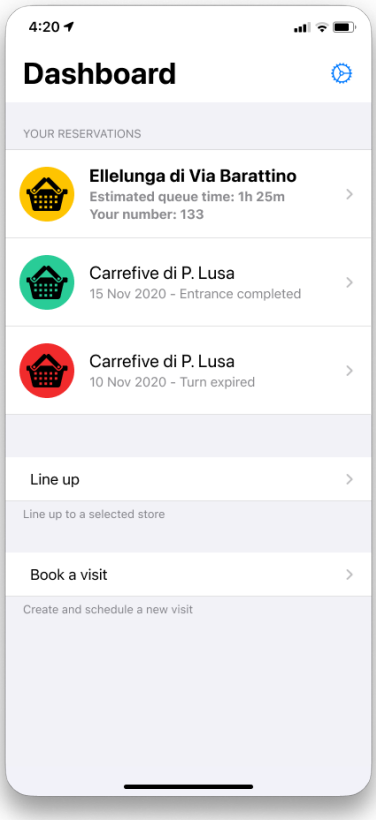


Figure 3.2: App dashboard

Figure 3.3: QRCode to be scanned

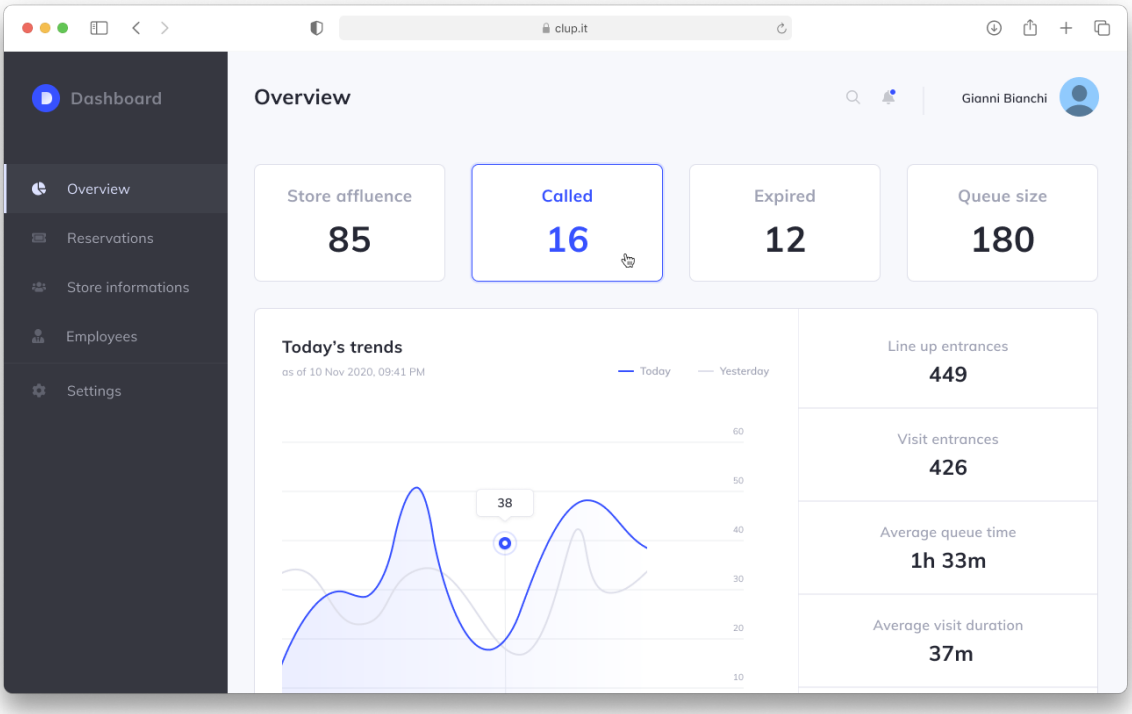


Figure 3.4: Web application dashboard

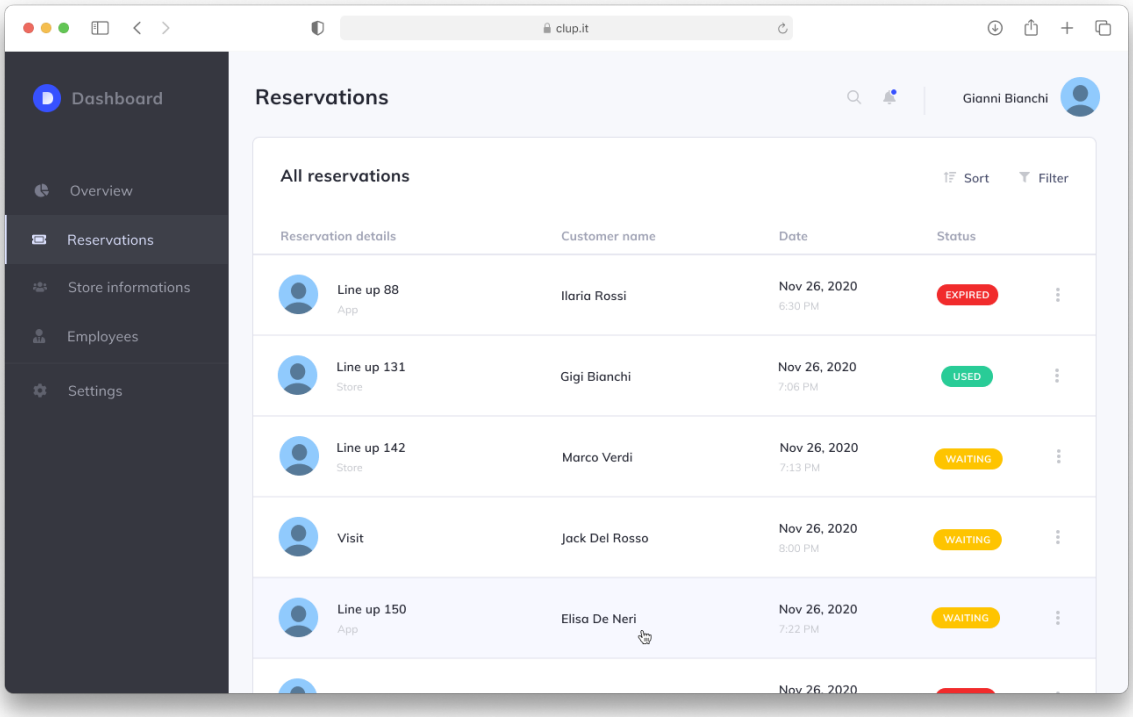


Figure 3.5: Web application reservations page

3.1.2 Hardware Interfaces

The CLup applications interact with three types of actors and two of them share the same hardware requirements:

- Regarding the customer: he/she needs an iOS/Android smartphone with a working Internet connection and GPS sensor. The application will not require a lot of computational power, therefore any recent (last couple of years) smartphone will be suitable.
- Regarding the store manager and the employees: he/she needs a modern web browser and an Internet connection. The web application will run easily on any desktop computer of the last decade.

3.1.3 Software Interfaces

The system will use the following external software interfaces:

- **Public geodata provider:** the system will connect to a public geodata service API (like Google Maps or OpenStreetMap and the like) to compute a route from the user's location to the grocery store and in particular to retrieve an estimated travel time
- **Android/iOS system APIs:** the mobile application will be developed for iOS and Android, therefore it will interact with the underlying system's primitives.

3.1.4 Communication Interfaces

The mobile application and the web application will communicate with CLup via an internet connection.

3.2 Functional Requirements

3.2.1 User Interfaces

The application in use by the customer will let the user line up, book a visit, and view the details about the queue or the booked visit. The web application in use by the store manager will let him view store information and statistics. The employee will use the web application to line up on behalf of visitors, to call them, to check entrances, and report exits. Functional requirements are fully described in the next subsection.

The following mockups represent a basic idea of what the mobile app and the web app will look like.

3.2.2 Hardware Interfaces

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- Regarding the store manager and the employees: he/she needs a modern web browser and an Internet connection. The web application will run easily on any desktop computer of the last decade.

3.2.3 List of requirements

R1	Visitors are allowed to register as customers through the CLup application
R2	The store manager is allowed to register as store manager through the CLup web app
R3	Customers are allowed to log in inside the application
R4	The store manager and the employee are allowed to login in inside the web application
R5	The store manager can insert and edit store information
R6	The store manager can create and edit the employees' accounts associated to his/her store
R7	The employee can line up a visitor who asked for that and can give him/her the number associated with the position in the queue

R8	The employee can report the entrance related to a line up number or a visit and the exit of each person from the store
R9	The line up numbers and the visits are invalidated after a period of time if not used to enter the store
R10	The employee can see the line up numbers/visits that are allowed to enter the store
R11	The CLup system notifies the employee when it's time to call a visitor who previously asked to line up at the entry point
R12	The store manager can see charts and analysis related to entrances made with the QR code
R13	Customer can generate a QR code to enter the store
R14	The CLup system can acquire the scanned QR code
R15	The CLup application has a section to line up
R16	The CLup application shows the estimated queue waiting time, the queue size, the estimated travel time and the number related to the position in the queue
R17	The application monitors the customer's position and computes the estimated travel time
R18	The application notifies the customer when the estimated queue waiting time is near the estimated travel time
R19	The system generates a unique (in an appropriate time interval) number to identify the position in the queue
R20	The system pushes forward the queue based on the reported exits and the scheduled visits
R21	The CLup application has a section to book a visit
R22	The CLup application shows available time slots for visits
R23	The system schedules visits based on related details
R24	The customer can insert additional details like what he/she is going to buy, the estimated visit duration or what departments he/she will go to)
R25	The CLup system can compute the estimated visit duration for long term customers based on previous visits

3.2.4 Mapping

Goal	Requirements	Domain assumptions
G1	R1, R2, R3, R4, R6	D5, D18, D19
G2	R3, R4, R6, R8, R9, R11, R17, R18, R19, R20	D1, D3, D4, D5, D7, D8, D10, D14, D15, D18, D19
G3	R3, R4, R6, R8, R10, R14	D3, D7, D11, D12, D13, D16, D18, D19
G4	R4, R6, R7	D2, D3, D6, D12, D13
G5	R4, R5, R6, R7, R8, R10, R15, R20, R21, R23	D1, D2, D5, D6, D7, D15, D17, D18, D19
G6	R4, R6, R7, R9, R11	D1, D2, D3, D5, D6, D8, D10, D15, D18, D19
G7	R3, R21, R22, R24	D1, D3, D5, D9, D10, D13, 18
G8	R3, R13, R15, R16, R19	D1, D2, D3, D5, D9, D10, D13, D18
G9	R4, R5, R12, R14	D1, D5, D11, D18, D19
G10	R3, R16, R17, R18	D4, D5, D10, D12, D13, D14, D18

G1	**Everyone can use and interact with the CLup system accordingly with itsfeatures and processes**
R1	Visitors are allowed to register as customers through the CLup application
R2	The store manager is allowed to register as store manager through the CLup web app
R3	Customers are allowed to log in inside the application
R4	The store manager and the employee are allowed to login in inside the web application
R6	The store manager can create and edit the employees' accounts associated to his/her store
D5	The user has a working internet connection

D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

G2	**All customers who reserve a place in the queue will be called**
R3	Customers are allowed to log in inside the application
R4	The store manager and the employee are allowed to login in inside the web application
R6	The store manager can create and edit the employees' accounts associated to his/her store
R8	The employee can report the entrance related to a line up number or a visit and the exit of each person from the store
R9	The line up numbers and the visits are invalidated after a period of time if not used to enter the store
R11	The CLup system notifies the employee when it's time to call a visitor who previously asked to line up at the entry point
R17	The application monitors the customer's position and computes the estimated travel time
R18	The application notifies the customer when the estimated queue waiting time is near the estimated travel time
R19	The system generates a unique (in an appropriate time interval) number to identify the position in the queue
R20	The system pushes forward the queue based on the reported exits and the scheduled visits
D1	All customers use CLup to access the store
D3	Store has a capacity greater than 0
D4	GPS is enabled between the line up request and the departure to approach the store
D5	The user has a working internet connection
D7	The store has an available employee to check for entrances and to report exits
D8	The store employee who lines up customers will call them when they are allowed to enter the store
D10	The customer's device, the store and the CLup system have a syncronized date and time
D14	The estimated time to enter the store is greater than the estimated time to approach the store

D15	The customer stay at the store is limited in time
D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

G3	**Allow customers to enter the store once their number has been called or ifthey have booked a visit for that time slot**
R3	Customers are allowed to log in inside the application
R4	The store manager and the employee are allowed to login in inside the web application
R6	The store manager can create and edit the employees' accounts associated to his/her store
R8	The employee can report the entrance related to a line up number or a visit and the exit of each person from the store
R10	The employee can see the line up numbers/visits that are allowed to enter the store
R14	The CLup system can acquire the scanned QR code
D3	Store has a capacity greater than 0
D7	The store has an available employee to check for entrances and to report exits
D11	A QR code scanner will be available entering the store
D12	The store is physically accessible
D13	There is a route from the customer to the store
D16	No two customers have the same number when entering at the same time
D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

G4	**Customers who go to the supermarket without a number/booking are allowedto line up at the store**
R4	The store manager and the employee are allowed to login in inside the web application
R6	The store manager can create and edit the employees' accounts associated to his/her store
R7	The employee can line up a visitor who asked for that and can give him/her the number associated with the position in the queue

D2	The CLup line up system is enabled only when entrances control is needed
D3	Store has a capacity greater than 0
D6	The store has an available employee to serve customers who physically want to line up and retrieve a number
D12	The store is physically accessible
D13	There is a route from the customer to the store

G5	**Inside the grocery store it must be feasible to follow Covid19 regulations**
R4	The store manager and the employee are allowed to login in inside the web application
R5	The store manager can insert and edit store information
R6	The store manager can create and edit the employees' accounts associated to his/her store
R7	The employee can line up a visitor who asked for that and can give him/her the number associated with the position in the queue
R8	The employee can report the entrance related to a line up number or a visit and the exit of each person from the store
R10	The employee can see the line up numbers/visits that are allowed to enter the store
R15	The CLup application has a section to line up
R20	The system pushes forward the queue based on the reported exits and the scheduled visits
R21	The CLup application has a section to book a visit
R23	The system schedules visits based on related details
D1	All customers use CLup to access the store
D2	The CLup line up system is enabled only when entrances control is needed
D5	The user has a working internet connection
D6	The store has an available employee to serve customers who physically want to line up and retrieve a number
D7	The store has an available employee to check for entrances and to report exits
D15	The customer stay at the store is limited in time
D17	The customer who specifies what he/she will buy/what departments he/she will go to will comply with his/her estimations

D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

G6	**Outside the grocery store there must not be long queues or overcrowding**
R4	The store manager and the employee are allowed to login in inside the web application
R6	The store manager can create and edit the employees' accounts associated to his/her store
R7	The employee can line up a visitor who asked for that and can give him/her the number associated with the position in the queue
R9	The line up numbers and the visits are invalidated after a period of time if not used to enter the store
R11	The CLup system notifies the employee when it's time to call a visitor who previously asked to line up at the entry point
D1	All customers use CLup to access the store
D2	The CLup line up system is enabled only when entrances control is needed
D3	Store has a capacity greater than 0
D5	The user has a working internet connection
D6	The store has an available employee to serve customers who physically want to line up and retrieve a number
D8	The store employee who lines up customers will call them when they are allowed to enter the store
D10	The customer's device, the store and the CLup system have a syncronized date and time
D15	The customer stay at the store is limited in time
D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

G7	**Customer is allowed to book a visit through the CLup system**
R3	Customers are allowed to log in inside the application
R21	The CLup application has a section to book a visit
R22	The CLup application shows available time slots for visits

R24	The customer can insert additional details like what he/she is going to buy, the estimated visit duration or what departments he/she will go to)
D1	All customers use CLup to access the store
D3	Store has a capacity greater than 0
D5	The user has a working internet connection
D9	Stores are uniquely identified
D10	The customer's device, the store and the CLup system have a syncronized date and time
D13	There is a route from the customer to the store
D18	Customer who wants to directly interact with the CLup system has a compatible device

G8	**Customer is allowed to line up through the CLup system**
R3	Customers are allowed to log in inside the application
R13	Customer can generate a QR code to enter the store
R15	The CLup application has a section to line up
R16	The CLup application shows the estimated queue waiting time, the queue size, the estimated travel time and the number related to the position in the queue
R19	The system generates a unique (in an appropriate time interval) number toidentify the position in the queue
D1	All customers use CLup to access the store
D2	The CLup line up system is enabled only when entrances control is needed
D3	Store has a capacity greater than 0
D5	The user has a working internet connection
D9	Stores are uniquely identified
D10	The customer's device, the store and the CLup system have a syncronized date and time
D13	There is a route from the customer to the store
D18	Customer who wants to directly interact with the CLup system has a compatible device

G9	**The store manager is allowed to monitor entrances of customers that used theQR Code**

R4	The store manager and the employee are allowed to login in inside the web application
R5	The store manager can insert and edit store information
R12	The store manager can see charts and analysis related to entrances made with the QR code
R14	The CLup system can acquire the scanned QR code
D1	All customers use CLup to access the store
D5	The user has a working internet connection
D11	A QR code scanner will be available entering the store
D18	Customer who wants to directly interact with the CLup system has a compatible device
D19	Store has a CLup compatible device

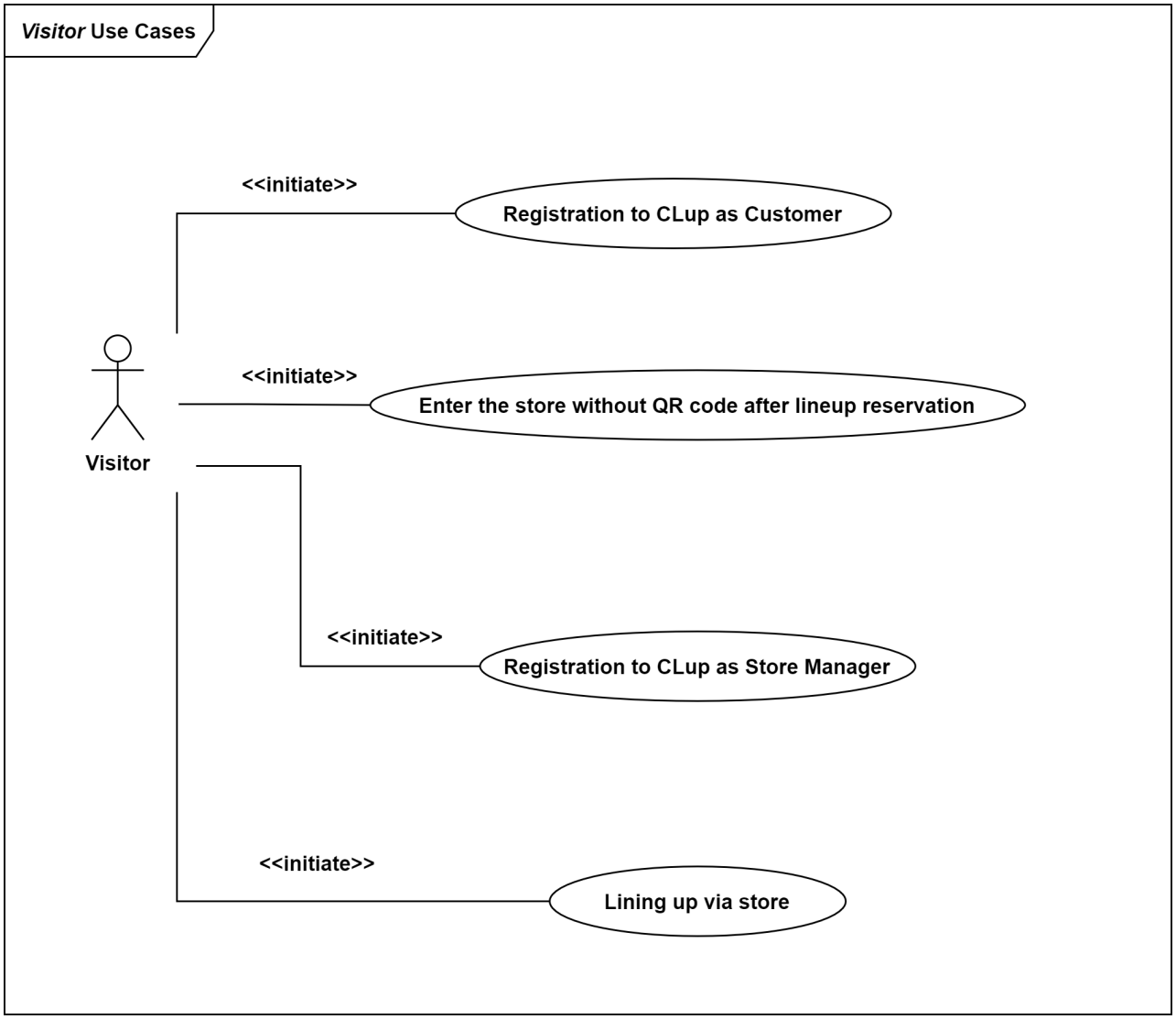
G10	**Customer is allowed to approach the store in time with respect to his positionin the queue**
R3	Customers are allowed to log in inside the application
R16	The CLup application shows the estimated queue waiting time, the queue size, the estimated travel time and the number related to the position in the queue
R17	The application monitors the customer's position and computes the estimated travel time
R18	The application notifies the customer when the estimated queue waiting time is near the estimated travel time
D4	GPS is enabled between the line up request and the departure to approach the store
D5	The user has a working internet connection
D10	The customer's device, the store and the CLup system have a syncronized date and time
D12	The store is physically accessible
D13	There is a route from the customer to the store
D14	The estimated time to enter the store is greater than the estimated time to approach the store
D18	Customer who wants to directly interact with the CLup system has a compatible device

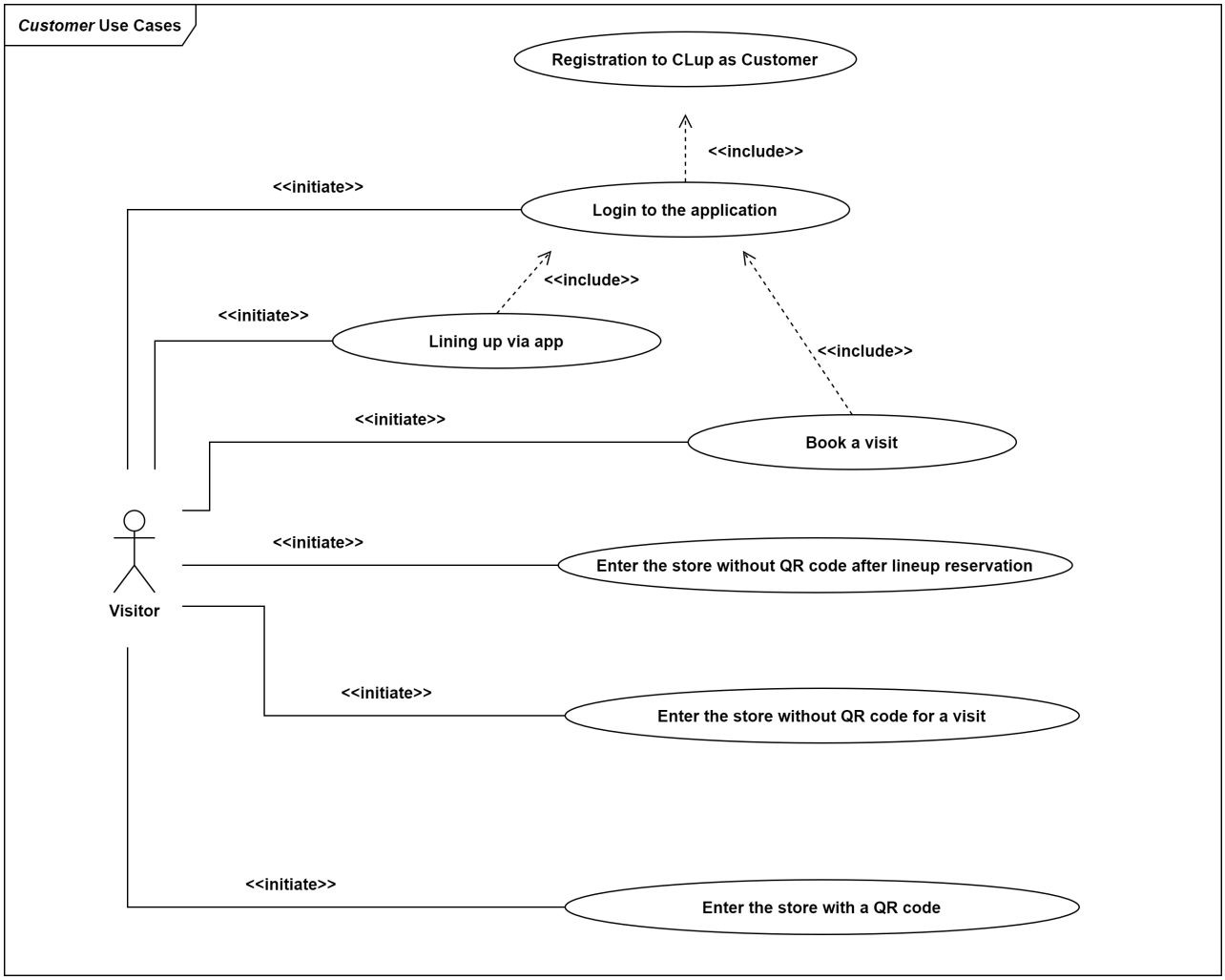
3.2.5 Use Cases

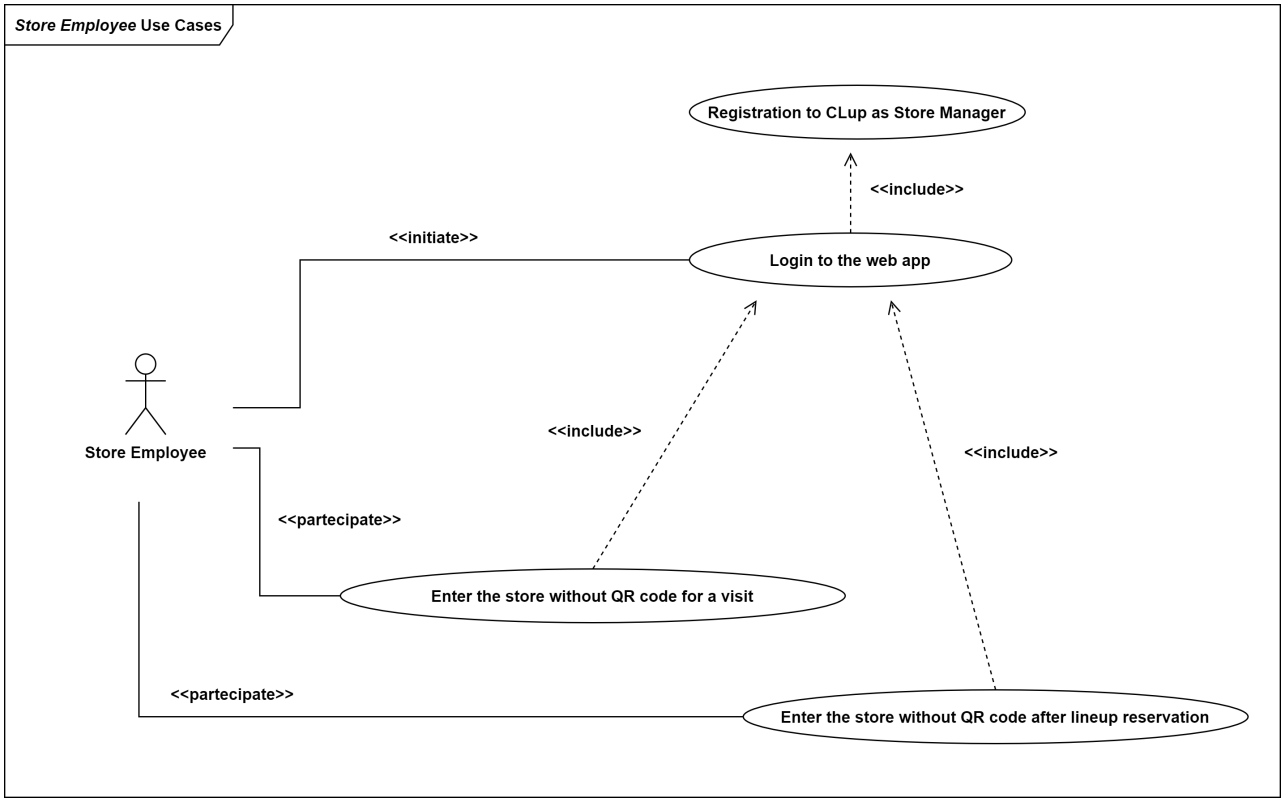
In this section, we present some use cases of the CLup System. Use cases diagram is first illustrated to give a general and abstract view of the actors and use cases associated with them (*Section 3.2.3.1*). After that, all use cases illustrated in the diagram are described in their particular (*Section 3.2.3.2*).

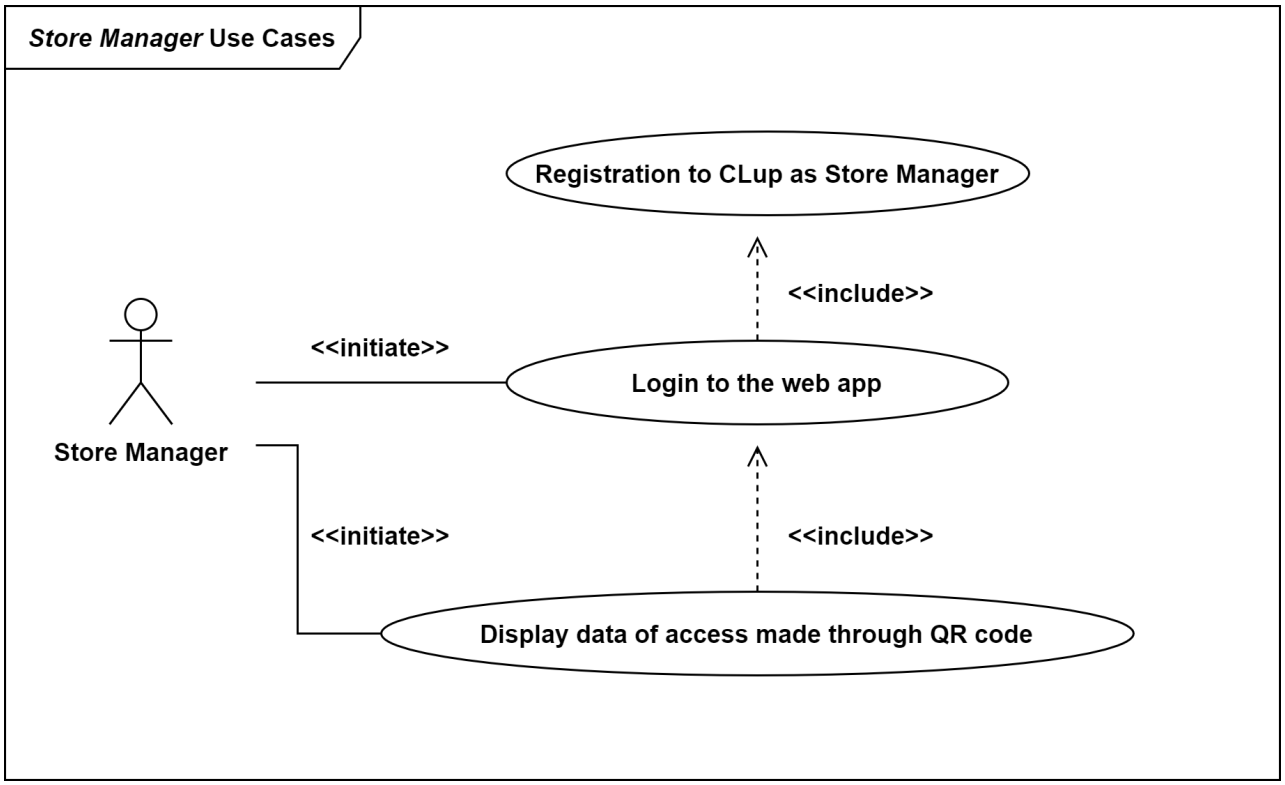
3.2.5.1 Use Cases Diagrams

To facilitate the readability of the diagram, it is divided into 4 diagrams, each dedicated to a single actor.




Customer Use Cases
Registration to CLup as Customer
<<include>>
<<initiate>>
Login to the application
<<include>>
<<initiate>>
Lining up via app
<<include>>
<<initiate>>
Book a visit
Visitor
<<initiate>>
Enter the store without QR code after lineup reservation
<<initiate>>
Enter the store without QR code for a visit
<<initiate>>
Enter the store with a QR code


Store Employee Use Cases
Registration to CLup as Store Manager
<<include>>
<<initiate>>
Login to the web app
Store Employee
<<include>>
<<include>>
<<partecipate>>
Enter the store without QR code for a visit
<<partecipate>>
Enter the store without QR code after lineup reservation


Store Manager Use Cases
Registration to CLup as Store Manager
<<include>>
<<initiate>>
Login to the web app
Store Manager
<<initiate>>
<<include>>
Display data of access made through QR code

3.2.5.2 Use Cases Description

1. **Registration to CLup as Customer**

Name	Registration to CLup as a Customer
Actors	Visitor
Entry Condition	/
Event Flow	The Event Flow is: (a) The Visitor opens the CLup application (b) The Visitor clicks on the "Sign up" button (c) The Visitor fills in all the mandatory fields (d) The Visitor clicks on the "Confirm" button (e) The System stores the information about the Visitor
Exit Condition	The Visitor is registered and he/she is now a Customer.
Exception	The Exceptions are: (a) The Visitor chooses an email or a username already used by another Customer (b) The Visitor inserts invalid information Both the exceptions listed above are notified and the Visitor is returned to step (c)
Special Requirements	/

2. **Registration to CLup as Store Manager**

Name	Registration to CLup as Store Manager
Actors	Visitor
Entry Condition	/

Event Flow	The Event Flow is: (a) The Visitor opens the CLup web app (b) The Visitor clicks on the "Sign up and register your activity" button (c) The Visitor fills in all the mandatory fields on himself/herself (d) The Visitor fills in all the mandatory fields on the Store and he/she clicks on the "Next" button (e) The Visitor sign up all the Store Employees that will be able to interact with the system (f) The Visitor clicks on the "Confirm" button (g) The System stores the information about the Visitor, the Store and the Store Employees
Exit Condition	The Visitor is registered and he/she is now a Store Manager. The system has saved all store information and Store Employees accounts have been registered.
Exception	The Exceptions are: (a) The Visitor chooses an email or a username already used by another Customer (b) The Visitor inserts invalid information The exceptions listed above are notified and the Visitor is returned to step where error occurred: (c) or (d) or (e)
Special Requirements	/

3. **Login to the application**

Name	Login to the application
Actors	Customer
Entry Condition	/
Event Flow	The Event Flow is: (a) The Customer opens the CLup application (b) The Customer clicks on the "Login" button (c) The Customer inserts his/her username and password (d) The Customer clicks on the "Confirm" button

Exit Condition	The Customer is logged.
Exception	The Exceptions are: (a) The Customer inserts wrong username and/or password The exception listed above is notified and the Customer is returned to step (c)
Special Requirements	/

4. **Login to the web app**

Name	Login to the web app
Actors	Store Manager/Store Employee
Entry Condition	/
Event Flow	The Event Flow is: (a) The Store Manager/Store Employee opens the CLup web app (b) The Store Manager/Store Employee clicks on the "Login" button (c) The Store Manager/Store Employee inserts his/her username and password (d) The Store Manager/Store Employee clicks on the "Confirm" button
Exit Condition	The Store Manager/Store Employee is logged.
Exception	The Exceptions are: (a) The Customer inserts wrong username and/or password The exception listed above is notified and the Customer is returned to step (c)
Special Requirements	/

5. **Lining up via store**

Name	Lining up via store
Actors	Visitor, Store Employee

Entry Condition	The Store Employee is logged in and he/she is at the entrance of the store. The visitor is at the store.
Event Flow	The Event Flow is: (a) The Visitor addresses the Store Employee at the entrance to book a "ticket" for the queue. (b) The Store Employee accesses the section of the web app dedicated to book a ticket for the queue on behalf of the Visitor. (c) The Store Employee clicks on the "book a ticket" button (d) The System receives the request, elaborates it and it retrieves the number relative to the lineup (e) The Store Employee communicates Visitor the number
Exit Condition	The Customer has been inserted through CLup in the queue of the chosen store and he/she has an identification number of his position.
Exception	/
Special Requirements	/

6. **Lining up via app**

Name	Lining up via app
Actors	Customer
Entry Condition	The Customer is logged in.

Event Flow	The Event Flow is: (a) The Customer accesses the section of the app dedicated to lining up (b) The Customer clicks on the "Lineup" button (c) The Customer selects the store he wants to Lineup and presses the "Confirm" button (d) The System receives the request, elaborates it and retrieves the number relative to the lineup. (e) The System shows informations about the queue estimated time. (f) The Customer could press the "Generate a QR code" button (g) If the previous event is achieved, the System receives the request, elaborates it and it retrieves a QR code
Exit Condition	The Customer has been inserted through CLup in the queue of the chosen store and he/she has an identification number of his position. He/She can view data about his position in the queue. If he/she has chosen to generate the QR he has a QR queue available.
Exception	/
Special Requirements	/

7. **Book a visit**

Name	Book a visit
Actors	Customer
Entry Condition	The Customer is logged in.

Event Flow	The Event Flow is: (a) The Customer accesses the section of the app dedicated to booking a visit (b) The Customer clicks the "book a visit" button (c) The Customer selects the store where he/she wants to book a visit (d) The Custoemr could insert information about what he/she will buy, what departments he/she will visits and the expected visit duration. (e) The Customer clicks on the "Next" button (f) The System shows the available time slots compatible with the request of the Customer (g) The Customer chooses a time slot (h) The System stores the request, elaborates it and it and schedules the visit based on the available information
Exit Condition	The Customer has a reserved visit, he/she can view the summary of his/her reservation.
Exception	/
Special Requirements	/

8. **Enter the store without QR code after lineup reservation**

Name	Enter the store without QR code after lineup reservation
Actors	Customer/Visitor, Store Employee
Entry Condition	The Customer/Visitor has the number and he/she is at the store entrance. The Employee is logged in.
Event Flow	The Event Flow is: (a) The Customer/Visitor shows the Store Employee his/her number (b) The Store Employee checks the number in the dedicated section on the web app (c) The Store Employee tells the System, via the web app, that the checked number has entered (d) The Customer/Visitor enters the store

Exit Condition	The Customer/Visitor is inside the store and the system has registered the entrance.
Exception	The Exceptions are: (a) The Customer/Visitor shows an invalid number The resolution of the above exception is left to the Store Employee
Special Requirements	/

9. **Enter the store without QR code for a visit**

Name	Enter the store without QR code for a visit
Actors	Customer, Store Employee
Entry Condition	The Customer knows the information related to his visit and he/she is at the store entrance. The Store Employee is logged to the web app.
Event Flow	The Event Flow is: (a) The Customer shows the Store Employee the informations about his/her visit (b) The Store Employee checks the reservation in the dedicated section on the web app (c) The Store Employee tells the System, via web app, that the visit is started (d) The Customer enters the store
Exit Condition	The Customer/Visitor is inside the store and the system has registered the entrance.
Exception	The Exceptions are: (a) The Customers shows informations about an invalid visit The resolution of the above exception is left to the Store Employee
Special Requirements	/

10. **Enter the store with a QR code**

Name	Enter the store with a QR code
Actors	Customer
Entry Condition	The Customer has with him the QR code associated to the entrance. He/She is at the store entrance.
Event Flow	The Event Flow is: (a) The Customer scans the generated QR code at the entrances (b) The Customer enters the store
Exit Condition	The Customer/Visitor is inside the store. User information is stored in the system.
Exception	The Exceptions are: (a) The QR code is not recognized (b) The QR code is not valid to enter in the store For the first exception the Customer is returned to the step (a). For the second exception the resolution is left to the Store Employee
Special Requirements	/

11. **Register exit from store**

Name	Register exit from store
Actors	Customer/Visitor, Store Employee
Entry Condition	The Customer/Visitor is inside the store, the employee is logged to the web app.
Event Flow	The Event Flow is: (a) The Customer exits from the store (b) The Store Employee registers on the web app an exit from the store
Exit Condition	The system has correctly saved the exit from the store.
Exception	/

Special Requirements	/

12. **Display data of the accesses made through QR code**

Name	Display data of the accesses made through QR code
Actors	Store Manager
Entry Condition	The Store Manager is logged to the web app.
Event Flow	The Event Flow is: (a) The Store Manager accesses the section of the web app dedicated to the display of collected data (b) The Store Manager visualizes the statistics and data on entrances
Exit Condition	/
Exception	The Exceptions are: (a) The System has not yet registered any access made through QR code
Special Requirements	/

3.2.6 Sequence Diagrams

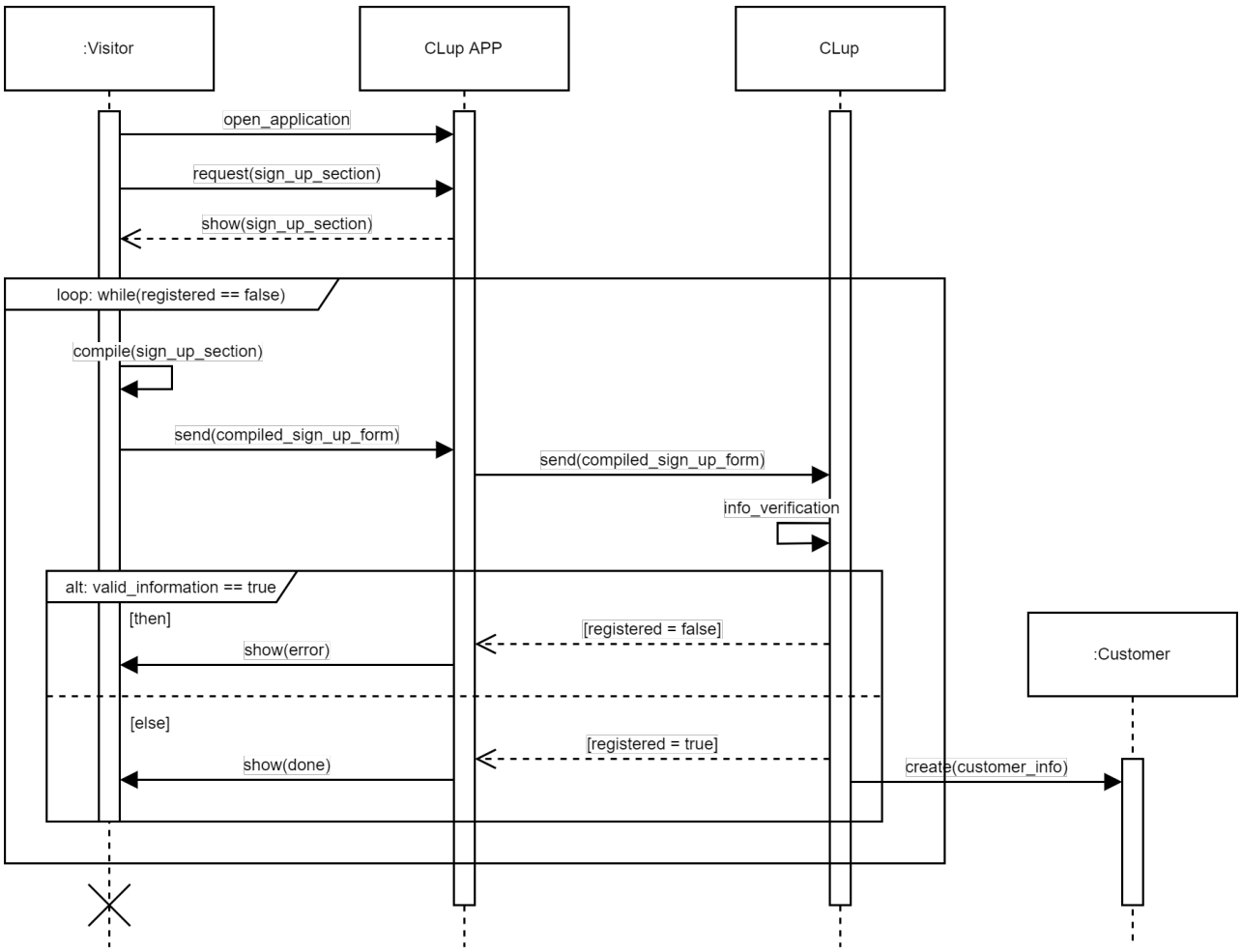


Figure 3.6: Registration to CLup as Customer

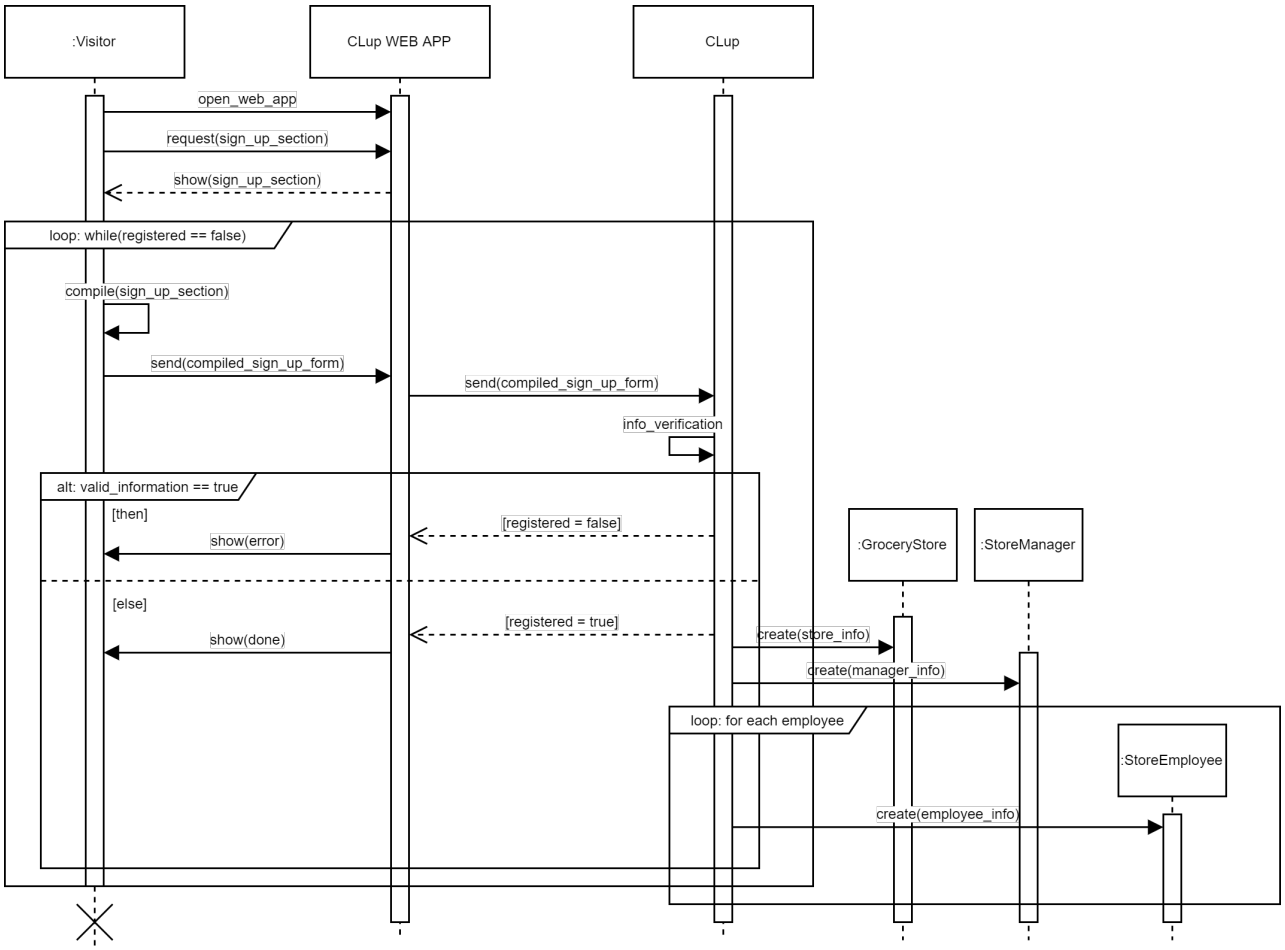


Figure 3.7: Registration to CLup as Store Manager

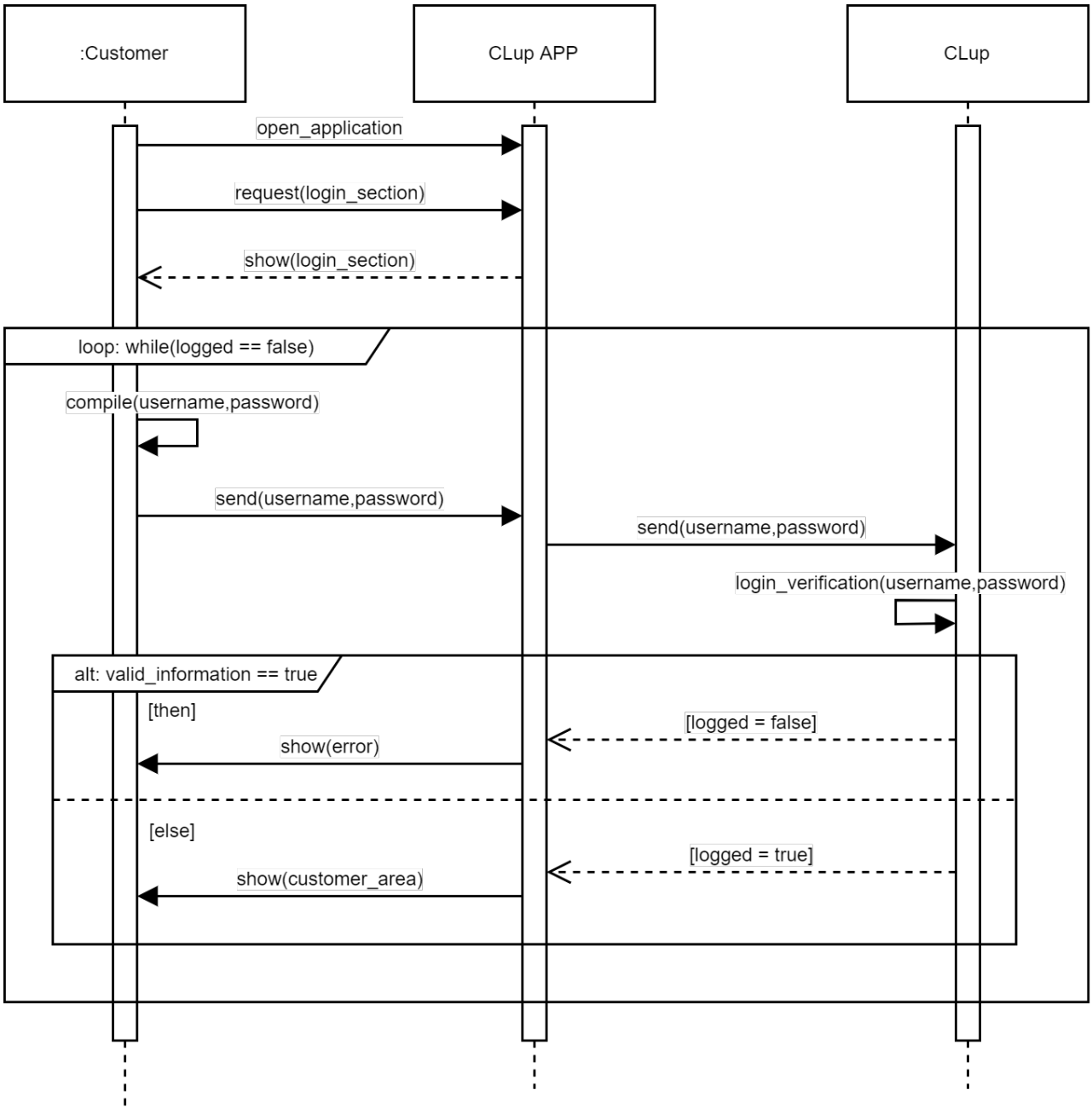


Figure 3.8: Login to the application

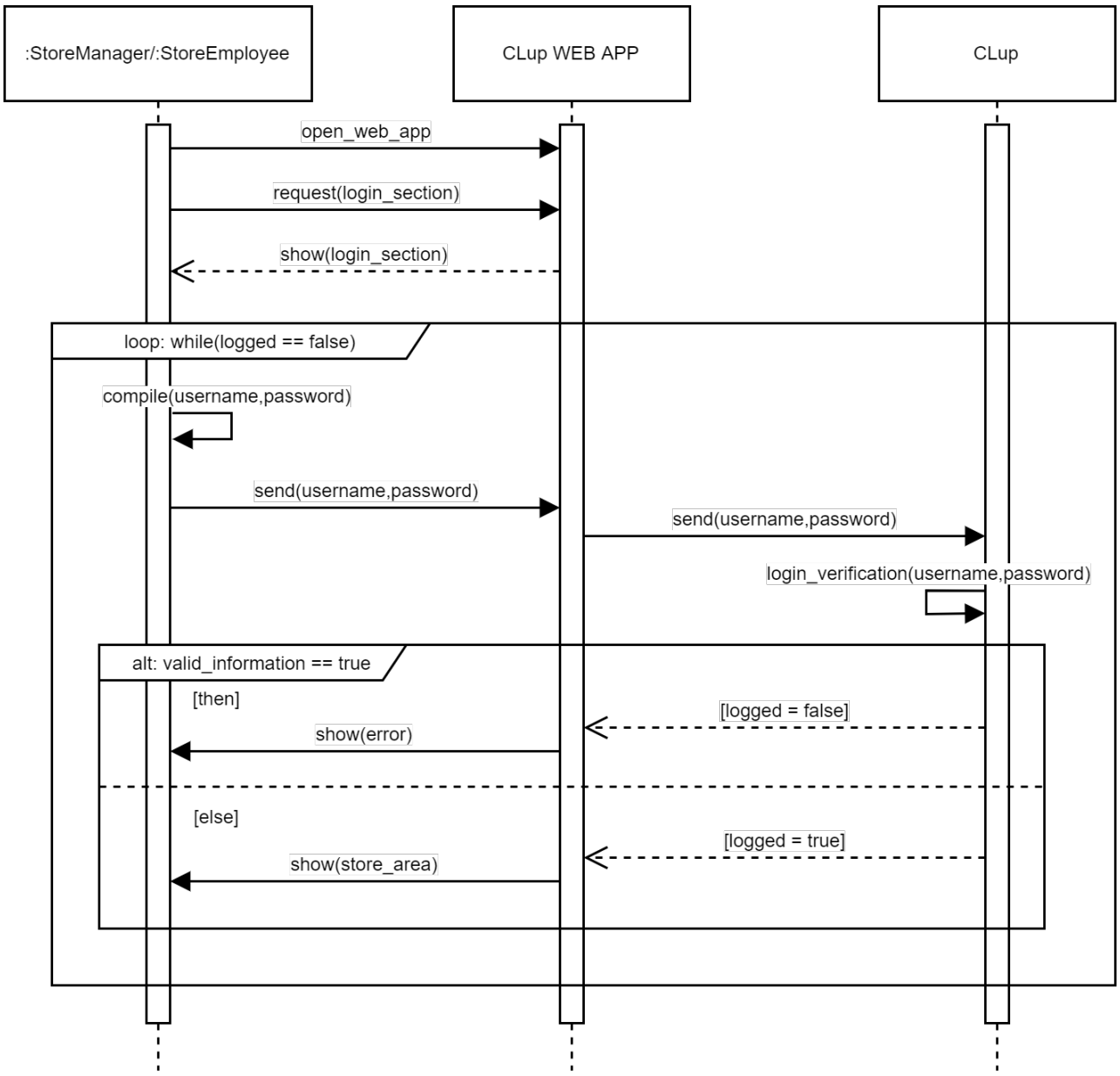


Figure 3.9: Login to the web app

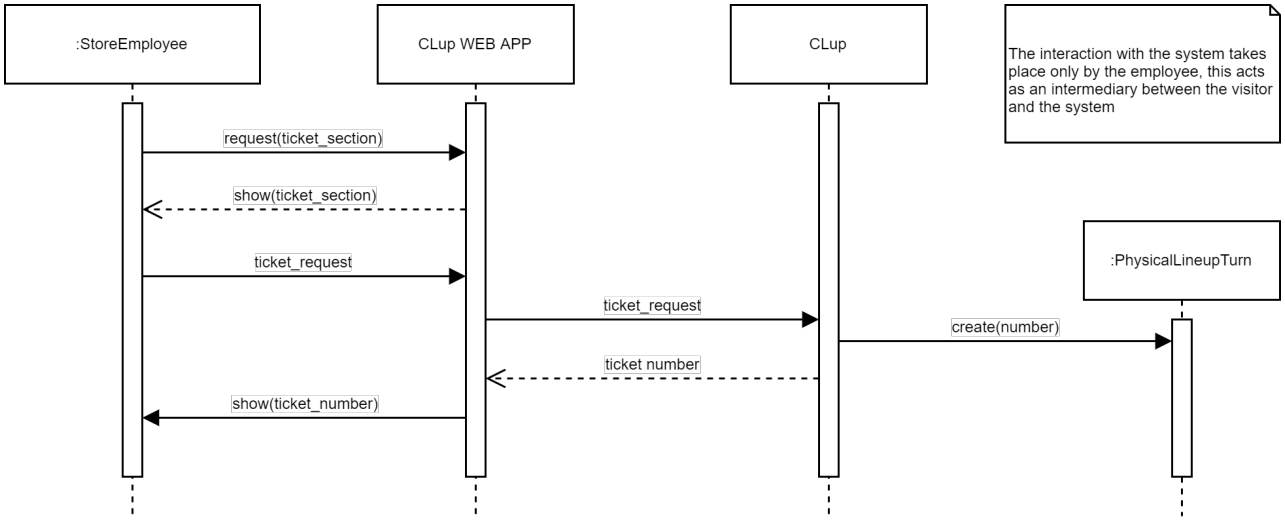


Figure 3.10: Lining up via store

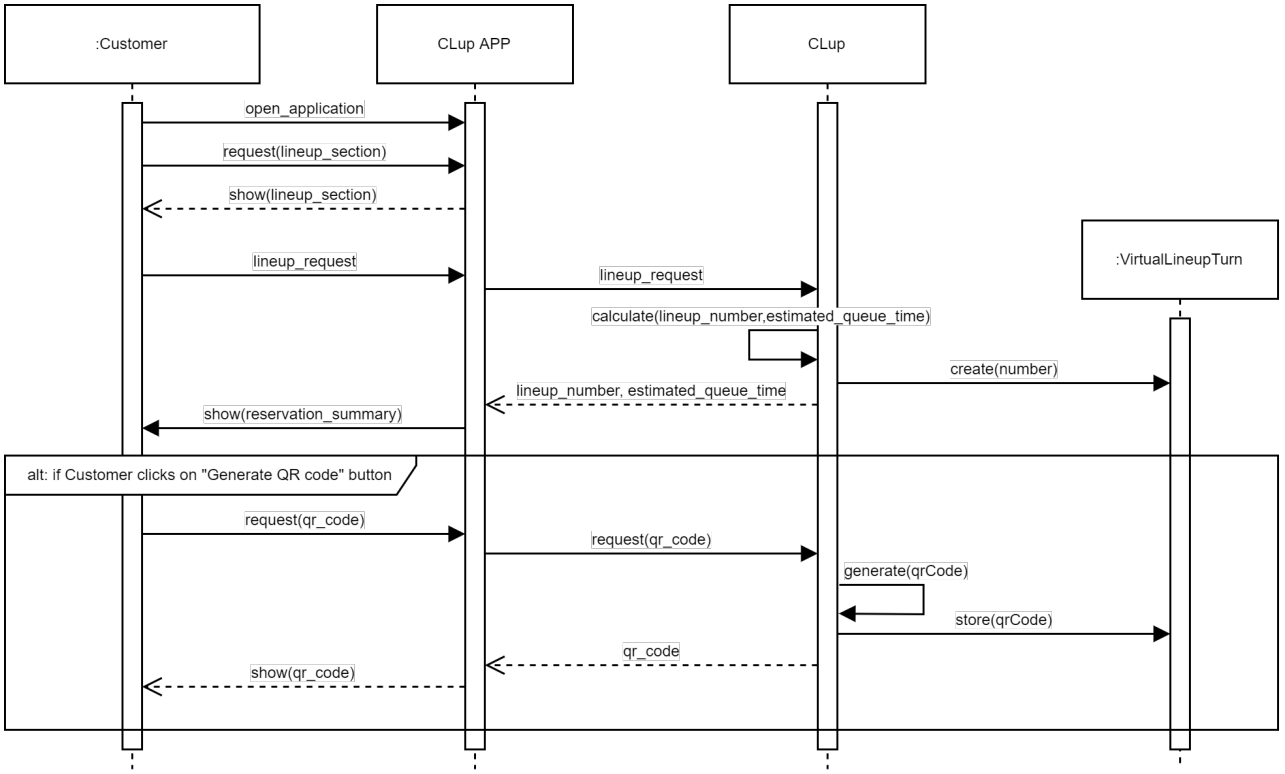


Figure 3.11: Lining up via app

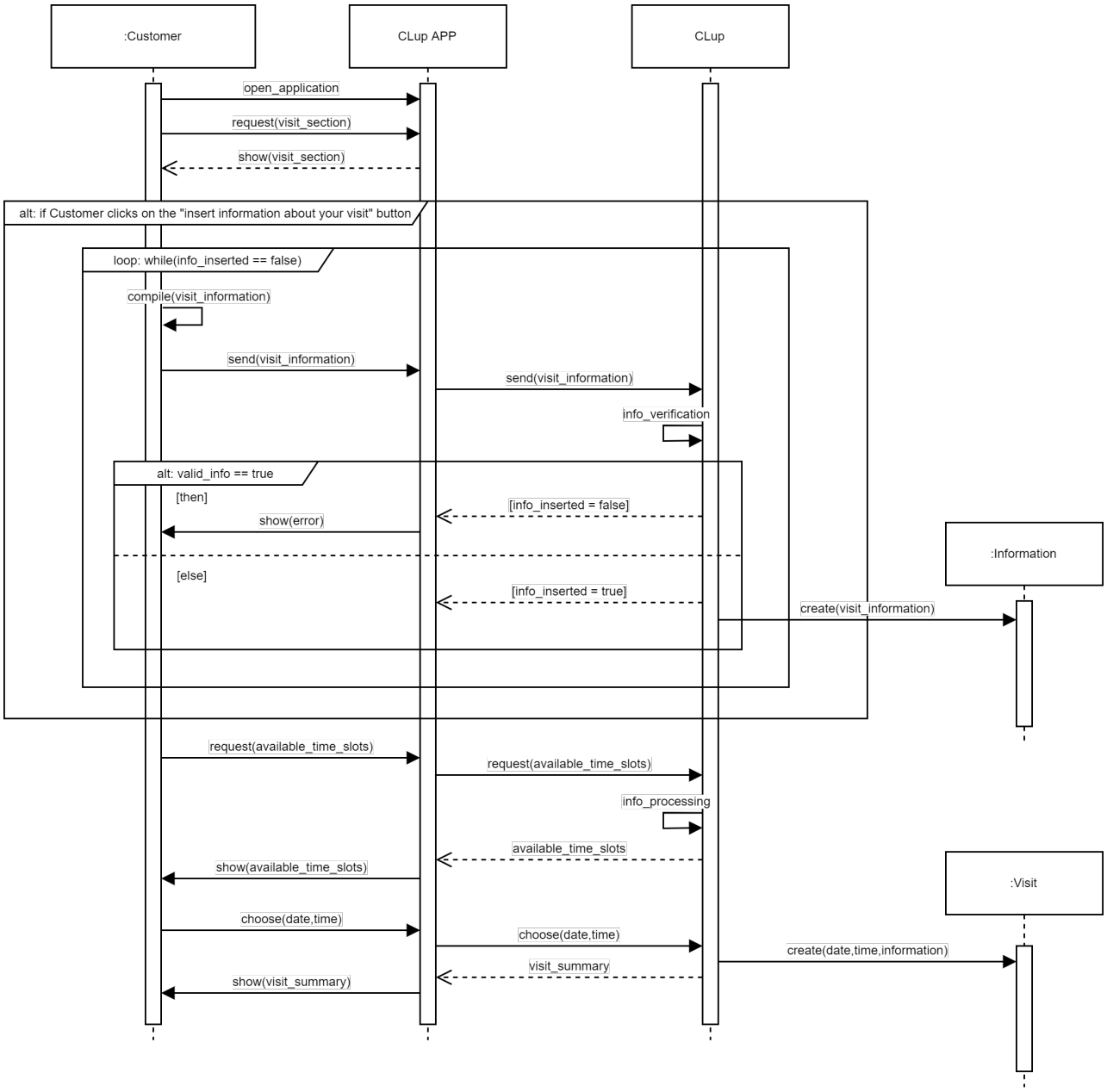


Figure 3.12: Book a visit

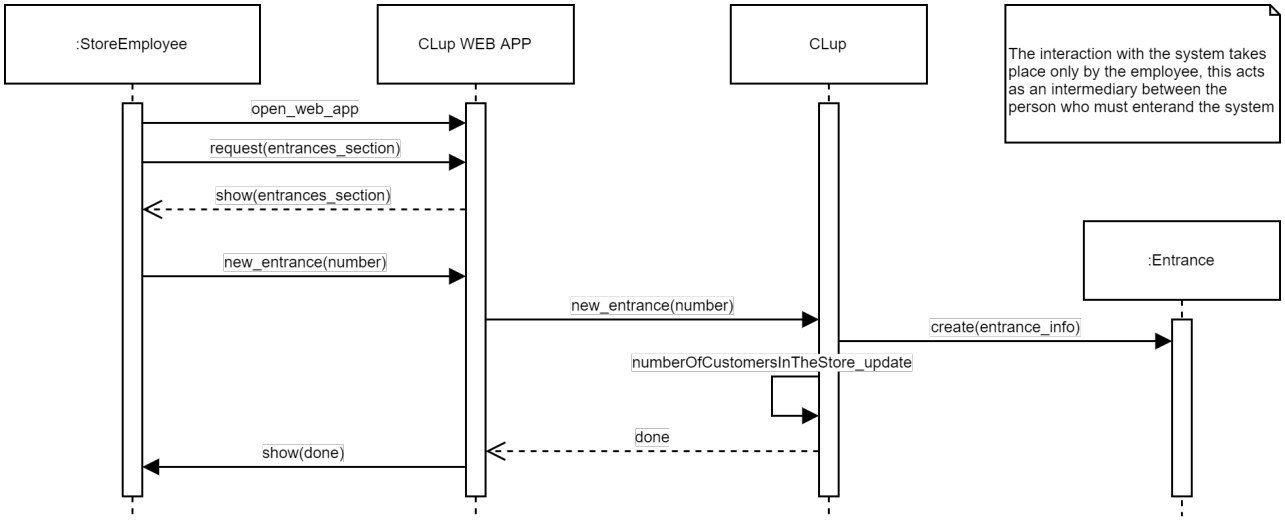


Figure 3.13: Enter the store without QR code after lineup reservation

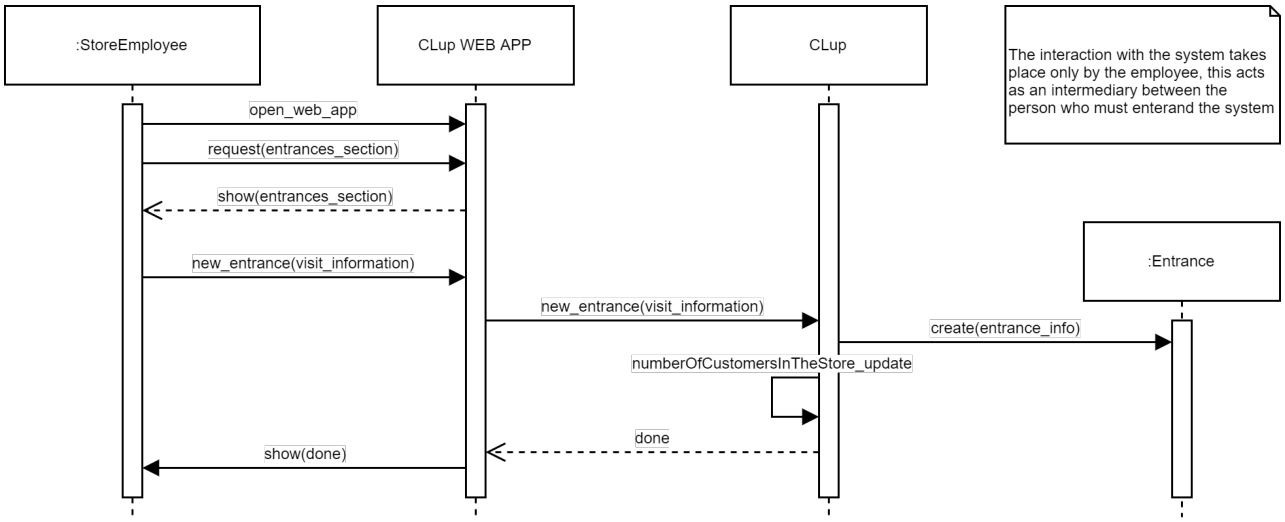


Figure 3.14: Enter the store without QR code for a visit

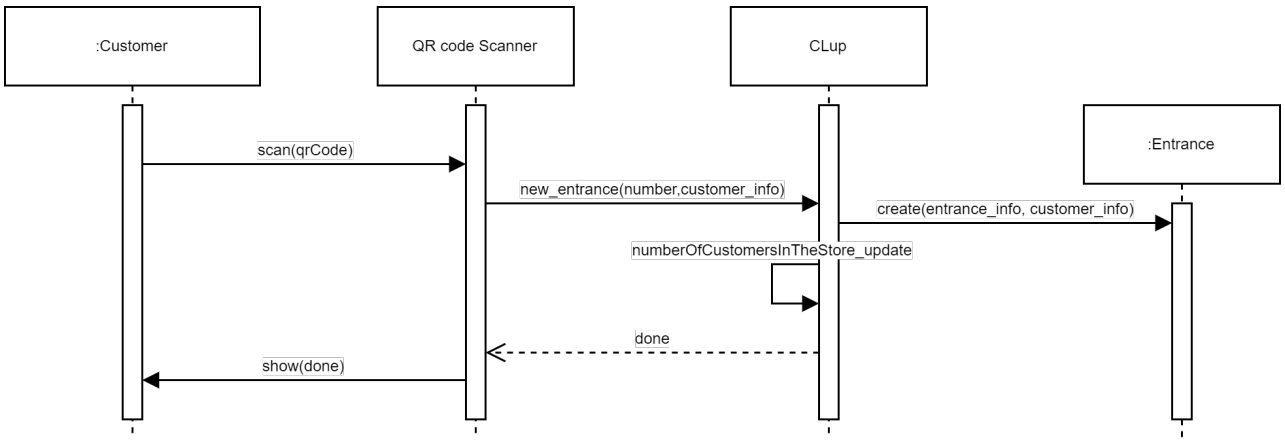


Figure 3.15: Enter the store with a QR code

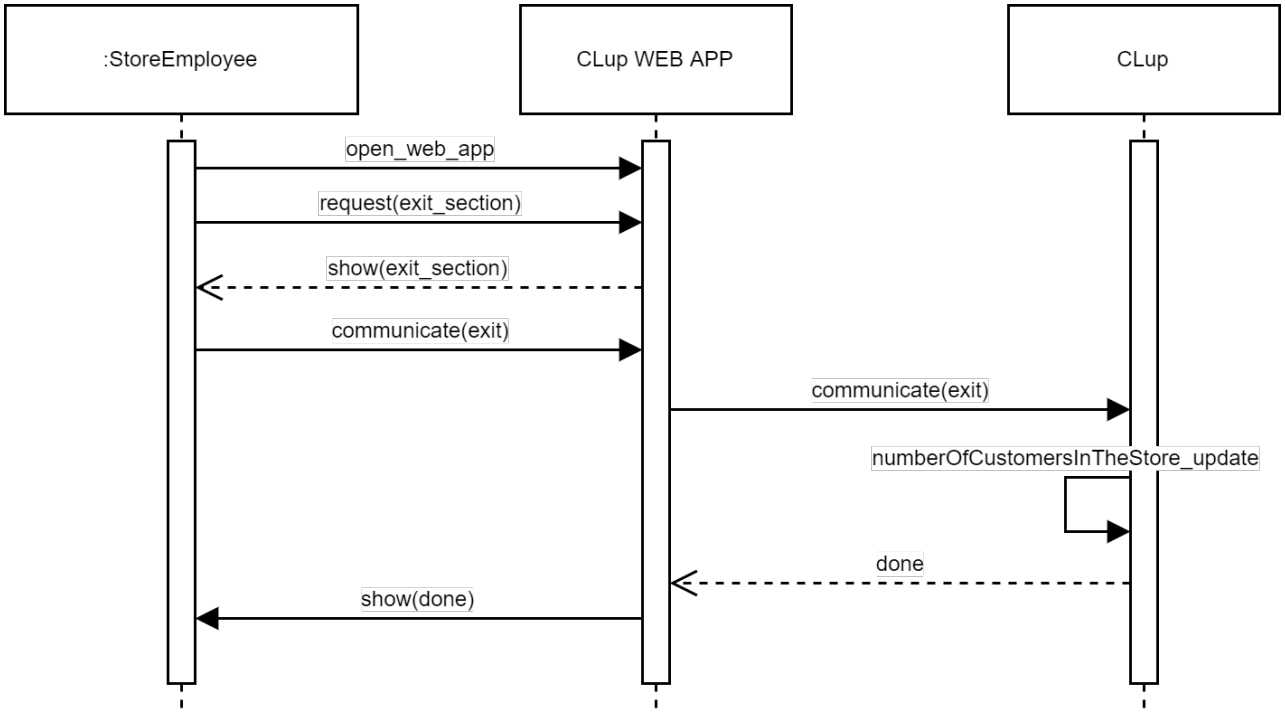


Figure 3.16: Register exit from store

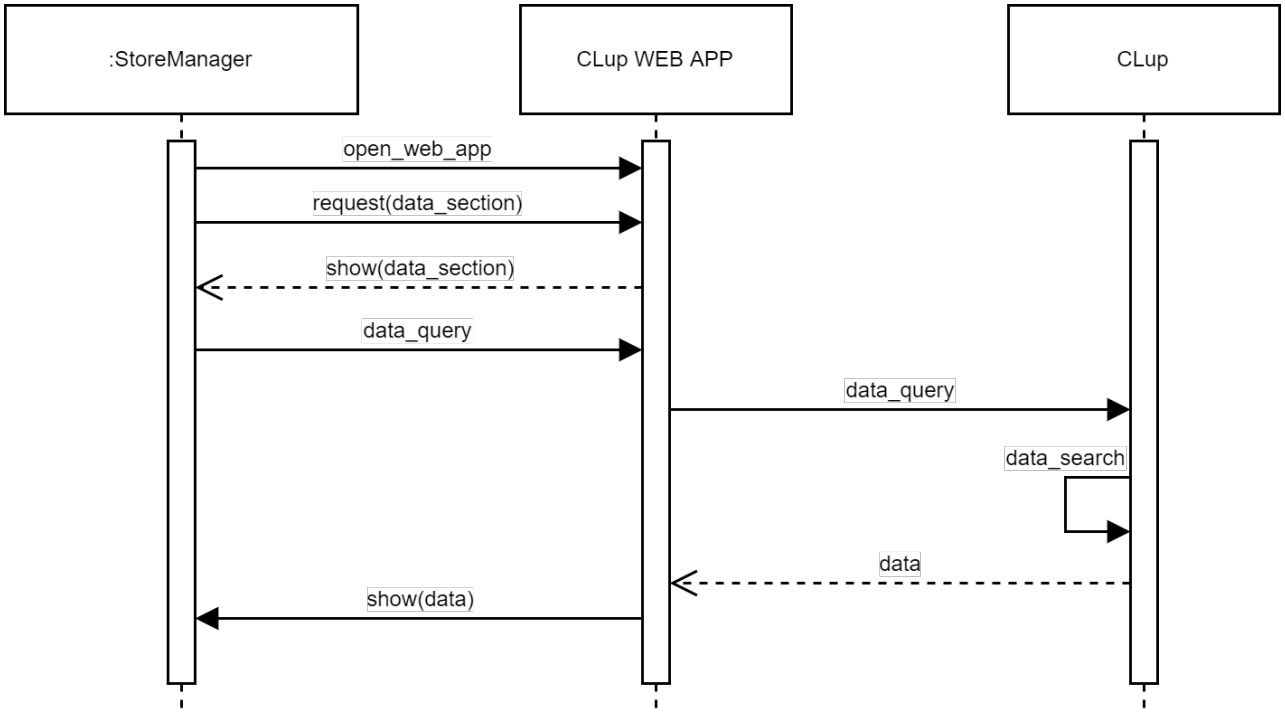


Figure 3.17: Display data of the accesses made through QR code

3.3 Performance Requirements

The system has to be able to serve a great number of users simultaneously. It has to provide a slow response time to requests. In particular, the application and the web application must react in the order of hundreds of milliseconds, except in the case of connectivity issues which must be correctly detected and handled.

3.4 Design Constraints

3.4.1 Standards compliance

About the privacy of data, the CLup project is subjected to the General Data Protection Regulation (GDPR), a regulation in EU law on data protection and privacy for all individuals within the European Union (EU) and the European Economic Area (EEA).

There are no specific units of measure to adopt. The system has to adopt international standards about date and time use and representation.

3.4.2 Hardware limitations

As specified in the Hardware limitations (2.4.2) and Hardware Interfaces (3.2.2) sections are described in detail the hardware specifications. In the following is reported a summary of all the hardware requirements:

- Regarding the customer: Internet connection (2G/3G/4G/Wi-Fi), iOS/Android smartphone, and a GPS sensor
- Regarding the store manager and the employees: Internet connection (2G/3G/4G/Wi-Fi), modern web browser

3.4.3 Any other contraint

Since everyone needs to go to the supermarket the application and the web application should be easy to use and provide intuitive ways to interact with them.

3.5 Software System Attributes

3.5.1 Reliability

The system has to be able to run continuously without any interruptions for long periods. To be fault-tolerant the system backend deployment must take advantage of some sort of replication and redundancy. The system must have offline backups of the data storage to exploit in disaster recovery after a data loss.

3.5.2 Availability

Given the fact that CLup is not an emergency service or anything related to critical situations, the system must provide availability of 99.9%. This means that the average time between the occurrence of a fault and service recovery (MTTR) has to be contained at around 0.365 days per year.

3.5.3 Security

The data provided by the users contain some sensitive information, so the security aspect cannot be underestimated. The central database must be protected with all the available measures to avoid any external or internal attack. The passwords inside the data store have to be encrypted and in case of password recovery, this must never be sent in clear.

To communicate over the internet CLup must use some sort of encryption to avoid traffic sniffing and spoofing, thus avoiding cheating attacks and guaranteeing privacy and consistency.

3.5.4 Maintanability

The system must guarantee a high level of maintainability. Appropriate design patterns should be used, together with good standards. The code must be well documented and hard-coding must be avoided. A testing routine has to be provided and it has to cover at least 75% of the entire codebase, excluding interfaces code.

3.5.5 Portability

The application must be developed for two different platforms: iOS and Android smartphones. The web application must run on any OS (like Windows, Mac OS, Linux, etc) that supports a web browser. Even mobile devices like iPads and Android tablets must be able to access the web app.

4. Formal Analysis Using Alloy

In this section, we include the alloy model of CLup. In this model we want to prove that:

- A Visitor can line up at the store entry point, he/she will be called by the employee and then he will enter the store showing his/her number
- A Customer can line up with the CLup application, he/she will be called and then he/she will enter the store showing his/her number
- A Customer can line up with the CLup application and can generate the QRCode, he/she will be called and then he/she will enter the store with the QRCode
- A Customer can book a visit and then he/she will enter the store

We have chosen these 4 situations because they well represent the core concepts around CLup.

4.1 Signatures

```
open util/time

abstract sig Bool{}
one sig TRUE extends Bool{}
one sig FALSE extends Bool{}

abstract sig Person{}

abstract sig StoreClient extends Person{}

sig Employee extends Person{}

sig StoreManager extends Person{}

sig Visitor extends StoreClient{}

sig Customer extends StoreClient{}

sig Location{}

one sig Store{
    location: Location,
    storeManager: StoreManager,
    employees: set Employee,
    capacity: Int,
    realTimeOccupancy: Int one -> Time
} {
    capacity > 0
    all r: realTimeOccupancy.Time | r > 0
}

abstract sig ReservationStatus{}
one sig WAITING extends ReservationStatus{}
one sig CALLED extends ReservationStatus{}
```

```
one sig USED extends ReservationStatus{}
one sig EXPIRED extends ReservationStatus{}

abstract sig Reservation{
    client: StoreClient,
    store: Store,
    status: ReservationStatus one -> Time,
    entrance: Entrance lone -> Time
}{
    all t: Time | (entrance.t ≠ none) iff (status.t = USED)
}

sig Visit extends Reservation{
    informations: VisitInformations
} {
    all t: Time | status.t ≠ CALLED
}

abstract sig LineUpTurn extends Reservation{
    lineUpNumber: Int
}{
    lineUpNumber > 0
}

sig PhysicalLineUpTurn extends LineUpTurn{}

sig VirtualLineUpTurn extends LineUpTurn{
    estimatedQueueTime: Int one -> Time,
    estimatedTravelTime: Int one -> Time,
    qrCode: lone QRCode
}{
    all e: estimatedQueueTime.Time | e ≥ 0
    all e: estimatedTravelTime.Time | e ≥ 0
    all t: Time | estimatedQueueTime.t ≥ estimatedTravelTime.t
}

sig Entrance{
    checkedBy: (Employee + QRCode) lone -> Time
} {
    all t: Time | checkedBy.t ≠ none iff (some r: Reservation | r.entrance.t = this)
    all t: Time | checkedBy.t in QRCode implies (all v: Visit + PhysicalLineUpTurn | not (this in v.
        ↪ entrance.t))
}

sig VisitInformations{
}

sig QRCode{
}
```

4.2 Facts

```
//Each reservation has one entrance
fact {
    all r: Reservation | #r.entrance.Time = 1
}

//LineUpTurn status evolution
fact {
    all t: Time | all l: LineUpTurn | (l.status.t = CALLED) implies (not WAITING in l.status.(t.next))
    all t: Time | all l: LineUpTurn | (l.status.t = USED) implies (not WAITING in l.status.(t.next) ∧
        ↪ not CALLED in l.status.(t.next) ∧ not EXPIRED in l.status.(t.next))
    all t: Time | all l: LineUpTurn | (l.status.t = EXPIRED) implies (not WAITING in l.status.(t.next)
        ↪ ∧ not CALLED in l.status.(t.next) ∧ not USED in l.status.(t.next))
}

//Visit status evolution
fact {
```

```
    all t: Time | all l: Visit | (l.status.t = USED) implies (not WAITING in l.status.(t.next) ∧ not
        ↪ EXPIRED in l.status.(t.next))
    all t: Time | all l: Visit | (l.status.t = EXPIRED) implies (not WAITING in l.status.(t.next) ∧ not
        ↪  USED in l.status.(t.next))
}

//When a customer is called the queue time equals the travel time
fact {
    all t: Time | all r: VirtualLineUpTurn | (r.status.t = CALLED) implies (r.estimatedQueueTime.t = r.
        ↪ estimatedTravelTime.t)
}

//When a VirtualLineUpTurn is expired the queue time and the travel time are 0
fact {
    all t: Time | all r: VirtualLineUpTurn | (r.status.t = EXPIRED) implies (r.estimatedQueueTime.t = 0
        ↪  ∧ r.estimatedTravelTime.t = 0)
}

//When a customer enters the store the queue time and the travel time are 0
fact {
    all t: Time | all r: VirtualLineUpTurn | (r.status.t = USED) implies (r.estimatedQueueTime.t = 0 ∧
        ↪ r.estimatedTravelTime.t = 0)
}

//Different visits have different visit informations
fact {
    all disj v1, v2: Visit | v1.informations ≠ v2.informations
}

//A PhysicalLineUpTurn is associated to a Visitor
fact {
    all r: Reservation | r.client in Visitor iff r in PhysicalLineUpTurn
}

//Different Reservations have different clients
fact {
    all disj r1, r2: Reservation | r1.client ≠ r2.client
}

//Different Entrances have different QRCodes
fact {
    all disj e1, e2: Entrance | all qr: QRCode | all t: Time | (e1.checkedBy.t = qr) implies (e2.
        ↪ checkedBy.t ≠ qr)
}

//Different VirtualLineUpTurns have different QRCodes
fact {
    all disj v1, v2: VirtualLineUpTurn | v1.qrCode ≠ v2.qrCode
}

//An entrance related to a VirtualLineUpTurn is either checked by an employee or it has a qrCode
fact {
    all v: VirtualLineUpTurn | (some e: v.entrance.Time | some emp: Employee | emp in e.checkedBy.Time)
        ↪  implies v.qrCode = none
}

//LineUpNumber and estimatedQueueTime relation
fact {
    all disj l1, l2: VirtualLineUpTurn | all t: Time | (l1.estimatedQueueTime.t ≥ l2.estimatedQueueTime
        ↪ .t) iff (l1.lineUpNumber > l2.lineUpNumber)
}

//Different LineUpTurns have different LineUpNumbers
fact {
    all disj l1, l2: LineUpTurn | l1.lineUpNumber ≠ l2.lineUpNumber
}

//Store capacity constraint
fact {
    all s: Store | s.realTimeOccupancy.Time ≤ s.capacity
}

//Different Reservations have different Entrances
fact {
```

```
    all disj r1, r2: Reservation | r1.entrance.Time & r2.entrance.Time = none
}
```

4.3 Predicates

```
//A Visitor lines up via store, is called and then he/she enters the store
pred VisitorLinesUpAtTheStore[u: Visitor, s: Store, r: PhysicalLineUpTurn, t: Time, emp: Employee] {
    r.client = u
    r.store = s
    r.status.t = WAITING
    r.entrance.t = none
    emp in s.employees
}
pred VisitorIsCalledAtTheStore[u: Visitor, s: Store, r: PhysicalLineUpTurn, t: Time, emp: Employee] {
    VisitorLinesUpAtTheStore[u, s, r, t, emp]
    r.status.t = WAITING
    r.status.(t.next) = CALLED
    r.entrance.(t.next) = none
}
pred VisitorEntersTheStoreAtTheStore[u: Visitor, s: Store, r: PhysicalLineUpTurn, t: Time, e: Entrance,
    ↪  emp: Employee] {
    VisitorIsCalledAtTheStore[u, s, r, t, emp]
    let t' = t.next | (
    r.status.(t') = CALLED and
    r.status.(t'.next) = USED and
    r.entrance.(t'.next) = e and
    s.realTimeOccupancy.(t').next = s.realTimeOccupancy.(t'.next) and
    e.checkedBy.(t'.next) = emp
    )
}


//A Customer lines up via app, is called and then he/she enters the store normally
pred CustomerLinesUp[u: Customer, s: Store, r: VirtualLineUpTurn, t: Time] {
    r.client = u
    r.store = s
    r.status.t = WAITING
    r.estimatedQueueTime.t > r.estimatedTravelTime.t
    r.entrance.t = none
}
pred CustomerIsCalled[u: Customer, s: Store, r: VirtualLineUpTurn, t: Time] {
    CustomerLinesUp[u, s, r, t]
    r.status.t = WAITING
    r.status.(t.next) = CALLED
    r.estimatedQueueTime.(t.next) = r.estimatedTravelTime.(t.next)
    r.entrance.(t.next) = none
}
pred CustomerEntersTheStore[u: Customer, s: Store, r: VirtualLineUpTurn, t: Time, e: Entrance, emp:
    ↪ Employee] {
    CustomerIsCalled[u, s, r, t]
    let t' = t.next | (
    r.status.(t') = CALLED and
    r.status.(t'.next) = USED and
    r.entrance.(t'.next) = e and
    s.realTimeOccupancy.(t').next = s.realTimeOccupancy.(t'.next) and
    emp in s.employees and
    e.checkedBy.(t'.next) = emp and
    r.estimatedQueueTime.(t'.next) = r.estimatedTravelTime.(t'.next) and
    r.estimatedQueueTime.(t'.next) = 0
    )
}


//A Customer lines up via app, is called and then he/she enters the store with a QRCode
pred CustomerLinesUpQRCode[u: Customer, s: Store, r: VirtualLineUpTurn, t: Time, qr: QRCode] {
    CustomerLinesUp[u, s, r, t]
    r.qrCode = qr
}
```

```
pred CustomerIsCalledQRCode[u: Customer, s: Store, r: VirtualLineUpTurn, t: Time, qr: QRCode] {
    CustomerIsCalled[u, s, r, t]
    CustomerLinesUpQRCode[u, s, r, t, qr]
}
pred CustomerEntersTheStoreQRCode[u: Customer, s: Store, r: VirtualLineUpTurn, t: Time, e: Entrance, qr
    ↪ : QRCode] {
    CustomerIsCalledQRCode[u, s, r, t, qr]
    let t' = t.next | (
    r.status.(t') = CALLED and
    r.status.(t'.next) = USED and
    r.entrance.(t'.next) = e and
    r.entrance.(t'.next).checkedBy.(t'.next) = qr and
    s.realTimeOccupancy.(t').next = s.realTimeOccupancy.(t'.next) and
    r.estimatedQueueTime.(t'.next) = r.estimatedTravelTime.(t'.next) and
    r.estimatedQueueTime.(t'.next) = 0
    )
}


//A Customer books a visit and then enters the store
pred CustomerBooksAVisit[u: Customer, s: Store, r: Visit, t: Time] {
    r.client = u
    r.store = s
    r.status.t = WAITING
    r.entrance.t = none
}
pred CustomerEntersTheStoreVisit[u: Customer, s: Store, r: Visit, t: Time, e: Entrance, emp: Employee]
    ↪ {
    CustomerBooksAVisit[u, s, r, t]
    r.status.(t.next) = USED
    emp in s.employees
    e.checkedBy.(t.next) = emp
    s.realTimeOccupancy.t.next = s.realTimeOccupancy.(t.next)
    r.entrance.(t.next) = e
}
```

4.4 Results

```
run VisitorEntersTheStoreAtTheStore for 5 but 3 Time
run CustomerEntersTheStore for 5 but 3 Time
run CustomerEntersTheStoreQRCode for 5 but 3 Time
run CustomerEntersTheStoreVisit for 5 but 2 Time
```

4.4.1 Proof of consistency

4.4.2 Generated world

Here we include one generated world related to the CustomerEntersTheStoreQRCode pred. The 3 images show the evolution over time of the generated world. We can notice that the Customer is called when the estimatedQueueTime equals the estimatedTravelTime (fig 4.2), that the Entrance is checked through the QRCode and not by an employee and that the realTimeOccupancy increases after the entrance (fig 4.3).

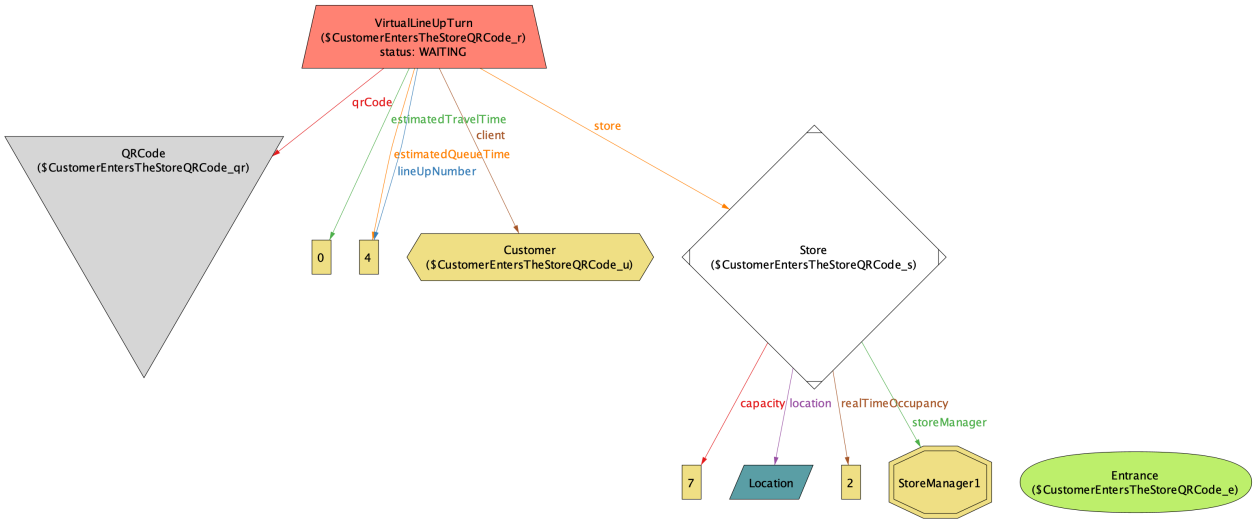


Figure 4.1: The Customer is waiting in virtual line [Time0]

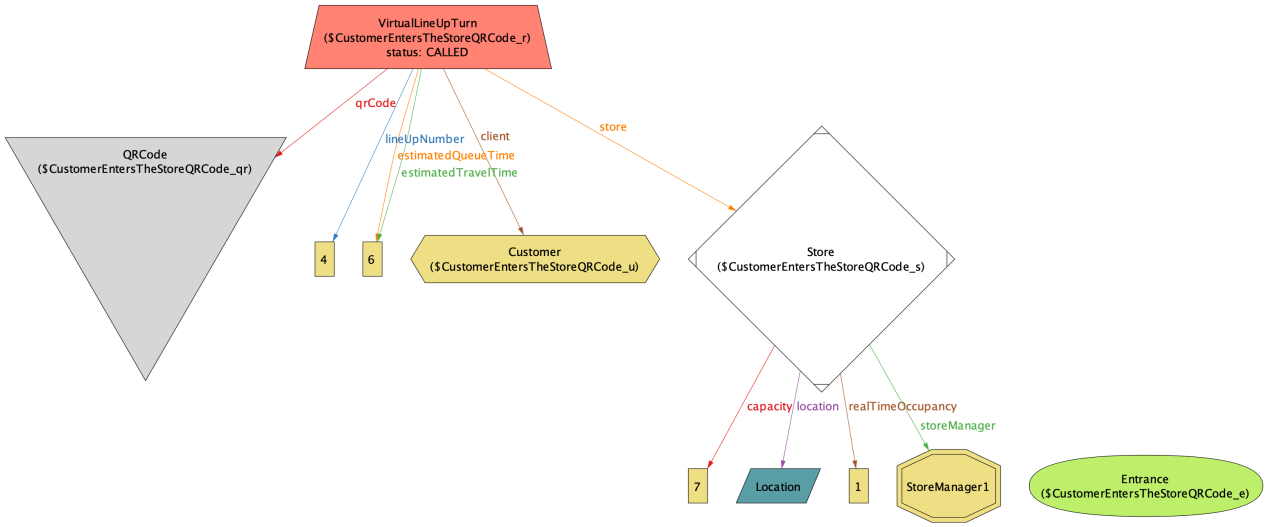


Figure 4.2: The Customer is called [Time1]

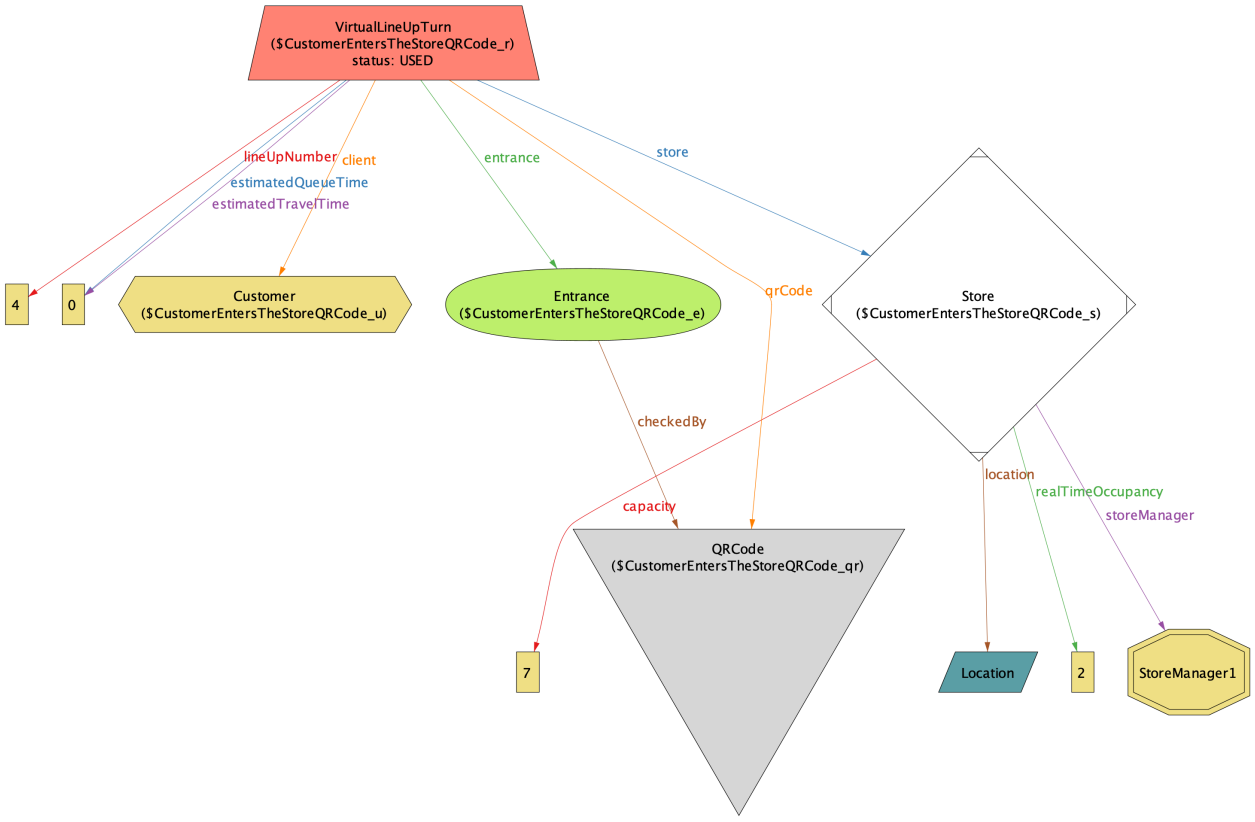


Figure 4.3: The Customer enters the Store [Time2]

5. Effort Spent

5.1 Marco Di Gennaro

Time	**Task**
2h	Work on the LaTeX document structure
2h	Discussion on chapter 1 (Content definition)
1h 30m	Writing of sections 1.3, 1.4, 1.5, and 1.6
5h 30m	Discussion on chapter 2 (Content definition)
6h	Writing of sections 2.1 and 2.2
8h	Discussion on chapter 3 (Content definition)
45m	Updates on class-diagram and state-diagrams in chapter 2
1h 30m	Writing of scenarios in section 2.1
30m	Updates on chapters 1 and 2
4h	Writing of sections 3.2 (Use Cases, Use Case Diagrams)
5h	Writing of sections 3.2 (Sequence Diagrams)
5h	Discussion on chapter 4 (Content definition)
41h 45m	**Tot**

5.2 Luca Danelutti

Time	Task
2h	Discussion on chapter 1 (Content definition)
1h 30m	Writing of sections 1.1 and 1.2
5h 30m	Discussion on chapter 2 (Content definition)
2h 15m	Writing of sections 2.3 and 2.4
8h	Discussion on chapter 3 (Content definition)
1h 30m	Writing of scenarios in section 2.1
45m	Updates on chapters 1 and 2
5h	Writing of sections 3.1 and 3.2
3h 30m	Drawing of mockups of section 3.1
1h 15m	Writing of sections 3.3, 3.4 and 3.5
5h	Discussion on chapter 4 (Content definition)
5h 15m	Writing of chapter 4
41h 30m	**Tot**

6. References

- Diagrams made with: draw.io
- Mockups made with: Figma
- LaTeX code made with: Visual Studio Code (LaTeX Workshop, LaTeX Utilities)
- Alloy models made with: Visual Studio Code (Alloy, Alloy VSCode)
- Alloy models runned and checked with: alloytools
- Alloy code included in this document with: alloy-latex-highlighting